

Modelling learning for a better safety culture within an organization using a virtual safety coach: Reducing the risk of postpartum depression via improved communication with parents

Linn-Marie Weigl^a, Fakhra Jabeen^b, Jan Treur^{a,b,*}, H. Rob Taal^c, Peter H.M.P. Roelofsma^{b,c}

^a Vrije Universiteit Amsterdam, Social AI Group, Amsterdam, The Netherlands

^b Delft University of Technology, Safety and Security Science Section, Delft, The Netherlands

^c Erasmus University Medical Centre, Department of Pediatrics, Division Neonatology, Erasmus MC, University Medical Center-Sophia Children's Hospital, Rotterdam, The Netherlands

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ABSTRACT

This paper describes an extension of a safety culture within hospital organizations providing more transparency and acknowledgement of all actors, and in particular the parents. It contributes a model architecture to support a hospital to develop such an extended safety culture. It is illustrated for prevention of postpartum depression. Postpartum depression is a commonly known consequence of childbirth for both mothers and fathers. In this research, we computationally analyze the risk factors and lack of support received by fathers. Therefore, we use shared mental models to model the effects of poor and additional communication by healthcare practitioners to mitigate the development of postpartum depression in both the mother and the father. Both individual mental models and shared mental models are considered in the design of the computational model. The paper illustrates the benefits of simple support in terms of communication during childbirth, which has lasting effects, even outside the hospital. For the impact of additional communication, a Virtual Safety Coach is designed that intervenes when necessary to provide support, i.e., when a health care practitioner doesn't. Moreover, organizational learning is also modelled to improve the mental models of both the Safety Coach and the Health Care Practitioner.

1. Introduction

Learning is an integral part of organizations. Therefore, organizational learning (Kim, 1997), has been coined as a key concept, as it facilitates further development, both within individuals, and as a result, within teams and organizations. This can lead to better governance and an adequate safety culture, also known as 'safety culture' or 'just culture'. The term refers to a culture within an organization that promotes open communication, transparency, and trust amongst the practitioners in any field (Solomon, 2016). It is a tool to facilitate organizational learning.

In a healthcare organization, healthcare practitioners from multiple disciplines form healthcare teams, who strive to ensure the safety of patients. These teams coordinate and communicate throughout a certain medical procedure in a very cohesive manner to avoid all the risks that can be associated with healthcare. Moreover, these institutions maintain stability by following the protocols related to their medical procedures,

and therefore, often these protocols are evaluated and modified to ensure patient safety (Crossan et al., 1999). For instance, childbirth is a sensitive and a daily occurring natural phenomenon in hospitals, that follows a certain protocol or procedure. In a protocol like this, there are steps in place, for before, during and after, that healthcare practitioners must follow to ensure a safe and healthy delivery of the child. The main aim is to keep the mother and the baby safe during the whole process of delivery.

Safety culture encompasses realizing omissions and mistakes and not being scrutinized for the mistake or omission but instead learning from it. Practitioner-patient communication is a valuable step that can result in improved therapeutic outcomes (Hassan, 2018). However, most of the time, delivery protocols are only in place for processes and changes or deviations in processes that may occur for the baby or the mother (Taal, 2022). They fail to consider the possible adverse effects that may happen to the other-half or the family of a neonate. Bedside manners are within the curriculum of medical studies; however, the importance of adequate

* Corresponding author.

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patient communication is often underestimated and, often considered to be a less valued step, and sometimes even a forgotten step, within the protocol. A lack of communication with both the mother and partner can result in feelings of isolation. Moreover, the different situational roles of parents and health care practitioners (HCPs) do not allow for open communication. This barrier is a factor that may develop mental health problems in parents, such as postpartum depression (PPD) (Goodman, 2004). While maternal PPD is awarded attention, the same cannot be said for paternal postpartum depression (Goodman, 2004). The feeling of isolation often contributes to paternal postpartum depression (PPPD), since fathers are not the active actors during the childbirth process, and little attention is awarded to them during the process. Paternal PPD is accompanied by adverse effects affecting both the mother and the child. This paper discusses methods that could facilitate better support for a father with the aim of decreasing the frequency of fathers experiencing mental health issues (Goodman, 2004, 2008).

In this paper, we use computational models to discuss a) how a deviation in the childbirth process may lead to poor communication towards the parent(s). We also present b) how a virtual safety coach can facilitate the healthcare practitioners for effective communication with parents in the context of childbirth process. Lastly, we address c) how organizational learning can play a role in improving the mental models underlying communication. A virtual AI Coach can also help health practitioners to keep the parents intact (i.e., psychologically and socially) during the whole process. The designed models encompass protocols with common knowledge for all actors involved, as well as their own individual knowledge. The research focuses on reducing paternal postpartum depression and illustrates the positive influence this has on maternal postpartum depression. So, we present ways to encourage open and adequate communication both from the father's side and the healthcare practitioner's side. The aim is to expand the definition of safety culture, to involve not only the medical practitioners but also the patients and their families through the means of improved communication. In return, this implementation depicts the benefits of open communication and its subsequent effect of decreasing the risk of both the mother and father developing PPD (Goodman, 2004). For more detailed references see Section 2.

2. Background literature

In this section, we present the background literature of our work. We will discuss the risk factors for maternal postpartum depression (Mayers et al., 2020), together with their consequences (Rao et al., 2020). Then we explain risk factors for paternal postpartum depression along with possible outcomes (Goodman, 2008). We will also discuss how postpartum depression can be prevented (Dennis, 2004; Smythe et al., 2022). Specifically, how paternal postpartum depression can be prevented, which in return has significant influence on reducing maternal postpartum depression. Moreover, we will discuss how computational causal modelling can play its role preventing the related risks.

