Second-Order Adaptive Network Models for Shared Mental Models in Medical Teamwork for Neonatal Resuscitation

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Summary

A *medical error* indicates that the expected action has not been completed in the medical treatment. *Patient safety* defined as 'the prevention of harm to patients' is a vital concept in medical teams and is essential in improving quality of medical treatment. *Safety culture* is defined as "the product of individual and group perceptions, attitudes, values, competencies, and patterns of behavior that decide the commitment to, and the style and proficiency of, an organization's health and safety management". The terminology for safety has evolved from a focus on error to patient safety to adopting a safety culture with adequate shared mental models. That evolution reflects a process of shifting responsibility from individuals to the whole organization. More recently, scholars is advocating medical organization to get rid of blame culture and embrace just safety culture. *Blame culture* is a set of organizational norms and attitudes characterized by being reluctant to accept responsibility or to take risks for errors because of being afraid of criticism or management blame. *Just safety culture* refers to a culture that encourages open dialogue to promote safer practices. On the face of it, healthcare organizations should quickly abandon blame culture and choose a just culture. However, it's not easy to deploying a just safety culture in reality. Good implement of just safety culture in a medical team requires much teamwork effort. When it comes to teamwork effort, the shared mental model has received a lot of attention in the literature on medical team performance. A *mental model* means the intelligence that imitates relation structures of external processes. A *shared mental model* of a team means a large or complete overlap of the team members' individual mental models. A useful method to analysis shared mental models of a team is adaptive network-oriented modeling, which refers to modeling complex processes by adaptive networks. The AI technology has the potential to help a medical team deploy just safety culture. But research on how AI can involve in the workflow of existing medical team is limited. Thus, in hoping of solving the problem: *How can AI participate in the application of just safety culture to neonatal resuscitation*? This study chooses these points to explore: how AI improves the efficiency of team communication, how AI leverages organizational learning, and how AI points out defects and prevents errors. From the perspective of result, these converge into *how AI can help improve the performance of the medical team*. That leads to the main research question of this research: *How to use an adaptive network-oriented modeling method to analysis the AI-coach's contribution in a medical team's ventilation operation to save baby in danger?*

To answer the research question, six conditions are analyzed by adaptive network-oriented modeling method, modeling and simulation of each condition are presented at a chapter. In this thesis, chapter one is introduction to background and key concepts of this research. These key concept includes shared mental model, organizational learning, and research method of adaptive network-oriented modeling. In addition, the study case of application scenarios are described in detail. Besides, the managerial and societal relevance are discussed. Chapter 2 presents how to use an adaptive network-oriented

modeling method to simulate the team's perfect ventilation operation to save the baby in danger without introducing organizational learning. The protocol condition means that the team gives the baby ventilation according to the protocol followed and makes no mistake. The baby finally recovers successfully. Chapter 3 shows how to use an adaptive network-oriented modeling method to simulate the team's perfect ventilation operation to save the baby in danger with introducing organizational learning. Comparing to the condition in chapter 2, team members in chapter 3 both have some imperfect knowledge. But with introducing of organizational learning, both of them fix their imperfect knowledge by learning from correct organizational knowledge. This condition shows how organizational learning can contribute to prevent team members from making a mistake because of imperfect knowledge. In both chapter 2 and chapter 3, a network and its simulations are presented to show team members' mental process, their actions, learning effects, and their behavior in real world. In addition, in chapter 3, organizational mental process and learning effects are presented as well. Chapter 4 presents how to use an adaptive network-oriented modeling method to simulate the team's ventilation operation to save the baby in danger with partial mistake. In this condition, the nurse has imperfect knowledge in preparing pure ventilation and that leads to failure of the first time of ventilation. After the doctor observes the failure, the doctor helps the nurse fix her mistake. That helps a successful next pure ventilation action. Chapter 5 shows how to use an adaptive network-oriented modeling method to simulate the team's ventilation operation to save the baby in danger with extreme mistakes. In this extreme condition, all team members have imperfect knowledge in all preparations so that the ventilation action fails. In both chapter 4 and chapter 5, networks and their simulations are presented to show team members' mental process, their actions, learning effects, and their behavior in real world. Chapter 6 presents how to use an adaptive network-oriented modeling method to simulate the AI-coach's engagement in the team's ventilation operation to save the baby in danger without organizational learning. This chapter shows how the AI-coach help prevent the mistake condition in chapter 4. The AI-coach in this condition has the function of monitoring and warning. When the AI-coach notice the nurse has the tendency to make a mistake, the AI-coach will warn the nurse. Chapter 7 presents how to use an adaptive network-oriented modeling method to simulate the AI-coach's engagement in the team's ventilation operation to save the baby in danger with organizational learning. This chapter shows how the AI-coach help prevent the mistake condition in chapter 5. The AI-coach in this condition has the function of monitoring and promoting knowledge transferring. In this condition, both team members fix their imperfect knowledge as the result of organizational learning promoted by AI-coach. In both chapter 6 and chapter 7, networks and their simulations are presented to show team members' and the AI-coach's mental process, their actions, learning effects, and their behavior in real world. These simulation results also presents function of the AI-coach. Chapter 8 discuss what networks and simulations of chapter 2-7 reveal. In addition, addressed problem above, the research object and the main research question are discussed again. Besides, managerial and societal relevance are addressed again. Last but not the least, limits and future extension of this research is discussed from the perspective of complexity, complication and the relationship with the real world.

Content

1. Introduction

A *medical error* indicates that the expected action has not been completed in the medical treatment (Garrouste-Orgeas, 2012). In traditional thinking, medical errors were considered to be equal to incompetence. In addition, punishment was considered to be an efficient way to motivate individuals not to make errors. However, these kind of traditional thinking would make participants in healthcare reluctant to reveal errors and that would further reduce opportunities to learn from errors. Thus, thinking started changing in the 1990s. Sometimes individuals make errors because of defects in equipment, training, management, organizations and the design of the system (Rasmussen, Jens, 1990). In this case, there is no point in punishing individuals, because those defects have not been eliminated, and more people will make errors because of these defects in the future. Instead, it makes more sense to remove these defects to prevent errors (Emanuel et al., 2009). The analysis of the causes of errors from the individual level to the systematic level shows the shift of attention from medical errors to patient safety (Donaldson, Liam, 2002).

Patient safety defined as ‘the prevention of harm to patients’ is a vital concept in medical teams and is essential in improving quality of medical treatment (Aspden et al., 2004). In health care, the term *harm* means temporary or permanent physical or psychological damage caused by inappropriate medical treatment. Two key indirectly causes of harm and errors are organizational system failure and technical failure (National Quality Forum, 2004). The former one is related to organizational culture, protocols/processes, management, transfer of knowledge. The latter one is related to equipment and external resource. Causes of harm are complex, so minimizing the probability of harm and promoting patient safety require complex efforts. According to Kirwan et al. (2013), in medical treatment, a higher degree of safety culture is related to a higher degree of patient safety.

The definition of *safety culture* is “the product of individual and group perceptions, attitudes, values, competencies, and patterns of behavior that decide the commitment to, and the style and proficiency of, an organization’s health and safety management”. A short understanding is to form a culture that promotes safety in the group. Safety culture in medical treatment is a complex concept and by categorized in to 12 domains by Lee et al. (2019). These domains are organizational commitment to patient safety, managers’ support and actions for patient safety, non-punitive response to error, organizational learning and continuous improvement, staffing adequacy, feedback and communication openness, job satisfaction, working conditions, stress recognition, hospital handoffs and transitions, teamwork within units, and teamwork across units. The evolution from medical errors to patient safety to safety culture is actually a process of transferring responsibility from individual to organization.

More recently, researchers encourage medical organizations to get rid of *blame culture* and embrace *just culture*. *Blame culture* a set of organizational norms and attitudes characterized by being reluctant to accept responsibility or to take risks for errors because of being afraid of criticism or management blame. This culture breeds fear and mistrust within the organization and leads members to pass the buck to each other for self-protection. That leads to no personal initiative or innovative ideas, because members are unwilling to risk making mistakes. Even if the team does not take the initiative to choose the blame culture, some highly bureaucratic team management characteristics will lead to the spontaneous formation of a blame culture within the team. These characteristics include rigid adherence to rules and compliance, and an effort to accurately distribute responsibility to each member, even if the failure is mainly caused by system defects. This kind of environment is not conducive to the development of honest and hard-working people, but to those who are good at cunning and do not want to take responsibility (Kirwan et al., 2009). In health care organizations, blame culture makes subordinates dare not question their superiors. For instance, the nurse is reluctant to question the doctor. That not only leads the organization to loss opportunities to optimize knowledge, but also lead those who remain silent bear the psychological burden. In extreme condition, people keep silent about the mistakes of their superiors and even do harm to patients (Tangirala et al. 2008).

Just culture (which also called *just safety culture*) refers to a culture that encourages open dialogue to promote safer practices. In just safety culture, people are willing to question existing practices, show dissent and concerns and reveal mistake without fear of being targeted and punished (Tucker et al. 2008). The just culture can be combined with organizational learning (Khatri et al. 2009). Organizational learning is considered to be one of the most vital factors influencing organizational safety. *Organizational learning* is defined as the process by which an organization develops new knowledge from the individual experience of the members of the organization. *Experience* is what happens when an organization performs a task. *Knowledge* is defined as justified personal belief. Knowledge is divided into explicit knowledge and tactic knowledge. The former one refers to knowledge that can be expressed by words, sentences, documents and other explicit forms. The latter one refers to knowledge that exists in people' mind but is hard to articulate in explicit forms (Kogut&Zander, 1992). Organizational learning and knowledge will be introduced in detail later in this chapter. From the perspective of organizational learning, a just culture means that an organization is able to identify, report, and investigate incidents and to take appropriate actions that increase the quality of patient care and reduce the probability of recurrence of errors (Khatri et al. 2009). Kirk et al. (2007) introduce basic features of a just safety culture. These features are organization's overall commitment to quality, unrestricted reporting and identification of negative incidents, thorough and fast investigation of patient safety incidents, extensive communication and information sharing of safety issues, organizational learning, staff training and education, and team working for patient safety issues.

Good implement of just safety culture in a medical team requires much teamwork effort. How to contribute to the implementation of a just culture is worth studying. As a concept closely related to team performance, the shared mental model has received a lot of attention in the literature on medical team performance. The concept of the shared mental models are often applied to help analyze the performance and safety of medical teams (Burtscher, 2012). A *model* is an imitation of a process and has a similar relational structure to that process (Craik, 1943). The concept of *model* was applied to mental models by Craik in 1943. He points out that a *mental model* means the intelligence that imitates relation structures of external processes. The mental model enable the intelligence to predict external processes. A *shared mental model* of a team means a large or complete overlap of the team members' individual mental models. A high degree of shared mental model is vital to the team's good performance (Mathieu et al., 2000). Currently, team members build the team's shared mental model through communications and observing other members' actions. When all team members have imperfect knowledge at the same area for team tasks, the team won't have a perfect shared mental model. When one team member has imperfect knowledge for a team task, but others don't point it out and fix it, the team still will not have a perfect shared mental model (Jonker et al., 2010). The concepts of mental model and shared mental model will be introduced in detail later in this chapter. Van Ments et al (2021) computationally analyzes a medical team's shared mental model by the method of adaptive network-oriented modeling.

Network-oriented modelling method is a research method helps to formalize and visually analyze team members' mental models and their behaviors. In a higher-order adaptive network, states and their connections are used to model team members' mental process and actions. In addition, in higher levels, self-model states are used to model adaption of the network structure of base level. A network model can be automatically transformed into a numerical mathematical form (difference or differential equation format) and be input into available dedicated simulation software. That helps visually analyze by simulation graphs all dynamics and adaption over time, for example supporting what-if analysis (Treur, 2016, 2020b). The network-oriented modelling method will be introduced in detail later in this chapter.

While addressing just safety culture, the researcher of this research focus on neonatal patients who are one of the most vulnerable patient groups (Edwards, 2005). Neonatal patients are very small and fragile. Many of them have immature organ systems and superimposed serious diseases. A single neonatal patient is likely to receive care from a medical team instead of a single medical staff. Higher complexity not only increase the probability of errors but also improve the safety and efficiency requirements of medical equipment (Raju et al., 2011). Luckily, the introduction of artificial intelligence (AI) technology helps to promote just safety culture in neonatal medical treatment. Artificial intelligence refers to computer program imitating intelligent human behavior (Kok et al., 2009). According to Henry et al (2022), AI has great potential to participate in neonatal medical treatment. There are detailed and precise medical protocols for neonatal medical treatment (Saraiva et al, 2022). The huge recorded data provide the learning samples for the intervention of artificial intelligence. By learning these data, AI is able to predict neonatal mortality and morbidity. In addition, AI can be used to record the treatment of neonatal patients by medical teams in real time and make analysis based on this record. However, the research on the application of AI in neonatal medical treatment is still in its infancy. The research on how AI is involved in the work of medical teams and how members interact with AI is innovative and worth discussing (Henry et al, 2022).

The above description indicate the problem that this research wants to emphasize and solve: *How can AI participate in the application of just safety culture to neonatal resuscitation*? Since just safety culture is a complex concept, this research only involves in part of it. Directly relevant points include how AI improves the efficiency of team communication, how AI leverages organizational learning, and how AI points out defects and prevents errors. From the perspective of the result, the ultimate object of this research is to explore *how AI can help improve the performance of the medical team*. Since neonatal resuscitation contains too many scenarios, this research just choose one study case. The study case of this research is from a teaching video from University of Nottingham about giving ventilation to newborn baby in danger (HELM, 2020). The concept of shared mental model and the method of adaptive network-oriented modelling are used to analyze how to solve the addressed problem and to reach the research object.

The innovation point of this research is that this research uses the research method of adaptive network-oriented modeling and the conception of organizational learning to explore in the scenario of a medical team giving ventilation to a newborn baby in danger, how the AI-coach can contribute in increasing team performance by helping the team form higher degree of shared mental model.

1.1 Research Question

To achieve the research object, a series of research questions are raised. The main research question is: *How to use an adaptive network-oriented modeling method to analysis the AI-coach's contribution in a medical team's ventilation operation to save baby in danger?*

The main research question is refined into 6 sub-questions presented at Table 1-1.

Table 1-1: An overview of sub-questions

1. How to use an adaptive network-oriented modeling method to simulate the team's perfect ventilation operation to save the baby in danger without introducing organizational learning?
2. How to use an adaptive network-oriented modeling method to simulate the team's perfect ventilation operation to save the baby in danger with introducing organizational learning?

3. The nurse has imperfect knowledge in preparing pure ventilation and that leads to failure of the first time of ventilation. After the doctor observes the failure, the doctor helps the nurse fix her mistake. That helps a successful next pure ventilation action. How to use an adaptive network-oriented modeling method to simulate this process?
4. In an extreme condition, all team members have imperfect knowledge in all preparations so that the ventilation action fails. How to use an adaptive network-oriented modeling method to simulate this process?
5. The nurse has imperfect knowledge in preparing pure ventilation and is about to fail the first time of ventilation. The AI-coach monitors that the nurse has imperfect knowledge and warns the nurse to avoid making mistakes. How to use an adaptive network-oriented modeling method to simulate this process?
6. The nurse has imperfect knowledge in preparing pure ventilation while the doctor has imperfect knowledge in preparing the combination of compression and ventilation. The AI-coach monitors that both team members have imperfect knowledge. The AI-coach obtains both members' right knowledge by feed forward learning and let team members get their missing knowledge by feedback learning. How to use an adaptive oriented modeling method to simulate this process?

Here introduce the chapters of the thesis. Chapter 1 is this introduction. Chapter 2-7 answer sub-question 1-6. Each chapter will present an adaptive network model, an introduction of states, and a discussion of simulation results. Chapter 8 will discuss all the situations comprehensively and draw a conclusion.

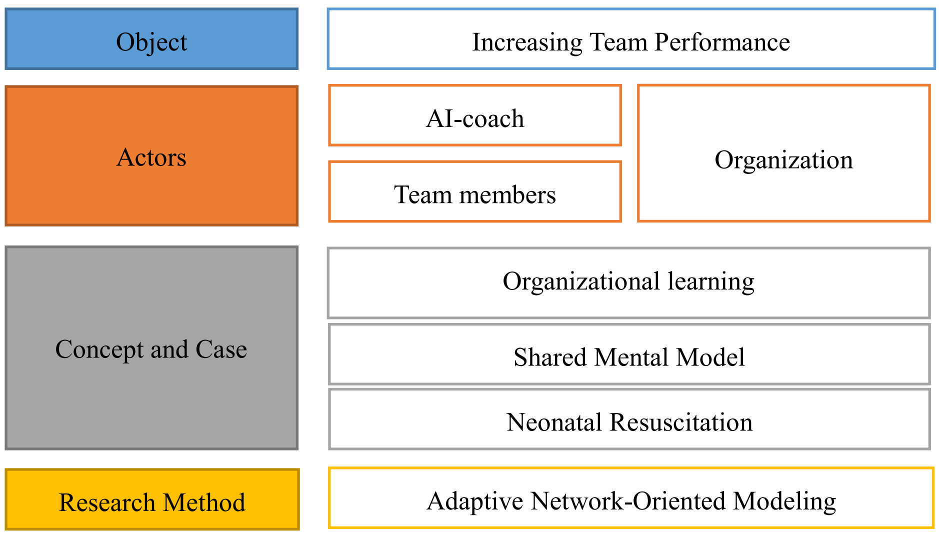


Fig1-1: Overview of object, involved actors, concept and case, and research method.

1.2 Research Method: Adaptive Network-Oriented Modeling

Network representations form a tool to conceptualize process with a 60 years history. Network-oriented modeling refers to modeling complex processes by networks. These processes include processes in reality and conceptual processes. That approach provides a powerful tool to present states and causal relations of these processes. By combining a temporal dimension and the principle of self-modeling, that approach shows not only dynamics of states, but also changes of connections over time. (Treur, 2016, 2020b). Networks nodes *X* has states value vary over time t and that values are represented by *X(t)*. Characteristics that define a network are *connectivity characteristics* $\boldsymbol{\omega_{X,Y}}$, *aggregation characteristics* $\boldsymbol{c_Y}$, and *timing characteristics* $\boldsymbol{\eta_Y}$. If state *Y* is influenced by state *X*, then there is a connections from state *X* to *Y*. And $\boldsymbol{\omega}_{X,Y}$ represents strength of this connection. When state *Y* is influenced by several states X_i, the aggregated impact of connections from these states X_i to *Y* is represented by a combination function $\mathbf{c}_Y$. There are multiple forms of combination functions, presented in (Treur, 2020). Each state *Y* has a speed factor $\boldsymbol{\eta}_Y$ specifying how fast *Y* changes. For the purpose of simulation, networks should be transform from graph form to numerical form:

$$impact_{X,Y}(t) = \omega_{X,Y}(X(t))$$

$$aggimpact_Y(t) = c_Y\left(impact_{X_1,Y}(t), \ldots, impact_{k,Y}(t)\right) = c_Y\left(\omega_{X_1,Y}X_1(t), \ldots, \omega_{X_kY}X_k(t)\right)$$

$$Y(t+\Delta t) = Y(t) + \eta_Y[aggimpact_Y(t) - Y(t)]\Delta t = Y(t) + \eta_Y[c_Y\left(\omega_{X_1,Y}X_1(t), \ldots, \omega_{X_kY}X_k(t)\right) - Y(t)]\Delta t$$

In software environment developed by Jan Treur, a computational network engine based on the third generic equations deal with the processing of all network states with their network characteristics. (Treur, 2020b). Relations within a mental model can be adaptive, thus, first-order adaptation called *plasticity* is applied to represent these adaptive relations. For instance, the first-order self-model **W**-state and **T**-state are applied to express the adaptive connection weight $\boldsymbol{\omega}_{X,Y}$ and the adaptive parameter of threshold value. The first-order adaptation can be controlled by second-order adaptation called *metaplasticity*. For instance, the resistance factor for the first-order self-model **W**-state of hebbian learning effects can be adaptive and be represented by the second-order self-model **M**-state. In addition, adaption speed of the first-order self-model T-state can be adaptive and be represented by the second-order self-model $\mathbf{H_T}$-state (Treur, 2016, 2020b).

1.3 Mental Model

A model is an imitation of a process and has a similar relational structure to that process (Craik, 1943). The key to this imitation is to imitate the target’s relational structure instead of other first-order properties like color and material. He gives two examples, one is tide-predicating machine designed by Lord Kelvin and the other one is the calculating machine. The former one imitates the causal relational structure of tides so that it can predict amplitude and variation of tides in different moments and places. The latter one imitates the relational structure of physical processes so that the calculating machine can help analysis of these process even if the calculating machine doesn't know any material changes in these process (Williams, 2018). The concept of model was applied to mental models by Craik in 1943. He points out that a mental model means the intelligence that imitates relation structures of external processes. Using a mental model, the intelligence gets the ability to predict the corresponding external process. In organisms, these representations and predictions are based on neural structures. These neural structures only imitate the (causal) relation structure of external process instead of material changes of external processes. (Craik, 1943). Shih and Alessi (1993) give another explanation of mental models. In their definition, mental models are a person's understanding of the environment. That understanding consists of a representation of different states and relations of these states. Maynard and Gilson (2014) addresses the importance of mental model in team performance. Team members rely on a mental model to understand and predict other team members' states and actions and to interact with other team members. A mental model enables the team member to form a mechanism to collect information, to predict, to understand, and to make decisions on actions to take (Gentner & Stevens, 2014).

Educational science regards mental model as an important carrier of learning. A popular term *model-based learning* refers to people learn by constructing coherent mental models representing and communicating feeling, thoughts, ideas and subjective experience of a person (Mayer, 1989). During learning, mental models' formation and adaptation can happen by accommodation or by assimilation. The former one means a mental model's revision while the latter one means a mental model's refinement or extension (Piaget, 1954). From the perspective of consequence, the previous mental model's relations of the former one don't apply anymore but of the latter one still apply. Observation learning and instructional learning are two important elements in mental model for learning. Observation learning happens when people observe others or themselves. 'Learning by doing' is a classic kind of observation learning. In addition, when learners observe their learning targets show some behaviors they want to learn, they will imitate these behaviors (Benbassat, 2014). Instructional learning happens when an expert provide supportive information including hints, questions, stories and more (Hogan, 1997). Learning of mental model can be controlled by metacognition. *Metacognition* refers to people's cognition of their own cognition process (Darling-Hammond, 2008). When different mental models involves in learning, metacognition enable switching between these mental models (van Ments, 2021b). Van Ments (2021b) presents a three-level cognitive architecture for mental models. The base level has mental models described by relations that can be applied to internal simulation. The internal simulation relates known facts to unknown facts and is common in prediction, reasoning and dreaming. The middle level reflects adaptation of mental models in the base level by revision, learning and other changes. The upper level has control of adaptation. Relations in the upper level represents changing relations of middle level. That three-level cognitive architecture will be applied in this research.

1.4 Shared Mental Models

A shared mental model has several definitions. Jonker et al state that a shared mental model is a knowledge structure of team members that makes them form precise explanations and expectations for a task, and makes them coordinate their movements to complete team tasks (Jonker et al., 2010). Maynard refers shared mental model to be the overlap or convergence among how members represent their team and task in their mental models. In another word, shared mental models represents the agreement among members. (Maynard & Gilson, 2014) A good shared mental model is necessary to a team's good performance, as it not only enable team members understand, explain, and predict team behaviors and but also enable team members understand how to corporate to complete a task according to some form of protocol. In another word, a good shared mental model contribute to a good team coordination which further contributed to good team performance (Burtscher et al., 2012). Since a team may hold multiple mental model states, there could be multiple shared mental model states at a specific time point. (Waller et al, 2004). The most important and most frequently cited research concentrates on shared mental models for teamwork and shared mental models for tasks. The former focuses on the relational structure of the team itself, while the latter focuses on the relational structure of the task. Shared mental models for teamwork means team members' agreement on how they will cooperate. For example, team members have a shared understanding of abilities and characteristics of people within the team and that enable the team to properly assign roles and responsibility. Shared mental models for teamwork enable team members to divide roles, to communicate, and to predict other's behaviors efficiently. That helps improve team performance. Shared mental models for tasks refers to the agreement among team members on the structure of the task. For example, team members have a shared understanding on sequence of how to complete a task and on how will external factors influence the task. Shared mental models for tasks help a team to well complete a task (Mathieu et al., 2005; Johnson et al 2008; McComb et al., 2014). The two kinds of shared mental models do not necessary occur at the same time. For example, in a new formed group, if each team member has a similar understanding of the task but is unfamiliar with the other team members, the shared mental model for teamwork is obviously weaker than the shared mental models for tasks. According to observation, in a new group where members are not familiar with each other, members tend to be more difficult to form a shared mental model on teamwork than on tasks. (Mathieu et al, 2000)

Similarity and *accuracy* are two important properties of the shared mental model. The former one reflects the extent of how team members' mental models are consistent with others (Mathieu et al., 2005). The latter one reflects the degree of how team members' mental models correctly resemble corresponding real world process (Edwards et al., 2006). A high degree of shared mental model enable team members to predict others' thinking and action. In a dynamic environment where plans always can't keep with changes, high degree of similarity is vital to a teams' tacit coordination (Rico, 2008). However, even if high degree of similarity enable a team's good coordination, that cannot guarantee the good performance. That's because, if every members has similar wrong mental model that cannot truly reflect real world process for their task, they might not complete their task well. That's why high degree of accuracy is required to achieve good team performance (Mathieu et al., 2005). Accuracy is always be measured by comparing with expert model. The expert model here refers to the model based on recorded experts' knowledge on the corresponding real world process for the task (Smith-Jentsch, 2005). A shared mental model can vary over time and that reflect *dynamics* of the shared mental model (McComb et al., 2014). The frequency of cooperation between team members in the past influences it. The distance between team members influences it as well. For example, there is evidence showing that working face to face leads to higher level of shared mental models than working in a virtual team via social media. In addition, communication affects shared mental models a lot and the level of the latter will rise with the more communication, and in turn helps the team complete tasks better (Haig et al, 2006). A shared mental model can be measured by approaches like Likert-type questionnaires, cognitive mapping techniques and pair-wise comparison ratings. All approaches quantify and compare the team members' cognition of the task (Gisick et al, 2018).

1.5 Organizational Learning

Organizational learning is defined as a change of organizational knowledge occurring as function of experience (Fiol et al., 1985). *Experience* is what happens when an organization performs a task. Experience can origin from success or failure. Experience is vary from being direct or being vicarious, from being novel or being old, and from being ambiguity or being heterogeneity (Schulz, 2002; Levitt&Marcg, 1988; Bohn, 1995; Haunschild&Sullivan, 2002; Sitkin, 1996). Experience can be measured by the number of times the task was executed. For instance, for a worker in a factory, his experience can be measured by the cumulated number of products he has produced. Similarly, for a doctor in hospital, his experience can be measured by the number of patient he have cured. By interacting with the context, experience can create knowledge. The context is made up with the environmental context and the organizational context. The environmental context consists of elements outside the organization including clients, competitors, regulators and institutions. The environmental context can vary along multiple dimensions including uncertainty, volatility, munificence and interconnectedness (Argote et al, 2011). Experience can be influenced by the context. For instance, for a factory, the number of clients will determine the number of product, and in turn influence how many products a worker produce. The organizational context consists of characteristics of the organization such as its culture, structure, memory, incentives, goals and more. The organizational context also include relations with other organizations. Knowledge will be created in the interaction between the experience and the context (Glynn,1994).

Knowledge is defined as justified personal belief. The knowledge can be expressed in multiple ways including dynamics of behaviors, routines and cognitions (Kogut&Zander, 1992). Knowledge can be divided into explicit knowledge and tactic knowledge. The former one refers to knowledge that can be expressed by words, sentences, documents and other explicit forms. The latter one refers to knowledge that exists in people' mind but is hard to articulate in explicit forms (Nonaka et al., 2009). Knowledge can also be divided into declarative knowledge (know what) and procedural knowledge (know how) (Edmondson, 2003). Knowledge can vary from different degree of causal ambiguity reflecting how consequences are related to causes. In addition, knowledge can vary from degree of demonstrability reflecting difficulty of expressing its correctness (Kane, 2010; Szulanski, 1996;). Organizational learning usually generate from a change in individual knowledge doesn't mean a change in individual knowledge is equal to organizational learning. Organizational learning only occurs when the change of individual knowledge is embedded into organizational knowledge and is available for other people within the organization to access. Knowledge reservoirs or repositories for such embedding consists of interactive memory system, social networks, tools, and routines (Walsh and Ungson, 1991; Argote and Ingram, 2000). Creating, retaining and transferring knowledge can be considered to be three sub-process of organizational learning. Knowledge creation means new knowledge is created when organizations learn from individual experience. New knowledge will be retained within organizational reservoirs or repositories mentioned above and that enable these knowledge to cumulate and persist over time. One person's knowledge can be transferred to other people in the same organization. Relational and cognitive, motivational and emotional factors all influence knowledge transfer efficiency (Osterloh&Frey, 2000; Levin et al., 2010; Darr, 1995). These three sub-process shows how organizational learning works.

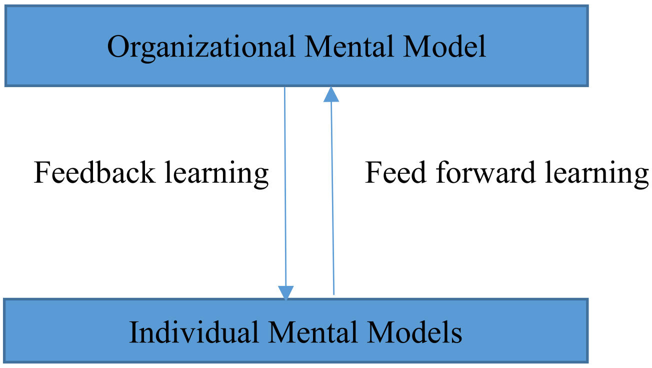


Fig 1-2: Mechanisms for Organizational Learning

Currently, research on computational formalization of organizational learning is rare (Canbaloğlu et al, 2022). Kim (1993) mentioned the following mechanisms of organizational learning:

(1) Individuals generate their mental model.
(2) The organization obtains knowledge from individuals, and
(3) The organization processing this knowledge and form an organizational mental model.
(4) The individuals update their knowledge by feedback learning from organizations.

This mechanism is useful for computational analysis of organizational learning.

1.6 Application Scenarios and Case Study

Neonatal resuscitation is an interesting application for this research. Newborn babies are sometimes born in a dangerous state. When they are purple, floppy, not breathing and with slow heart rate, they are in dangerous situation. It's critical that the team that should save the baby doesn't make mistakes. That's because the medical team's mistakes prolong the time the baby is in danger, which can even cost it its life. In a medical team, efficient communication prevents, detects and corrects errors in a timely manner. However, sometimes due to inefficient communication, medical staff makes mistakes and they don't know it. For example, some missing knowledge in preparations prevents them from successfully performing ventilating. For instance, sometimes, because of ineffective communication, their lack of knowledge about ventilation operations was not made up for in the preparation phase, and their ventilation operations failed. The failed operation prevents the baby from getting out of danger as soon as possible.

A teaching video from University of Nottingham about giving ventilation to newborn baby in danger provide a case of the application scenario. In this teaching video, the medical team operates two times of pure ventilation and one time of the combination of compression and ventilation and finally save the baby. This process will be abstracted to build adaptive network models. Based on these network models we will explore other situations, such as a medical team making mistakes, and an AI (Safety) coach intervening (HELM, 2020). In the protocol provided by this teaching video, the doctor (D) and the nurse (N) provide emergency ventilation for a newborn baby in danger. The baby (B) is born to be blue, floppy, not breathing, and with a very slow heart rate. If the ventilation successfully save baby from danger, the baby (B) will be pink, not floppy, breathing, and with a normal heart rate. In the team, the doctor (D) and the nurse (N) have different roles, each with their own tasks. The roles of doctor (D) are: leading the team, preparing ventilation, operating ventilation, evaluating baby's condition and ventilation, and solving problems during ventilation. The roles of the nurse (N) are: assisting the doctor (D), preparing ventilation, operating ventilation, observing and report baby's states. They will communicate about tasks that require co-operation, and they will also observe individual tasks. These communications and observations help form a shared mental model.

In this case, there are total 3 times of ventilation operations, including 2 times of pure ventilation and 1 time of combination of compression and ventilation. Here is an introduction of sequence of protocol without organizational learning:

1. The nurse (N) prepares the baby on operating table.
2. The team prepares for pure ventilation.
3. The nurse (N) gives the first time of pure ventilation.
4. The nurse (N) helps assess the baby. The doctor reports the baby's condition. The team decide to give a combination of compression and ventilation.

5. The team prepare for the combination of compression and ventilation.
6. The team give the combination of compression and ventilation.
7. The nurse (N) helps assess the baby. The doctor (D) reports the baby's condition. The team decide to give the second time of pure ventilation.
8. The nurse (N) gives the second time of pure ventilation.
9. The nurse (N) helps assess the baby and the doctor (D) reports the baby is out of danger.