2.1. Maternal postpartum depression and the related risk factors

The ICD-10 states that “in typical mild, moderate, or severe depressive episodes, the patient suffers from lowering of mood, reduction of energy, and decrease in activity. Capacity for enjoyment, interest, and concentration is reduced, and marked tiredness after even minimum effort is common” (World Health Organization(WHO), 1993). Postpartum depression refers to “mild mental and behavioural disorders associated with the puerperium” (World Health Organization(WHO), 1993). In industrialized countries 10 %-15 % of women experience major depressive episodes after giving birth (Maternal mental health and child health and development in resource-constrained settings, 2009, January 1). This statistic encompasses women with prior and without prior mental health issues. The phenomena of developing depression after childbirth, known as maternal postpartum depression

(MPPD), is among the most common mental health consequences. Determining causes, possible interventions and creating support systems for new mothers suffering from PPD is at the forefront of postnatal care research (Garthus-Niegel et al., 2022; Mayers et al., 2020; Rao et al., 2020), as it may prevail for extended periods (Rao et al., 2020; Smythe et al., 2022).

Reasons for postpartum depression include obstetric factors, psychological factors, biological factors, social factors and lifestyle (Abe-nova et al., 2022; Javaid et al., 2022). Women who are nulliparous generally benefit from technically oriented support such as help with breastfeeding. On the other hand, multiparous women require more mental support, as they are at a higher risk of developing PPD, due to the additional stress of having another child at home (Dunkel Schetter et al., 2016). Another factor is the risk of the birth, especially when doctors must deviate from the original birth plan. A deviation from normal protocol results in a higher risk of the mother developing PPD. Similarly, deviating (having a caesarean section) from the mothers' desires (having a natural birth), has the same effect (Ghaedrahmati et al., 2017). The mode of delivery also influences the risk of developing PPD, with a natural birth being the safest option (Silverman et al., 2017). In addition, although it is a highly debated topic, the use of epidurals has been identified to decrease the chances of mothers developing PPD (Ghaedrahmati et al., 2017). Amongst all other factors, age also plays a role. Women who are 35 years or older are at a higher risk of developing PPD. The lowest risk is for women between the ages of 25 and 29 (Silverman et al., 2017). The age factor pertains to the fact, that the riskiness of the birth is higher for the prior (Cavazos-Rehg et al., 2015). Lastly, a mother-to-be is 4–18 times more likely to develop PPD if their child is born underweight (<1500 g) (Ghaedrahmati et al., 2017).

In addition to the factors mentioned above, social factors must be acknowledged to decrease the risk of a mother developing PPD. The social network around the woman is the most important aspect regarding support. “Newly expecting mothers perceive their partner as their main support system” (Mayers et al., 2020; Smythe et al., 2022). Their partners often see signs of change and act upon them, to ensure the woman receives the necessary mental health support.

2.2. Consequences beyond the mother of postpartum depression

Mothers suffering from postpartum depression receive a great amount of attention, as the negative correlation between a mother's mental health and a child's development is widely known (Cerezo et al., 2008; Goodman, 2008). However, the spillover effect onto their partners is often not addressed. At the same time, father's support has been proven to benefit a mother's mental health (Goodman, 2004). “Maternal depression was identified as the strongest predictor of paternal depression during the postpartum period” (Goodman, 2004). 25 % of women who experience PPD have a partner who is also experiencing PPD (Goodman, 2008). Paternal postpartum depression is not a commonly known consequences of childbirth, as the attention, support and communication are directed towards the mother. This inequality in mental health services provided to mothers and fathers, results in fathers reporting feelings of isolation following childbirth. Most notably, this is prevalent following a traumatic birth, or simply a deviation from the original birth plan. This isolation creates insecurity and confusion for the fathers regarding their role (Mayers et al., 2020).

2.2.1. Paternal postpartum depression

The responsibility of a child can be overwhelming and intimidating. Moreover, childbirth is an intense experience for both mother and father. However, while mothers are fully involved and sufficiently supported, fathers often don't get the same treatment (Goodman, 2004). The lack of paternal support received, increases the difficulty, both technically and mentally, of having a child. This results in a high chance of fathers developing postpartum depression (Goodman, 2004, 2008).

While most partners feel as though the mother should be receiving

most of the attention, the extreme imbalance between the information available to them and information available to mothers is not justified (Mayers et al., 2020). Fathers feel as though they should be given or offered more support and information than what is currently the norm. Additionally, the quality of mental health support has been criticized. “Fathers require better recognition of their mental health needs from healthcare professionals” (Mayers et al., 2020).

Societal stigma often results in the fathers not seeking for help, as they are meant to be the providers of the family and don't allow themselves to suffer mentally. Moreover, as fathers are not briefed on PPD, they often don't see the signs and only accept the truth when it's too late for early intervention. Similarly, women may see a change in their partner. However, they do not have the priming of it potentially being PPD and therefore ignore the signs (Abenova et al., 2022).

The chances of paternal postpartum depression increase with unexpected childbirth, as a change of procedure while in the delivery room can be traumatizing for the father. The fear that develops in their minds, when there is no proper communication between healthcare personnel and the father in the delivery room causes the fathers to think of the worst possible outcomes (Pedersen et al., 2021). A lack of support and communication from healthcare practitioners directly to the partners, results in a sensation of helplessness, isolation, and confusion regarding the partners mental health issues (Melrose, 2010). Similarly to maternal PPD, paternal postpartum depression not only affects the father but also the mother and the child's development (Goodman, 2004, 2008; Rohde et al., 2005).