Proper operation of ventilation requires good preparation. That means in mental models, a connection from preparation to action of ventilation is important and worthy to research. Hebbian learning, learning from instruction and organizational learning all can be introduced to these connections. In addition, these connections can help express mistakes of team members and can provide application scenarios for the AI-coach's intervention.

1.7 Managerial and Societal Relevance

This research has a strong managerial meaning. For starters, a good shared mental models will contribute to a good team coordination, and that in turn contribute to good team performance. This research analyzes a medical team's shared mental model and explores how AI-coach can help the team form better shared mental model and in turn promote the team's performance. In management, how to help players cooperate better to improve team performance is so important. Thus, this research's exploration of shared mental models and the use of AI technology to improve shared mental models provides a valuable research idea for team management. Future research can also analysis how to manage a team better from the perspective of promoting shared mental model. In addition, organizational learning reflects knowledge creating, retaining, and transferring within an organization. The good use of organizational learning capabilities helps to quickly transfer experience and knowledge from the individual success and failure within the team to other team members. This helps improve the adaptability and rate of progress of the team. This research explore how organizational learning can promote a good shared mental model by promoting correct knowledge transferring and in turn contribute to the team's good performance. This provide a good managerial research direction and is very meaningful to these organization suffering deeply from blame culture. Besides, this research consider the technology of AI to be a resource to promote a medical team's shared mental model. The technology of AI can be applied to other teams as well. This research provide a good template for future extension of using AI assisting team management. Last but not least, this research use computational method to analysis shared mental model. That method can also be applied to quantitative and visual analysis of other managerial concept.

This research has a strong societal relevance as well. For starters, this research explore implement of just safety culture in neonatal resuscitation. That contributes to reducing possibility of harm occurs on newborn babies and in turn helps reduce grieving families and contributes to social stability. In addition, the research on implement of just safety culture can be extent to more areas and reducing workers' psychological pressure because of fear of speaking up. That enable honest and hardworking people survive better in organizations. On a societal level, this contributes to a culture of honesty and motivation. Besides, the adaptive oriented network modeling is a useful research method to analysis social process. This research can extent to analysis larger social phenomenon.

2. Adaptive Network Model for the Protocol Condition without Organizational Learning

The protocol condition means that the team gives the baby ventilation according to the protocol followed and makes no mistake. The baby finally recovers successfully.

The processes following the protocol condition are described by a second-order adaptive network model using the generic three-level cognitive architecture described in (Van Ments and Treur, 2021; Treur and Van Ments, 2022). The processes are modeled as a series of world states, actions and members that perform those actions.

2.1 Base Level Overview:

Figure 1-1 shows the layout of the base level states. On base plane of the network, address from top to bottom, context states prefixed with 'Con', the nurse's mental model states prefixed with 'NS', the nurse's action ownership states prefixed with 'NOS', the world states prefixed with 'WS', the doctor's action ownership states prefixed with 'DOS', the doctor's mental model states prefixed with 'DS', and the baby's condition states prefixed with 'BS'.

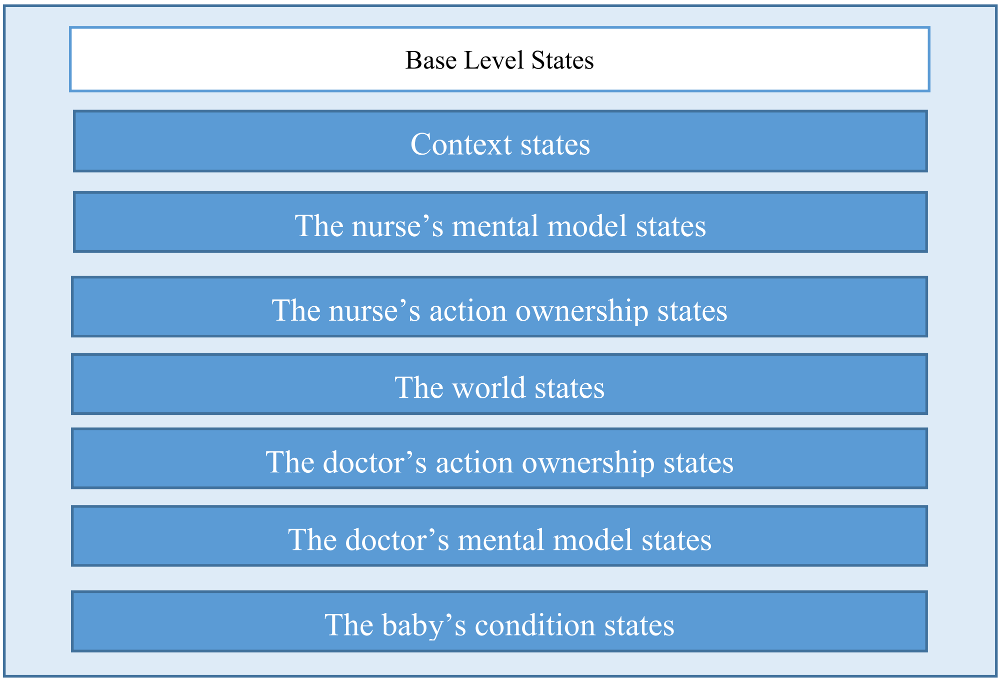


Figure 2-1 : Base Level States Distribution

The world states express the steps that take place in the world's reality for the followed protocol condition. The world states consist of light blue nodes and their connections in the middle part of the base plane. The shared mental model concerns individual models for the nurse and the doctor. The nurse's mental model consists of light green nodes and their connections, while the doctor's mental model consists of light-yellow nodes and their connections. Individual mental models reflect modeling of a real application scenario taking into account individual minds. The shared mental model reflects the team's consensus of mental modeling the real application scenario. Mental models specify who does what and in what order. In the followed the protocol condition, both the nurse and the doctor have a perfect mental model.

The application scenario consists of 14 steps, and each step has a corresponding mental model state for both team members and a corresponding world state. These 14 steps can be classified into 3 ventilation actions. Each ventilation action can be divided into preparations, giving ventilation to the baby, and assessing the baby after ventilation. These 3 ventilation actions are presented at Figure 1-2, while these 14 steps are explained in Table 1-1.

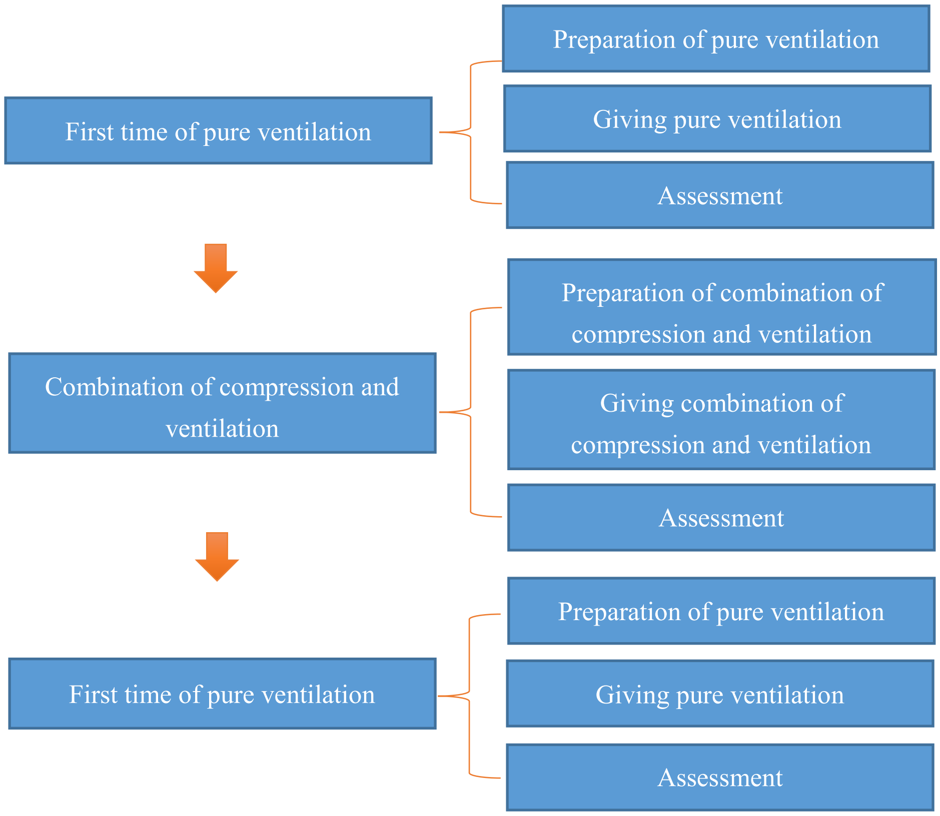
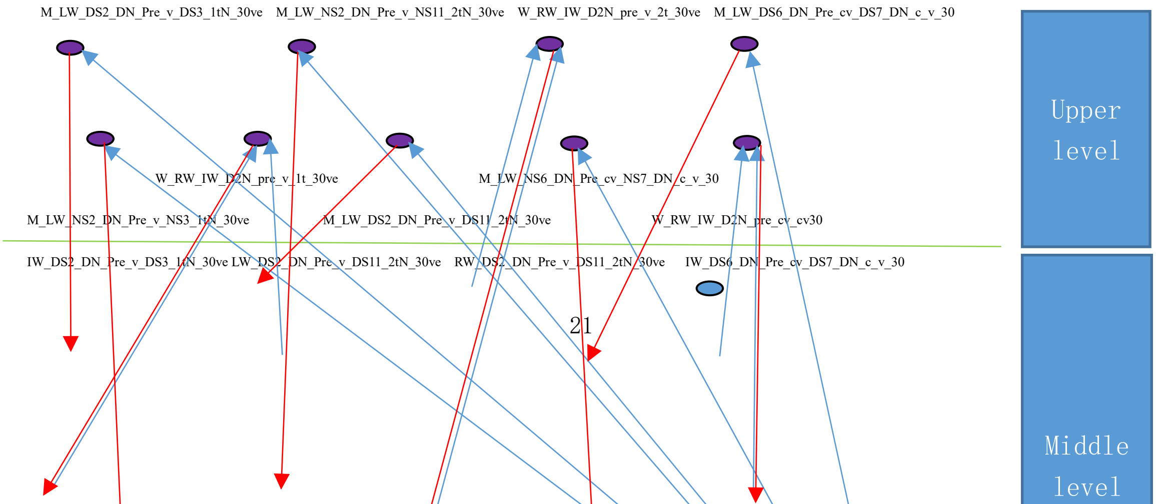


Figure 2-2: Sequence of Three times of Ventilation

Above the nurse's mental model are the context states, which for now only represents a contextual stress factor. This context state is expressed by a dark node. Under the doctor's mental model states are the baby's condition states that indicates whether the baby is out of danger. The baby's condition states are expressed by light pink nodes. Note these light pink nodes are surrounded by a big dark pink oval. When there are connections to the big dark pink oval that means connected to all light pink nodes. The doctor and the nurse both have actions in world. The nurse's action ownership states



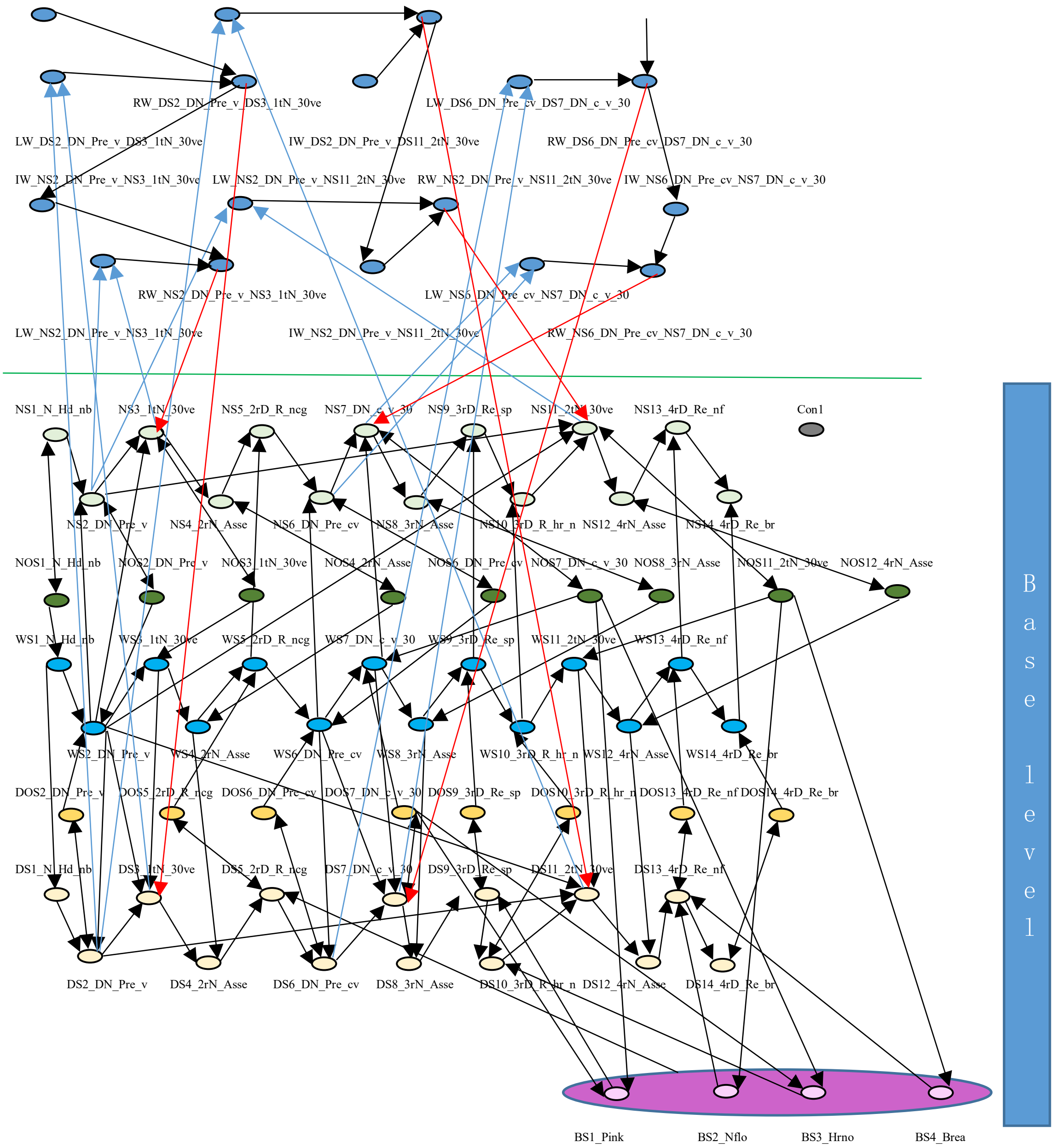


Fig 2-3: The Network Model of the Protocol Condition without Organizational Learning

are indicated by dark green nodes while the doctor's action ownership states are indicated by dark yellow nodes. An overview of base level states is presented in Table 1-1. In Table 1-1, the state prefix indicates the type of state. The state name marks the steps that make up the application scenario. The state names contain information of 'who does what' and 'on which time or round'. The explanation describes the content of these steps.

Within mental models, mental states are connected indicating the order in which the corresponding world states are to occur in the application scenario in the real world. For example, mental model states of giving ventilations are positively influenced by incoming connections from mental model states of preparation of ventilations; e.g., *NS11_2tN_30ve* has an incoming connection from *NS2_ DN_Pre_v*. That means, if the nurse doesn't activate well the preparation state for pure ventilation in her mental model, she will not successfully activate the mental model state of giving the second time of ventilation. In addition, mental model states are also influenced by observations. When one team member influences the world states, the other member(s) will adjust his/her mental model states according to the effects of observation in the real world of events involving change of world states and the baby's condition states.

Action ownership states are mental states but not mental model states themselves. Instead, they are the mediators through which mental model states influence world states. These mediators get input from mental model states and then become input of world states. This process expresses how the nurse's and the doctor's mental model determines execution of actions, then these actions change the real world. In addition, actions will give feedback information to the mental model states; this is expressed by mental model states that are influenced by incoming connections from corresponding action ownership states.

World states are connected according to the sequence in reality. In addition, to model the influence from actions, world states have connections from action ownership states. Besides, preparation of ventilations in real world will influence team members' mental model states of giving ventilation as well.

The baby's condition is influenced by actions of ventilations. The team's assessments also relies on observing the baby's condition. As a result, in the network model, the action ownerships states of three ventilations have connections towards the relevant baby's condition states. And the baby's condition states have connections toward the doctor's reporting mental model states.

2.2 Middle Level Overview:

The middle level consists of states that represent the adaptation of mental models. This is accomplished through the principle of (first-order) self-modeling applied to connection weights of mental models. For example, a connection weight $\boldsymbol{\omega}_{X,Y}$ from a state for preparation of ventilation to a state for giving ventilations is represented by a (first-order) self-model state $\mathbf{W}_{X,Y}$. These self-model states highlight a mental model's learning process, which can be an integration of instructional learning based on communication and internal hebbian learning (Stierlin, H., 1953). The states for instructional learning are prefixed by **IW**, the states for internal hebbian learning are prefixed by **LW**, and their integrated learning states are prefixed by **RW**. For the nurse, **IW**-states have an incoming connection from the doctor's **RW**-states. This represents that the nurse is learning from doctor's instructional communication. For the doctor, **IW**-states are with stable values assumed to have been obtained by instructional learning in the past. For hebbian learning, a persistence factor μ represents the fraction that persists each time unit. For example, $\mu = 0.95$ means that 5 percent of a learnt value is forgotten each time unit. The persistence factor μ can be adapted as well, as will be discussed for the upper level. For both team members, all their **LW**-states have second-order adaptive persistence factors which are influenced by the context state in the base level. From these learning states, the **RW**-states have downward connections to base level states to effectuate their role as representing connection weights. An overview of the states in the middle level is presented at Table 1-2.

2.3 Upper Level Overview:

States in the upper level control the adaptation of mental models. Within neuroscience, such control (over plasticity) is also called metaplasticity. In the upper level, second-order self-model **M**-states represent the persistence factors μ of the hebbian learning states (**LW**-states). These **M**-states have an upward connection from the context state representing the stress level. This means that the persistence factors μ of the hebbian learning states (**LW**-states) in middle level are context-sensitive: they depend on the circumstances. In this application scenario, a highly stressful context is assumed to bring damage to learning efficiency: learnt effects are easily forgotten. That means, the value of the context state determines the values of the **M**-states.

In the middle level, it is also adaptive how the total learning effect of the doctor transfer into the nurse's instructional learning effect. More specifically, the weights of the connections from the doctor's **RW**-states to the nurse's **IW**-states all are represented by second-order self-model states in the upper level. They all have a hebbian learning effect too. That means, knowledge is impaired as it is delivered from doctor to nurse. The scale of impairing is controlled by the persistence factor μ of $\mathbf{W}_{\mathbf{RW,IW}}$-states in the upper level. An overview of the upper level states is presented at Table 3-3.

The combination functions used in this network model are presented in Table 3-4.

2.4 Simulation for the Example Scenario

The protocol condition for ventilation means that the team should make no mistake and the baby is out of danger after a series of ventilation. If the second-order adaptive network model is valid, the simulation should yield some expected results. These are some criteria for validity:

- For starters, in mental models all steps are supposed to happen in sequence. That should be reflected in the simulation results, from WS1 to WS14, from NS1 to NS14, and from DS1 to DS14, the states should be activated in the order of numbers from 1 to 14.
- In addition, each team member first determines in the mental model the action he/she is going to do, then he/she will do this action in reality, and finally this action will affect the real world. That means, in simulation, states with the

same state name, are first activated in the mental model of the person doing the action, then the action ownership state is activated, and finally the world state is activated. For example, for the step of nurse holds the new born baby on the table and prepares for intubation, *NS1_N_Hd_nb* activates first, then *NOS1_ N_Hd_nb* activates, and finally *WS1_ N_Hd_nb* activates. Besides, some steps are jointly performed by the doctor and the nurse. That means, action ownership states of these steps should activate at the same time. For example, for the step that doctor and nurse together prepare for pure ventilation, *NOS2_ DN_Pre_v* and *DOS2_ DN_Pre_v* should activate at the same time.

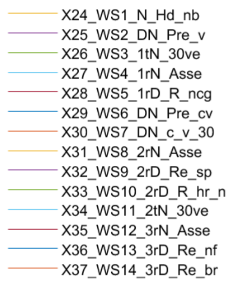
For convenience of inputting data to the software environment for simulation, a standard table format called role matrices was introduced in (Treur, 2020) to express the network characteristics of a network model like the one described above. The example simulation presented here was run from 0 to 50 seconds with stepsize Δt = 0.5. The contextual stress level was set relatively low, so that the context state has a value of 0.95, and that will lead **M**-states has a value no more than 0.95. For clear analysis, the results happen in the same simulation at the indicated time points have split into the graph of the world states, the baby states, and the context state, the graph of the nurse's states, and the graph of the adaptive states.

Here the research sets that when the value of a state is greater than 0.8, the state is activated well.

2.4.1 The world states, the baby states, and the context state

Fig 2-4 presents the process of application scenarios in the real world. The solid lines, the dashed lines, and the dashed and dotted line reflect value of the world states, baby states and the context state over time, respectively.

In such graphs, time is expressed using an abstract time unit. Around t = 2, the world state for the nurse's holding of the newborn baby on the table is activated, and that



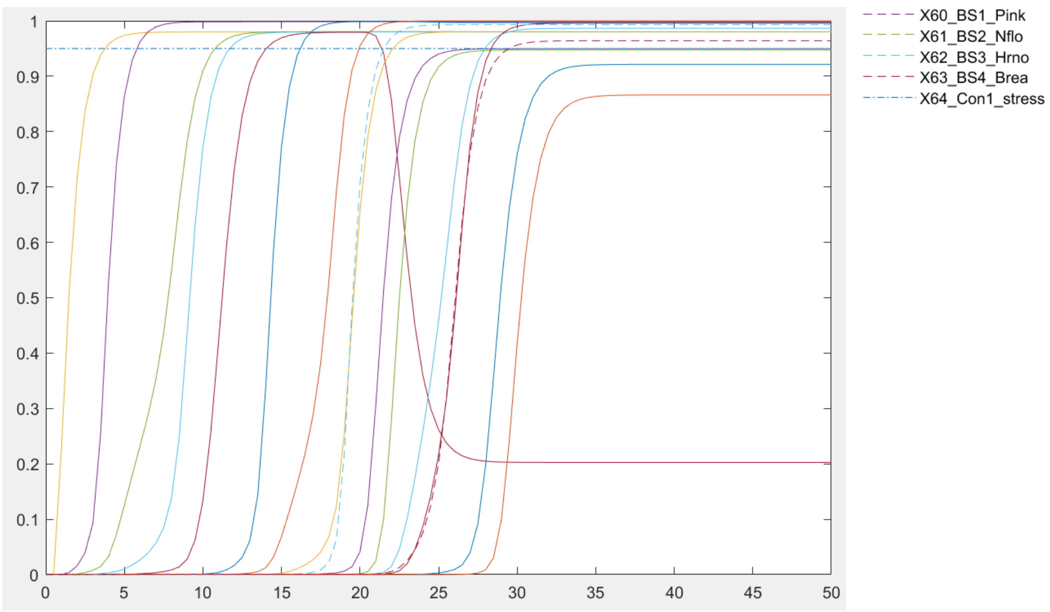


Fig 2-4: Simulation result of world states, baby states, the context state

marks the beginning of the ventilations. Around t = 5, the world state for the team's preparation for pure ventilation gets activated. Then, the world state for the nurse giving the first time of pure ventilation is active at around t = 9. That follows with the activation of the world state for the nurse helping the baby at around t = 10. The baby has no reaction at all and that activates the world state for the doctor reporting that the baby has no change at around t = 12. This means that the team needs to adjust the treatment method, thus the world state for the team preparing for the combination of compression and ventilation gets active at around t = 15. Later, the world state of team's giving that ventilation gets active at around t = 19. After that, the world state of the nurse's helping assess the baby for second round reach activated at around t = 21. Since the states for the baby is slightly pink and has normal heart rate get activated at around t = 20, the world states for doctor reporting that the baby is pink and with normal heart rate are active at around t = 23 and at around t = 24, respectively. When the baby changes, the doctor stops the judgment that the baby doesn't change, so that the world state for the doctor reporting the baby has no change is not active anymore at around t = 23. Since the baby doesn't fully recover, the team decides to perform a second pure ventilation. Since they already finish preparation of pure ventilation at around t = 5, the world state for the team directly giving the second pure ventilation reach activated at around t = 26. The second time of pure ventilation completely drags the baby out of danger as the states of the baby is not floppy anymore and of start breathing get activated around t = 27. So, after the world state for the nurse helping assess the baby for the third round is active at around t = 27, the world states for the doctor reporting the baby is not floppy and starts breathing get activated at t = 30 and t = 32, respectively.

Fig 2-4 proves validity of the network model. For starters, in this graph, the world states activate in a sequence from WS1 to WS14. That means steps in real world happens in right sequence. In addition, *X60_BS1_Pink* and *X62_BS3_Hrno* rise simultaneously right after the rise of *X30_WS7_DN_c_v_30*. That means 30 seconds of the combination of compression are partially effective because the baby is pink and with normal heart rate after operation. In the same way, the simultaneous rise of *X61_BS2_Nflo* and *X63_BS3_Brea* right after the rise of *X34_WS11_2tN_30ve* means second time of pure ventilation make the baby completely out of danger as the baby is not floppy anymore and start breathing. In summary, steps in correct sequence and the baby is completely out of danger after ventilations confirm the validity of the network model design.

2.4.2 The Doctor's Mental Processes Based on His Mental Model

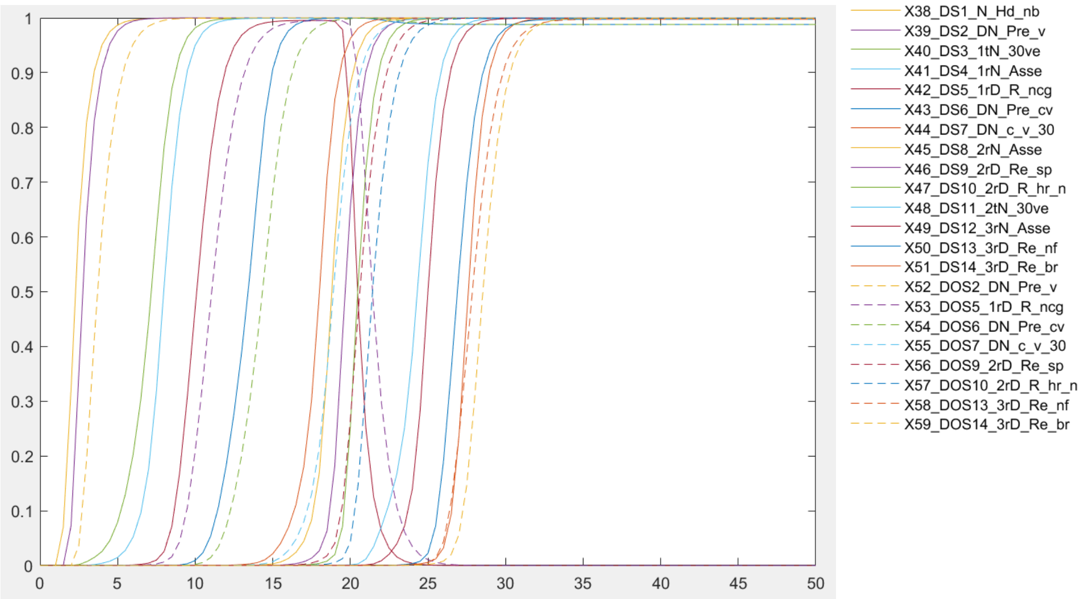


Fig3-5: Doctor Mental Model and Action Ownership States

Fig 2-5 shows simulation results of the doctor's the mental model and action ownership states. Solid lines and dashed lines refer to values of the doctor's mental model and the doctor's action ownership states over time, respectively. Around $t = 3.5$, after the doctor observing the nurse hold the new born baby who need ventilation on the table, his first mental model state get activated. Immediately after, the doctor know the team should prepare pure ventilation for the baby, so the doctor's mental model state and its corresponding action ownership state for the team preparing pure ventilation are active at around $t = 4$s and $t = 5$s, respectively. That means the doctor complete preparing pure ventilation in real world. Right after, with his own knowledge and observation of the nurse's action in reality, the doctor's mental model state for nurse's first time of giving pure ventilation and the first round of assessment are active at around $t = 8$s and $t = 9$s, respectively. After starting the assessment and observing no changes in the baby, the doctor's mental model state and its corresponding action ownership state for reporting the baby has no change get activated at around $t = 11$ and $t = 12$, respectively.

The doctor knows the baby needs more treatments, so the activation of the doctor's mental model state and its corresponding action ownership state for the team's preparation of the combination of compression and ventilation happens at around t = 14.5 and t = 15.5. After well preparation, the doctor is able to successfully give the combination of compression and ventilation for 30 seconds. Thus, the doctor's mental model state and action ownership state for that action are active at around t = 19 and t = 20. Before giving ventilation, the doctor expects the nurse to help assess the baby after the ventilation finish, so the doctor's mental model state for the nurse helping assess for second round get activated at around t =19.5s. The ventilation works well this time because baby is pink and with normal heart rate. By observing that, the doctor's mental model states and their corresponding action ownership states first for he reporting the baby is pink and then for reporting the baby has normal heart rate become activated at around t = 20.5, t = 21.5 (for reporting the baby is pink), t = 21 and t = 22 (for reporting normal heart rate). At the same time, the doctor's mental model state for reporting the baby has no change is not active anymore at around t = 23. Seeing the baby partially recovers, the doctor decides to give the baby more treatment and assess the baby again. Thus, the doctor's mental model state for nursing giving second time of pure ventilation and helping assess the baby's condition get active at around t = 25 and t =25.5. After second time of pure ventilation, the baby is not floppy anymore and start breathing. By observing that, the doctor's mental model states and their corresponding action ownership states first for he reporting the baby is not floppy and then for reporting the baby start breathing become activated at around t = 28, t = 29 (for reporting the baby is not floppy), t = 28.5 and t = 29.5 (for reporting the baby start breathing).

Fig 2-5 confirms validity of the network model design as well. The doctor's mental model states happen according to right sequence of steps. All the doctor's action ownership states get activated right after activation of their corresponding mental model states. That means, the doctor follows the protocol and cooperates with the nurse to successfully save the baby.

2.4.3 The Nurse's Mental Processes Based on Her Mental Model

Fig 2-6 shows activation levels of the nurse's the mental model and action ownership states. Solid lines and dashed lines refer to values of the nurse's mental model states and the action ownership states over time, respectively. The nurse's first mental model state for holding the new born baby on the table keeps a high value all the time. And that makes its corresponding action ownership state gets activate at around t = 1. Right after, the nurse's mental model state for the team preparing first time of pure ventilation gets activated at around t = 4 and t = 5. After preparation, the nurse gets available to complete the first time of pure ventilation. Thus, the nurse's mental model state and corresponding action ownership state for giving first time of pure ventilation reach activation at t = 8 and t = 9.5, respectively. After ventilation, the team needs to assess the baby so that the nurse's mental model state and its corresponding action ownership state for helping assess the baby is active at around t = 9 and t = 10. Right after observing the doctor reports the baby has no change, the nurse's mental model state for that gets activated at around t = 14.

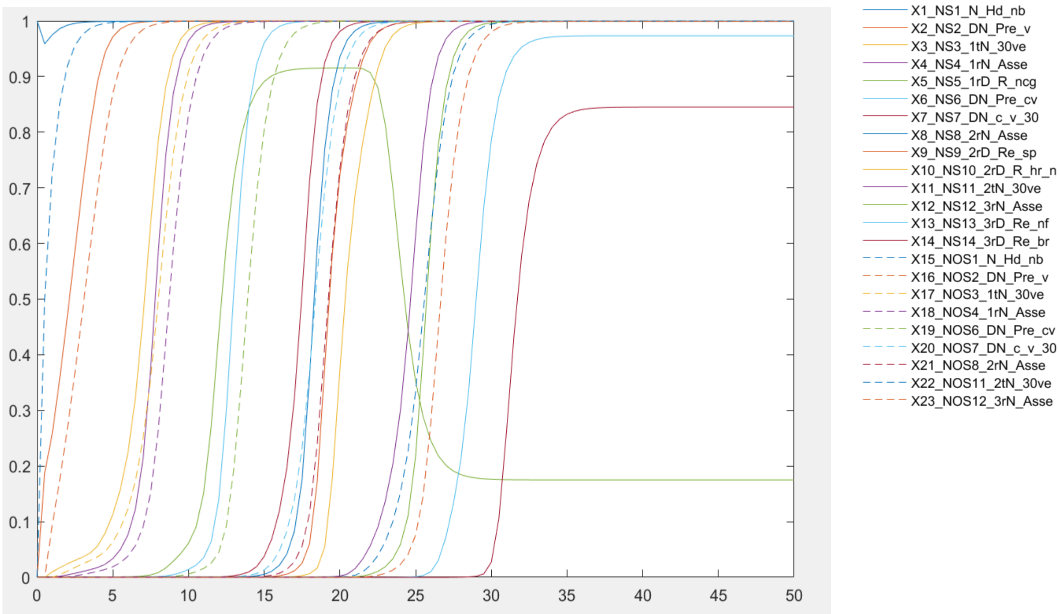


Fig 2-6: Nurse Mental Model and Action Ownership States

After knowing further treatment to the baby is needed, the nurse's mental model state and its corresponding action ownership state for the team preparing for the combination of compression and ventilation get activated at around $t = 14.5$ and $t = 15.5$. Right after, the nurse's mental model state and its corresponding action ownership state for giving that ventilation reach activation at around $t = 18$ and $t = 19$. Giving ventilation is followed by assessment, so the nurse's mental model state and its corresponding action ownership state for helping the second round of assessment get activated at around $t = 18.5$ and $t = 20$. After listening to the doctor's report, the nurse's mental model state for the doctor reporting the baby becomes pink and has normal heart rate become activated at around $t = 20$ and $t = 22$, respectively. The doctor knows further treatment is needed because the baby only partially recovered. Thus, the nurse's mental model state and its corresponding action ownership state for giving a second time of pure ventilation get activated at around $t = 25$ and $t = 26$, respectively. Right after that, a third round of assessment starts. The nurse's mental model state and its corresponding action ownership state for helping assess the baby gets activated at around $t = 26$ and $t = 27$, respectively. After that and observing the doctor's report, the nurse's mental model for the doctor reporting the baby is not floppy and starts breathing reach activation at around $t = 30$ and $t = 34$.

Fig 2-6 further demonstrates the validity of the designed network model. The nurse's mental model states happen according to right sequence of steps. All her action ownership states get activated right after activation of their corresponding mental model states. That means, the nurse follows the protocol and cooperates with the doctor to successfully save the baby.

2.4.4 Adaptation States

Fig 2-7 shows activation levels of the self-model states. In the team members' mental models, weights of the connections from the mental model state for preparation of ventilation to the mental model state for giving ventilations are adaptive. These connections are in particular: connections from preparation of pure ventilation to giving first time of pure ventilation for 30 seconds, connections from preparation of pure ventilation to giving second time of pure ventilation for 30 seconds, and connections from preparation of the combination of compression and ventilation to giving the combination of compression and ventilation for 30 seconds.

These first-order self-model states are classified into instructional learning states (**IW**-states), internal self-learning states (**LW**-states), and integrated learning (**RW**-states). All **LW**-states represent hebbian learning. Their persistence factor **μ** are adaptive according to the stress context as well. That are second-order self-model **M**-states in the upper level. The doctor's total learning has influence on the nurse's instructional learning, by the communication connections between them which are adaptive as well: their weights are represented by the $\mathbf{W_{RW\text{-}IW}}$-states in the upper level.

In Fig 2-7, the doctor always knows how he should instruct the nurse: the **IW**-states of the doctor are at a high level all the time. Since the value for the context state is stable at 0.95 all the time and that represents a low context stress, all **M**-states get activated at around $t = 2$.

For connections from the team preparing pure ventilation to the nurse giving the first time of pure ventilation, **LW**-states of the nurse and the doctor both get activated at around $t = 9$, the **RW**-state of the doctor is active at around $t = 9$ as well. It takes some time for the doctor delivers his/her knowledge to the nurse. So, the $\mathbf{W_{RW\text{-}IW}}$ –state for that ventilation get activated at around $t = 15$. Right after, **IW**-state of the nurse reach activation at around $t = 17$. For connections from the team preparing pure ventilation to the nurse giving second time of pure ventilation, **LW**-states and **RW**-states of the nurse and the doctor, all get activated at around $t = 27$. Then, the $\mathbf{W_{RW\text{-}IW}}$ –state for that ventilation get activated at around $t = 34$. Right after, the **IW**-state of the nurse reach activation at around $t = 36$. For connections from the team preparing the combination of compression and ventilation to the nurse giving the combination of compression and ventilation, **LW**-states and **RW**-states of the nurse and the doctor, all reach activation at around $t = 19$. Then, the $\mathbf{W_{RW\text{-}IW}}$ –state for that ventilation get activated at around $t = 28$. Right after, **IW**-state of the nurse reach activation at around $t = 29$. Since the nurse has perfect knowledge for preparing and giving ventilation herself, she is well prepared before the doctor gives instruction, thus her **RW**-states always get activated the same time as their corresponding **LW**-states.

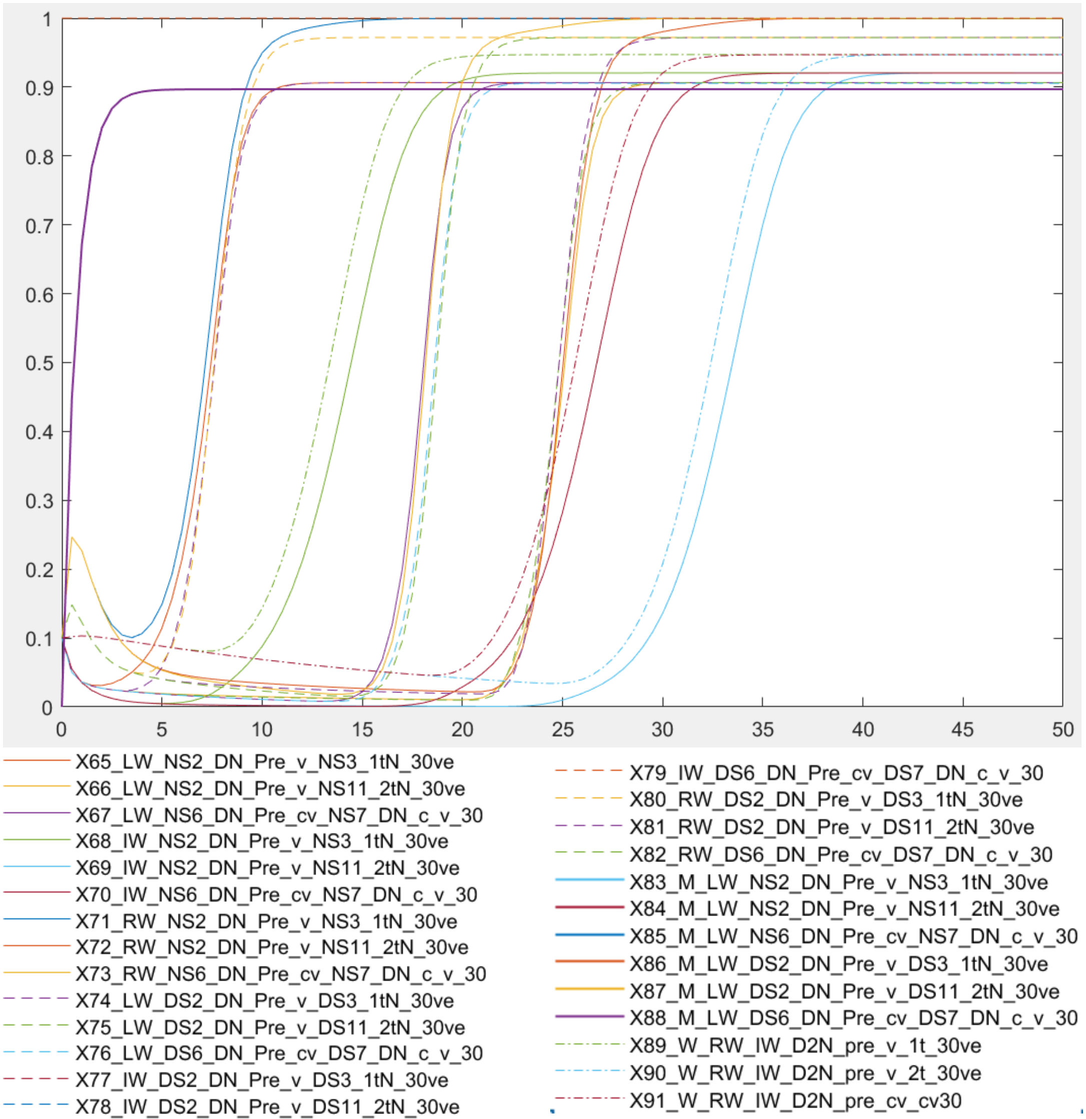


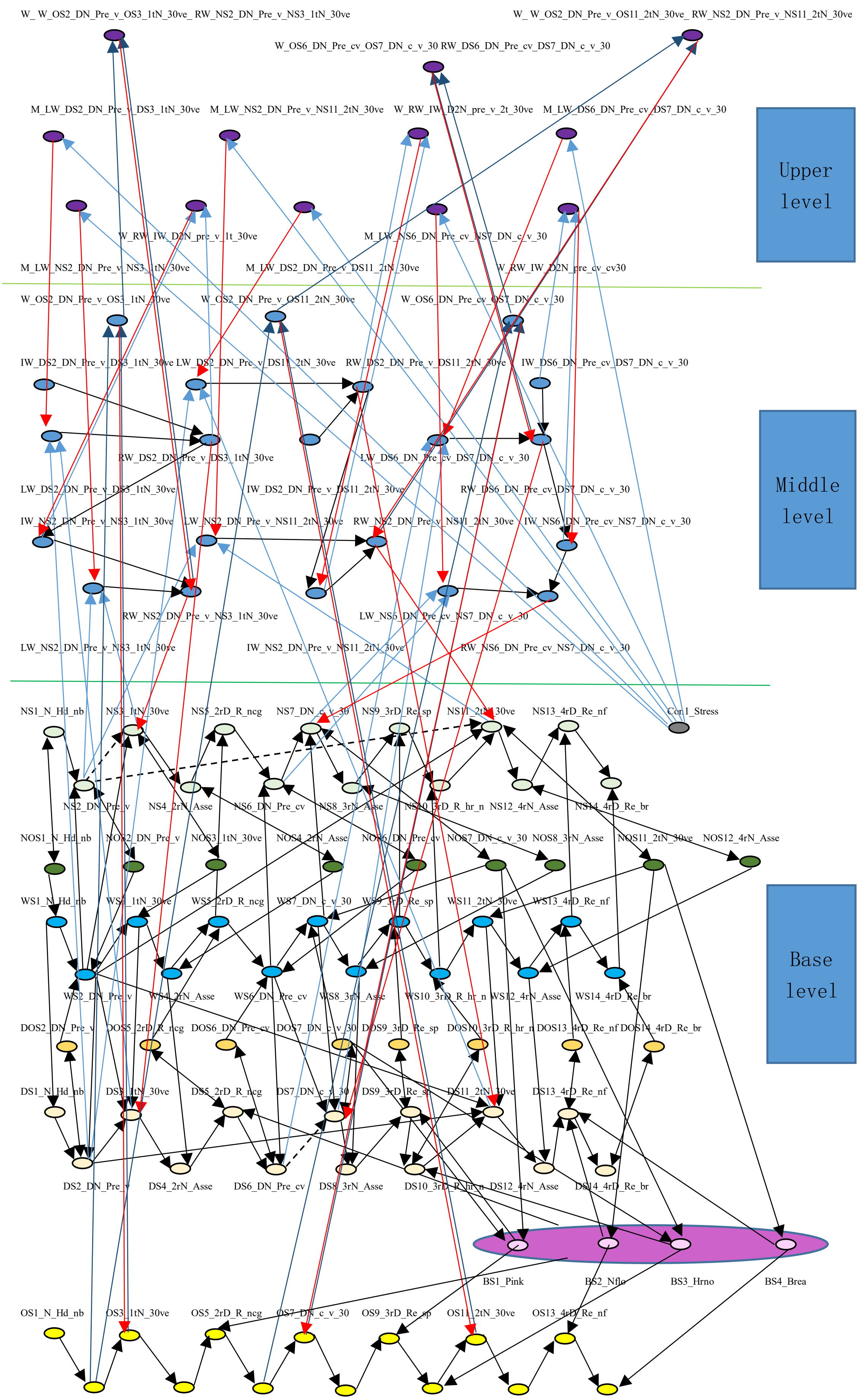
Fig 2-7: Simulation results of adaptation states

3. Adaptive Network Model for the Protocol Condition with Organizational Learning

3.1 Network Model introduction

This network model adds organizational learning to the network model in the previous chapter. In the initial situation of this network model, there is no connection from the nurse's mental model state for preparing pure ventilation to the nurse's mental model state for 2 times of the nurse giving 30 seconds of pure ventilation in the nurse's mental model. In addition, within the doctor's mental model there is no connection from the doctor's mental model state for the team preparing the combination of compression and ventilation to the team giving 30 seconds of the combination of compression and ventilation. That means, both team members lack knowledge and have some missing connections in their mental model. Luckily, both team members are able to get perfect knowledge from the organization. The organization here can be considered to be a perfect knowledge database perhaps acquired in the past from all members of the organization. After the team learns from the organization, the missing connections are build. New states in base level are located at the bottom of the base level. New states in middle level and upper level are located at the top of the middle level and the upper level, respectively. These new states are introduced in Table 4-1 and Table 4-2.

Table 4-1 and Table 4-2 show new added base level states and self-model states for adaptation, respectively. In the base level, 14 organizational mental model states are added. They and their connections form an organizational mental model. The organizational mental model is a perfect mental model for saving the baby. So, team members gain their missing knowledge to develop their own perfect mental model through organizational learning. In the organizational mental model, weights of the connections from preparation of ventilation to giving ventilation are represented by first-order self-model **W**-states. These states have connections toward all team members' first-order self-model states for weights of the connections from preparation to giving ventilation. This lets the latter go from 0 to a high value. That means the organization can help the team repair missing knowledge. This is modeled by first-order connections between the organization and individual W-states. The weights of these connections in the middle plane are also adaptive. Thus, in upper level, second-order self-model states are included to express these adaptive connection weights.



W_ W_OS2_DN_Pre_v_OS3_1tN_30ve_ RW_NS2_DN_Pre_v_NS3_1tN_30ve
W_ W_OS2_DN_Pre_v_OS11_2tN_30ve_ RW_NS2_DN_Pre_v_NS11_2tN_30ve
W_OS6_DN_Pre_cv_OS7_DN_c_v_30 RW_DS6_DN_Pre_cv_DS7_DN_c_v_30
M_LW_DS2_DN_Pre_v_DS3_1tN_30ve
M_LW_NS2_DN_Pre_v_NS11_2tN_30ve
W_RW_IW_D2N_pre_v_2t_30ve
M_LW_DS6_DN_Pre_cv_DS7_DN_c_v_30
Upper level
W_RW_IW_D2N_pre_v_1t_30ve
M_LW_NS6_DN_Pre_cv_NS7_DN_c_v_30
M_LW_NS2_DN_Pre_v_NS3_1tN_30ve
M_LW_DS2_DN_Pre_v_DS11_2tN_30ve
W_RW_IW_D2N_pre_cv_cv30
W_OS2_DN_Pre_v_OS3_1tN_30ve
W_OS2_DN_Pre_v_OS11_2tN_30ve
W_OS6_DN_Pre_cv_OS7_DN_c_v_30
IW_DS2_DN_Pre_v_DS3_1tN_30ve
LW_DS2_DN_Pre_v_DS11_2tN_30ve
RW_DS2_DN_Pre_v_DS11_2tN_30ve
IW_DS6_DN_Pre_cv_DS7_DN_c_v_30
RW_DS2_DN_Pre_v_DS3_1tN_30ve
LW_DS6_DN_Pre_cv_DS7_DN_c_v_30
LW_DS2_DN_Pre_v_DS3_1tN_30ve
IW_DS2_DN_Pre_v_DS11_2tN_30ve
RW_DS6_DN_Pre_cv_DS7_DN_c_v_30
IW_NS2_DN_Pre_v_NS3_1tN_30ve
LW_NS2_DN_Pre_v_NS11_2tN_30ve
RW_NS2_DN_Pre_v_NS11_2tN_30ve
IW_NS6_DN_Pre_cv_NS7_DN_c_v_30
Middle level
RW_NS2_DN_Pre_v_NS3_1tN_30ve
LW_NS6_DN_Pre_cv_NS7_DN_c_v_30
LW_NS2_DN_Pre_v_NS3_1tN_30ve
IW_NS2_DN_Pre_v_NS11_2tN_30ve
RW_NS6_DN_Pre_cv_NS7_DN_c_v_30
NS1_N_Hd_nb
NS3_1tN_30ve
NS5_2rD_R_ncg
NS7_DN_c_v_30
NS9_3rD_Re_sp
NS11_2tN_30ve
NS13_4rD_Re_nf
Cor1_Stress
NS2_DN_Pre_v
NS4_2rN_Asse
NS6_DN_Pre_cv
NS8_3rN_Asse
NS10_3rD_R_hr_n
NS12_4rN_Asse
NS14_4rD_Re_br
NOS1_N_Hd_nb
NOS2_DN_Pre_v
NOS3_1tN_30ve
NOS4_2rN_Asse
NOS6_DN_Pre_cv
NOS7_DN_c_v_30
NOS8_3rN_Asse
NOS11_2tN_30ve
NOS12_4rN_Asse
WS1_N_Hd_nb
WS3_1tN_30ve
WS5_2rD_R_ncg
WS7_DN_c_v_30
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WS11_2tN_30ve
WS13_4rD_Re_nf
WS2_DN_Pre_v
WS4_2rN_Asse
WS6_DN_Pre_cv
WS8_3rN_Asse
WS10_3rD_R_hr_n
WS12_4rN_Asse
WS14_4rD_Re_br
Base level
DOS2_DN_Pre_v
DOS5_2rD_R_ncg
DOS6_DN_Pre_cv
DOS7_DN_c_v_30
DOS9_3rD_Re_sp
DOS10_3rD_R_hr_n
DOS13_4rD_Re_nf
DOS14_4rD_Re_br
DS1_N_Hd_nb
DS3_1tN_30ve
DS5_2rD_R_ncg
DS7_DN_c_v_30
DS9_3rD_Re_sp
DS11_2tN_30ve
DS13_4rD_Re_nf
DS2_DN_Pre_v
DS4_2rN_Asse
DS6_DN_Pre_cv
DS8_3rN_Asse
DS10_3rD_R_hr_n
DS12_4rN_Asse
DS14_4rD_Re_br
BS1_Pink
BS2_Nflo
BS3_Hrno
BS4_Brea
OS1_N_Hd_nb
OS3_1tN_30ve
OS5_2rD_R_ncg
OS7_DN_c_v_30
OS9_3rD_Re_sp
OS11_2tN_30ve
OS13_4rD_Re_nf

OS2_DN_Pre_v OS4_2rN_Asse OS6_DN_Pre_cv OS8_3rN_Asse OS10_3rD_R_hr_n OS12_4rN_Asse OS14_4rD_Re_br

Fig 3-1: Network Model for the Protocol Condition with Organizational Learning

3.2 Simulation for the Example Scenario

In the protocol condition with organizational learning, team members acquire missing knowledge and make up for missing connections between their mental model states through organizational learning. In a valid network model, the initial value of the connection weight corresponding to the missing knowledge should be 0, and then be activated by organizational learning. Besides, the world states and mental model states in team members' mental models should get activated in the order in which the steps happens in the real world.

In this section, simulation results are present and discussed to confirm validity of the network model. Again, the standard table format (called role matrices) that represents network characteristics were input into dedicated software for simulation. For clear analysis, results are divided into 6 different graphs. Though, all graphs display fragments of the same simulation. The example simulation presented here was run from 0 to 50 time units with step size Δt = 0.5. The context state for stress gets a stable value of 0.95. Here the research sets that when a state is activated well, the value of a state should be greater than 0.8.

3.2.1 Adaptation States

Organizational learning is most intuitively reflected in the adaptation states. Fig 3-2 shows values of first-order self-model states of the nurse and the organization, and values of second-order self-model states of the nurse's hebbian learning persistence factor, and connection weights from the organizational first self-model states to the nurse's first-order self-model states over time. Fig 3-3 shows values of first-order self-model states of the doctor and the organization, and values of second-order self-model states of the doctor's hebbian learning persistence factor, the weight of the connection from organizational first-order self-model states to the doctor's first-order self-model states. In addition, Fig 3-3 shows second-order self-model states of connection weights for the doctor instructing the nurse more than Fig 3-2. In Fig 3-2, for connection weights from the team preparing pure ventilation to the nurse giving 2 times of pure ventilation, the nurse's self-learning effects and instructional learning are always not active. The nurse's 2 second-order self-model states for persistence factor of her self-learning are always under 0.1. As a result, the nurse's 2 first-order self-model W-states for self-learning effects achieve a highest value of 0.5 at around t = 9 and t = 23, respectively. Second-order self-model states which control influence of doctor's total learning effects to the nurse's instructional learning effects are always lower than 0.1. That leads the nurse's 2 first-order self-model W-states for instructional learning to be stably under 0.1. That means, the nurse not only misses knowledge from preparation of pure ventilation to giving pure ventilation but also is unable to learn effectively from the doctor’s instruction.

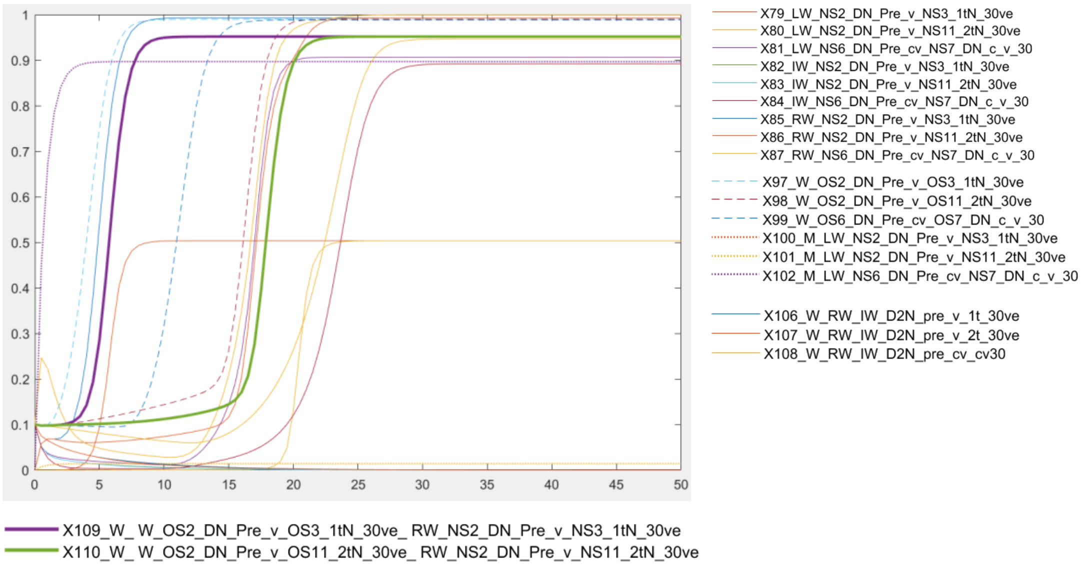


Fig 3-2: Simulation Results of Adaptation States (1)

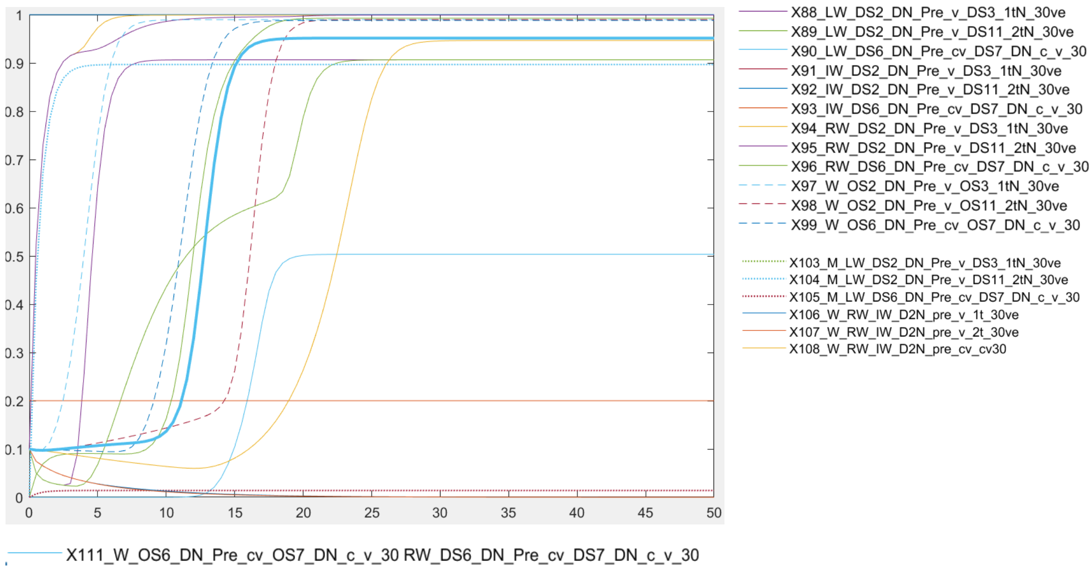


Fig 3-3: Simulation Results of Adaptation States (2)

Luckily, the nurse can learn from the organization with perfect knowledge. The first-order self- modelled **W**-states for organizational self-learning effect from preparation to giving two times of pure ventilation get activated at around t = 5 and t = 17, respectively. Right after, second order self-model states for weight of the connection from organizational self-learning effect to the nurse’s total learning effect reach activation at around t = 7 and t = 19, respectively. That means the nurse can begin unimpeded access to knowledge from the organization. As a result, the nurse's first-order self-model **W**-states for total learning effects from preparation to two times of giving pure ventilation get activated at around t = 6 and t = 18. The nurse's first-order self-model **W**-states for total learning effects reach activation 1 time unit earlier than the corresponding second-order self-model states control the nurse learn from the organization because the nurse can learn as soon as the values of the latter are above 0, she does not need to wait until the latter are fully active.

As for the rest of states in Fig 3-2, they are not directly related to organizational learning of nurses. For the weight of the connection from the team preparing the combination of compression and ventilation to the team giving that ventilation, the nurse's second-order self-model state for persistence factor of self-learning gets activated at around t = 2. The second-order self-model state controls influence from the doctor's total learning effect to the nurse's instructional learning effect get activated at around t =25 but always be above 0. The nurse's first-order self-model **W**-states for self-learning effect and instructional learning effect on connection weights get activated at around t = 17.5 and t = 18. The rest of the states will be analysed in Fig 3-3.

In Fig 3-3, for the weight of the connection from the team preparing the combination of compression and ventilation to the team giving that ventilation, the doctor's self-learning effects and instructional learning are always not active. The doctor's second order self-model states for persistence factor of his self-learning is always under 0.1. That leads the doctor's self-learning effect never get activated. Around t = 20, the doctor's first-order self-model **W**-state for his self-learning effect reaches its top value of 0.5. In addition, the doctor's first-order self-model **W**-state for his instructional learning effect is stable at 0.2. That means the doctor lacks the knowledge from preparation of the combination of compression and ventilation to giving that ventilation.

Luckily, the organizational learning helps the doctor as well. In Fig 3-3, for the weight of the connection from the team preparing the combination of compression and ventilation to the team giving that ventilation, the first-order self-model **W**-states for organizational self-learning effect gets activated at around t = 12.5. Right after, the second-order self-model state for the weight of the connection from organizational self-learning effect to the doctor's total learning effect reach activation at around t = 14. That means the doctor is able to learn his missing knowledge. As a result of organizational learning, the doctor's first-order self-model **W**-state for total learning effect gets activated at around t = 13.5. The doctor's first-order self-model **W**-state for total learning effects reach activation 0.5 time unit earlier than the corresponding second-order self-model state for the doctor learning from the organization because he can start learning when the latter state is above 0 as well.

Here we review the rest of the states in Fig 9. The doctor has sufficient knowledge in pure ventilation, so his second-order self-model states for the persistence factor gets activated well at around t = 2. Her/his first-order self-model **W**-states for self-learning effects of the weight of the connection from the team preparation of pure ventilation to the nurse giving two times of pure ventilation get activated at around $t = 5.5$, $t = 20$ (for self-learning effects). The first-order self-model **W**-states for her/his instructional learning effects for pure ventilations are stable at 1 all the time. The first-order self-model **W**-states for his total learning effects for 2 times of pure ventilation both get activated at around $t = 2$.

These two graphs confirm validity of organizational learning. Though team members miss some knowledge at beginning, they fill their knowledge gap through organizational learning later on.

3.2.2 The World States, the Baby States and the Context State

Fig 3-4 shows the simulation of the world states, baby states and the context state over time. The solid lines, the dashed lines, and the dashed and dotted line reflect value of the world states, baby states and the context state over time, respectively. The context state is stable at 0.95 all the time. That limits the persistence factors of the team members' self-learning effects to be no higher than 0.95.

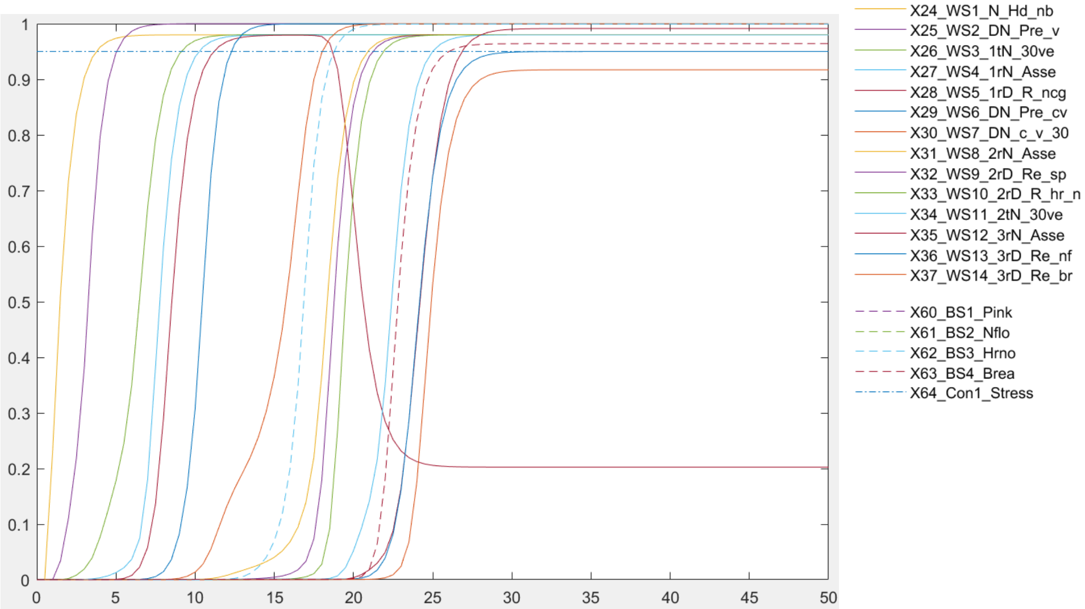


Fig 3-4: Simulation results of the World States, Baby States and The Context State

Around $t = 2.5$, the world state for the nurse holding the new-born baby on the table is activated, and that marks the beginning of ventilations. Around $t = 4$, the world state for the team preparing for pure ventilation reach activation. Then, the world state for the team giving first time of pure ventilation is active at around $t = 7.5$. It is 2.5 time units later than activation of the second-order self-model state for the weight of the connection from preparation of pure ventilation to giving that ventilation. Without organizational learning the nurse cannot successfully give a first time of ventilation. Around $t = 8.5$, the world state for the nurse helping assess the baby reaches activation. Right after, the world state for the doctor reporting the baby has no change gets activation at around t = 9.5. That means the team need to give more treatment; the world state for the team preparing for the combination of compression and ventilation gets active at around t = 11. Later, the world state of team's giving that ventilation gets active at around t = 17.5. The 6.5 time unit's gap between the world state for the team preparing the combination of compression and ventilation to giving that ventilation is because the doctor takes some time to learn from the organization. After that, the world state of the nurse's helping assess the baby for a second round is activated at around t = 19.5. Since baby states for the baby is slightly pink and has normal heart rate get activated at around t = 18, the world states for doctor reporting the baby is pink and with normal heart rate are active at around t = 20 and at around t = 21, respectively. At around the same time, the world state for the doctor reporting the baby has no change is not active anymore at around t = 20. That follows with more treatment. The world state for the team directly giving the second pure ventilation reach activated at around t = 23. The second time of pure ventilation successfully save the baby as baby states for the baby is not floppy anymore and start breathing get activated around t = 23.5. So, after the world state for the nurse helping assess the baby for the third round is active at around t = 25, the world states for the doctor reporting the baby is not floppy and starts breathing get activated at t = 25 and t = 26.5, respectively.

Fig 3-4 confirms validity of the network model. The world states get activated in the correct order corresponding to the steps in the real world. Second, the activation of baby's states right after ventilations proves team's ventilation finally save the baby by following protocol. These all means the network model is well designed to shown real application scenarios.