2.2.2. Consequences of paternal postpartum depression

Positive parent-infant interaction is the key to ensuring children's good psychological, cognitive and language development. Partners of women who suffer from PPD experience higher parenting stress, which results in less optimal father-infant interaction (Goodman, 2008). In other words, parent-infant interaction is highly influenced by the mental well-being of the parents. Similarly, another study indicated that PPPD might have important implications on the family's mental health and wellbeing. A high correlation was found between the depression of one parent and the other, producing significantly adverse effects on the other parent and child (Goodman, 2004). Moreover, a study indicated that children of fathers with PPPD reported increased emotional and psychological issues (Rohde et al., 2005).

Depression is also sometimes termed as ‘a preventable killer’, because inadequate handling of such psychiatric disorders may lead to the death of a partner, making the situation more complex (Biebel et al., 2018; Kenyon, 2015; Mayers et al., 2020). To ensure prosperity for a child's future life, hospitals should aim to identify signs of possible development of PPD in mothers and fathers. Moreover, they should try to restore mental health as soon as possible (Melrose, 2010). Tackling perinatal mental health support can reap long-term benefits for both the parents and the child (Mayers et al., 2020).

2.3. What can be done more to prevent paternal postpartum depression

A study by Mayers et al. (Mayers et al., 2020) quoted fathers on their experiences and desires after childbirth.

“I read the information my wife was given”.
 “It didn't cover anything about the father and I felt lost”.
 “Leaflets on what to look out for, as you can't always remember what you are told in the immediate aftermath”.
 “Some Mental Health support, as well as social worker support and referral to a therapist”.
 “[I] had not given birth so had no cause for sympathy. A leaflet for my wife and a page for the fathers to read which wasn't enough” (Mayers et al., 2020).

Partners of new mothers have expressed the need to a better understanding on how they can support the new mothers, as well as

themselves. Specifically, clear communication and information regarding treatment and medication, to help the women, as well as to ease their own concerns. Currently, there is not enough support or information provided, and in the cases where support is given, the quality on average, is very low (Mayers et al., 2020). Due to the social stigma of a man's role in society, as well as the pressure of having to be a protector and a provider, fathers have expressed reservations about joining groups for support (Darwin et al., 2017). Darwin et al. concluded that fathers are reluctant and unable to seek help, as they “question the legitimacy of their experiences” and believe that the woman should have priority, especially when they perceive the facilities to help with mental health are under-resourced (Darwin et al., 2017). A further issue raised, was that verbally communicated information was often forgotten, especially when this information was relayed during a stressful time (Mayers et al., 2020).

Fathers have expressed their desire to receive information regarding postnatal mental illness (Pedersen et al., 2021), having someone to talk to, and direct healthcare service support that is specifically targeted towards them. The provided support currently does not seem enough, specifically in deviations that may happen during the process (Taal, 2022), which in return diminishes their ability to support themselves and the mother properly. A simple solution given by a father could be “any offer of help and support” (Mayers et al., 2020). The opportunity to have someone to talk to, as well as simply being acknowledged, was regarded as being very valuable. A referral to a therapist or social worker was suggested (Mayers et al., 2020).

Moreover, a standard agreed-upon method of receiving information for fathers would be in the form of readily available leaflets or various other types of written materials, as they would be easily accessible at any point in time. Emphasis was assigned to the helpfulness of having written material depicting other men's experience. This made them “realize you're not in the boat by yourself” (Darwin et al., 2017). The areas that are generally lacking within the support services are informational support and aftercare. “Early interventions to help fathers cope with stress may be needed to reduce the risk of future deterioration of emotional wellbeing” (Mayers et al., 2020; Pedersen et al., 2021).

3. Conceptual analysis of underlying processes and means to model them

This section presents the preliminary analysis of the underlying process that will be considered for modelling the communication and learning behavior for the safety coach, health practitioner and parents (addressed in Section 4). Firstly (in Section 3.1), we explain safety culture in the context of a parent seeking help and support during the procedure. Secondly (in Section 3.2), we explain how organizational learning can play a role in encouraging communication during the process of childbirth. Lastly, we explain the role of the mental models in Section 3.3, along with the cognitive architecture used to model them and the learning of them.

3.1. Safety culture

A good safety culture facilitates learning. Safety culture encompasses realizing omissions and mistakes, realizing that one may not fully be at fault, admitting to the errors and not being scrutinized for the error, but instead learning from it. Applying a safety culture creates an open environment for further development. It decreases the frequency of errors since individuals are willing to admit to them, instead of trying to cover up which may worsen the situation (Darwin et al., 2017). Facilities, which would benefit greatly from integrating a just safety culture, are hospitals. “A blame-free, nonpunitive culture encourages clinicians to report errors and truly learn from their mistakes. It also supports organizations in efforts to better understand their errors and make improvements” (Beyea, 2004). The basis of this is founded on open communication with the goal of moving away from extreme punishment

or a blameless culture and instead moving towards a just culture (Boysen, 2013). The scope of this paper doesn't refer to just safety culture in the classical sense, which encompasses a medical professional speaking up to avoid immediate medical mistakes. It addresses just safety culture by the father's willingness to speak up and ask for support. The awareness that all actors inside the delivery room, including medical professionals and parents, are complex beings with desires and that they possess an understanding of what is needed to ensure overall success and health, is essential (Smythe et al., 2022). In addition, the understanding and acknowledgement that the actions currently taken may not be sufficient in some cases holds similar importance. Although the action of asking for support communication itself is not an active preventative measure, the resulting support serves as a tool to avoid possible long-term mental-health consequences (Kenyon, 2015; Mayers et al., 2020). This perspective aims to bridge the gap between mental and physical health and emotional health, as they are not only independent of each other, but also dependent on each other (Pinto-Foltz & Logsdon, 2008). By expanding the view of the involved actors, it allows for a more well-rounded approach with various points of view and an ever-increasing just safety culture (Darwin et al., 2017; Hassan, 2018; Ratnapalan & Uleryk, 2014).