3.2.3 The Nurse's Mental Processes Based on Her Mental Model

Fig 2-5 shows the nurse's mental model and her corresponding action ownership states. Solid lines and dashed lines refer to values of the nurse's mental model and her action ownership states over time, respectively. The nurse's first mental model state for holding the new born baby on the table keeps a high value all the time. And that makes its corresponding action ownership state gets activated at around t = 1. Right after, the nurse's mental model state and its corresponding action ownership state for the team preparing first time of pure ventilation gets activated at around t = 4 and t = 5, respectively. That follows with giving a first time of ventilation. The nurse's mental model state and corresponding action ownership state for she giving first time of pure ventilation reach activation at t = 6.5 and t = 7.5, respectively. After that, the nurse's mental model state and its corresponding action ownership state for she helping assess

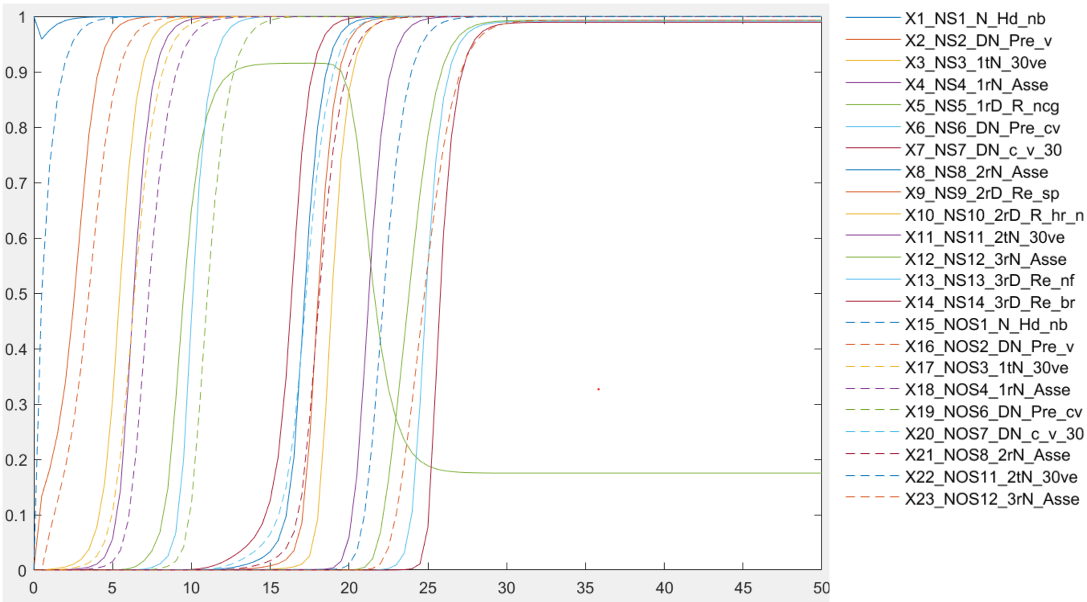


Fig 3-5: Nurse Mental Model and Action Ownership States

the baby is active at around $t = 7.5$ and $t = 8.5$, respectively. Right after overserving the doctor report the baby has no change, the nurse's mental model state for that gets activated at around $t = 11$. Almost at the same moment, the nurse's mental model state for the team preparing the combination of compression and ventilation reach activation as well. Later that mental model state's corresponding action ownership state for preparation is active at around $t = 12$. That follows with the activation of the nurse's mental model state and its corresponding state for giving that ventilation at around $t = 17.5$ and $t = 19$, respectively. The 6.5 seconds gap in the nurse's mental model is between the team preparing and giving the combination of compression and ventilation is because the doctor need time to acquire knowledge from organization. Giving ventilation follows with assessment, so the nurse's mental model state and its corresponding action ownership state for her second round of helping assess the baby activated at around $t = 18.5$ and $t = 19.5$, respectively. By observing the doctor's report, the nurse's mental model states for the doctor reporting the baby becomes pink and has normal heart rate reach activation at around $t = 19$ and $t = 20.5$, respectively. At the same time, the nurse's mental model state for the doctor reporting the baby has no change is not active anymore since around $t = 21$. As she know the team will give more treatment, her mental model state and its corresponding action ownership states for the team giving second ventilation get activated at around $t = 21$ and $t = 22.5$, respectively. That follows with activation of the nurse's mental model state and its corresponding action ownership state for third round of assessment at around $t = 24.5$ and $t = 26$, respectively. By observing the doctor's report, the nurse's mental model state for doctor reporting the baby is not floppy and start breathing become activated at around $t = 25$.s and $t = 26.5$, respectively.

Fig 3-5 further demonstrates network design to be valid. The nurse's mental model states gets activated according to right sequence of steps. All her action ownership states get activated right after activation of their corresponding mental model states. That means, by following protocol, the nurse save the baby with the doctor.

3.2.4 The Doctor's Mental Processes Based on His Mental Model

Fig 3-6 shows simulation results of the doctor's the mental model and action ownership states. Solid lines and dashed lines refer to values of the doctor's mental model and the doctor's action ownership states over time, respectively. Around t = 3.5s, after the doctor observing the nurse hold the new born baby who need ventilation on the table, his first mental model state get activated. Immediately after, the doctor know the team should prepare pure ventilation for the baby, so the doctor's mental model state and its corresponding action ownership state for the team preparing pure ventilation are active at around t = 4s and t = 4.5s, respectively. That means the doctor complete preparing pure ventilation in real world. Right after, with his own knowledge and observation of the nurse's action in reality, the doctor's mental model state for nurse's first time of giving pure ventilation and the first round of assessment are active at around t = 4.5s and t = 6s, respectively. Observing the baby has no change, the doctor's mental model state and its corresponding action ownership state for reporting the baby has no change get activated at around t = 8s and t = 9s, respectively. According to protocol, the baby need more treatment so the doctor's mental model state and its corresponding action ownership state for the team's preparation of the combination of compression and ventilation is active at around t = 10.5s and t = 12s, respectively. Well preparation means that the doctor is able to give that ventilation for 30s. Thus, the mental model state and its corresponding action ownership state for that action get activated at around t = 16.5s and t = 18s, respectively. After thinking giving ventilation, the doctor thinks the assessment as well. Thus, the doctor's mental model state for the nurse helping assess for second round get activated at around t =17.5s. After that ventilation, the doctor observe the baby is slightly pink and with normal heart rate again. The doctor's mental model states and their corresponding action ownership states for reporting these reach activation at around t = 18 s, t = 19s (for the baby is slightly pink), t = 19s and t = 20s (for the baby is with normal heart rate), respectively. At the same moment, the doctor's mental model and its corresponding state for reporting the baby has no change become inactive at around t = 18s and t = 18.5s. In hoping of the baby totally be safe, the nurse gives another time of pure ventilation for 30 seconds and start assessing again. Overserving the baby finally is not floppy and start breathing, the doctor's mental model states and their corresponding action ownership for reporting these get activated at around t = 23s, t = 24s (for the baby is not floppy), t = 23.5s and t = 24.5s (for the baby starts breathing).

Fig 3-6 confirms validity of the network model design as well. The doctor's mental model states happens according to right sequence of steps. All the doctor's action ownership states get activated right after activation of their corresponding mental model states. That means, the doctor follows the protocol and cooperates with the nurse to successfully save the baby.

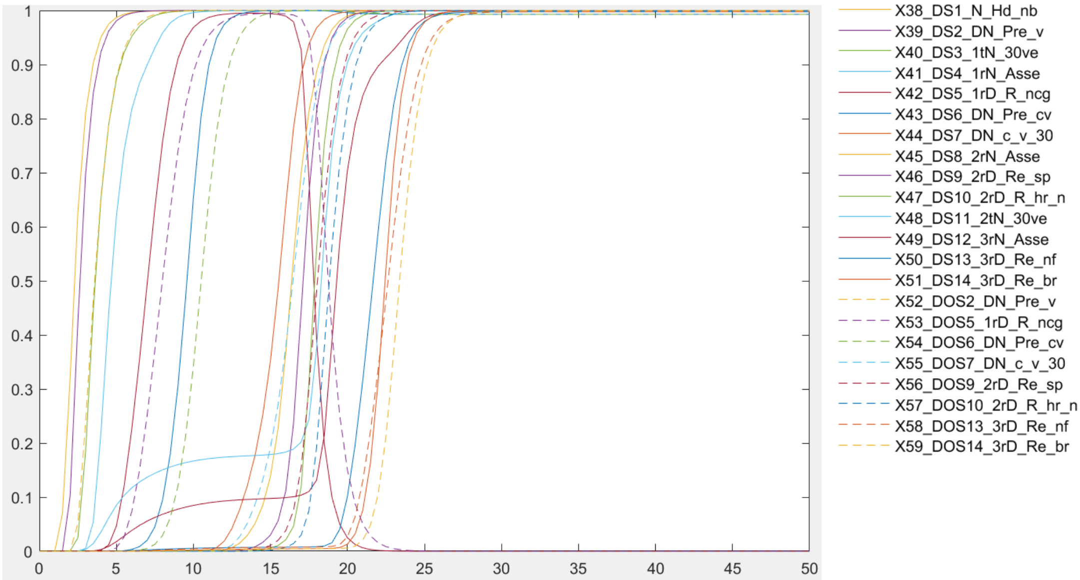


Fig 3-6: Doctor Mental Model and Action Ownership States

3.2.5 Organizational States:

The organization has perfect knowledge for process of this application scenario. When the team members lack necessary knowledge, they will learn from the organization. Here the organization can be understood as database with recording of correct operations.

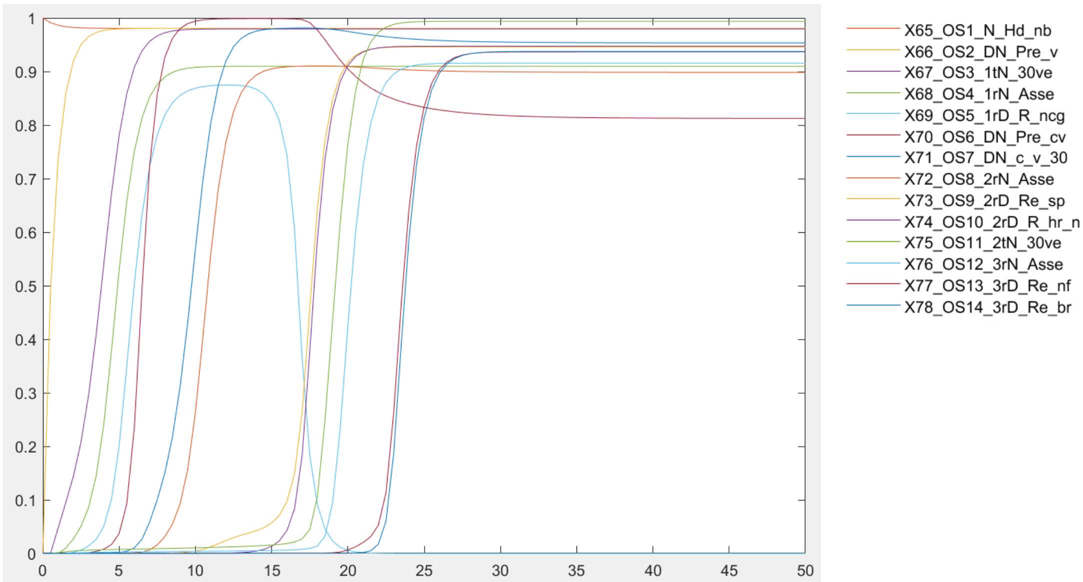


Fig 3-7: Organizational States' Simulation Results

Fig 3-7 shows value of organizational mental model states overtime. The organizational mental model state for the nurse holding the new-born baby on the table is activated all the time. That activates the organizational mental model state for the team preparing pure ventilation at around $t = 2$. Right after, the organizational mental model state for the team giving first time of pure ventilation is active at around $t = 5$. Later, observing the baby's condition, the organizational mental model state for the nurse helping and assess the baby and for the doctor reporting the baby has no change reach activation at around $t = 6$ and $t = 8$, respectively. The organizational mental model knows that new treatment is necessary so the organizational mental model states for the team preparing and giving the combination of compression and ventilation get active at around $t = 7.5$ and $t = 11$. When the organization observe baby's condition, the organization knows that next treatment even 0.5 faster than expecting the doctor to reporting the baby has no change. Later, the organizational mental model for the nurse helping assessment gets activated at around $t = 12.5$. After the team learn from organizations and finish that ventilation in the real world, the baby partially recovered. Organizational mental model for the doctor reporting the baby is slightly pink and has normal heart rate reach activation both at around $t = 19$. In fact the former is slightly faster than the latter. Right after, the organization expect the nurse to give second time of pure ventilation and assess the baby again. The organizational mental model states for these get activated at around $t = 20$ and $t = 21.5$. After the nurse give that ventilation and the baby completely recover in real world, the organizational mental model states for the doctor reporting the baby is not floppy and start breathing both reach activation at around $t = 25$. The former one is slightly faster than the latter one as well. Fig 3-7 confirms validity of the network model design as well. In the organizational mental model, mental model states for preparing and giving ventilations activated on time to allow the team to obtain their missing knowledge.

4. Adaptive Network Model for a Partial Mistake Condition

4.1 Network Model Introduction

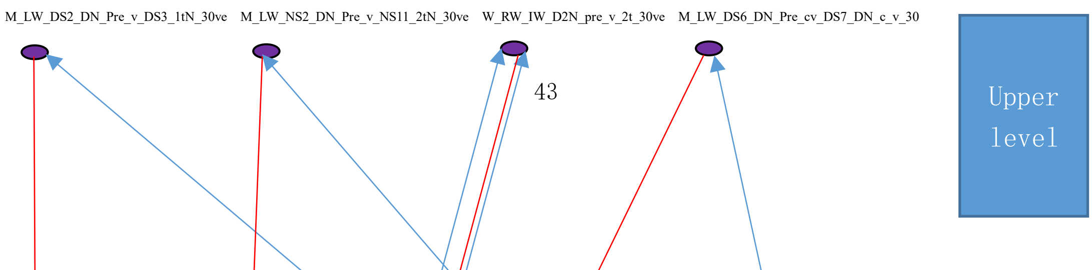
In the considered partially mistake condition, the nurse has imperfect knowledge in the preparing ventilation, and that lead to mechanical frequency related errors in the first time of giving pure ventilation. After the doctor notice the failure of the ventilation, (s)he helps the nurse fix her imperfect knowledge, so (s)he is well prepared for pure ventilation. That helps her complete giving a second time of pure ventilation without any error.

To represent this situation, this research modifies the network characteristics of the network model in Chapter 3 without changing the graphical representation of the model. That means the network model of partial mistake condition has the same states and extremely similar base connectivity with the network model of Chapter 3. The only different in their base connectivity is *NS4_1rN_Asse* in partial mistake condition has an added connection from *NS1_N_Hd_nb*. This difference enable *NS4_1rN_Asse* in partial mistake condition still able to get activated even if *NS3_1tN_30ve* in this condition is stable at 0. In addition to this difference, other network characteristics such as connection weight, parameters of the combination function are different as well. The most important network characteristics that make this network model represents partial mistake condition are threshold values of *NS2_DN_pre_v*'s and *NS3_1tN_30ve*'s combination functions are high as 1.5 and 1.8, respectively. That enables *NS2_DN_pre_v* stays in low level (means not prepared) at the beginning but at a high level (means well prepared) later. That also enables *NS3_1tN_30ve* stay in low value all the time. This will be discussed in simulation results in detail. Since states of partial mistake condition are the same with the protocol condition without organizational learning, readers can refer introduction of states in Chapter 3.

4.2 Simulation for Example Scenarios

If the network model of partial mistake result is valid, several results should be presented. For starters, when the nurse has imperfect knowledge, nurse's states for her preparing pure ventilation should be at a low value. When the nurse has perfect knowledge, nurse's states for her preparing pure ventilation should get activated. In addition, in team members' mental model and the world states, states should happen in the order of process.

As before, for convenience of inputting data to the software environment for simulation, a standard table format called role matrices is introduced to express the network characteristics of the network model described above. The example simulation presented here was run from 0 to 50 time units with step size Δt = 0.5. The contextual stress level was set relatively low, so that the context state has a value of 0.95, and that will lead **M**-states has an upper limit value no more than 0.95. For clear analysis, the results happen in the same simulation at the indicated time points have split into the graph of the world states, the baby states and the context state, the graph of the nurse's states, the graph of the doctor's states and the graph of the adaptation states.



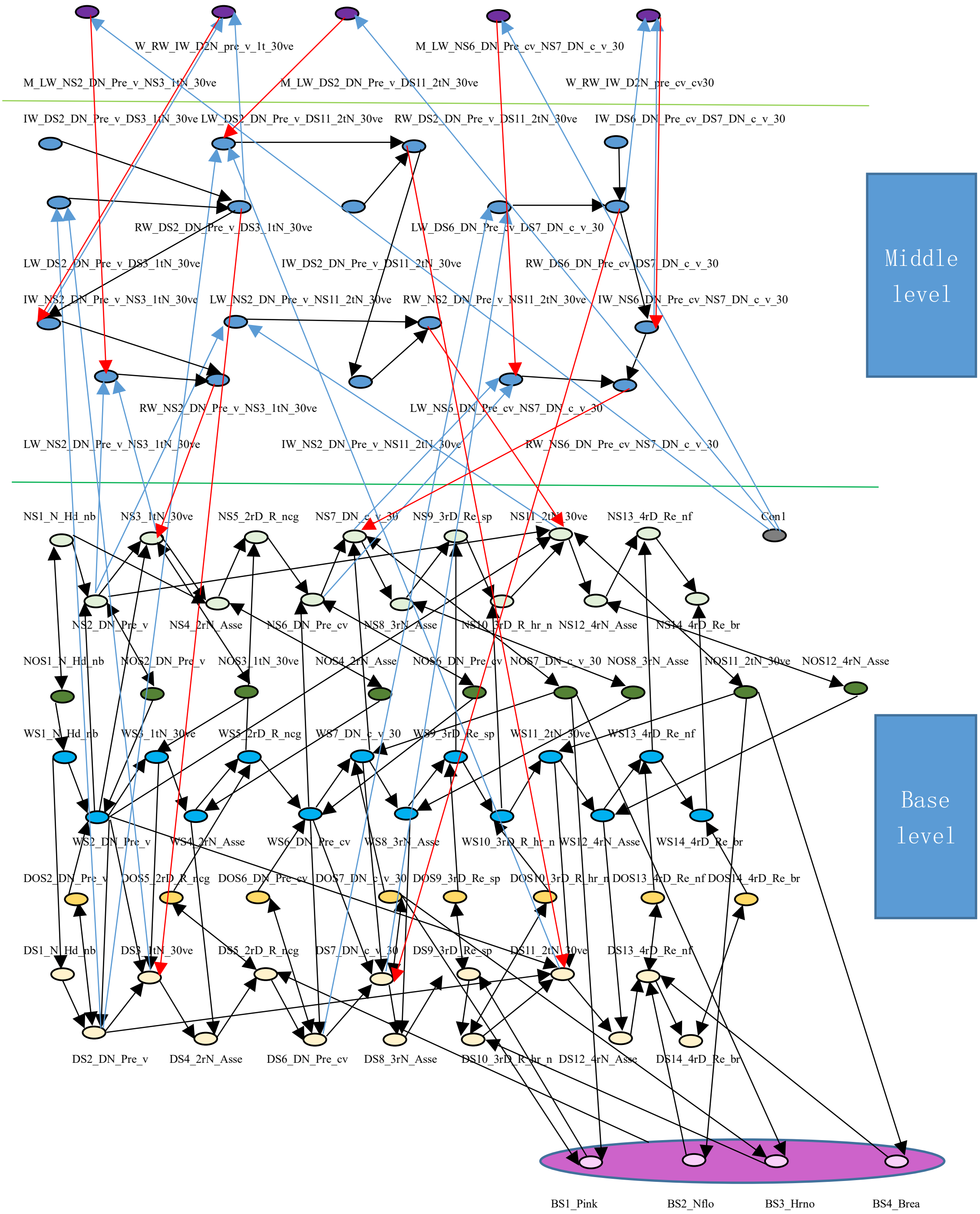


Fig 4-1: Adaptive Network Model for Partial Mistake Condition

Here the research sets that when the value of a state is greater than 0.8, the state is activated well. Since the nurse makes a mistake, her states will be introduced first. That follows with the description of adaptation states that also show influence of her imperfect knowledge on the network model's structure. Finally, the rest of the states will be introduced.

4.2.1 The Nurse's Mental Processes Based on Her Mental Model

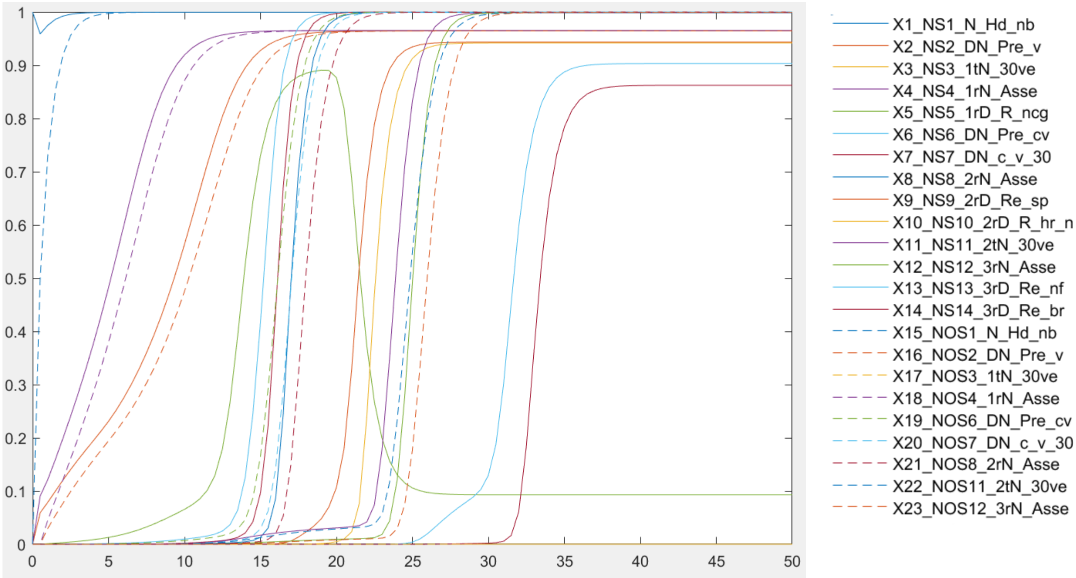


Fig 4-2: Nurse Mental Model and Action Ownership States

The nurse's states directly show the process from the nurse make mechanical frequency errors to the doctor helps her fill in the missing knowledge. Fig 4-2 shows the nurse's mental model and action ownership states over time. Mental model states are solid lines and action ownership states are dashed lines. The nurse's mental model state for holding the baby on the table is active all the time. Its corresponding action ownership states get activated at around t = 2. However, the nurse's states for she preparing pure ventilation doesn't get activated well right after that. That means, the nurse has imperfect knowledge in preparation of pure ventilation. That leads the nurse's states for she is giving first time of ventilation never get activated. These perfectly express that the nurse makes mechanical frequency error because of poor preparation. Later, the doctor notices the error and helps the nurse to obtain missing knowledge. Thus, the nurse's mental model state and its corresponding action ownership states for she preparing pure ventilation get activated at around t = 17.5 and t = 18.5, respectively. The nurse's mental model states and its corresponding action ownership state for she helping assessment get activated at around t = 8 and t = 9, respectively. Unsurprisingly, the doctor reported no change in the baby. The nurse's mental model state for that reach activation at around t = 16. That follows with new treatment. The nurse's mental model states and their corresponding action ownership states for the team preparing and giving the combination of compression and ventilation for 30 seconds get activated at t = 16.5, t = 18 time unit (for preparation), t = 17.5 and t = 19 (for giving ventilation), respectively. After that, the second round of assessment starts. The nurse's mental model state and its corresponding action ownership state for she is helping the second round of assessment get activated at around t = 18.5 and around t = 19.5, respectively. Right after, her mental model states for the doctor reporting the baby becomes pink and has normal heart rate are active at around t = 22.5 and t = 23.5, respectively. At the same time, her mental model states for the doctor reporting no change is not active at around t = 20 time unit. To completely save the baby, the nurse's mental model state and its corresponding action ownership states for the team giving second ventilation get activated at around $t = 25$ and $t = 26$, respectively. Right after, the nurse's mental model state and its corresponding action ownership state for third round of assessment reach activation at around $t = 33.5$ and $t = 35$, respectively.

The nurse's states addressed the validity of the network model. Values of her states overtime perfectly reflects the process for she having imperfect knowledge, she making an error, and she obtaining her missing knowledge.

4.2.2 Adaptation States

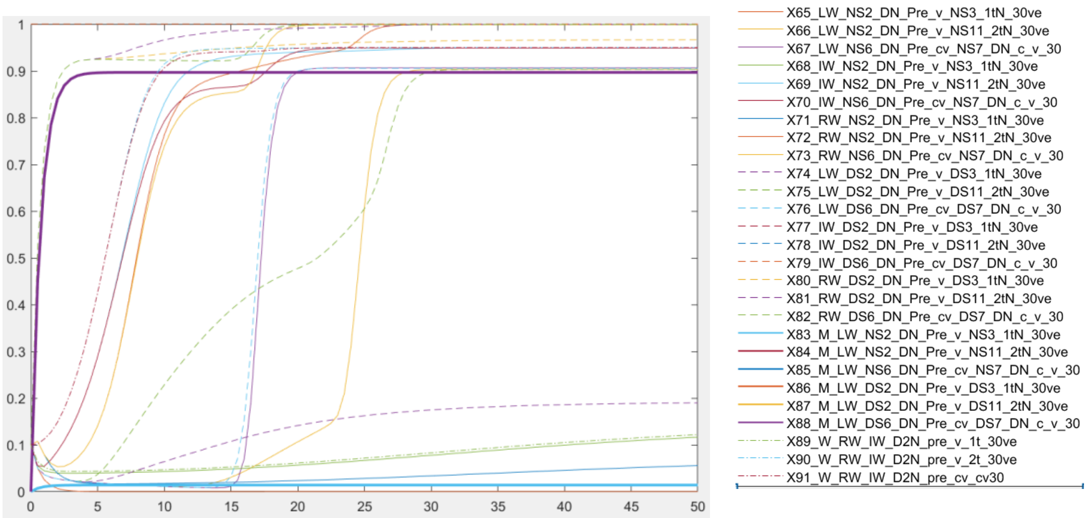


Fig 4-3: Simulation Results of Adaptation States

Fig 4-3 shows values of adaptation states over time. For the nurse's weight of the connection from the team preparing pure ventilation to she is giving first time of pure ventilation, the first-order self-model **W**-state for her self-learning effects are lower than 0.1 all the time. In addition, the first-order self-model **W**-state for her instructional learning effects is lower than 0.2 all the time. Thus, the first-order self-model **W**-state for the total learning effects is lower than 0.1 all the time. These are because the second order self-model **M**-state for the resistance factor state for that weight of connection stays below 0.05 and because the second order self-model **Www**-state for weight of connection reflects the doctor's total learning effects delivered to the nurse's instructional learning effects stays below 0.2. It is worth mentioning that all other second order self-model **M**-states for resistance factors for team members' self-learning effects are active at around $t = 2$. In addition, all other second order self-model **Www**-states for weight of connection reflects the doctor's total learning effects delivered to the nurse's instructional learning effects are active at $t = 8$.

For the nurse's weight of the connection from the team preparing pure ventilation to she is giving a second time of pure ventilation, the first-order self-model **W**-state for her self-learning effects get activated at around $t = 25.5$ time unit. That's because of the hebbian learning effect, her/his state has to be activated at around the mental model state for she is giving a second time of pure ventilation. Since the doctor is helping him/her obtain missing knowledge after (s)he notices her failure, the first-order self-model **W**-state for the instructional effects reach activation at around t = 9.5. The first-order self-model **W**-state for the total learning effects gets activated at around t = 10.5.

For the nurse's weight of the connection from the team preparing the combination of ventilation and compression to the team giving that ventilation, the first-order self-model **W**-state for her self-learning effects gets activated at around t = 18. The first-order self-model **W**-state for her instructional learning effects and total learning effects gets activated at around t = 10 and t = 11, respectively.

For the doctor's weight of the connection from the team preparing pure ventilation to the nurse giving first time of pure ventilation, first-order self-model **W-**states for his self-learning effects is never activated. That's because of hebbian learning effects and his mental model state for giving that ventilation never gets activated. However, his first-order self-model **W**-state for instructional learning effects is activated all the time and his first-order self-model **W**-state for total learning effects reach activation at around t = 2. That is because the doctor has perfect knowledge.

For the doctor's weight of the connection from the team preparing pure ventilation to the nurse giving second time of pure ventilation, the first-order self-model **W**-state for his instructional learning effects is activated all the time. In addition, first-order self-model **W**-states for his self-learning effects and total learning effects get activated at around t = 27, and t = 2.

For the doctor's weight of the connection from the team preparing the combination of ventilation and compression to the team giving that ventilation, the first-order self-model **W**-state for his instructional learning effects is activated all the time. In addition, first-order self-model **W**-states for his self-learning effects and total learning effects reach activation at around t = 18, and t = 2.

The adaptation states strengthen the validity of the network model. They clearly show impact of the nurse's imperfect knowledge on her learning effects.

4.2.3 The World States, the Baby States and the Context State

Fig 4-4 shows the process of partial mistake condition in the real world. The solid lines, the dashed and dotted line and the dashed lines reflect value of the world states, the context state and baby states over time, respectively.

The world state for nurse's holding the new-born baby on the table is activated at around t = 2. That marks the team start medical treatment. The world state for the team's preparation for pure ventilation is not activated right after that. That's because the team actually don't prepare well. Then, the world state for the nurse giving first time of pure ventilation is never active. That's the result of poor preparation. The doctor notices the mechanical frequency error of the nurse, so he teaches the nurse perfect knowledge. That helps the world state for the team's preparation for pure ventilation gets activated at 12.5. The team found no change in the baby during the assessment. Thus, the world state for the nurse helping the first round of assessment and for the doctor report the baby has no change is active at around t = 10 and t = 14.5. New treatment starts with the activation of the world states for the team preparing for the combination of compression and ventilation and giving that ventilation at

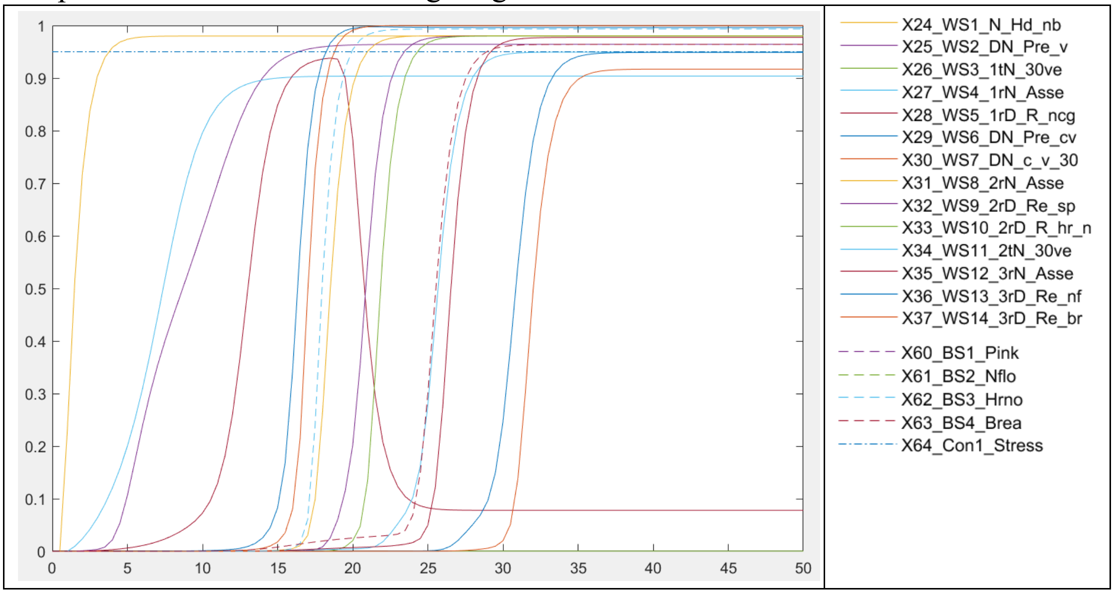


Fig 4-4: Simulation Results of the World States, Baby States, and the Context State

around t = 17.5 and t = 18. That treatment works so that the baby state for the baby is slightly pink and the baby has normal heart rate get activated at around t = 19. The second round of assessment start with the activation of the world state of the nurse's helping assess for the second time at around t = 19.5. The world states for the doctor reports changes of the baby get activated at around t = 22 and t = 23. The world state for the doctor reports the baby has no change is not active at around t = 20 as well. To make the baby totally safe, the world state for the nurse directly giving the second pure ventilation reach activated at around t = 26. Around the same time, the baby is totally safe. The world states for the nurse helps assessment and for the doctor report the baby is not floppy and starts breathing are activated at around t = 27.5, t = 32 and t = 33, respectively.