This approach to safety culture has the ability to extend the range of the benefits from short-term to long-term. Communication is not strictly a medical step; where if a mistake occurs, it expresses itself in direct consequences. However, it should be considered a valuable medical step, as it entails a simple skill that all individuals know, and can prevent consequences that aren't immediate, but can be visible in the long term (Hassan, 2018). The goal is to encourage the implementation of a well-rounded treatment where the effects don't stop when one leaves the hospital.

3.2. Organizational learning

Crossan et al. (1999) define organizational learning as:

“a dynamic process. Not only does learning occur over time and across levels, but it also creates a tension between assimilating new learning (feed forward) and exploiting or using what has already been learned (feedback). Through feed-forward processes, new ideas and actions flow from the individual to the group to the organization levels. At the same time, what has already been learned feeds back from the organization to group and individual levels, affecting how people act and think” (Crossan et al., 1999).

“Feed forward relates to exploration. It is the transference of learning from individuals and groups through to the learning that becomes embedded-or institutionalized-in the form of systems, structures, strategies, and procedures (Hedberg, 1981; Shrivastava, 1983). Feedback relates to exploitation and to the way in which institutionalized learning affects individuals and groups” (Crossan et al., 1999).

The four I's of organizational learning are intuiting, interpreting, integrating, and institutionalizing. The first two relate to an individual, the second and third to a team or group and the third and last to an organization (Crossan et al., 1999). These overlaps are links between the levels. For organization learning to occur, the understanding that an “organization operates in an open system, rather than having a solely internal focus” (Crossan et al., 1999) is crucial. In other words, there is a transfer of knowledge between individuals, groups and organizations (Kim, 1997). According to Peter Senge's theory successful learning has the capacity to change and manage change, where an organization can adopt system thinking, shared mental models and shared vision can help learn in teams (Ratnapalan & Uleryk, 2014).

3.3. Mental models

Mental models are at the base of an individual's actions. Kim

describes them as follows:

“Mental models represent a person's view of the world, including explicit and implicit understandings. Mental models provide the context in which to view and interpret new material, and they determine how stored information is relevant to a given situation” (Kim, 1997).

Interesting to note is the similarity between the two I's for individuals mentioned earlier and Kim's definition of mental models. The definition encompasses both 'intuiting' ('a person's view of the world, including explicit and implicit understandings') and 'interpreting' ('interpret new material'). Mental models are useful for individuals to create internal simulations based on certain circumstances. Moreover, new mental models or additions or revisions to mental models can be learned. This is encompassed by Piaget, who assigns importance to the marriage of accommodation (adapting ones individual internal concepts based on experiences) and assimilation (integrating ones experiences into ones individual internal concepts) as the keys to learning (Kim, 1997; Piaget, 1970).

Shared mental models are various mental models that ideally align themselves in a manner that they become shared knowledge. Therefore, their representation may not only rely on differential knowledge of a member, but they may also represent an overlap or convergence among their mental models in relation to a task or procedure. As shared mental models are related to a mutual goal, it relies mainly on understanding requirements and steps taken during a procedure. They can be equated to the third I, 'integrating'. Integrating refers to a shared understanding and mutual adjustment, creating interactive systems (Crossan et al., 1999). To facilitate integration, interpretation must be done by the means of communication (Bouma, Canbaloglu, Treur, & Wiewiora, 2023).

3.4. Cognitive architecture used for shared mental models

Network-Oriented Modelling is a technique that can be used to model interconnected and interactive causal processes that are temporal by nature (Treur, 2016). Given the direct relation between dynamics and causal relations, as highlighted in (Treur, 2016), this classical approach is extended to contain the notion of dynamics in a network structure. These notions of causality and dynamics have been incorporated and are part of a more refined structure and semantics of the considered networks. More specifically, the nodes in a network are interpreted here as states (or state variables) that vary over time, and the connections are interpreted as causal relations that define how each state can affect other states over time. To acknowledge this perspective of dynamics and causality on networks, this type of network has been called a temporal-causal network (Treur, 2016).

Temporal-causal networks are the foundation of dynamic Network-Oriented Modelling. While the popular approach of causal modelling comes with limitations, the addition of dynamic features provides a more detailed and truthful representation of the real-world (Treur, 2016). This dynamic perspective is based on a continuous time dimension, represented by real numbers. The temporal dimension enables modelling by cyclic causal networks as well, and also timing of causal effects can be modelled in detail. Due to this, causal reasoning and simulation is possible for networks that inherently contain cycles, such as networks modeling mental or brain states, or networks describing social interaction. (Treur, 2016).

The research conducted for this paper is performed addressing mental processes using internal mental models, which are modeled in a network-oriented manner (see (Treur, 2016, 2020)). It encompasses a social structure, depicting how people interact amongst themselves, as well as network structures that depict an individual's mental processes, in this case also including internal mental models, (Treur & Van Ments, 2022). These models can also be used to reflect adaptive organizational behavior (Canbaloglu et al., 2022). In this technique, a network can be

Table 1
Combination Functions used in the Self-Modelling Network Model.

	Notation	Formula	Parameters
Advanced logistic sum	$\mathbf{alogsitic}_{\sigma, \tau}(V_1, \dots, V_k)$	$\left[\frac{1}{1 + e^{-\sigma(V_1 + \dots + V_k - \tau)}} - \frac{1}{1 + e^{\sigma\tau}} \right] (1 + e^{-\sigma\tau})$	Steepness σ Excitability threshold τ
Step once	$\mathbf{steponce}_{\alpha, \beta}(V)$	1 if $\alpha \leq t \leq \beta$ for time t , else 0	Start time α End time β
Monitor	$\mathbf{monitor}_{\tau}(V_1, V_2)$	1 if $V_1 - V_2 \geq \tau$, else 0	Activation threshold τ

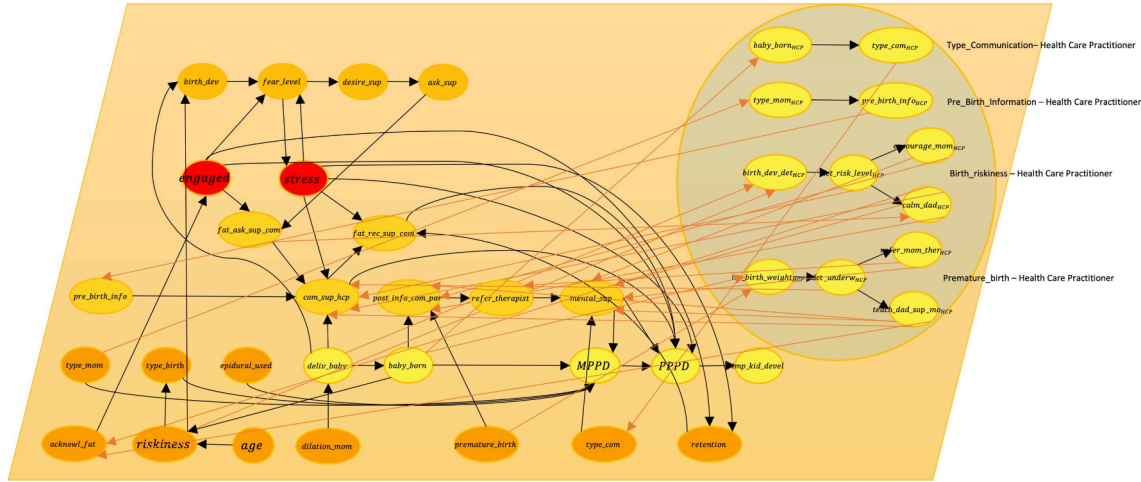


Fig. 1. Connectivity of the Base Model of the Childbirth Process.

represented by a labelled graph containing states, also known as nodes, where each state X is connected to another state Y and where X has a causal impact on Y , at a certain time, with some strength and speed. A, a temporal-causal network is characterized by (Treur, 2016):

- Connectivity characteristics:
Connections from a state X to a state Y and their weights $\omega_{X,Y}$.
- Aggregation characteristics:
For any state Y , some combination function $c_Y(\dots)$ defines the aggregation that is applied to the single causal impacts $\omega_{X,Y}X(t)$ on Y from its incoming connections from states X .
- Timing characteristics:
Each state Y has a speed factor η_Y defining how fast it changes for a given causal impact.

The related difference equation (1) incorporates these characteristics in a standard numerical format (Treur, 2016), i.e.:

$$Y(t + \Delta t) = Y(t) + \eta_Y [c_Y(\omega_{X_1,Y}X_1(t), \dots, \omega_{X_k,Y}X_k(t)) - Y(t)] \Delta t \quad (1)$$

Here the X_i are the states from which state Y gets incoming connections. Numerous combination functions are available to address the issue of aggregating multiple impacts (Treur, 2016). Those which were used for this research are shown in Table 1.

The modelling of adaptive networks is based on network reification (or self-modeling network), which entails extending the base model by reification states, also referred to as self-model states. Reification is defined as “representing something abstract as a material or concrete thing, or making something abstract more concrete or real” (Treur, 2020). The self-model states are part of a higher order adaptation and are visually placed on a higher plane than the base level. Similar to how the base level can be adaptive, the first reification level, also known as first-order self-model, can also be adaptive by nature. Therefore, the higher-order adaptive levels are not limited to one, as the construction

can be iterated indefinitely. Network reification for a temporal-causal network means that for the adaptive network structure characteristics $\omega_{X,Y}$, $c_Y(\dots)$, η_Y for each state Y of the base network, additional network states $W_{X,Y}$, C_Y , H_Y (called reification states) are introduced respectively (Treur, 2020). Different simulating environments are used to simulate the (shared) mental models in Matlab and Python. In section 6, we explain how these characteristics can be used to simulate a model in Python.

4. The designed network model

The model discussed in this paper focuses on childbirth at a hospital, where the father is constantly present in the delivery room, even in circumstances where a deviation from a standard protocol may happen (Taal, 2022). It mainly encompasses the communication process starting shortly before childbirth and ending once the parents leave the hospital. The majority of the states in the model reflect communication actions, specifically geared towards the father. The communication process may (or may not) take place during and after childbirth, even in circumstances where a deviation can occur.

The research described in this paper extends to two levels of adaptation (two self-modelling levels) on top of the base level. Therefore, in Section 4.1, we present the base model, which shows the model. In section 4.2, we add the adaption level through self-modelling network and the role of a healthcare practitioner and a virtual safety coach (AIC). Lastly, in Section 4.3., we present how organization learning can influence the learning of the safety coach. Please note that the model presented in the following sections are mainly related to the communication between the healthcare practitioner (HCP) and the father of a neonate during the process of childbirth.

4.1. Base level of the adaptive network model

The base level, depicted in Fig. 1 (yellow parallelogram), contains

Table 2
Base Level States (including HCP Mental Model).