4.2.4 The Doctor's Mental Processes Based on His Mental Model

Fig 4-5 shows activation conditions of the doctor's the mental model and action ownership states over time. Solid lines and dashed lines refer to values of the doctor's mental model and the doctor's action ownership states over time, respectively. After the doctor observing the nurse hold the new born baby who need ventilation on the table, his first mental model state get activated at around t = 3. Right after, treatment starts, so the doctor's mental model state and its corresponding action ownership state for the team preparing pure ventilation get activated at around t = 4.5 and t = 5, respectively.

However, observing the nurse make mechanical frequency errors, the doctor’s mental model state for the nurse’s first time of giving pure ventilation is never active. That follows with activation of the doctor’s mental model states for the nurse helping the first round of assessment and for he reporting the baby has no change at around $t = 11$ and $t = 13$. The doctor’s action ownership for he reporting no change is active at around $t = 14$. To save the baby, the doctor’s mental model states and action ownership states for preparing and giving the combination of compression and ventilation get activated at around $t = 16$, $t = 17$ (for preparation), $t = 16.5$ and $t = 17.5$ (for giving ventilation), respectively. Right after, the doctor’s state for the nurse helping assess for second round get activated at around $t = 20$. This time, the baby partial recovers. Thus, the doctor’s mental model states and their action ownership states for reporting these reach activation at around $t = 20.5$, $t = 21$ (for the baby is slightly pink), $t = 22$ and $t = 22.5$ (for the baby is with normal heart rate), respectively. At the same time, the doctor’s mental model state and its corresponding action ownership state for reporting no change are not active at $t = 18$ and $t = 19$, respectively. Hoping totally save the baby from danger, the nurse gives the baby second time of pure ventilation and start assessment for the third round. The doctor’s mental model states for those are active at around $t = 27$ and 28.5. Observing the baby is finally safe, the doctor’s mental model states and their action ownership states for he reporting the baby is not floppy and start breathing get activated at around $t = 30$, $t = 31.5$ (for being not floppy) , $t = 30.5$, and $t = 32$ (for starting breathing).

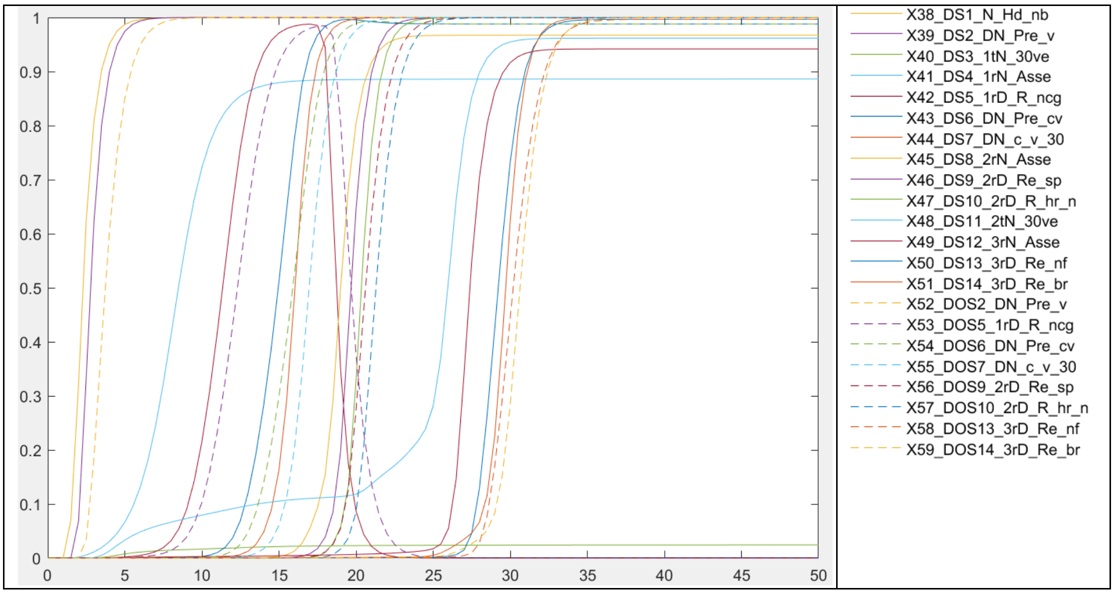


Fig 4-5: Doctor Mental Model and Action Ownership States

5. Adaptive Network Model for Extreme Mistake Condition

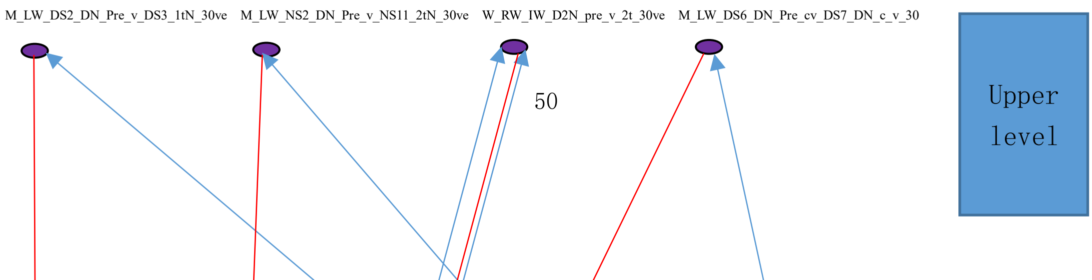
5.1 Network model Introduction

In extreme mistake condition, the nurse has imperfect knowledge in preparing pure ventilations, and that lead to mechanical frequency related errors when she gives pure ventilation. In addition, the doctor has imperfect knowledge in preparing the combination of compression and ventilation. That leads the team don't give that ventilation properly. This condition is actually similar to initial situation of the doctor and the nurse in Chapter 4, but there is no longer an organization with perfect knowledge for teams to learn from. In this condition, we suppose both team members don't fix each other's problem because of lack of communication. The doctor fails to supplement the missing knowledge of nurses because their communication is inefficient. The nurse fails to supplement doctors' missing knowledge because nurses are afraid of authority to point out mistakes.

To present this situation, this research adjusts the network characteristics of the network model in Chapter 3. The network model of extreme mistake condition has the same states and very similar base connectivity with the network model of Chapter 3. The different in their base connectivity is *NS4_1rN_Asse* in partial mistake condition has an added connection from *NS1_N_Hd_nb*. In addition, *NS12_3rN_Asse* has an added connection from *NS8_2rN_Asse*. The former difference enable *NS4_1rN_Asse* in extreme mistake condition still able to get activated even if *NS3_1tN_30ve* in this condition is stable at 0. The latter difference help *NS12_3rN_Asse* in this condition reach activation even if *NS11_2tN_30ve* will never be activated. In addition to difference in base connectivity, other network characteristics such as connection weight, parameters of combination functions are different as well. High threshold values are important to keep team members' mental model states corresponding their missing knowledge in preparation at low levels. These will be discussed in simulation results in detail. Since states of extreme mistake condition are the same with the protocol condition without organizational learning, readers can refer introduction of states in Chapter 3.

5.2 Simulation for Example Scenarios:

If the network model of extreme mistake is valid, there should be several expected results in simulation. For starters, when the nurse lacks perfect knowledge in pure ventilation, nurse's mental model state for her preparing pure ventilation should be at low values. The same goes for doctors, his imperfect knowledge in the team preparing the combination of compression and ventilation means his mental model state for that should be stable at low levels.



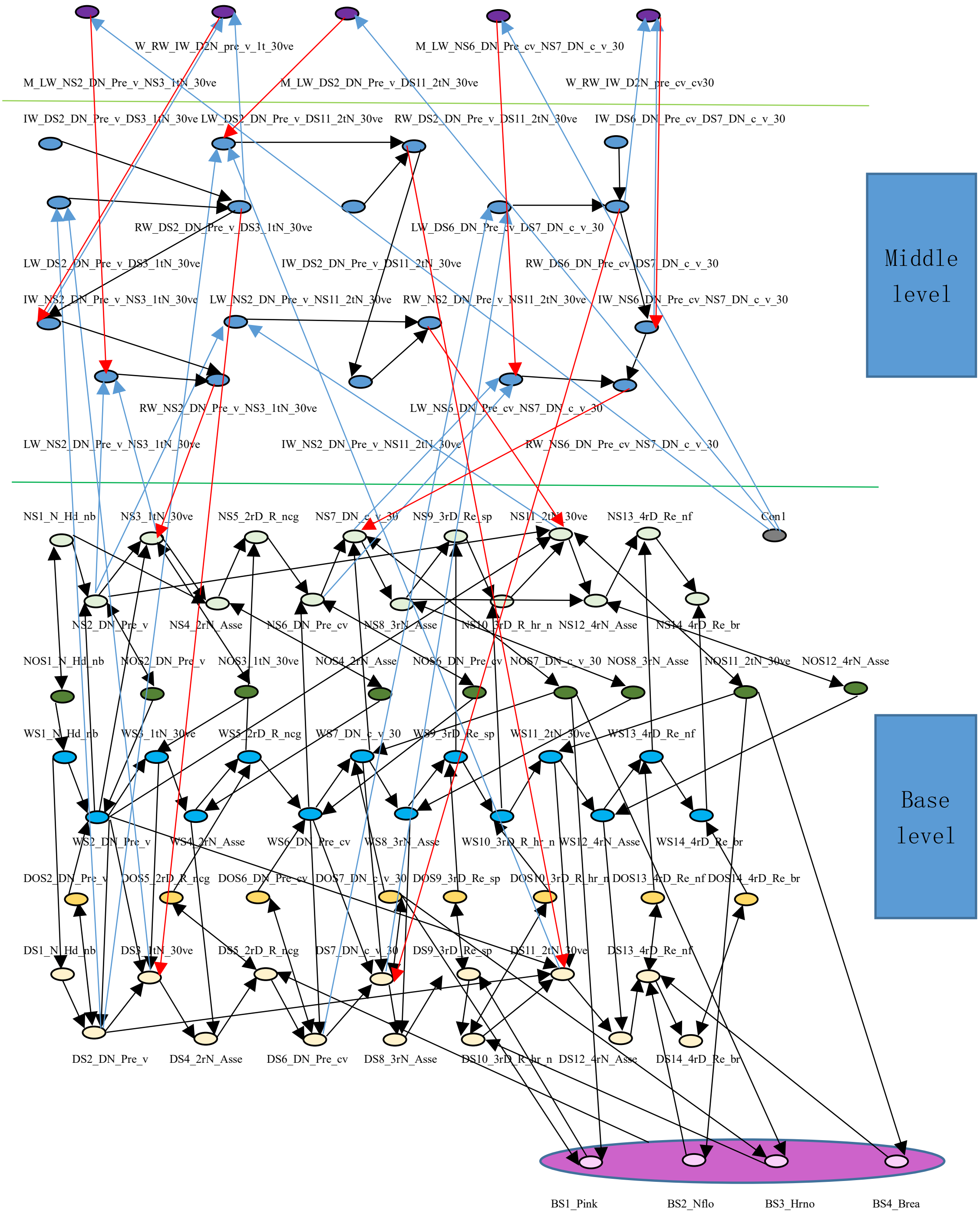


Fig 5-1: Adaptive Network for Extreme Mistake Condition

Again, the network model is specified into a standard table format called role matrices for the convenience of inputting the network characteristics to software environment for simulation. The example simulation presented here was run from 0 to 50 time units with stepsize Δt = 0.5. Below will discuss simulation results of state activation based on current network characteristics. The contextual stress level is set to be relatively low, so that the context state has a value of 0.95, and that will lead **M**-states has a value no more than 0.95. For clear analysis, the results happen in the same simulation at the indicated time points have split into the graph of the nurse's states, the graph of the doctor's states, the graph of the world states, the baby states and the context state, and the graph of the adaptation states.

Here the research sets that when the value of a state is greater than 0.8, the state reach activation well. Since team members both have imperfect knowledge and make mistakes, their states will be discussed first. That follows with description of the adaptation states that reflect how their imperfect knowledge influence learning effects. Finally, other states will be discussed.

5.2.1 The Nurse's Mental Processes Based on Her Mental Model

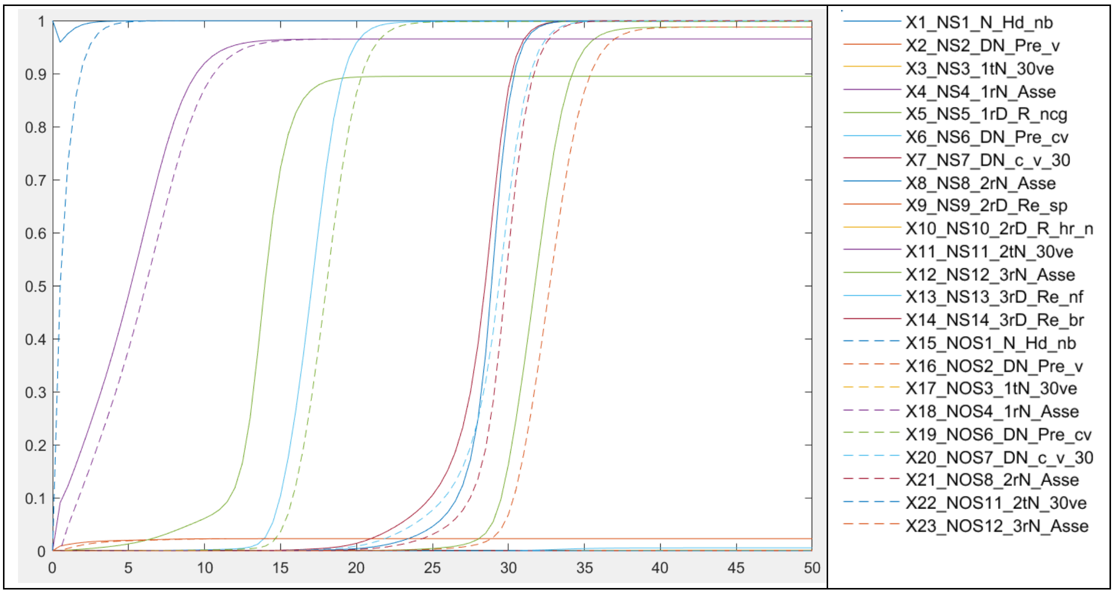


Fig 5-2: Nurse Mental Model and Action Ownership States

The nurse's states clearly show the consequence of her imperfect knowledge in preparation of pure ventilation. In Fig 5-2, the solid lines show the nurse's mental model while the dashed lines show action ownership states over time. The nurse's mental model state for holding the baby on the table always stay active. Its corresponding action ownership states get activated at around $t = 2$. However, the nurse's mental model state and its corresponding action ownership state for her preparing pure ventilation never get activated. That means, the nurse has imperfect knowledge in preparation of pure ventilation. That leads the nurse's mental model state and its corresponding action ownership state for she is giving first time of ventilation never get activated. These means that the nurse makes mechanical frequency error because of poor preparation.

The nurse's mental model states and its corresponding action ownership state for helping the first round of assessment get activated at around $t = 8$ and $t = 9$, respectively. That follows with activation of the nurse's mental model state for the doctor reporting no change in the baby at around $t = 15.5$. After that, new treatment starts. Since the nurse has perfect knowledge in the combination of compression and ventilation. Her mental model state and corresponding action ownership state for that preparation reach activation at around $t =$ and $t = 18.5$ and $t = 20$, respectively. That follows with the activation of her mental model states and their corresponding action ownership states for giving that ventilation and for helping the second round of assessment at around $t = 29.5$, $t = 30.5$ (for giving that ventilation), $t = 30$ and $t = 31$ (for helping assessment), respectively. These means, the nurse does what she is supposed to do during this ventilation, except to remind the doctor that he has a mistake. So, the baby showed no signs of recovery. The nurse's mental model state for the doctor reporting the baby is slightly pink and with normal heart rate never reaches activation. Her mental model state for the doctor reporting the baby has no change is still active. The nurse is supposed to give second time of pure ventilation. But due to her imperfect knowledge in preparation for pure ventilation, her mental model state and corresponding action ownership state for giving that ventilation never get activated. In third round assessment, her mental model state and its corresponding action ownership state get activated at around $t = 33.5$ and $t = 34.5$. But her mental model state for the doctor reporting the baby is not floppy and start breathing never get activated. These means the team fail to make baby recover by 3 times of ventilation.

The nurse's states addressed the validity of the network model. The results show that she has been unable to successfully ventilate the baby due to lack of perfect knowledge. She has perfect knowledge in preparing for the combination of compression and ventilation so she do what she should do except warning the doctor out of being afraid of authority. That ventilation need both team members do well so it fails as well.

5.2.2 The Doctor's Mental Processes Based on His Mental Model

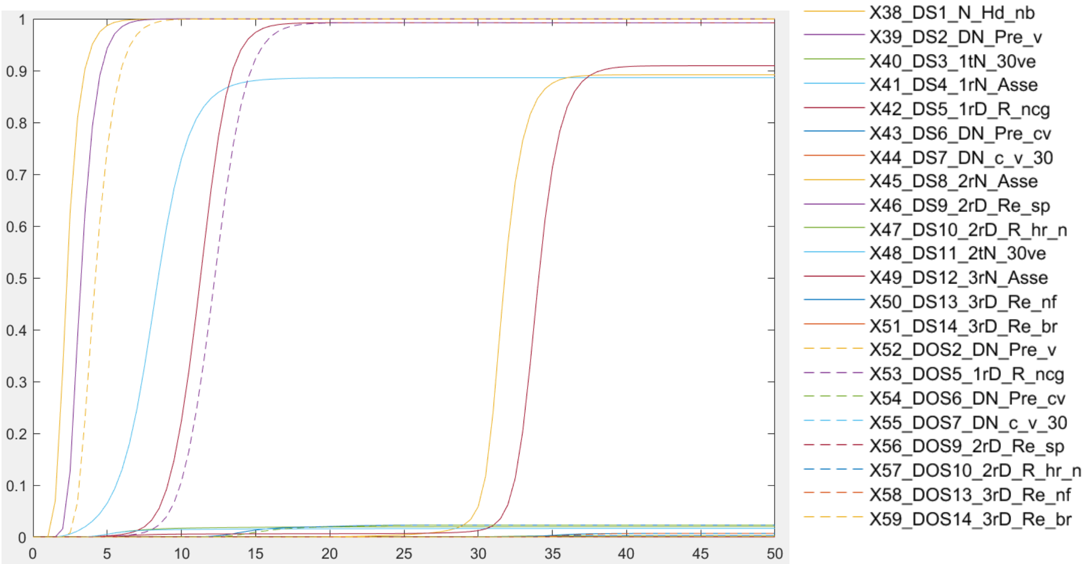


Fig 5-3 Doctor Mental Model and Action Ownership States

In Fig 5-3, the solid lines and the dashed lines refer to values of the doctor's mental model and the doctor's action ownership states over time, respectively. The doctor's mental model state for the nurse holding the new born baby who need ventilation on the table get activated at around $t = 3$. Right after, treatment starts, so the doctor's mental model state and its corresponding action ownership state for the team preparing pure ventilation get activated at around $t = 4.5$ and $t = 5$, respectively. However, observing the nurse make mechanical frequency errors, the doctor's mental model state for the nurse's first time of giving pure ventilation is never active. Due to lack of effective communication, he does not succeed in helping the nurses to make up for the missing knowledge. After the activation of the doctor's mental model state for the nurse helping first time of assessment at around $t = 11$. His mental model state and its corresponding action ownership state for he reporting the baby has no change get activated at around $t = 13$ and $t = 14$. That follows with new round of treatment. However, he has imperfect knowledge in preparing the combination of compression and ventilation. The nurse also doesn't warn him for that because she afraid of authority. These leads the doctor's mental model states and action ownership states for preparing and giving that ventilation never activated. In the second round of assessment, his mental model state for the nurse help that assessment get activated at around $t = 33$. However, he doesn't see the change of baby so that his mental model state for reporting no change is still active while his mental model states and their corresponding states for reporting the baby is slightly pink and with normal heart rate stay not activated. After seeing the nurse fail her second time of giving pure ventilation, his mental model state for her giving that ventilation never be active as well. Right after, his mental model state for the nurse helping third round of assessment get activated at around $t = 30$. Seeing the baby still doesn't recover, his mental model state for reporting no change is still active while his mental model states and corresponding action ownership states never reach activation.

5.2.3 Adaptation States

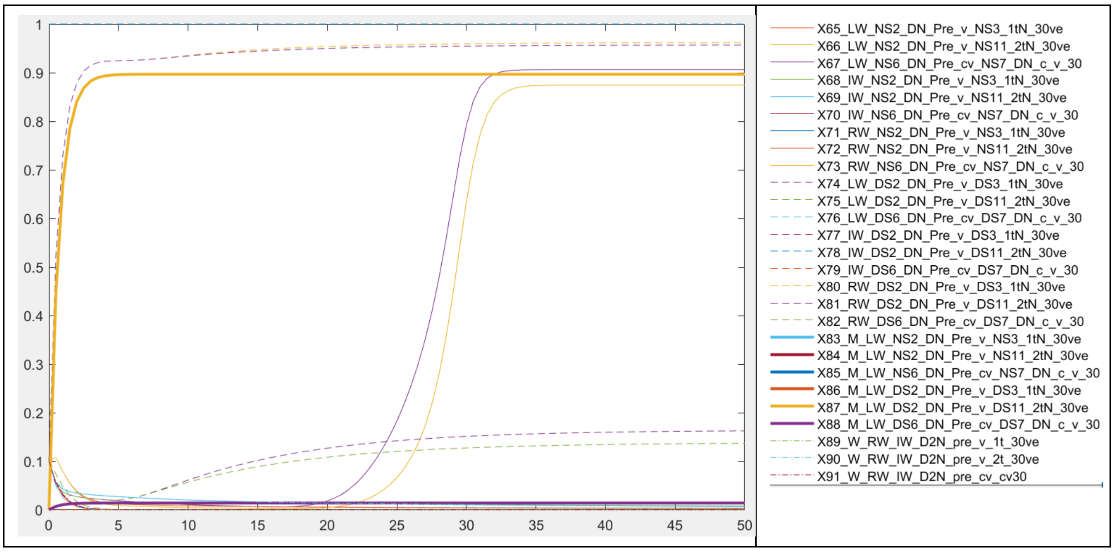


Fig 5-4: Simulation Results for Adaptation States

Fig 5-4 shows values of adaptation states over time. For the nurse's weight of the connection from the team preparing pure ventilation to her giving 2 times of pure ventilation, the first-order self-model **W**-states for her self-learning effects are lower than 0.1 all the time. In addition, the first-order self-model **W**-states for her instructional learning effects are lower than 0.2 all the time as well. The combined result is the first-order self-model **W**-states for the total learning effects are lower than 0.1 all the time. These are because the second order self-model **M**-states for the resistance factor state for that weight of the connection stays below 0.05 and because the second order self-model **Www**-state for the weight of connection reflects the doctor's total learning effects delivered to the nurse's instructional learning effects stays below 0.1. These perfectly express the nurse's imperfect knowledge in preparation of pure ventilation makes her not available to complete giving that ventilation. These also shows inefficient communication between nurses and doctors does not help nurses to troubleshoot in a timely manner.

For the nurse's weight of the connection from the team preparing the combination of ventilation and compression to the team giving that ventilation, the first-order self-model **W**-state for her self-learning effects reach activation at around $t = 30$. The first-order self-model **W**-state for her instructional learning effects is never active. Her first-order self-model **W**-state for total learning effects get activated at around $t = 31.5$. In addition, her second order self-model **M**-states for resistance factor get activated at around $t = 2$ but for the weight of the connection from the doctor's total learning effects to the nurse's instructional learning effects is never active. These shows the nurse doesn't get good instruction from the doctor for preparing the combination of compression and ventilation. That's because the doctor doesn't prepare well for that. Since the nurse still has sufficient knowledge for preparation, she is well prepared in the end.

For the doctor's weight of the connection from the team preparing pure ventilation to the nurse giving first time of pure ventilation, the first-order self-model **W**-states for his self-learning effects is never activated. That's because of hebbian learning effects and his mental model state for giving that ventilation never gets activated. However, his first-order self-model **W**-state for instructional learning effects is activated all the time and his first-order self-model **W**-state for total learning effects reach activation at around t = 2. In addition, his second order self-model states for the resistance factors get activated at around t = 2. These are because the doctor has perfect knowledge.

For the doctor's weight of the connection from the team preparing the combination of ventilation and compression to the team giving that ventilation, the first-order self-model **W**-state for his instructional learning effects, self-learning effects, and total learning effects are never active. In addition, his second order self-model state for resistance factor is also never activated. These show the doctor lack perfect knowledge to complete that ventilation and show he never get effective warning from the nurse.

The adaptation states strengthen the validity of the network model. They clearly show impact of the extreme mistake condition where team members both lack some key knowledge, and both don't get effective help from each other.

5.2.4 The World States, the Baby States and the Context State

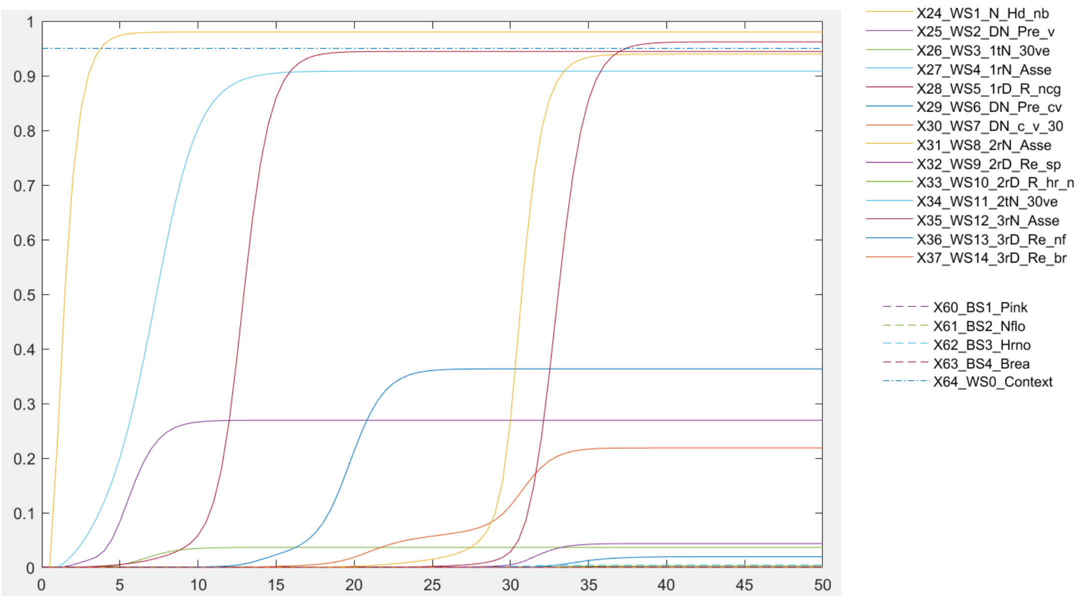


Fig 5-5: Simulation Results for the World States, Baby States and the Context State

In Fig 5-5, the solid lines, the dashed and dotted line and the dashed lines reflect value of the world states, the context state and baby states over time, respectively. The world state for the nurse holding the new-born baby on the table reach activation at around t = 2. That follows with the world state for the team's preparation for pure ventilation is never active. That state slowly rises to 0.28 at around t = 10 because of the doctor's contribution. However, the nurse is never well-prepared so that the team will never be well prepared. That lead to the world state for the nurse giving first time of pure ventilation never get activated. Thus, the world state for the nurse helping the first round of assessment and for the doctor report the baby has no change is active at around t = 10 and t = 14.5. In new treatment, the nurse is well prepared, but the doctor is not well prepared. However, the nurse doesn't warn the doctor for his imperfect knowledge because she is afraid of authority. These lead the world state for the team preparing and giving the combination of compression and ventilation never reach activation. These states slowly rise but stays under 0.3 because of the nurse's contribution. However, without the doctor's contribution, these states will never be active. The world state for the nurse helps the second round of assessment get activated at around t = 32. The failure makes the world state for the doctor reporting no change is still active but the world states for him reporting the baby is slightly pink and with normal heart rate are never active. Right after, the world state for the nurse giving second time of pure ventilation never get activated because she still has imperfect knowledge because of lack of effective communication with the doctor. The world state for the nurse helps the second round of assessment get activated at around t = 34. The failure result in that the world state for the doctor reporting no change is still active but the world states for he reporting the baby is not floppy and start breathing are never active.

The world states and baby states confirm the validity of the network model. If one person fails in an action that requires teamwork, the entire team will fail. The world states presents the extreme failures of team action because of both member holds imperfect knowledge and lack effective communication.

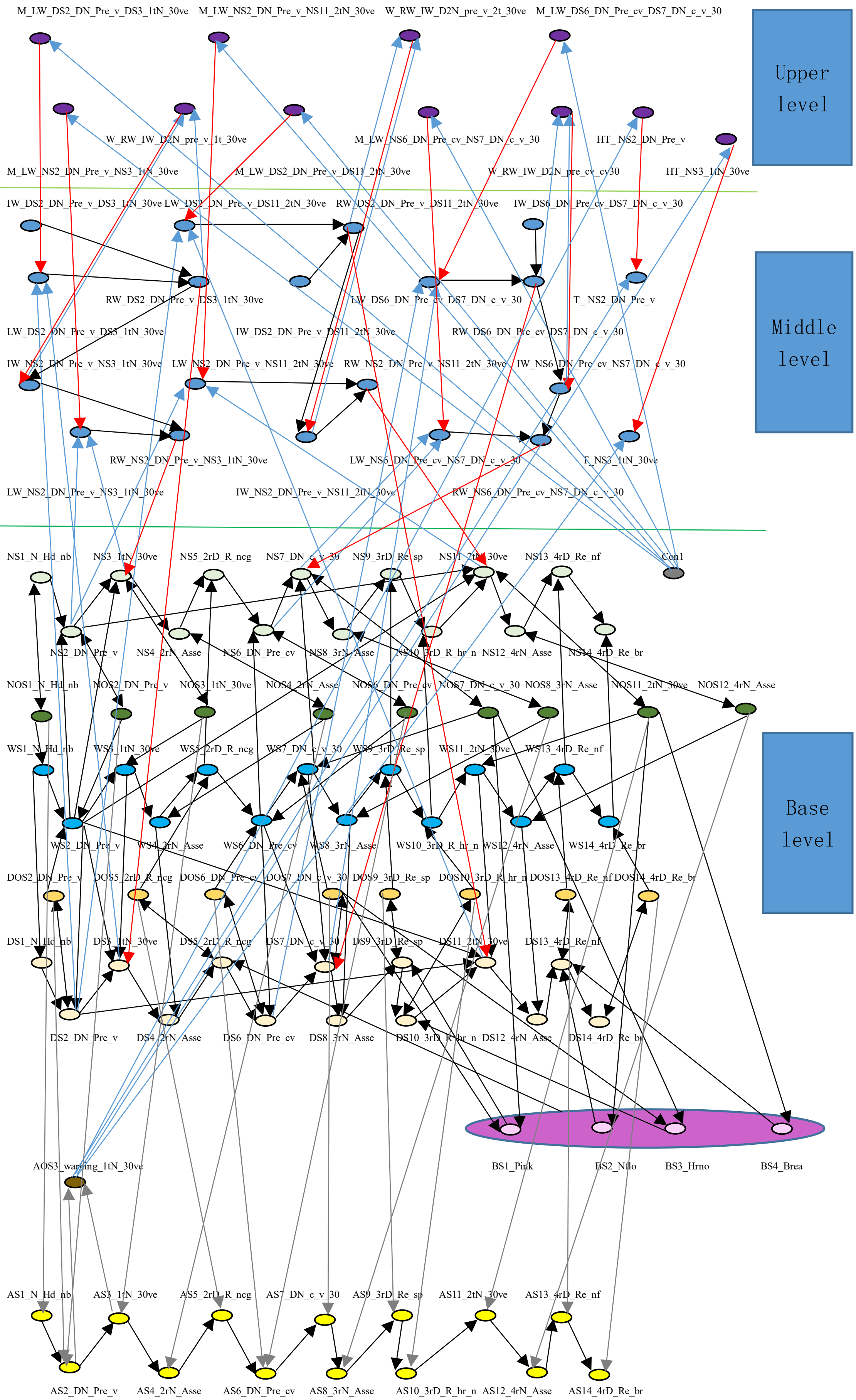
6. Adaptive Network Model for the AI-coach's Engagement without Organizational Learning

6.1 Network Model Introduction

In this condition, the nurse has imperfect knowledge in preparing pure ventilation. But when she just start giving first time of pure ventilation and is at the early phase of making a mechanical frequency related error, the AI-coach detects her action through sensors. To prevent further damage, the AI-coach warns her for she is about to fail to give a correct pure ventilation and tell her the right way to do that. Learning from the AI-coach, the nurse is able to do the first time of pure ventilation correctly. This condition is transformed from the previous partial mistake condition in Chapter 5 plus the involvement of the AI-coach. Since there is no introduction of organizational learning, the expression of the AI-coach is making high threshold values of the nurse's mental model states for she is preparing and giving a first time of pure ventilation dropping down. That can be realized by influencing the adaptation speed for these threshold value adaptations.

Comparing to the protocol condition without organizational learning, this condition adds the AI-coach's mental model states and actions ownership states, the first-order self-model **W**-states for threshold values of the nurse's mental model states for she is preparing and giving a first time of pure ventilation, second order self-model states for speed of threshold mentioned above. For new added states, states in base level are presented at Table 7-1, states in middle level and states in upper level are introduced at Table 7-2.