State Number	State Name	Explanation	Level	
X ₁	type_mom	Pre-Birth: Determining whether the mother is nulliparous (first child) or multiparous (already has 1+ child)	Base Level	
X ₂	artificiality_birth	Pre-Birth: Determining the naturalness of the birth: natural birth or caesarean section		
X ₃	epidural_used	Pre-Birth: Determining if an epidural will be administered		
X ₄	deliv_baby	Intra-Birth: Delivery of the baby; the woman is in labour		
X ₅	baby_born	Post-Birth: The baby is born		
X ₆	MPPD	Post-Birth: The risk of maternal postpartum depression		
X ₇	PPPD	Post-Birth: The risk of paternal postpartum depression		
X ₈	imp_kid_devel	Post-Birth: The risk of impeding child flourishing/development		
X ₉	pre_birth_info	Pre-Birth: Information given to parents		
X ₁₀	com_sup_hcp	Intra-Birth: Communication from HCP to parents		
X ₁₁	fat_ask_sup_com	Intra-Birth: Father asks HCP for support communication		
X ₁₂	fat_rec_sup_com	Intra-Birth: Father receives support communication from HCP		
X ₁₃	post_info_com_par	Post-Birth: Information given to parents		
X ₁₄	refer_therapist	Post-Birth: Referral by HCP of parent(s) to a therapist		
X ₁₅	mental_sup	Post-Birth: Receive additional mental support		
X ₁₆	acknowl_fat	Acknowledgement of the father as an actor in childbirth by HCP		
X ₁₇	age	Age of mother: whether she is between the ages of 25-29 or not		
X ₁₈	riskiness	Riskiness of giving birth for the mother		
X ₁₉	dilation_mom	Dilation of the mother		
X ₂₀	premature_birth	Premature birth		
X ₂₁	type_com	Type of communication received/used: verbal or written		
X ₂₂	retention	Ability to retain information received		
X ₂₃	engaged	Level of active engagement		
X ₂₄	stress	Level of stress		
X ₂₅	birth_dev	Deviation from original birth plan		
X ₂₆	fear_level	Level of fear		
X ₂₇	desire_sup	Desire for support		
X ₂₈	ask_sup	Willingness to ask for support		
X ₂₉	birth_dev_det _{HCP}	Intra-Birth: Detecting a birth deviation		Base Level - HCP Mental Model
X ₃₀	det_risk_level _{HCP}	Intra-Birth: Determining the risk of a given birth deviation		
X ₃₁	encourage_mom _{HCP}	Intra- & Post-Birth: Encouraging the mother positively		
X ₃₂	calm_dad _{HCP}	Intra- & Post-Birth: Calming the father		
X ₃₃	irr_birth_weight _{HCP}	Post-Birth: Detecting irregular birth weight of the child		
X ₃₄	det_underw _{HCP}	Post-Birth: Determining the child as underweight		
X ₃₅	refer_mom_ther _{HCP}	Post-Birth: Referring the mother to a therapist		
X ₃₆	teach_dad_sup_mom _{HCP}	Post-Birth: Teaching the father how to support the mother (technically and mentally)		
X ₃₇	baby_born _{HCP}	Post-Birth: The baby is born		
X ₃₈	type_com _{HCP}	Type of communication used: verbal or written		
X ₃₉	type_mom _{HCP}	Pre-Birth: Determining whether the mother is nulliparous (first child) or multiparous (already has 1+ child)		
X ₄₀	pre_birth_info _{HCP}	Pre-Birth: Giving information to parents		

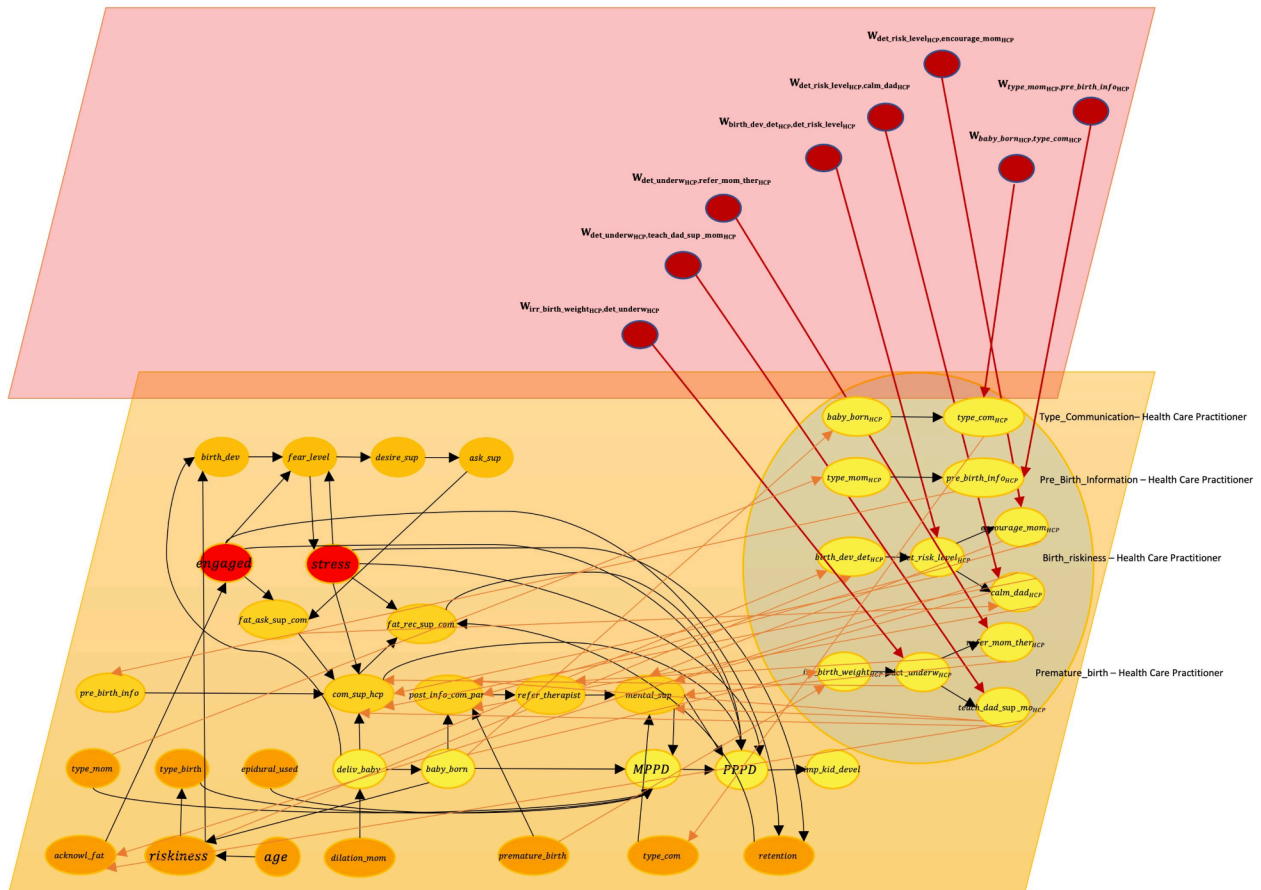


Fig. 2. Connectivity of First-Order Adaptive Network Model Case (a) first-Order Self-Model States (or First Reification Level States).

Table 3
Additional Base Level and First-Order Self-Model States (or First Reification Level States).

State Number	State Name	Explanation	Level
X41	birth_dev_det _{AIC}	Intra-Birth: Detecting a birth deviation	Base Level - AIC Mental Model
X42	det_risk_level _{AIC}	Intra-Birth: Determining the risk of a given birth deviation	
X43	encourage_mom _{AIC}	Intra- & Post-Birth: Encouraging the mother positively	
X44	calm_dad _{AIC}	Intra- & Post-Birth: Calming the father	
X45	irr_birth_weight _{AIC}	Post-Birth: Detecting irregular birth weight of the child	
X46	det_underw _{AIC}	Post-Birth: Determining the child as underweight	
X47	refer_mom_ther _{AIC}	Post-Birth: Referring the mother to a therapist	
X48	teach_dad_sup_mom _{AIC}	Post-Birth: Teaching the father how to support the mother (technically and mentally)	
X49	baby_born _{AIC}	Post-Birth: The baby is born	
X50	type_com _{AIC}	Type of communication used: verbal or written	
X51	type_mom _{AIC}	Pre-Birth: Determining whether the mother is nulliparous (first child) or multiparous (already has 1+ child)	
X52	pre_birth_info _{AIC}	Pre-Birth: Giving information to parents	
X61	W _{birth_dev_det_AIC,det_risk_level_AIC}	Reified representation state for connection weight $\omega_{\text{birth dev det, det risk level AIC}}$	First reification level
X62	W _{det_risk_level_AIC,encourage_mom_AIC}	Reified representation state for connection weight $\omega_{\text{det risk level AIC, encourage mom AIC}}$	
X63	W _{det_risk_level_AIC,calm_dad_AIC}	Reified representation state for connection weight $\omega_{\text{det risk level AIC, calm dad AIC}}$	
X64	W _{irr_birth_weight_AIC,det_underw_AIC}	Reified representation state for connection weight $\omega_{\text{irr birth weight AIC, det underw AIC}}$	
X65	W _{det_underw_AIC,refer_mom_ther_AIC}	Reified representation state for connection weight $\omega_{\text{det underw AIC, refer mom ther AIC}}$	
X66	W _{det_underw_AIC,teach_dad_sup_mom_AIC}	Reified representation state for connection weight $\omega_{\text{det underw AIC, teach dad sup mom AIC}}$	
X67	W _{baby_born_AIC,type_com_AIC}	Reified representation state for connection weight $\omega_{\text{baby born AIC, type com AIC}}$	
X68	W _{type_mom_AIC,pre_birth_info_AIC}	Reified representation state for connection weight $\omega_{\text{type mom AIC, pre birth info AIC}}$	
X69	H _{encourage_mom_AIC}	Reified representation state for speed factor $\eta_{\text{encourage mom AIC}}$	
X70	H _{calm_dad_AIC}	Reified representation state for speed factor $\eta_{\text{calm dad AIC}}$	
X71	H _{refer_mom_ther_AIC}	Reified representation state for speed factor $\eta_{\text{refer mom ther AIC}}$	
X72	H _{teach_dad_sup_mom_AIC}	Reified representation state for speed factor $\eta_{\text{teach dad sup mom AIC}}$	
X73	H _{type_com_AIC}	Reified representation state for speed factor $\eta_{\text{type com AIC}}$	
X74	H _{pre_birth_info_AIC}	Reified representation state for speed factor $\eta_{\text{pre birth info AIC}}$	
X75	con_act_AIC	Context state for determining activation of the AIC	