Based on the network model for the protocol condition without organizational learning, new connections are added to these new states. The AI-coach keeps monitoring the team's actions, so that new connections marked by light black arrow from the team's action ownership states to the AI-coach's corresponding mental model states are added. When the AI-coach is going to warn the nurse, new connections from the AI-coach's mental model states to the AI-coach's action ownership state is added as well. In addition, the AI-coach helps the nurse to obtain her missing knowledge and to prevent mistakes, so that connections from the AI-coach's action ownership state to these new adaptation **T**-states related to threshold values are added. In addition to new states and new connections, other network characteristics also were changed. Simulation results will be introduced below.



Upper level
Middle level
Base level
M_LW_DS2_DN_Pre_v_DS3_1tN_30ve
M_LW_NS2_DN_Pre_v_NS11_2tN_30ve
W_RW_IW_D2N_pre_v_2t_30ve
M_LW_DS6_DN_Pre_cv_DS7_DN_c_v_30
W_RW_IW_D2N_pre_v_1t_30ve
M_LW_NS6_DN_Pre_cv_NS7_DN_c_v_30
HT_NS2_DN_Pre_v
M_LW_NS2_DN_Pre_v_NS3_1tN_30ve
M_LW_DS2_DN_Pre_v_DS11_2tN_30ve
W_RW_IW_D2N_pre_cv_cy30
HT_NS3_1tN_30ve
IW_DS2_DN_Pre_v_DS3_1tN_30ve
LW_DS2_DN_Pre_v_DS11_2tN_30ve
RW_DS2_DN_Pre_v_DS11_2tN_30ve
IW_DS6_DN_Pre_cv_DS7_DN_c_v_30
RW_DS2_DN_Pre_v_DS3_1tN_30ve
LW_DS6_DN_Pre_cv_DS7_DN_c_v_30
T_NS2_DN_Pre_v
LW_DS2_DN_Pre_v_DS3_1tN_30ve
IW_DS2_DN_Pre_v_DS11_2tN_30ve
RW_DS6_DN_Pre_cv_DS7_DN_c_v_30
IW_NS2_DN_Pre_v_NS3_1tN_30ve
LW_NS2_DN_Pre_v_NS11_2tN_30ve
RW_NS2_DN_Pre_v_NS11_2tN_30ve
IW_NS6_DN_Pre_cv_NS7_DN_c_v_30
RW_NS2_DN_Pre_v_NS3_1tN_30ve
LW_NS6_DN_Pre_cv_NS7_DN_c_v_30
T_NS3_1tN_30ve
LW_NS2_DN_Pre_v_NS3_1tN_30ve
IW_NS2_DN_Pre_v_NS11_2tN_30ve
RW_NS6_DN_Pre_cv_NS7_DN_c_v_30
NS1_N_Hd_nb
NS3_1tN_30ve
NS5_2rD_R_ncg
NS7_DN_c_v_30
NS9_3rD_Re_sp
NS11_2tN_30ve
NS13_4rD_Re_nf
Con1
NS2_DN_Pre_v
NS4_2rN_Asse
NS6_DN_Pre_cv
NS8_3rN_Asse
NS10_3rD_R_hr_n
NS12_4rN_Asse
NS14_4rD_Re_br
NOS1_N_Hd_nb
NOS2_DN_Pre_v
NOS3_1tN_30ve
NOS4_2rN_Asse
NOS6_DN_Pre_cv
NOS7_DN_c_v_30
NOS8_3rN_Asse
NOS11_2tN_30ve
NOS12_4rN_Asse
WS1_N_Hd_nb
WS3_1tN_30ve
WS5_2rD_R_ncg
WS7_DN_c_v_30
WS9_3rD_Re_sp
WS11_2tN_30ve
WS13_4rD_Re_nf
WS2_DN_Pre_v
WS4_2rN_Asse
WS6_DN_Pre_cv
WS8_3rN_Asse
WS10_3rD_R_hr_n
WS12_4rN_Asse
WS14_4rD_Re_br
DOS2_DN_Pre_v
DOS5_2rD_R_ncg
DOS6_DN_Pre_cv
DOS7_DN_c_v_30
DOS9_3rD_Re_sp
DOS10_3rD_R_hr_n
DOS13_4rD_Re_nf
DOS14_4rD_Re_br
DS1_N_Hd_nb
DS3_1tN_30ve
DS5_2rD_R_ncg
DS7_DN_c_v_30
DS9_3rD_Re_sp
DS11_2tN_30ve
DS13_4rD_Re_nf
DS2_DN_Pre_v
DS4_2rN_Asse
DS6_DN_Pre_cv
DS8_3rN_Asse
DS10_3rD_R_hr_n
DS12_4rN_Asse
DS14_4rD_Re_br
AOS3_warning_1tN_30ve
BS1_Pink
BS2_Nflo
BS3_Hrno
BS4_Brea
AS1_N_Hd_nb
AS3_1tN_30ve
AS5_2rD_R_ncg
AS7_DN_c_v_30
AS9_3rD_Re_sp
AS11_2tN_30ve
AS13_4rD_Re_nf
AS2_DN_Pre_v
AS4_2rN_Asse
AS6_DN_Pre_cv
AS8_3rN_Asse
AS10_3rD_R_hr_n
AS12_4rN_Asse
AS14_4rD_Re_br

Fig 6-1: Adaptive Network Model for the AI-coach's Engagement without Organizational Learning

6.2 Simulation for Example Scenarios:

If the network model of this condition is valid, expected results should occur in simulation. When the nurse lacks perfect knowledge on pure ventilation, the nurse's mental model states for her preparing and giving pure ventilation will have low values. The threshold for these two states should stay at high levels. After theAI-coach's action ownership state for warning the nurse start rising, second-order self-model states for adaptation speed of first-order self-model **T**-states for these threshold values should start to rise as well. After that, the first-order self-model **T**-states for these threshold values should decrease because of the influence from the AI-coach's action ownership state for warning. That will lead to increasing values of the nurse's mental model states for preparing and giving a first time of pure ventilation, and that marks that the nurse's imperfect knowledge has been fixed.

As before, the network model was specified the standard table format called role matrices for the convenience of inputting these network characteristics to the software environment for simulation. The example simulation presented here was run from 0 to 50 with step size Δt =0.5. Simulation results of state activation based on the current network model and its characteristics will be discussed below. The contextual stress level is set to be relatively low, so that the context state has a value of 0.95, and that will lead to **M**-states values no more than 0.95. For clear analysis, the results of the same simulation at the indicated time points have been split into (1) the graph of states that embodies the function of the AI-coach, (2) the graph of the adaptation states, and (3) the nurse's states, the graph of the doctor's states, the graph of the world states, the baby states and the context state.

6.2.1 States Modelling the Function of the AI-coach

In Fig 6-2, the dashed lines, the dashed and the dotted lines, the solid lines, and the dotted lines represent the nurse's action ownership states, the doctor's action ownership states, the AI-coach's mental model states and the AI-coach's action ownership states, respectively. In the AI-coach's mental model, except *AS2_DN_Pre_v* and *AS3_1tN_30ve*, all other the AI-coach's mental model states get activated right after team members' corresponding action ownership states. These reflects the AI-coach is monitoring the team's actions. For the AI-coach's mental model state for the team preparing pure ventilation, it rises to 0.5 first when the doctor's action ownership state for preparing pure ventilation get activated. Since the nurse's action ownership state for that preparation is not activated, the AI-coach's warning function is activated. The AI-coach's mental model state for the nurse giving first time of pure ventilation automatically reaches activation from as a result of its own database. Then, the AI-coach is able to activate the state for warning nurse to give correct pure ventilation. Fig 6-3 presents the warning process. The rise of the AI-coach's mental model states for

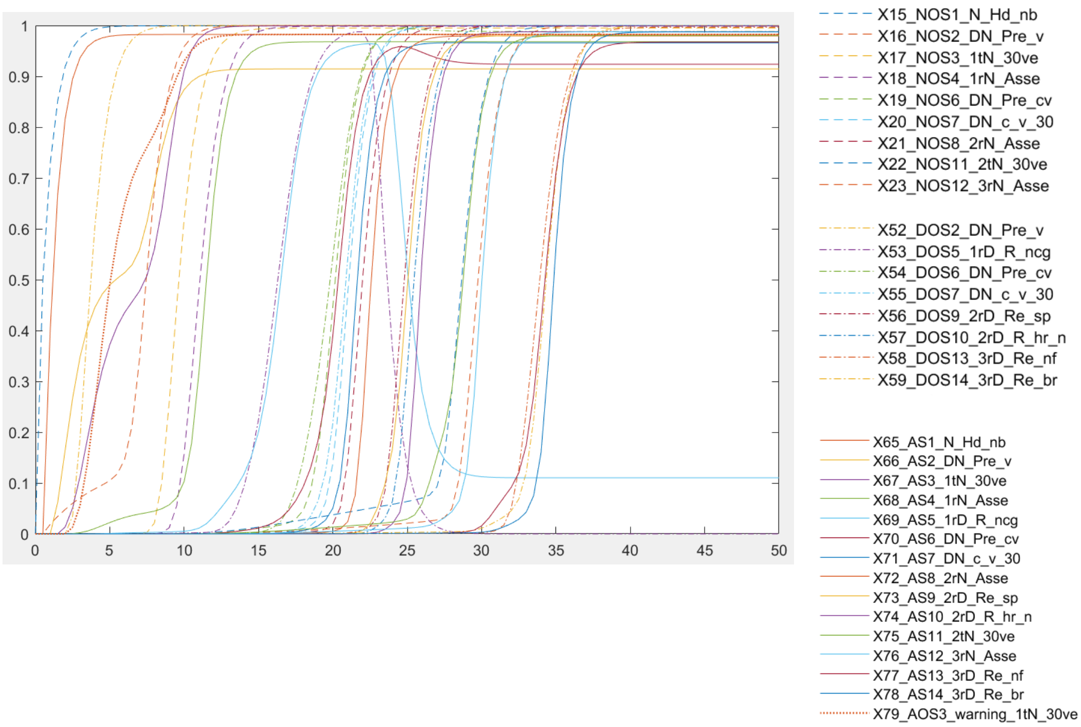


Fig 6-2: Simulation Results that Show the AI-coach's Monitoring

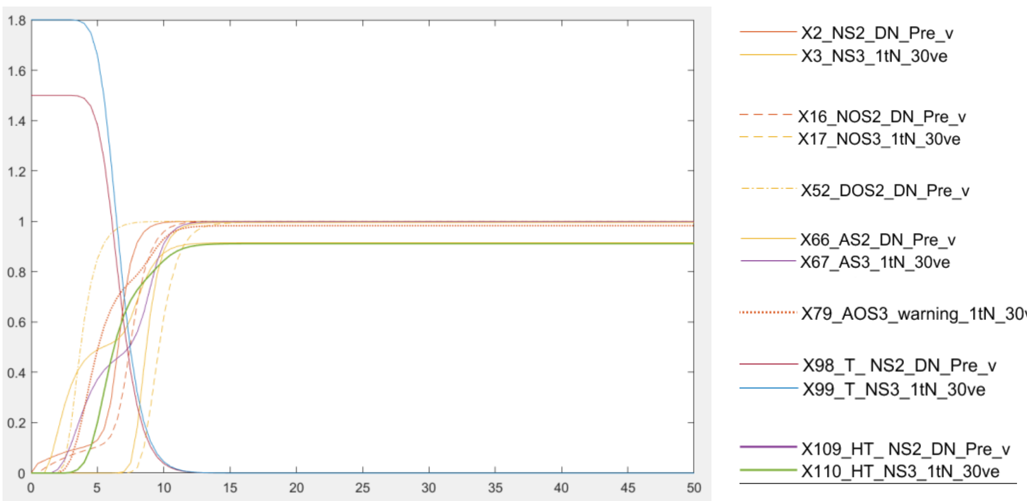


Fig 6-3: Simulation Results that Show Effects of the AI-coach's Warning

the team preparing pure ventilation and the nurse giving pure ventilation make that the AI-coach's mental model state for warning the nurse giving correct pure ventilation gets activated. That leads second-order self-model states for (adaptation) speed of the corresponding first-order self-model **T**-states for threshold values to increase. Since the first-order self-model **T**-states for threshold values has negative connections from the AI-coach's action ownership state for warning the nurse giving pure ventilation, the rise of latter one lead the former ones to decrease. With lower threshold value, the nurse's mental model states for the team preparing the pure ventilation and for giving first time of pure ventilation get activated at around t =7.5 and *t* =10. Thus, the nurse is well prepared and successfully giving first time of pure ventilation with the help of the

AI-coach. Activations of the remaining states will be introduced in latter subsections.

6.2.2 The Nurse’s Mental Processes Based on Her Mental Model

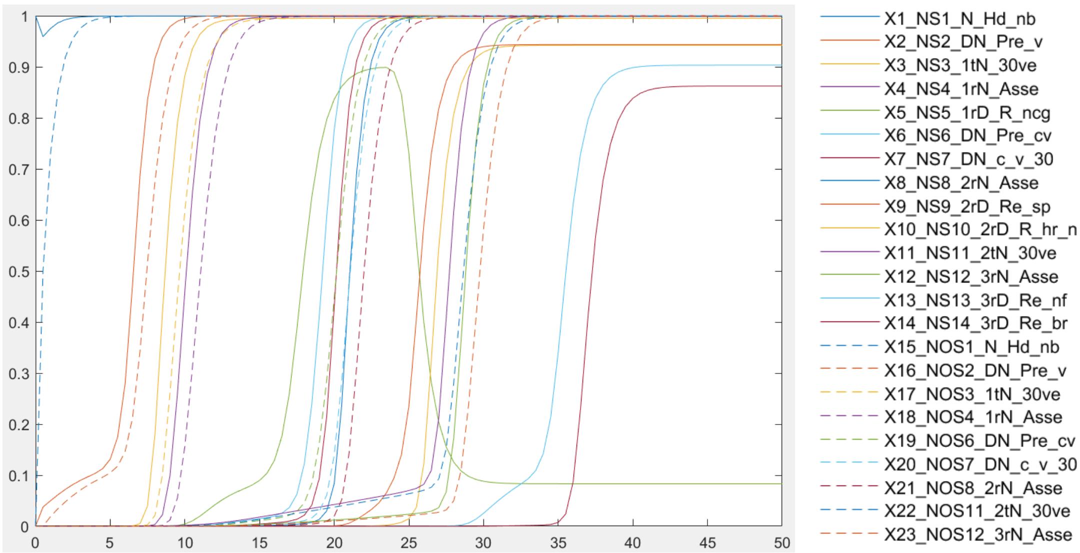


Fig 6-4: Nurse Mental Model and Action Ownership States

In Fig 6-4, solid lines and dashed lines refers to the nurse’s mental model states and action ownership states, respectively. The nurse’s mental model state for holding the baby on the table is always active. Its corresponding action ownership states reach activation at around *t* =2. Before *t* =5, the nurse’s mental model state for the team preparing the pure ventilation keeps at a value lower than 0.2. That means the nurse is not preparing well. Around *t* =4, the AI-coach warns the nurse for her imperfect behaviour. That leads the nurse’s mental model state and its corresponding action ownership state for preparing pure ventilation rises in a nearly vertical curve and reach activation at around *t* =7.5 and *t* =9. That is followed by activation of the nurse giving first time of pure ventilation at around *t* =9.5 and *t* =11. After that, the nurse helps the first-round assessment. The nurse’s mental model state and corresponding action ownership states for that get activated at around *t* =11 and 12.5, respectively. Right after, the nurse’s mental model state for the doctor reporting no change in the baby is active at around *t* =19.5. To save the baby, a new treatment starts. The nurse’s mental model states and corresponding action ownership states for the team preparing and giving the combination of compression and ventilation reach activation at around *t* =20, *t* =21.5 (for preparation), *t* =21, and *t* =22 (for giving ventilation). Then, the nurse’s mental model state and their corresponding action ownership state for helping the second-round assessment get activated at around *t* =22 and *t* =23.5. Since the baby partially recovers, the nurse’s mental model state for the doctor reporting no change is not active at around *t* =25. The nurse’s mental model states for the doctor reporting that the baby is slightly pink and with normal heart rate reach activation at around *t* =26.5 and *t* =28, respectively. The baby’s complete recovery requires more treatment. Thus, the nurse’s mental model state and its corresponding action ownership state for giving the second time of pure ventilation get activated at around *t* =28.5 and *t* =30, respectively. The new ventilation totally saves the baby out of danger. Thus, in third round of assessment, the nurse's mental model state and action ownership state for helping that assessment reach activation at around t =30 and t =31.5. Right after, the nurse's mental model states for the doctor reporting that the baby is not floppy and starts breathing get activated at around t =37 and t =39.

The nurse's states addressed the validity of the network model. The results show that she doesn't prepare well at the beginning due to the lack of perfect knowledge. With the help of the AI-coach's warning, she realizes that and obtains perfect knowledge. Finally, the nurse makes no mistake in giving pure ventilations.

6.2.3 The Doctor's Mental Processes Based on His Mental Model

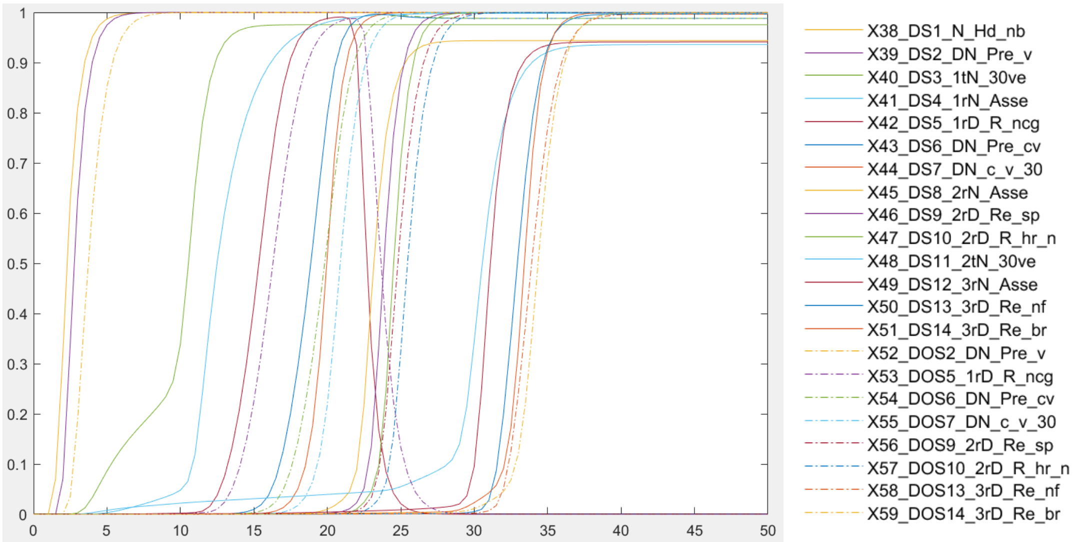


Fig 6-5: Doctor Mental Model and Action Ownership States

In Fig 6-5, solid lines and dashed lines refer to values of the doctor's mental model states and the doctor's action ownership states over time, respectively. Around t =3.5, after observing the nurse holds the newborn baby who need ventilation on the table, the doctor's mental model state for that is active. Right after, the doctor's mental model state and its corresponding action ownership state for preparing pure ventilation are active at around t =3.5 and t =5, respectively. That means the doctor prepared well. Right after, with his own knowledge and observation of the nurse's action, the doctor's mental model state for nurse giving a first time of pure ventilation and the first round of assessment are active at around t =12 and t =14.5, respectively. The baby has no change, thus the doctor's mental model state and its corresponding action ownership state for reporting that reach activation at around t =16.5 and t =17.5, respectively.

A new treatment is required so that the doctor's mental model state and its corresponding action ownership state for the team preparing and giving the combination of compression and ventilation is active at around t = 19.5 , t = 20.5 (for preparation), t = 20 and t = 21 (for giving ventilation), respectively. After giving ventilation, assessment starts. Thus, the doctor's mental model state for the nurse helping assess for the second round gets activated at around t =24.5. After that ventilation, the doctor observes the baby is slightly pink and with normal heart rate again. The doctor's mental model states and their corresponding action ownership states for reporting these reach activation at around t = 25, t = 26 (for the baby is slightly pink), t = 25.5 and t = 26.5 (for the baby is with normal heart rate), respectively. At the same moment, the doctor's mental model and its corresponding state for reporting the baby has no change become inactive at around t = 22 and t = 22.5, respectively. To complete saving baby, the nurse gives the second time of pure ventilation. After that, the nurse helps the third round of assessment. The doctor's mental model states for these get activated slightly before t = 32 and slightly after t = 32, respectively. Observing the baby is totally safe, the doctor's mental model states and their corresponding states for reporting the baby is not floppy and starts breathing reach activation at around t =34, t =35 (for the baby is not floppy), t =34.5 and t =35.5 (for the baby starts breathing).

6.2.4 The World States, the Baby states and the Context State

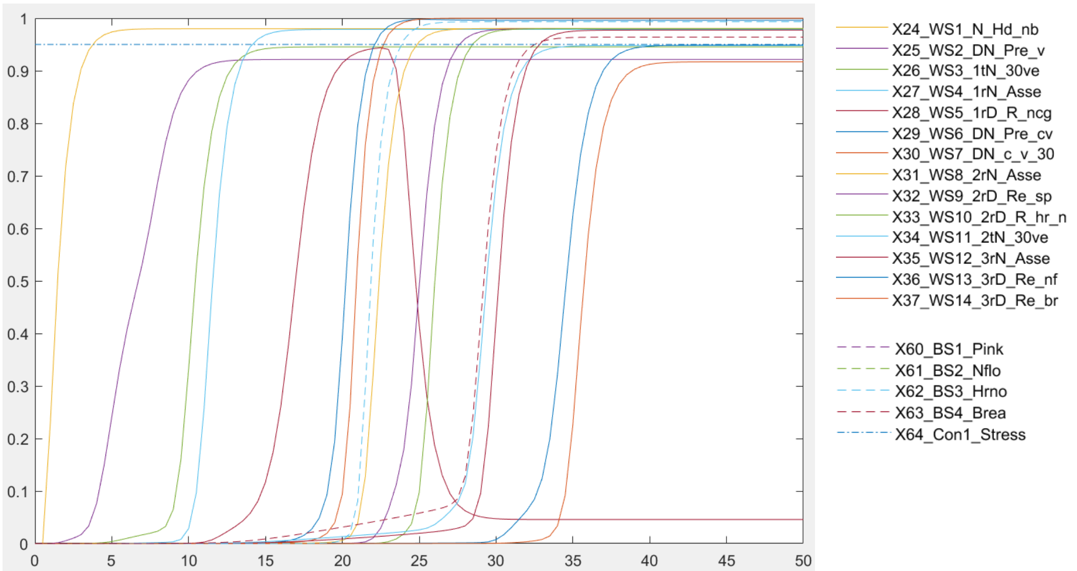


Fig 6-6: Simulation Results for the World States, Baby States and the Context State

In Fig 6-5, the solid lines, the dashed and dotted line, and the dashed lines reflect values of the world states, the context state and baby states over time, respectively. The world state for nurse's holding the new-born baby on the table is activated at around t =2. That means the team starts saving the baby. The world state for the team preparing for pure ventilation gets activated at around t =9. That means, after the AI-coach warns the nurse, she is finally well-prepared so that the team are finally well- prepared as well. Then, the world state for the nurse giving the first time of pure ventilation gets activated at around t =11.5, that means with the warning of the AI-coach, she successfully gives a pure ventilation. In the partial mistake condition, that state is never activated, so that the AI-coach makes a good contribution. In the first round of assessment, the world state of the nurse helping that assessment and for the doctor reporting the baby has no change reach activation at around *t* =12.5 and *t* =17. The baby still needs more treatment. Thus, the world states for the team preparing and giving a combination of compression and ventilation get activated at around *t* =20.5 and *t* =21. After that, the baby partially recovers. The baby states for the baby is slightly pink and has normal heart rate are active at around *t* =25. So, the world state for the nurse helping the second round of assessment and for the doctor reporting the baby is slightly pink and with normal heart rate reach activation at around *t* =24, *t* =26, and *t* =27. To have the baby completely safe, the world state for the nurse giving the second time of pure ventilation gets activated at around 30.5. Almost at the same time, the baby is not floppy anymore and start breathing. The baby states for these reach activation at around *t* =30.5. In the third round of assessment, the world state for the nurse helping the assessment and for the doctor reporting the baby is not floppy and starts breathing get activated at around *t* =31, *t* =35.5 and *t* =37.

Adaptation States

Fig 6-5 reflects the values of adaptation states over time. The first picture shows the effects of the AI-coach warning. The AI-coach's warning results in rising of second-order self-model states for the adaptation speed of the first-order self-model **T**-states for the threshold values. Combining with the influence from the AI-coach's warning, that makes the first-order self-model **T**-states for threshold values decrease. That will enable the nurse's mental model states for preparing pure ventilation and for giving the first time of pure ventilation increase rapidly.

The second picture shows the team members' learning effects. All second-order self-model **M**-states for the persistence factor of the self-learning effects of the doctor and the nurse get activated at around *t* =2. For the nurse's weight of the connection from the team preparing pure ventilation to giving the first time of pure ventilation, the first-order self-model **W**-states for self-learning effects, instructional learning effects, and total learning effects get activated at around *t* =10, *t* =9 and *t* =9. The first-order self-model **W**-state for self-learning effects is at a low level and decreasing until around *t* =7. That shows the bad influence of imperfect knowledge. Because of the principle of hebbian learning, the low level of the nurse's mental model state for preparing and giving second time of pure ventilation leads that the first-order self-model state for self-learning effects stays at a low level. The AI-coach mainly has a positive influence on the nurse's self-learning effects. After the AI-coach's warning, these two mental model states start rising much faster and that leads to fast rising of the first-order self-model **W**-state for self-learning effects. The doctor provides some instructions, but the instructional learning effects before *t* =5 are relatively weak. The first-order self-model **W**-state for total learning effects is lower than 0.2 before *t* =5, that shows the nurse's poor preparation.

For the nurse's weight of the connection from the team preparing pure ventilation to giving the second time of pure ventilation, the first-order self-model **W**-states for self-learning effects, instructional learning effects, and total learning effects get activated at around *t* =29, *t* =20 and *t* =15. In this process, the doctor's instruction contributes more to the nurse's total learning effects. The later activation of the first-order self-model **W**-state for the self-learning effects is because of the principle of hebbian learining.

For the nurse's weight of the connection from the team preparing the combination of compression and ventilation to the team giving that ventilation, the first-order self-model **W**-states for self-learning effects, instructional learning effects, and total learning effects get activated at around *t* =20, *t* =10 and *t* =10. This process is not related to the AI-coach's contribution so no further discussion here.

For the doctor, all his first-order self-model **W**-states for instructional learning effects are activated all the time. For the doctor's weight of the connection from the team preparing pure ventilation to giving the first time of pure ventilation, his first-order self-model **W**-states for self-learning effects and total learning effects get activated at around *t* =10 and *t* =3. For the doctor's weight of the connection from the team preparing pure ventilation to giving the second time of pure ventilation, the first-order self-model **W**-states for self-learning effects and total learning effects get activated at around *t* =33 and *t* =15. For the doctor's weight of the connection from the team preparing the combination of compression and ventilation to the team giving that ventilation, the first-order self-model **W**-states for self-learning effects and total learning effects become active at around *t* =10 and *t* =3. The first-order self-learning **W**-states for total learning effects get activated much earlier than self-learning effects because in order to reduce the influence of the doctor's self-learning effects in this condition, the doctor's instructional learning effects contributed 90% to doctor's total learning effect. In addition, the threshold values of the first-order self-model **W**-states for total learning effects are slightly different, which makes that these states get activated at different times.

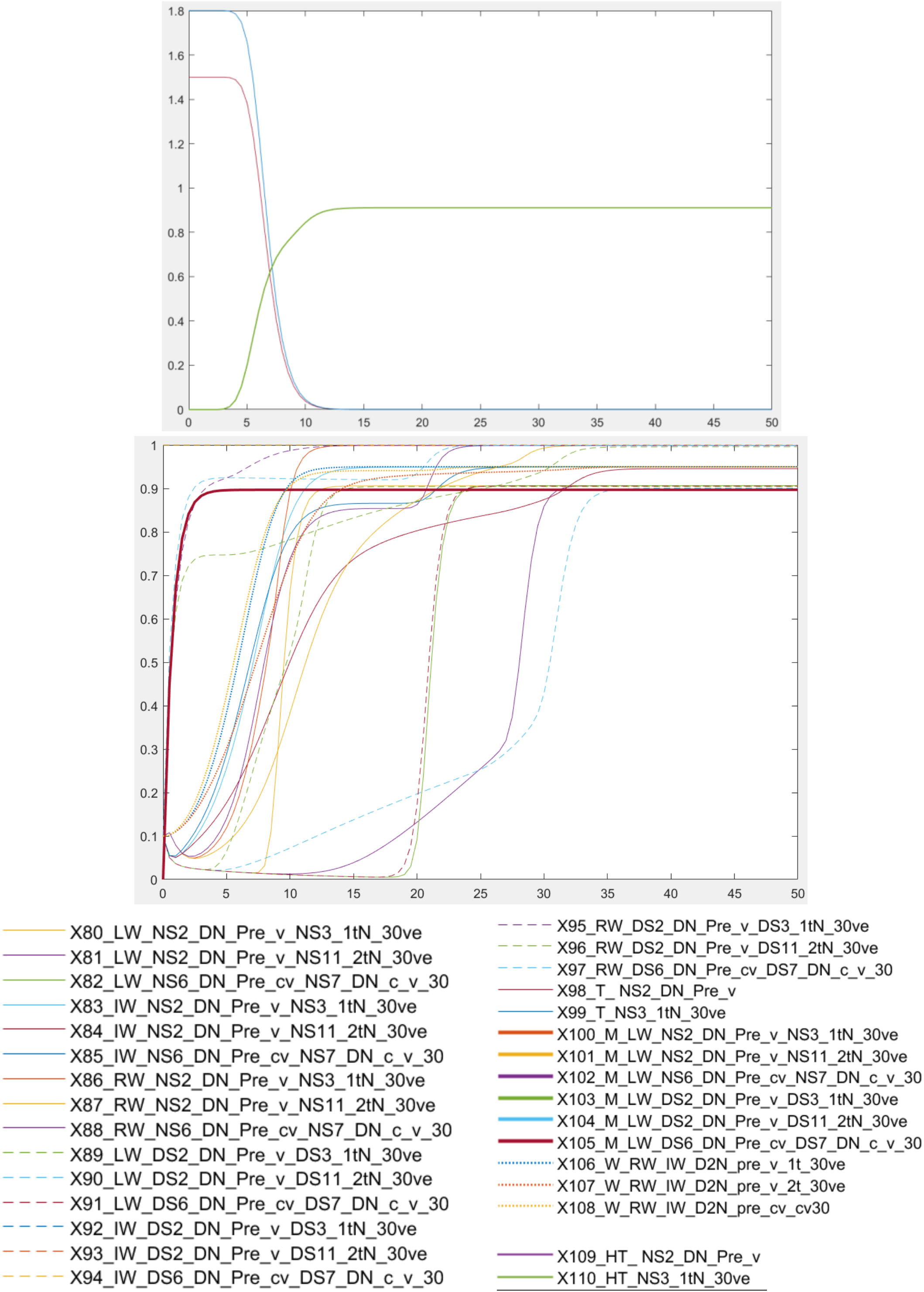


Fig 6-6: Simulation Results of Adaptation States

7. Adaptive Network Model for the AI-coach's Engagement with Organizational Learning

7.1 Network introduction

In this condition, the nurse has imperfect knowledge in preparing pure ventilation and the doctor has imperfect knowledge in preparing the combination of compression and ventilation at beginning. The AI-coach can help them avoid mistakes by using organizational learning. In the team, the knowledge of doctors and nurses is complementary. They each mastered the knowledge that each other lacked. The AI-coach can obtain their knowledge by feedforward learning and send improved knowledge back through feedback learning. The process of how the AI-coach help the team correct their imperfect knowledge is presented in Fig 7-1. In this process, for starters, the AI-coach obtains knowledge from the doctor, so that the AI-coach has an imperfect mental model same as the doctor. Since the AI-coach masters the knowledge that the nurse lacks, the nurse learns from the AI-coach to correct her imperfect knowledge. As a result, the nurse has a perfect mental model. Then, the AI-coach learns from the nurse and has a perfect mental model as well. Finally, the doctor learns from the AI-coach and obtain his missing knowledge. That means all team members are well prepared in the end.

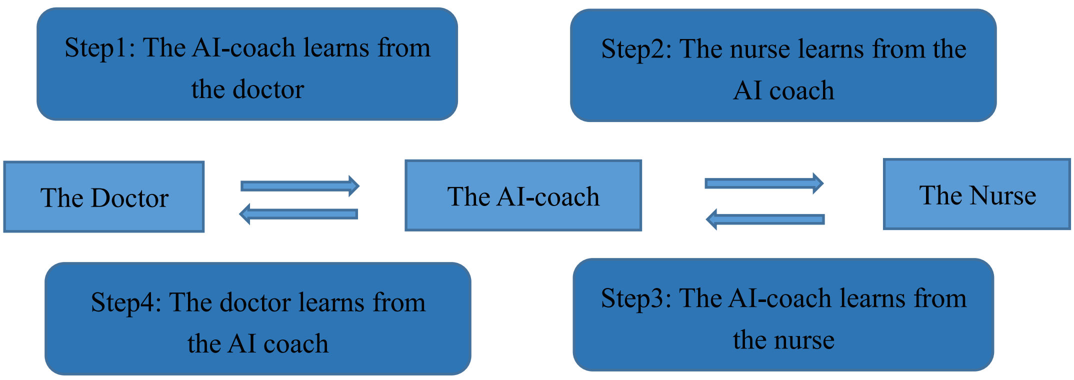
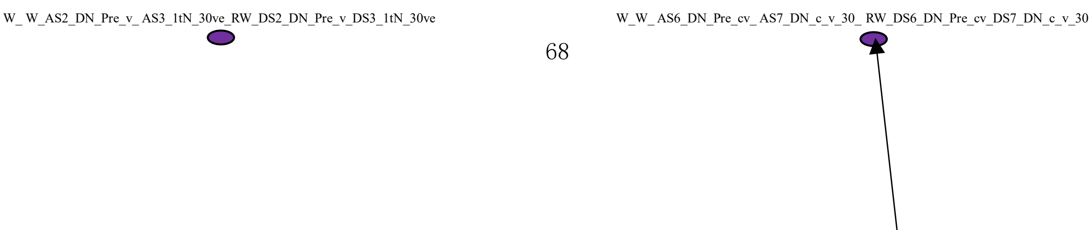
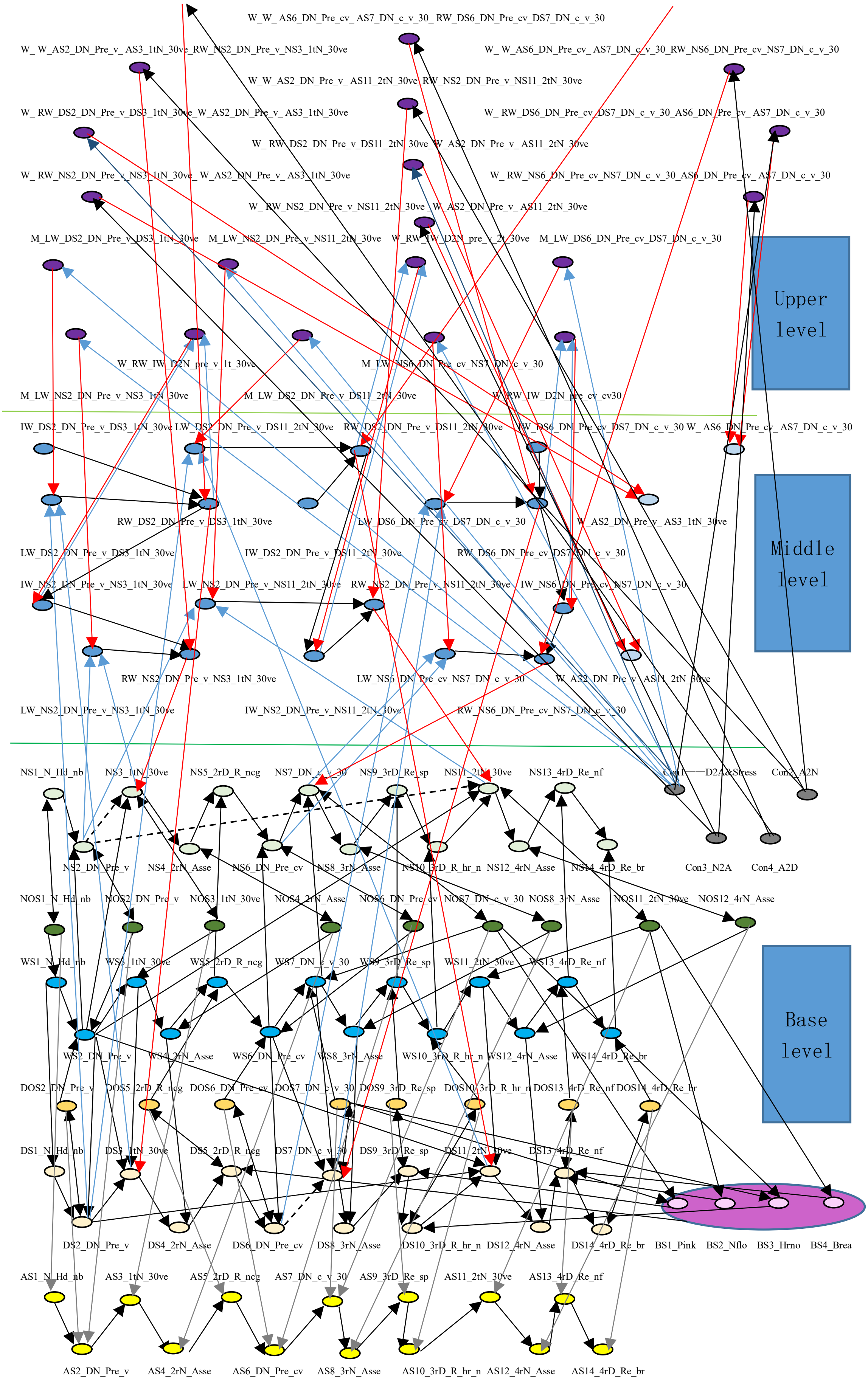


Fig 7-1: Process of the AI-coach Applies Organizational Learning

In the network, organizational learning are mainly reflected at the middle level and the upper level. For the base level, readers can refer mental model states of the doctor, the nurse and the AI-coach to Chapter 1 and Chapter 7. New added context states and adaptation states are introduced in Table 8-1 and Table 8-2.

Three new added first-order self-model states reflect the AI-coach's mastery of knowledge. These new added second order self-model states controls organizational learning effects, and they themselves are controlled by the 4 new added context states.





W_W_AS6_DN_Pre_cv_AS7_DN_c_v_30_RW_DS6_DN_Pre_cv_DS7_DN_c_v_30
W_W_AS2_DN_Pre_v_AS3_1tN_30ve_RW_NS2_DN_Pre_v_NS3_1tN_30ve
W_W_AS6_DN_Pre_cv_AS7_DN_c_v_30_RW_NS6_DN_Pre_cv_NS7_DN_c_v_30
W_W_AS2_DN_Pre_v_AS11_2tN_30ve_RW_NS2_DN_Pre_v_NS11_2tN_30ve
W_RW_DS2_DN_Pre_v_DS3_1tN_30ve_W_AS2_DN_Pre_v_AS3_1tN_30ve
W_RW_DS6_DN_Pre_cv_DS7_DN_c_v_30_AS6_DN_Pre_cv_AS7_DN_c_v_30
W_RW_DS2_DN_Pre_v_DS11_2tN_30ve_W_AS2_DN_Pre_v_AS11_2tN_30ve
W_RW_NS2_DN_Pre_v_NS3_1tN_30ve_W_AS2_DN_Pre_v_AS3_1tN_30ve
W_RW_NS6_DN_Pre_cv_NS7_DN_c_v_30_AS6_DN_Pre_cv_AS7_DN_c_v_30
W_RW_NS2_DN_Pre_v_NS11_2tN_30ve_W_AS2_DN_Pre_v_AS11_2tN_30ve
M_LW_DS2_DN_Pre_v_DS3_1tN_30ve
M_LW_NS2_DN_Pre_v_NS11_2tN_30ve
W_RW_IW_D2N_pre_v_2t_30ve
M_LW_DS6_DN_Pre_cv_DS7_DN_c_v_30
Upper level
W_RW_IW_D2N_pre_v_1t_30ve
M_LW_NS6_DN_Pre_cv_NS7_DN_c_v_30
M_LW_NS2_DN_Pre_v_NS3_1tN_30ve
M_LW_DS2_DN_Pre_v_DS11_2tN_30ve
W_RW_IW_D2N_pre_cv30
IW_DS2_DN_Pre_v_DS3_1tN_30ve
LW_DS2_DN_Pre_v_DS11_2tN_30ve
RW_DS2_DN_Pre_v_DS11_2tN_30ve
IW_DS6_DN_Pre_cv_DS7_DN_c_v_30
W_AS6_DN_Pre_cv_AS7_DN_c_v_30
RW_DS2_DN_Pre_v_DS3_1tN_30ve
LW_DS6_DN_Pre_cv_DS7_DN_c_v_30
W_AS2_DN_Pre_v_AS3_1tN_30ve
Middle level
LW_DS2_DN_Pre_v_DS3_1tN_30ve
IW_DS2_DN_Pre_v_DS11_2tN_30ve
RW_DS6_DN_Pre_cv_DS7_DN_c_v_30
IW_NS2_DN_Pre_v_NS3_1tN_30ve
LW_NS2_DN_Pre_v_NS11_2tN_30ve
RW_NS2_DN_Pre_v_NS11_2tN_30ve
IW_NS6_DN_Pre_cv_NS7_DN_c_v_30
RW_NS2_DN_Pre_v_NS3_1tN_30ve
LW_NS6_DN_Pre_cv_NS7_DN_c_v_30
W_AS2_DN_Pre_v_AS11_2tN_30ve
LW_NS2_DN_Pre_v_NS3_1tN_30ve
IW_NS2_DN_Pre_v_NS11_2tN_30ve
RW_NS6_DN_Pre_cv_NS7_DN_c_v_30
NS1_N_Hd_nb
NS3_1tN_30ve
NS5_2rD_R_ncg
NS7_DN_c_v_30
NS9_3rD_Re_sp
NS11_2tN_30ve
NS13_4rD_Re_nf
Con1
D2A&Stress
Con2_A2N
NS2_DN_Pre_v
NS4_2rN_Asse
NS6_DN_Pre_cv
NS8_3rN_Asse
NS10_3rD_R_hr_n
NS12_4rN_Asse
NS14_4rD_Re_br
Con3_N2A
Con4_A2D
NOS1_N_Hd_nb
NOS2_DN_Pre_v
NOS3_1tN_30ve
NOS4_2rN_Asse
NOS6_DN_Pre_cv
NOS7_DN_c_v_30
NOS8_3rN_Asse
NOS11_2tN_30ve
NOS12_4rN_Asse
WS1_N_Hd_nb
WS3_1tN_30ve
WS5_2rD_R_ncg
WS7_DN_c_v_30
WS9_3rD_Re_sp
WS11_2tN_30ve
WS13_4rD_Re_nf
Base level
WS2_DN_Pre_v
WS4_2rN_Asse
WS6_DN_Pre_cv
WS8_3rN_Asse
WS10_3rD_R_hr_n
WS12_4rN_Asse
WS14_4rD_Re_br
DOS2_DN_Pre_v
DOS5_2rD_R_ncg
DOS6_DN_Pre_cv
DOS7_DN_c_v_30
DOS9_3rD_Re_sp
DOS10_3rD_R_hr_n
DOS13_4rD_Re_nf
DOS14_4rD_Re_br
DS1_N_Hd_nb
DS3_1tN_30ve
DS5_2rD_R_ncg
DS7_DN_c_v_30
DS9_3rD_Re_sp
DS11_2tN_30ve
DS13_4rD_Re_nf
DS2_DN_Pre_v
DS4_2rN_Asse
DS6_DN_Pre_cv
DS8_3rN_Asse
DS10_3rD_R_hr_n
DS12_4rN_Asse
DS14_4rD_Re_br
BS1_Pink
BS2_Nflo
BS3_Hrno
BS4_Brea
AS1_N_Hd_nb
AS3_1tN_30ve
AS5_2rD_R_ncg
AS7_DN_c_v_30
AS9_3rD_Re_sp
AS11_2tN_30ve
AS13_4rD_Re_nf
AS2_DN_Pre_v
AS4_2rN_Asse
AS6_DN_Pre_cv
AS8_3rN_Asse
AS10_3rD_R_hr_n
AS12_4rN_Asse
AS14_4rD_Re_br

Fig 7-2: Adaptive Network for the AI-coach's Engagement with Organizational Learning

In table 8-1, the first context state is always active while the rest of them will be activated at a specific time set by *steponce* function. This function has a parameter called α. Before t = α, the value of the function is 0. After t = α, the value of the function is 1.

7.2 Simulation for Example Scenarios:

If the network is valid, simulation result should shows team members' imperfect knowledge at the beginning and then effects of organizational learning. In this network, in order to highlight the effects of organizational learning, when team members lack

perfect knowledge, the corresponding self-learning effects and instructional learning effects of this knowledge is set to be 0. That means, team members obtain their missing knowledge only through feedback learning from the AI-coach.

As before, the network is specified standard table format called role matrices for the convenience of inputting the network characteristics to software environment for simulation. The example simulation presented here was run from 0 to 50 with stepsize Δt =0.5. Below is the discussion of simulation results of state activation based on current network characteristics. The contextual stress level is set to be extremely low, so that the context state has a value of 1, and that will lead M-states has an upper limit value no more than 1. For clear analysis, the results happen in the same simulation have been divided into the graph of the adaptation states, context states, modelling the function of the AI-coach, the nurse's states, the doctor's states, and the world states, the baby states. Adaptation states and context states directly reflect the organizational learning effects so that they will be introduced first. In this subsection, monitoring function of the AI-coach will be introduce as well.

7.2.1 States Modelling the Function of the AI-coach

In Fig 7-3, second order self-model **Www**-states for the weight of the connection from the doctor's total learning effects to the nurse's instructional learning effects all stay under 0.1. That's to eliminate the nurse's instructional learning effects to highlight the function of organizational learning. Second order self-model **M**-states for resistance factors for all self-learning effects all get activated at around t =2. Since first-order self-model **W**-states that corresponding to team members' missing knowledge have speed values of 0, these self-learning effects is also eliminated to highlight the contribution of organizational learning.

The doctor's first-order self-model **W**-states for total weight of the connection from preparation of pure ventilation to giving 2 times of pure ventilation both get activated at around t =2. But the doctor's first-order self-model **W**-state for total weight of the connection from preparation of the combination of compression and ventilation to giving that ventilation is stable at 0 before t =25. These mean the doctor is well prepared for pure ventilation but lacks perfect knowledge for the combination of compression and ventilation.

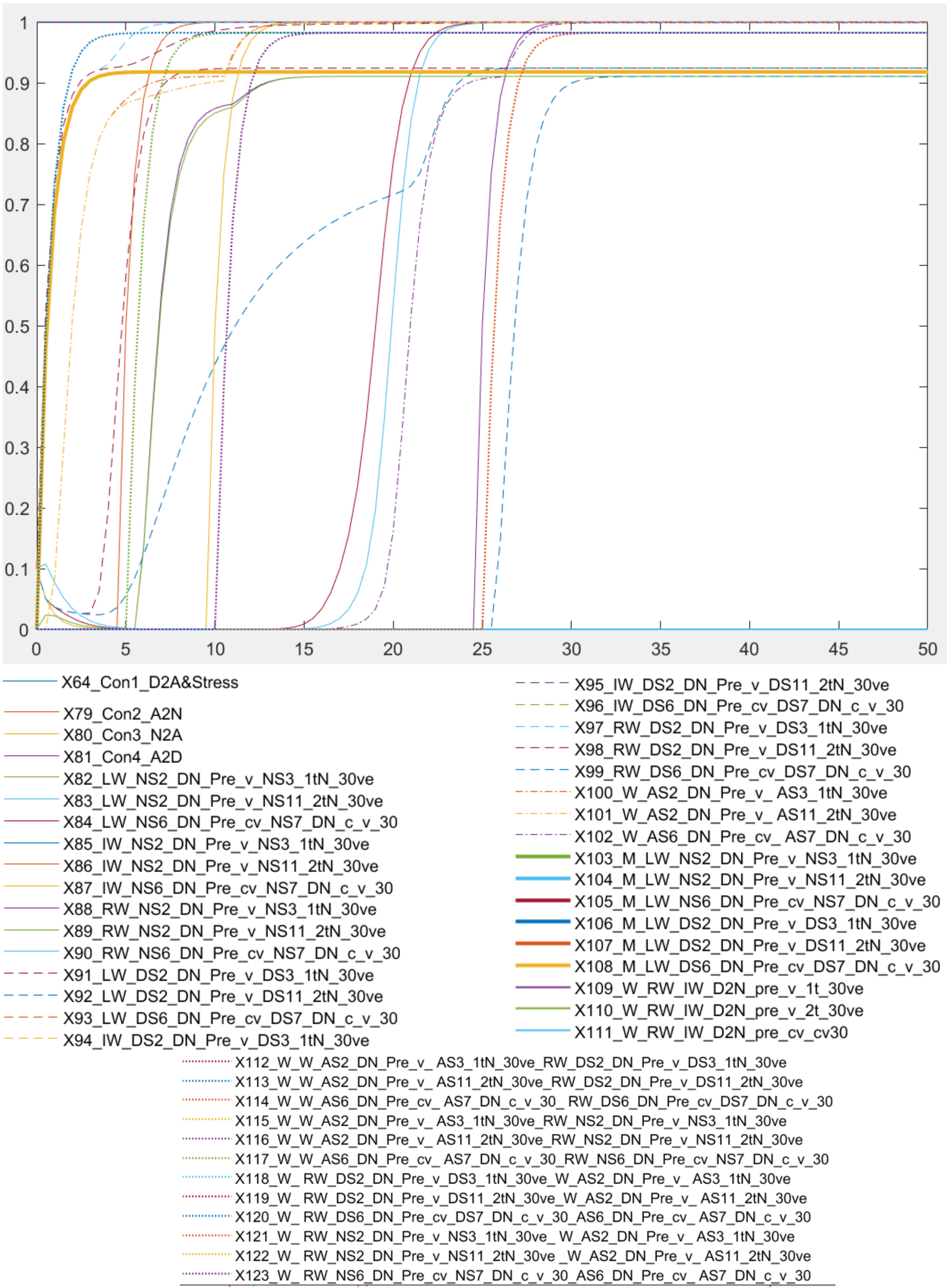


Fig 7-3: Simulation Results for Adaptation States

The context state that controls the doctor gives feed forward learning to the AI-coach is always active. So, the AI-coach can copy the doctor's total learning effects at the beginning. The AI-coach's first-order self-model **W**-states for total weight of the connection from preparation of pure ventilation to giving 2 times of pure ventilation both get activated at around t =3.5. But the AI-coach's first-order self-model **W**-state for total weight of the connection from preparation of the combination of compression and ventilation to giving that ventilation is stable at 0 before t =15.

The nurse's first-order self-model **W**-states for total weight of the connection from preparation of pure ventilation to giving 2 times of pure ventilation are both stable at 0 before t =5. But the nurse's first-order self-model **W**-states for total weight of the connection from preparation of the combination of compression and ventilation to giving that ventilation reaches activation at around t =21. These mean the nurse has imperfect knowledge for pure ventilation but she is well-prepared for the combination of compression and ventilation.

The doctor's first-order self-model **W**-states for total weight of the connection from preparation of pure ventilation to giving 2 times of pure ventilation both get activated at around t =2. But the doctor's first-order self-model **W**-states for total weight of the connection from preparation of the combination of compression and ventilation to giving that ventilation is stable at 0 before t =25. These mean the doctor is well prepared for pure ventilation but lack perfect knowledge for the combination of compression and ventilation.

The context state that controls the doctor gives feed forward learning to the AI-coach is always active. So, the AI-coach can copy the doctor's total learning effects at the beginning. The AI-coach's first-order self-model **W**-states for total weight of the connection from preparation of pure ventilation to giving 2 times of pure ventilation both get activated at around t =3.5. But the AI-coach's first-order self-model **W**-states for total weight of the connection from preparation of the combination of compression and ventilation to giving that ventilation is stable at 0 before t =15.

The nurse's first-order self-model **W**-states for total weight of the connection from preparation of pure ventilation to giving 2 times of pure ventilation are both stable at 0 before t =5. But the nurse's first-order self-model **W**-states for total weight of the connection from preparation of the combination of compression and ventilation to giving that ventilation reaches activation at around t =21. These means the nurse has imperfect knowledge for pure ventilation but she is well-prepared for the combination of compression and ventilation.

At t =5, the context state that controls the AI-coach gives feedback learning to the nurse gets activated. So the nurse starts gain her missing knowledge from the AI-coach. Her first-order self-model **W**-states for total weight of the connection from preparation of pure ventilation to giving 2 times of pure ventilation both reach activation at around t =8. That means the nurse has perfect knowledge.

At t =10, the context state that controls the AI-coach gets feedforward learning to the nurse reaches activation. Thus the AI-coach starts learning from the nurse to make its knowledge perfect as well. Its first-order self-model **W**-states for total weight of the connection from preparation of the combination of compression and ventilation to giving that ventilation reaches activation at around t =22.5. It's right after the nurse's corresponding state's activation. That means the AI-coach has perfect knowledge as well.

At t =25, the context state that controls the AI-coach gives feedback learning to the nurse reaches activation. That means the doctor finally is able to get his missing knowledge from the AI-coach. His first-order self-model **W**-states for total weight of the connection from preparation of the combination of compression and ventilation to giving that ventilation become active at around t =28. The doctor also has perfect knowledge in the end.

The adaptation states and the context states clearly shows the process of organizational learning. The AI-coach promotes the communicational efficiency between both team members. These results confirm the validity of the network.

Fig 7-4 reflects the AI-coach's monitoring function. In this graph, the AI-coach's mental model states for individual actions all get activated right after activation of corresponding action ownership states. The AI-coach's mental model states for teamwork actions get activated slightly earlier than action ownership states, that's because both team members' action ownership states have influence of the AI-coach's mental model states. Simultaneous influence superposition makes the AI-coach's mental model states reach activation faster than team members' action ownership states.

Here the AI-coach's mental model states will be described. The AI-coach's mental model state for the nurse holding the newborn baby on the table is active at around t =2.5. After observing first time of pure ventilation, The AI-coach's mental model states for the team preparing and the nurse giving that ventilation get activated at around t =4.5 and t =10. The 5.5 gap is because of organizational learning. By monitoring the first round of assessment, the AI-coach's mental model states for the nurse helping that assessment and for the doctor reporting the baby has no change reach activation at around get activated at around t =13.5 and t =15, respectively. The AI-coach knows new treatment will come. By observing the team complete preparing and giving the combination of compression and ventilation, the AI-coach's mental model states for these reach activation at around t =17 and t =22, respectively. The time gap is because of organizational learning as well. By monitoring the second round of assessment, the AI-coach's mental model states for the nurse helping the second round of assessment and for the doctor reporting the baby is slightly pink and with normal heart rate reach activation at around t =24, t =25, and t =26, respectively. Knowing the baby has change, the AI-coach's mental model state for the doctor reporting no change become not active at t =23. These are followed with the nurse giving second time of pure ventilation. The

AI-coach's mental model state for that reach activation at around t =26.5. By observing the third round of assessment, the AI-coach's mental model state for the nurse helping the assessment and for the doctor reporting the baby is not floppy and starts breathing get activated at around t =27.5, t =28.5 and t =29, respectively.

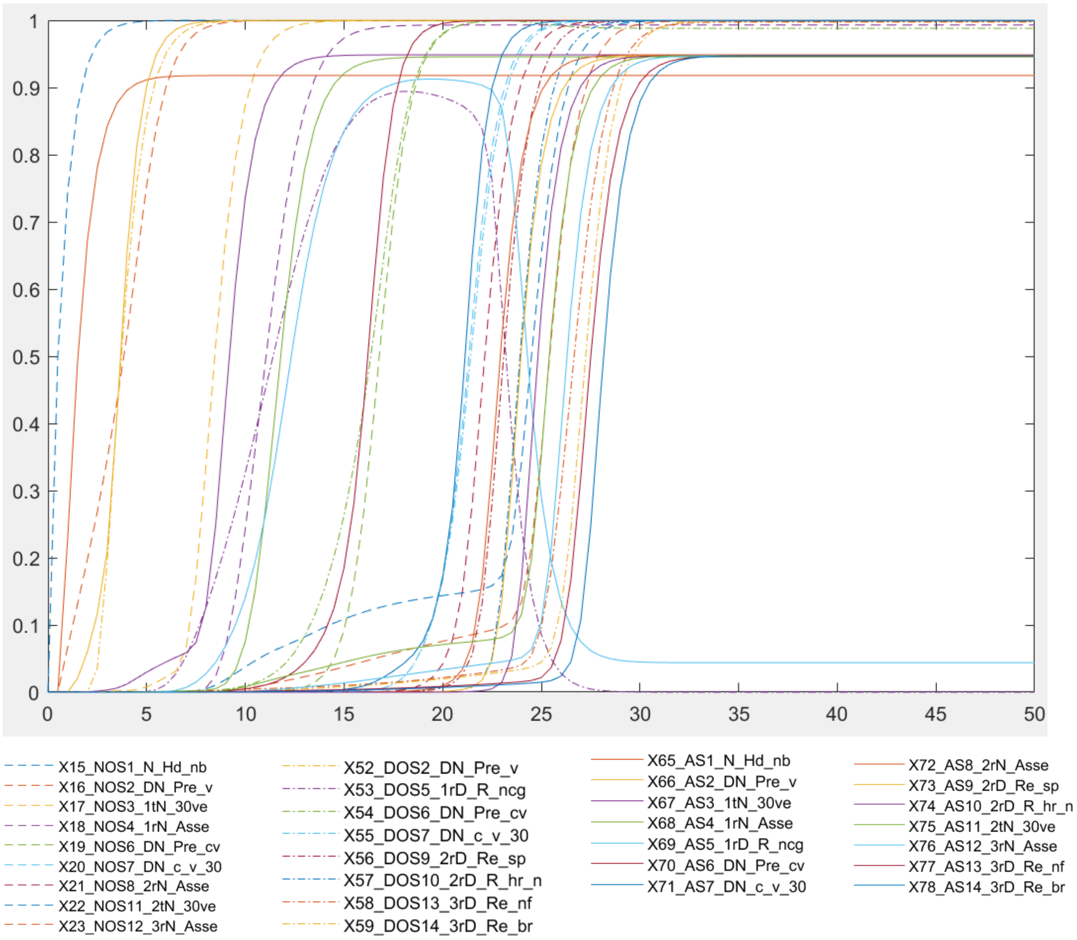


Fig 7-4: Simulation Results Shows Effects of the AI-coach's monitoring

7.2.2 The Nurse's Mental Processes Based on Her Mental Model

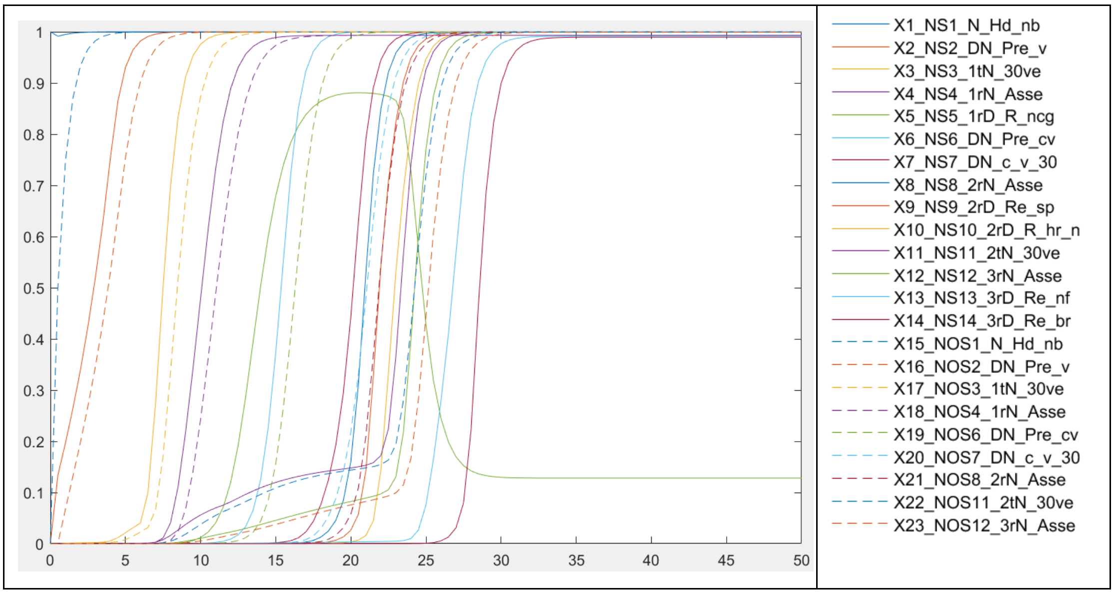


Fig 7-5: Nurse Mental Model and Action Ownership States

Fig 7-5 reflects the nurse's states. Her mental model states and his action ownership states all follow the order in which application scenario case occurs in the real world. That all reflect the validity of network design. The nurse's mental model state for the nurse holding the newborn baby on the table is always active. Her action ownership state for that gets activated at around t =2. Right after, her mental model states and their corresponding action ownership states for she preparing and giving first time of pure ventilation and for she helping the first round of assessment reach activation at around t = 4.5, t = 5.5 (for preparation), t = 8, t = 9.5 (for giving ventilation), t = 11.5 and t = 12.5 (for the assessment) , respectively. Observing the doctor reporting the baby has not change, the nurse's mental model state for that gets activated at around t = 15. The nurse realizes new treatment is required. Her mental model states and their corresponding action ownership states for the team preparing and giving for the combination of compression and ventilation and for she helping the second round of assessment get activated at around t = 15.5, t = 17 (for preparation), t = 21, t = 22 (for giving ventilation), t = 21.5 and t = 22.5 (for the assessment) , respectively. Seeing the doctor reporting the baby is slightly pink and has normal heart rate, the nurse's mental model states for these reach activated at around t = 22.5 and t = 23.5, respectively. At the same time, the nurse's mental model state for the doctor reporting no change is not active at around t = 23.5. That follows with final treatment. The nurse's mental model states and its corresponding action ownership states for she giving the second time of pure ventilation and helping third round of assessment get activated at around t = 24, t = 25.5 (for giving ventilation), t = 25 and t = 26 (for the assessment) , respectively. Observing the doctor reporting the baby is not floppy and start breathing, the nurse's mental states for these reach activation at around t = 28 and t = 29.5, respectively.

7.2.3 The Doctor's Mental Processes Based on His Mental Model

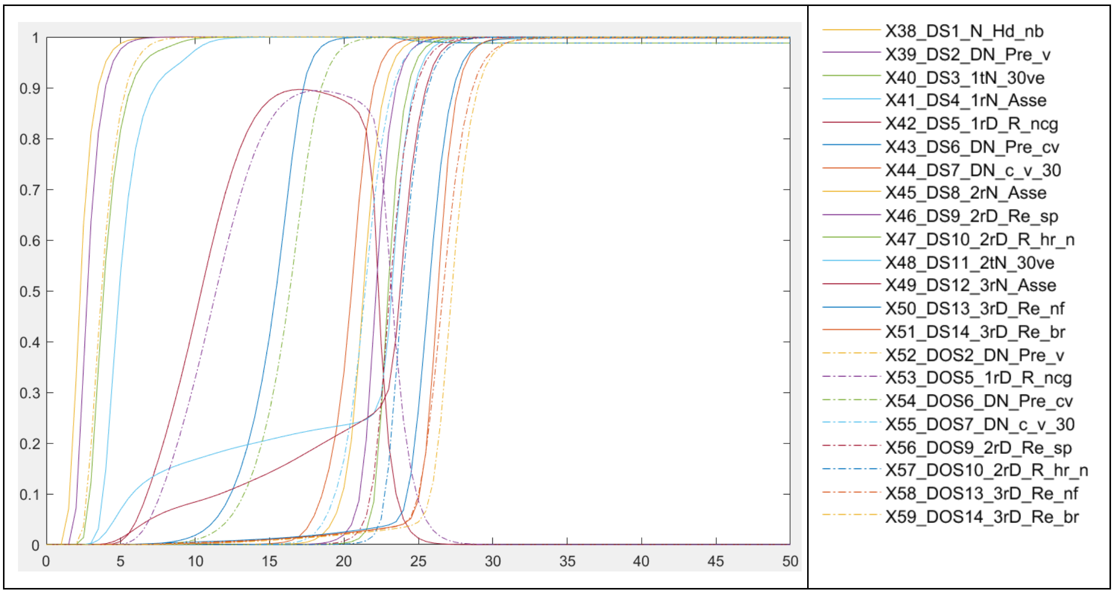


Fig 7-6: Doctor Mental Model and Action Ownership States

Fig 7-6 shows simulation results of the doctor's mental model and action ownership states. His mental model states and his action ownership states all follow the order in which application scenario case occurs in the real world. That all reflect the validity of network design. Around t = 3, after the doctor observing the nurse hold the new born baby who need ventilation on the table, his first mental model state get activated. Immediately after, the doctor knows the team should prepare pure ventilation for the baby, so the doctor's mental model state and its corresponding action ownership state for the team preparing pure ventilation are active at around t = 3.5 and t = 4.5, respectively. That means the doctor completes preparing pure ventilation in real world. Right after, the doctor's mental model state for nurse's first time of giving pure ventilation and helping the first round of assessment are active at around t = 5 and t = 6.5, respectively. Observing the baby has no change, the doctor's mental model state and its corresponding action ownership state for reporting the baby has no change get activated at around t = 13.5 and t = 14.5, respectively. The baby requires more treatments so that the doctor's mental model state and its corresponding action ownership state for the team preparing and giving the combination of compression and ventilation is active at around t = 16.5, t = 18 (for preparation), t = 22 and t = 23.5 (for giving ventilation), respectively. Right after, the doctor's mental model state for the nurse helping assess for the second round assessment gets activated at around t =23. The doctor observe the baby is slightly pink and with normal heart rate again. So the doctor's mental model states and their corresponding action ownership states for reporting these reach activation at around t = 23.5, t = 24.5 (for the baby is slightly pink), t = 24 and t = 25 (for the baby is with normal heart rate), respectively. At the same moment, the doctor's mental model and its corresponding state for reporting the baby has no change become inactive at around t = 22 and t = 23 , respectively. In hoping of the baby totally be safe, the nurse gives another time of pure ventilation for 30 seconds and start assessing again. The doctor's mental model states for these get activated at around t = 24.5 and t = 25, respectively. Overserving the baby finally is not floppy and start breathing, the doctor's mental model states and their corresponding action ownership for reporting these get activated at around t = 26.5, t = 28 (for the baby is not floppy), t = 27 and t = 28.5 (for the baby starts breathing) , respectively.

7.2.4 The World States and the Baby States

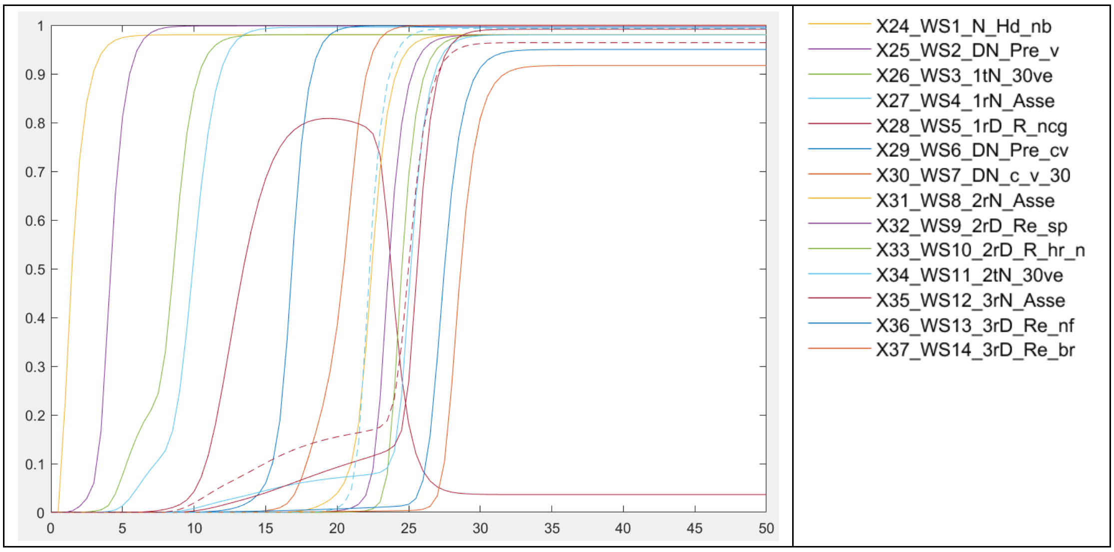


Fig 7-7: Simulation Results for the World States

The world state for the nurse holding the newborn baby on table is active at around t =2.5. After observe first time of pure ventilation, The world states for the team preparing and the nurse giving that ventilation get activated at around t =5 and t =9.5, respectively. Right after, the world states for the nurse helping that assessment and for the doctor reporting the baby has no change reach activation at around get activated at around t =11 and t =16.5, respectively. That means the baby needs new treatment. So the team complete preparing and giving the combination of compression and ventilation, the world states for these reach activation at around t =17 and t =21.5, respectively. That follows with the second round of assessment. The world state for the nurse helping the second round of assessment and for the doctor reporting the baby is slightly pink and with normal heart rate reach activation at around t =23, t =24.5, and t =25.5, respectively. At the same time, the AI-coach's mental model state for the doctor reporting no change become not active at t =22. These follows with the activation of the world state for the nurse giving second time of pure ventilation and for she helping the third round of assessment get activated at around t = 26 and t = 26.5, respectively. Right after, the world state for the doctor reporting the baby is not floppy and starts breathing get activated at around t =28, t =30, respectively.

8. Discussion

In this thesis, six second-order adaptive computational network models show processes for six conditions of a medical team of a doctor and a nurse giving ventilation to a newborn baby in danger with involvement of shared mental model. These conditions are, the protocol condition without organizational learning, the protocol condition with organizational learning, partial mistake condition, extreme mistake condition, the AI-coach involved condition without organizational learning, and the AI-coach involved condition with organizational learning. The design of these computational models' design is based on the network-oriented modeling approach and are simulated in a dedicated software environment introduced in (Treur, 2020). The computational mechanism for involvement of organizational learning is introduced in (Canbaloğlu et l, 2022). In these network models, actors include the nurse and the doctor, and sometimes the AI and the organization. Actors change the world by action ownership states. In turn, the world states and action ownerships states can change an actor's mental model as well. All network models enable representations and processing of all actors' internal simulation of their mental models, adaptive changes of these mental models (learning and forgetting), all actors' actions in the world, the dynamics of the interaction between actors and the world. To show the influence of stress on the forgetting effect of an internal hebbian learning process, a context state representing the context stress is always introduced. In these network models, learning effects consists of internal hebbian learning effects, instructional learning effects and organizational learning effects, all represented by self-model states and their dynamics. That shows how these learning effects influence the relation structure of mental models. Simulation experiments shows the formation of shared mental models for correct ventilation forms in the protocol conditions, how the formation of shared mental model for correct ventilation meets setbacks in mistake conditions, and how the AI-coach promotes the formation of shared mental models for correct ventilation in the AI-coach's engagement conditions.

The first conditions is protocol condition without organizational learning. At that condition, the team gives the baby ventilation according to the protocol followed and makes no mistake. In this situation, the team members perform their duties, communicate efficiently, and have an accurate understanding of ventilation. Simulation results show that this team forms a perfect shared mental model for ventilation. In addition, both team members' self-learning and instructional learning effects are generated very well. This is an ideal condition where the medical team is able to complete ventilation without any external assistance. Before 1990, researchers believes punishing individuals for medical errors can help avoid medical errors. In this case, the first condition is what these researchers want from punishing individuals. However, the punishing cannot always make medical workers completely infallible. Instead, that will force them be silent about errors that do not have obvious serious consequences, and that in turn can lead serious harm in the future. In addition, when medical workers do not realize that they have imperfect knowledge, even if they carefully give the corresponding action because of fear of punishment, the action will still fail because of imperfect knowledge. Besides, sometimes other teammates neither point out nor help these people with medical errors. On the face of it, they didn't make a direct error, but they also have to face potentially serious consequences together with people making errors. Organizational learning can contribute promoting just safety culture within the medical team. In second condition, both team members has some imperfect knowledge at the beginning. There are already perfect knowledge of correct completion of ventilation in organizational knowledge repositories. Through organizational learning, both team members obtain knowledge they lack. The simulation results show this process in adaptation level of mental model. Team members' first-order self-model **W**-states corresponding to the lack of knowledge are positively influenced by corresponding organizational first-order self-model **W**-states. The simulation results also show that under the influence of organizational learning, they got rid of the defect of imperfect knowledge in the initial stage and successfully completed the ventilation operation. In this condition, organizational learning improves accuracy of the medical team's shared mental model. The results can be used to advise medical teams to deploy efficient knowledge management systems to facilitate real-time access to organizational knowledge by medical members. In this way, the organization is able to create new knowledge on time when team members have new experience, to retain knowledge for long time and to transfer knowledge to team members on time when they have demand. That helps to improve the overall ability of members in the organization in the long run and reduce the risk of them making the errors mentioned by organizational knowledge.

The third condition shows a partial mistake condition. In this condition, the nurse has imperfect knowledge on pure ventilation and that leads to an incident without making serious consequence. After that, the doctor find out her mistake on time and help her be well prepared and complete second time of pure ventilation. The simulation results perfectly reveal this process. In this condition, the nurse is luckily enough because the doctor has her missing knowledge and communicate with her effectively on time to help her. It is common in medical treatment, an error leads to obvious harm means there are more errors without obvious harm. Sometimes learning from the latter helps avoid the former especially when they appear for similar reasons (Tucker et al. 2008). This condition reflects that. The nurse learn from the failure of first time of pure ventilation and success the second time of pure ventilation and avoid further harm. The extreme mistake condition shows that when team members both doesn't help fix others imperfect knowledge because of ineffective communication or fear of authority, harm can be severe. Simulation results show that both team members' imperfect knowledge leads to failures of corresponding ventilation. It also reflects that the blame culture sometimes fails to achieve its goal of avoiding team mistakes through blame. The fear of the blame culture does not enable medical workers to do the right thing through wrong knowledge, but rather makes them afraid to point out mistakes and challenge authority. Inefficient communication can sometimes be fatal, while health care workers sometimes don't actively say they don't understand out of fear.

For two mistake conditions, this research presents two schemes for the AI-coach to participate in preventing errors. The condition of the AI-coach's engagement without organizational learning corresponds to partial mistake condition. In that condition, the AI-coach keeps monitoring team members' actions. When the AI-coach notices the nurse's tendency to make an error, it warns her to avoid making that errors. The simulation results show the nurse's mental process for that very well. In the simulation, the direct result of the AI-coach's intervention is the rise of second-order self-model **HT**-States and decrease of first-order self-model **T**-states. That enable the activation of the nurse's mental model states for preparing and giving first time of pure ventilation which she fails in partial mistake condition. The condition of AI-coach's engagement without organizational learning provides two directions for the development of medical AI, those are, monitoring and warning. The involvement of the AI-coach will eliminate mistakes before they are formed. In this way, AI-coach play a role of a speaker without fear of authority and punishment and with effective communication ability. The AI-coach is well aware of the team members' respective responsibilities and knowledge and urges them to take responsibility, acquire the right knowledge and make the right actions. The condition of the AI-coach's engagement with organizational learning corresponds to extreme mistake condition. Compared to the situation without organizational learning, the AI-coach in this condition addresses more on promoting knowledge transfer between team members to prevent errors. In this condition, AI-coach interacts with team members by feedforward learning and feedback learning, obtains knowledge from both team members, and transfers correct knowledge back to both team members. In this way, both team members correct their imperfect knowledge. In simulation results, these are mainly reflected on adaptation level and control of adaptation level. AI-coach's first-order self-model **W**-states for its learning effects and team members' first-order self-model **W**-states for their learning effects influence each other. The transmission direction of the influence is controlled by second-order self-model **Www**-states in control of adaptation level. In this condition, team members' tendency of making mistake doesn't even appear because team members' imperfect knowledge is corrected in time so their action are guided by correct knowledge. In addition to monitoring function discussed already above, this condition shows that medical AI developers choose improving knowledge transferring between team members as a development direction. In this direction, AI-coach enable the organization to identify, report, and investigate incidents and to take appropriate actions that increase reduce the probability of recurrence of errors and in turn improve performance of members within this organization.

Six networks and their simulations together answers the main research. These networks visually present how to analysis the AI-coach's contribution in a medical team's ventilation operation to save baby in danger by an adaptive network-oriented modeling method. Networks of protocol condition show how the medical team ventilates correctly. Networks of mistake condition shows how imperfect knowledge, ineffective communication, fear of authority damage to the team's shared mental model and in turn reduce the team's performance. Networks of AI-coach's engagement show how AI-coach can prevent errors by monitoring, warning, and promoting knowledge transferring. The story line of these networks proves this research achieve its research object of exploring how AI can help improve the performance of the medical team. Since the AI-coach monitors team members' actions, speak up on time to prevent mistakes, promotes the team's ability to organizational learning, AI-coach helps overcome the shortcomings of a blame culture, reluctance to speak up, ineffective communication, and inability to detect and learn from potential mistakes early. In another word, AI-coach promotes just safety culture within an organization. That answers the problem addressed in introduction.

This research has a strong managerial meaning. For starters, a good shared mental models will contribute to a good team coordination, and that in turn contribute to good team performance. This research shows how to use the technology of AI to help a team form better shared mental model. That provide a research example of how to use AI to help team management by promoting shared mental model. In addition, organizational learning reflects knowledge creating, retaining, and transferring within an organization. Good organizational learning ability helps improve the adaptability and rate of progress of the team. This research presents a template of how to use AI improve a team's ability of organizational learning. Last but not least, this research use computational method to analysis shared mental model. That method can also be applied to quantitative and visual analysis of other managerial concept. This research has a strong societal relevance as well. For starters, this research explore implement of just safety culture in neonatal resuscitation. That helps reduce possibility of harm occurs on newborn babies and in turn helps reduce sad families and contributes to social stability. In addition, the research on implement of just safety culture can be extent to more areas and reducing workers' mental pressure because of fear of speaking up. That will encourage workers to be honest and hard working. On a societal level, this contributes to a culture of honesty and motivation. Besides, the adaptive oriented network modeling is a useful research method to analysis social process. This research can extent to analysis larger social phenomenon.

This research still has some limitations. For starters, this research is based on simulations. That means the result may not fully reflect the situation in real world. In addition, the case has a small size. Only two team members and one AI-coach are involved. The ventilation is also relatively less complicated than surgeries. These means the research result may not be fully applied to more complicated surgeries with more actors. Besides, only one mechanical frequency error is involved in this research. In real process of a medical team giving ventilation to new-born baby, there are many other errors.

Future study for expansion has several directions. For starters, field experiments can be designed to test performance of the AI-coach in real world. In addition, application scenarios can be changed. The medical scene is massive, there are always urgent cases where it is intolerable to waste time because of mistakes. Besides, medical groups can be bigger. That will result in more complex teamwork process and lead to more challenges. Last but not least, more managerial concept and psychological concepts related to teamwork can be introduced. The digital application of these concepts is worth studying.

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Appendix

Table 3-1: Overview of world states (WS), the nurse's mental model states (NS), the doctor's mental model states (DS), the baby's condition states (BS), and the context state (Con1)

State Prefix					State Name	Explanation
WS1	NS1	DS1	NOS1	-	N_Hd_nb	Nurse holds the new born baby on the table and prepares for intubation
WS2	NS2	DS2	NOS2	DOS2	DN_Pre_v	Doctor and nurse together prepare for pure ventilation
WS3	NS3	DS3	NOS3	-	1tN_30ve	Nurse gives baby 30 seconds of pure ventilation for the first time
WS4	NS4	DS4	NOS4	-	1rN_Asse	Nurse helps assess the baby's condition at the first round of assessment
WS5	NS5	DS5	-	DOS5	1rD_R_ncg	Doctor reports the baby has no change at the first round of assessment
WS6	NS6	DS6	NOS6	DOS6	DN_Pre_cv	Doctor and nurse together prepare for the combination of compression and ventilation
WS7	NS7	DS7	NOS7	DOS7	DN_c_v_30	Doctor and nurse together give baby 30 seconds of the combination of compression and ventilation
WS8	NS8	DS8	NOS8	-	2rN_Asse	Nurse helps assess the baby's condition at second assessment round
WS9	NS9	DS9	-	DOS9	2rD_Re_sp	Doctor reports the baby is slightly pink at second assessment round
WS10	NS10	DS10	-	DOS10	2rD_R_hr_n	Doctor reports the baby has normal heart rate at second assessment round
WS11	NS11	DS11	NOS11	-	2tN_30ve	Nurse gives baby 30 seconds of pure ventilation for the second time
WS12	NS12	DS12	NOS12	-	3rN_Asse	Nurse helps assess the baby's condition at third assessment round
WS13	NS13	DS13	-	DOS13	3rD_Re_nf	Doctor reports the baby is not floppy at third assessment round
WS14	NS14	DS14	-	DOS14	3rD_Re_br	Doctor reports the baby is breathing at third assessment round
Con1					-	Contextual stress factor
BS1					Pink	Baby is pink
BS2					Nflo	Baby is not floppy
BS3					Hrno	Baby has normal heart rate

BS4	Brea	Baby is breathing

Table 3-2: Overview of first-order self-model states

State name	Explanation
LW_NS2_DN_Pre_v_NS3_1tN_30ve	First-order self-model state for the nurse's weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the first time' as learnt by Hebbian learning
LW_NS2_DN_Pre_v_NS11_2tN_30ve	First-order self-model state for the nurse's weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the second time' as learnt by Hebbian learning
LW_NS6_DN_Pre_cv_NS7_DN_c_v_30	First-order self-model state for the nurse's weight of the connection from 'the state for preparing the combination of compression and ventilation' to 'the state for giving the combination of compression and ventilation for 30s' as learnt by Hebbian learning
IW_NS2_DN_Pre_v_NS3_1tN_30ve	First-order self-model state for the nurse's weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the first time' as learnt from instruction by the doctor
IW_NS2_DN_Pre_v_NS11_2tN_30ve	First-order self-model state for the nurse's weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the second time' as learnt from instruction by the doctor
IW_NS6_DN_Pre_cv_NS7_DN_c_v_30	First-order self-model state for the nurse's weight of the connection from 'the state for preparing the combination of compression and ventilation' to 'the state for giving the combination of compression and ventilation for 30s' as learnt from instruction by the doctor
RW_NS2_DN_Pre_v_NS3_1tN_30ve	First-order self-model state for the nurse's overall weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the first time'
RW_NS2_DN_Pre_v_NS11_2tN_30ve	First-order self-model state for the nurse's overall weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the second time'
RW_NS6_DN_Pre_cv_NS7_DN_c_v_30	First-order self-model state for the nurse's overall weight of the connection from 'the state for preparing the combination of compression and ventilation' to 'the state for giving the combination of compression and ventilation for 30s'

LW_DS2_DN_Pre_v_DS3_1tN_30ve	First-order self-model state for the doctor's weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the first time' as learnt by Hebbian learning
LW_DS2_DN_Pre_v_DS11_2tN_30ve	First-order self-model state for the doctor's weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the second time' as learnt by Hebbian learning
LW_DS6_DN_Pre_cv_DS7_DN_c_v_30	First-order self-model state for the doctor's weight of the connection from 'the state for preparing the combination of compression and ventilation' to 'the state for giving the combination of compression and ventilation for 30s' as learnt by Hebbian learning
IW_DS2_DN_Pre_v_DS3_1tN_30ve	First-order self-model state for the doctor's weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the first time' as known to the doctor
IW_DS2_DN_Pre_v_DS11_2tN_30ve	First-order self-model state for the doctor's weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the second time' as known to the doctor
IW_DS6_DN_Pre_cv_DS7_DN_c_v_30	First-order self-model state for the doctor's weight of the connection from 'the state for preparing the combination of compression and ventilation' to 'the state for giving the combination of compression and ventilation for 30s' as known to the doctor
RW_DS2_DN_Pre_v_DS3_1tN_30ve	First-order self-model state for the doctor's overall weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the first time'
RW_DS2_DN_Pre_v_DS11_2tN_30ve	First-order self-model state for the doctor's overall weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the second time'
RW_DS6_DN_Pre_cv_DS7_DN_c_v_30	First-order self-model state for the doctor's overall weight of the connection from 'the state for preparing the combination of compression and ventilation' to 'the state for giving the combination of compression and ventilation for 30s'

Table 3-3: Overview of second order self-model states

M_LW_NS2_DN_Pre_v_NS3_1tN_30ve	Second-order self-model state for the persistence factor of the Nurse's weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the first time' as learnt by Hebbian learning

M_LW_NS2_DN_Pre_v_NS11_2tN_30ve	Second-order self-model state for the persistence factor of the Nurse’s weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the second time' as learnt by Hebbian learning
M_LW_NS6_DN_Pre_cv_NS7_DN_c_v_30	Second-order self-model state for the persistence factor of the Nurse’s weight of the connection from 'the state for preparing the combination of compression and ventilation' to 'the state for giving the combination of compression and ventilation for 30s' as learnt by Hebbian learning
M_LW_DS2_DN_Pre_v_DS3_1tN_30ve	Second-order self-model state for the persistence factor of the Doctor’s weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the first time' as learnt by Hebbian learning
M_LW_DS2_DN_Pre_v_DS11_2tN_30ve	Second-order self-model state for the persistence factor of the Doctor’s weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the second time' as learnt by Hebbian learning
M_LW_DS6_DN_Pre_cv_DS7_DN_c_v_30	Second-order self-model state for the persistence factor of the Doctor’s weight of the connection from 'the state for preparing the combination of compression and ventilation' to 'the state for giving the combination of compression and ventilation for 30s' as learnt by Hebbian learning
W_RW_IW_D2N_pre_v_1t_30ve	Second-order self-model state for the nurse's weight of connection from 'the first-order self-model state for the doctor's total learning effect' to 'the first-order self-model state for nurse's instructional learning effect' on 'preparation of ventilation to giving first time of pure ventilation' as learnt by Hebbian learning
W_RW_IW_D2N_pre_v_2t_30ve	Second-order self-model state for the nurse's weight of connection from 'the self-model state for the doctor's total learning effect' to 'the first-order self-model state for nurse's instructional learning effect' on 'preparation of ventilation to giving second time of pure ventilation' as learnt by Hebbian learning
W_RW_IW_D2N_pre_cv_cv30	Second-order self-model state for the nurse's weight of connection from 'the first-order self-model state for the doctor's total learning effect' to 'the first-order self-model state for nurse's instructional learning effect' on 'preparation of the combination of

	compression and ventilation to giving the combination of compression and ventilation' as learnt by Hebbian learning

Table 3-4: Combination functions

	Notation	Formula	Parameters
Advanced logistic sum	$\textbf{alogistic}_{\sigma,\tau}(V_1, \ldots, V_k)$	$[\frac{1}{1+e^{-\sigma(V_1+\cdots+V_k-\tau)}} - \frac{1}{1+e^{\sigma\tau}}](1+e^{-\sigma\tau})$	Steepness $\sigma > 0$ Excitability threshold τ
Hebbian learning	$\textbf{hebb}_{\mu}(V_1, V_2, W)$	$V_1V_2(1-W)+\mu W$	V_1, V_2 activation levels of the connected states; W activation level of the self-model state for the connection weight μ persistence factor
identity	$\textbf{id}(V)$	V	-

Table 4-1: Overview of organizational mental model states

State Prefix	State Name	Explanation
OS1	N_Hd_nb	Nurse holds the new born baby on the table and prepares for intubation
OS2	DN_Pre_v	Doctor and nurse together prepare for pure ventilation
OS3	1tN_30ve	Nurse gives baby 30 seconds of pure ventilation for the first time
OS4	1rN_Asse	Nurse helps assess the baby's condition at the first round of assessment
OS5	1rD_R_ncg	Doctor reports the baby has no change at the first round of assessment
OS6	DN_Pre_cv	Doctor and nurse together prepare for the combination of compression and ventilation
OS7	DN_c_v_30	Doctor and nurse together give baby 30 seconds of the combination of compression and ventilation
OS8	2rN_Asse	Nurse helps assess the baby's condition at second assessment round
OS9	2rD_Re_sp	Doctor reports the baby is slightly pink at second assessment round
OS10	2rD_R_hr_n	Doctor reports the baby has normal heart rate at second assessment round
OS11	2tN_30ve	Nurse gives baby 30 seconds of pure ventilation for the second time
OS12	3rN_Asse	Nurse helps assess the baby's condition at third assessment round
OS13	3rD_Re_nf	Doctor reports the baby is not floppy at third assessment round
OS14	3rD_Re_br	Doctor reports the baby is breathing at third assessment round

Table 4-2: Overview of New added Self-Model States

State Name	Explanation
W_OS2_DN_Pre_v_OS3_1tN_30ve	First-order self-model state for the organizational weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the first time' as learnt by Hebbian learning.
W_OS2_DN_Pre_v_OS11_2tN_30ve	First-order self-model state for the organizational weight of the connection from 'the state for preparing pure ventilation' to 'the state for giving pure ventilation for 30s for the second time' as learnt by Hebbian learning.
W_OS6_DN_Pre_cv_OS7_DN_c_v_30	First-order self-model state for the organizational weight of the connection from 'the state for preparing the combination of compression and ventilation' to 'the state for giving the combination of compression and ventilation for 30s' as learnt by Hebbian learning.
W_ W_OS2_DN_Pre_v_OS3_1tN_30ve_ RW_NS2_DN_Pre_v_NS3_1tN_30ve	Second-order self-model state for the nurse's weight of connection from 'the first-order self-model state for the organizational learning effect' to 'the first-order self-model state for nurse's total learning effect' on 'preparation of ventilation to giving first time of pure ventilation' as learnt by Hebbian learning
W_ W_OS2_DN_Pre_v_OS11_2tN_30ve_ RW_NS2_DN_Pre_v_NS11_2tN_30ve	Second-order self-model state for the nurse's weight of connection from 'the first-order self-model state for the organizational learning effect' to 'the first-order self-model state for nurse's total learning effect' on 'preparation of ventilation to giving second time of pure ventilation' as learnt by Hebbian learning
W_OS6_DN_Pre_cv_OS7_DN_c_v_30 RW_DS6_DN_Pre_cv_DS7_DN_c_v_30	Second-order self-model state for the doctor's weight of connection from 'the first-order self-model state for the organizational learning effect' to 'the first-order self-model state for doctor's total learning effect' on 'preparation of the combination of compression and ventilation to giving the combination of compression and ventilation' as learnt by Hebbian learning

Table 7-1: New added Base Level States

State Prefix		State Name	Explanation
AS1	-	N_Hd_nb	Nurse holds the new born baby on the table and prepares for ventilation
AS2	-	DN_Pre_v	Doctor and nurse together prepare for pure ventilation
AS3	AOS3_warning	1tN_30ve	Nurse gives baby 30 seconds of pure ventilation for the first time
AS4	-	1rN_Asse	Nurse helps assess the baby's condition at the first round ofassessment
AS5	-	1rD_R_ncg	Doctor reports the baby has no change at the first round ofassessment
AS6	-	DN_Pre_cv	Doctor and nurse together prepare for the combination of compression and ventilation
AS7	-	DN_c_v_30	Doctor and nurse together give baby 30 seconds of the combination of compression and ventilation
AS8	-	2rN_Asse	Nurse helps assess the baby's condition at second assessment round
AS9	-	2rD_Re_sp	Doctor reports the baby is slightly pink at second assessment round
AS10	-	2rD_R_hr_n	Doctor reports the baby has normal heart rate at second assessment round
AS11	-	2tN_30ve	Nurse gives baby 30 seconds of pure ventilation for the second time
AS12	-	3rN_Asse	Nurse helps assess the baby's condition at third assessment round
AS13	-	3rD_Re_nf	Doctor reports the baby is not floppy at third assessment round
AS14	-	3rD_Re_br	Doctor reports the baby is breathing at third assessment round

Table 8: New added adaptation States

State Name	Explanation
T_ NS2_DN_Pre_v	First-order self-model state for threshold value of the nurse's mental model state for the nurse preparing pure ventilation
T_NS3_1tN_30ve	First-order self-model state for threshold value of the nurse's mental model state for the nurse giving first time of pure ventilation
HT_ NS2_DN_Pre_	Second order self-model state for speed of first-order self-model state for threshold value of the nurse's mental model state for the nurse preparing pure ventilation.
HT_NS3_1tN_30ve	Second order self-model state for speed of first-order self-model state

	for threshold value of the nurse's mental model state for the nurse giving first time of pure ventilation

Table 8-1: An overview of new added context states

State Name	Explanation
Con1_D2A&Stress	The context state that control context stress and the start of feedforward learning from the doctor to the AI-coach.
Con2_A2N	The context state that control the start of feedback learning from the AI-coach to the nurse.
Con3_N2A	The context state that control the start of feedforward learning from the nurse to the AI-coach.
Con4_A2D	The context state that control the start of feedback learning from the AI-coach to the doctor.

Table 8-2: An overview of new added adaptation states

State Name	W_AS2_DN_Pre_v_ AS3_1tN_30ve
Explanation	First-order self-model state for the AI-coach's weight of the connection from 'the state for the team preparing pure ventilation' to 'the state for the nurse giving first time of pure ventilation for 30s' as learnt by Hebbian learning.
State Name	W_AS2_DN_Pre_v_ AS11_2tN_30ve
Explanation	First-order self-model state for the AI-coach's weight of the connection from 'the state for the team preparing pure ventilation' to 'the state for the nurse giving second time of pure ventilation for 30s' as learnt by Hebbian learning.
State Name	W_AS6_DN_Pre_cv_ AS7_DN_c_v_30
Explanation	First-order self-model state for the AI-coach's weight of the connection from 'the state for the team preparing the combination of compression and ventilation' to 'the state for the team giving the combination of compression and ventilation for 30s' as learnt by Hebbian learning.
State Name	W_W_AS2_DN_Pre_v_ AS3_1tN_30ve_RW_DS2_DN_Pre_v_DS3_1tN_30ve
Explanation	Second order self-model state for feedback learning effects from the AI-coach to the doctor for the weight of the connection from the team preparing pure ventilation to the nurse giving first time of pure ventilation.
State Name	W_W_AS2_DN_Pre_v_ AS11_2tN_30ve_RW_DS2_DN_Pre_v_DS11_2tN_30ve
Explanation	Second order self-model state for feedback learning effects from the AI-coach to the doctor for the weight of the connection from the team preparing pure ventilation to the nurse giving second time of pure ventilation.
State Name	W_W_AS6_DN_Pre_cv_AS7_DN_c_v_30_RW_DS6_DN_Pre_cv_DS7_DN_c_v_30
Explanation	Second order self-model state for feedback learning effects from the AI-coach to the doctor for the weight of the connection from the team preparing the combination of compression and ventilation' to 'the state for the team giving the combination of compression.

State Name	W_W_AS2_DN_Pre_v_ AS3_1tN_30ve_RW_NS2_DN_Pre_v_NS3_1tN_30ve
Explanation	Second order self-model state for feedback learning effects from the AI-coach to the nurse for the weight of the connection from the team preparing pure ventilation to the nurse giving first time of pure ventilation.
State Name	W_W_AS2_DN_Pre_v_ AS11_2tN_30ve_RW_NS2_DN_Pre_v_NS11_2tN_30ve
Explanation	Second order self-model state for feedback learning effects from the AI-coach to the nurse for the weight of the connection from the team preparing pure ventilation to the nurse giving second time of pure ventilation.
State Name	W_W_AS6_DN_Pre_cv_AS7_DN_c_v_30_RW_NS6_DN_Pre_cv_NS7_DN_c_v_30
Explanation	Second order self-model state for feedback learning effects from the AI-coach to the nurse for the weight of the connection from the team preparing the combination of compression and ventilation' to 'the state for the team giving the combination of compression.
State Name	W_ RW_DS2_DN_Pre_v_DS3_1tN_30ve_W_AS2_DN_Pre_v_ AS3_1tN_30ve
Explanation	Second order self-model state for feedforward learning effects from the doctor to the AI-coach for the weight of the connection from the team preparing pure ventilation to the nurse giving first time of pure ventilation.
State Name	W_ RW_DS2_DN_Pre_v_DS11_2tN_30ve_W_AS2_DN_Pre_v_ AS11_2tN_30ve
Explanation	Second order self-model state for feedforward learning effects from the doctor to the AI-coach for the weight of the connection from the team preparing pure ventilation to the nurse giving second time of pure ventilation.
State Name	W_ RW_DS6_DN_Pre_cv_DS7_DN_c_v_30_AS6_DN_Pre_cv_ AS7_DN_c_v_30
Explanation	Second order self-model state for feedforward learning effects from the doctor to the AI-coach for the weight of the connection from the team preparing the combination of compression and ventilation' to 'the state for the team giving the combination of compression.
State Name	W_ RW_NS2_DN_Pre_v_NS3_1tN_30ve_ W_AS2_DN_Pre_v_ AS3_1tN_30ve
Explanation	Second order self-model state for feedforward learning effects from the nurse to the AI-coach for the weight of the connection from the team preparing pure ventilation to the nurse giving first time of pure ventilation.
State Name	W_ RW_NS2_DN_Pre_v_NS11_2tN_30ve _W_AS2_DN_Pre_v_ AS11_2tN_30ve
Explanation	Second order self-model state for feedforward learning effects from the nurse to the AI-coach for the weight of the connection from the team preparing pure ventilation to the nurse giving second time of pure ventilation.
State Name	W_ RW_NS6_DN_Pre_cv_NS7_DN_c_v_30_AS6_DN_Pre_cv_ AS7_DN_c_v_30
Explanation	Second order self-model state for feedforward learning effects from the nurse to the AI-coach for the weight of the connection from the team preparing the combination of compression and ventilation' to 'the state for the team giving the combination of compression.