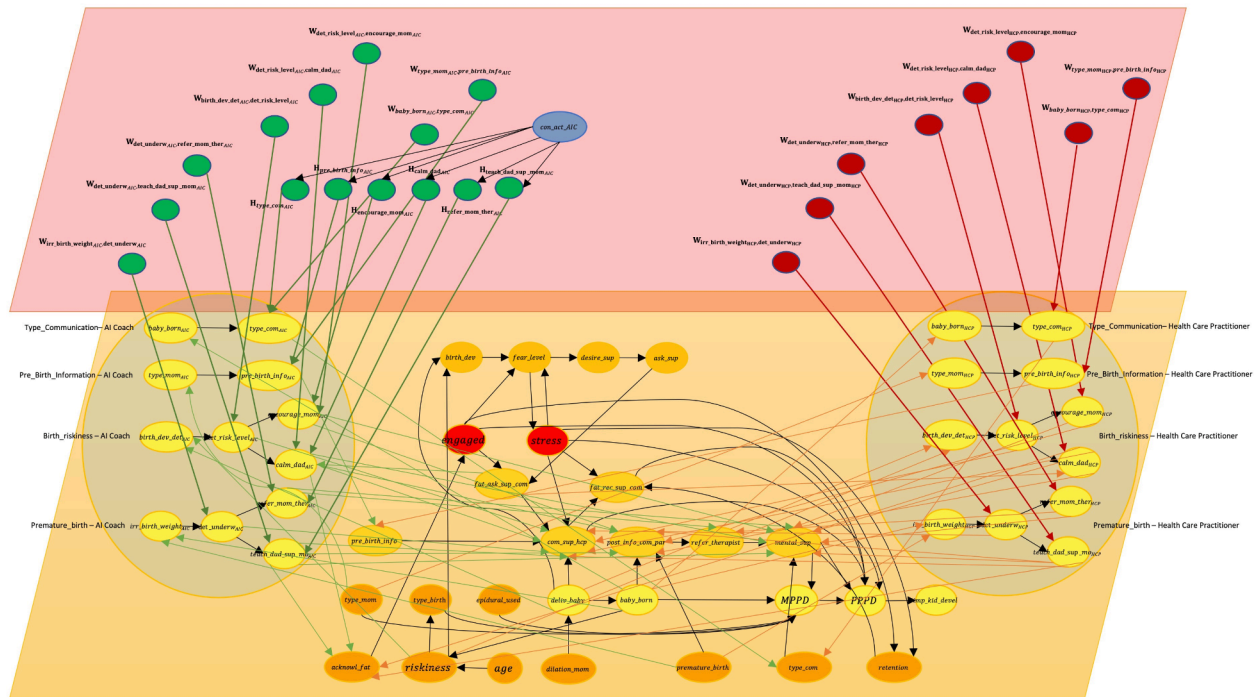


Fig. 3. Connectivity of First-Order Adaptive Network Model Case (b).

the world states and the mental model of the healthcare practitioner (HCP). The world states in the base level of the model can be one of five types: process states (yellow), context states (orange), emotion states (red), paternal states (light orange), or communication action states (dark yellow).

The process states define both the baby being delivered and then subsequently, for example hours or days, after birth, as well as the risk of developing maternal postpartum depression, the risk of developing paternal postpartum depression and the risk of impending child development. The context states influence the process states, the emotion

states and in some circumstances other context states. The emotion states represent the emotions of the actors that occur during childbirth which influence frequent communication. The paternal states indicate the process through which the father may go before reaching out for help. Lastly, the central part, the communication action states, depict the interaction between HCP and parents, specifically the father, throughout the childbirth process. The states were created based on the findings explained in Section 2 of this paper. The connectivity of the base model can be seen in Fig. 1, while the detailed description of the states of the base level is enlisted in Table 2.

Table 4
Case (c) First-Order Self-Model States (or First Reification Level States).

State Number	State Name	Explanation	Level
X53	W _{birth_dev_det_HCP_det_risk_level_HCP}	Reified representation state for connection weight $\omega_{\text{birth_dev_det_HCP_det_risk_level_HCP}}$	First reification level
X54	W _{det_risk_level_HCP_encourage_mom_HCP}	Reified representation state for connection weight $\omega_{\text{det_risk_level_HCP_encourage_mom_HCP}}$	
X55	W _{det_risk_level_HCP_calm_dad_HCP}	Reified representation state for connection weight $\omega_{\text{det_risk_level_HCP_calm_dad_HCP}}$	
X56	W _{irr_birth_weight_HCP_det_underw_HCP}	Reified representation state for connection weight $\omega_{\text{irr_birth_weight_HCP_det_underw_HCP}}$	
X57	W _{det_underw_HCP_refer_mom_ther_HCP}	Reified representation state for connection weight $\omega_{\text{det_underw_HCP_refer_mom_ther_HCP}}$	
X58	W _{det_underw_HCP_teach_dad_sup_mom_HCP}	Reified representation state for connection weight $\omega_{\text{det_underw_HCP_teach_dad_sup_mom_HCP}}$	
X59	W _{baby_born_HCP_type_com_HCP}	Reified representation state for connection weight $\omega_{\text{baby_born_HCP_type_com_HCP}}$	
X60	W _{type_mom_HCP_pre_birth_info_HCP}	Reified representation state for connection weight $\omega_{\text{type_mom_HCP_pre_birth_info_HCP}}$	
X61	W _{birth_dev_det_AIC_det_risk_level_AIC}	Reified representation state for connection weight $\omega_{\text{birth_dev_det_AIC_det_risk_level_AIC}}$	
X62	W _{det_risk_level_AIC_encourage_mom_AIC}	Reified representation state for connection weight $\omega_{\text{det_risk_level_AIC_encourage_mom_AIC}}$	
X63	W _{det_risk_level_AIC_calm_dad_AIC}	Reified representation state for connection weight $\omega_{\text{det_risk_level_AIC_calm_dad_AIC}}$	
X64	W _{irr_birth_weight_AIC_det_underw_AIC}	Reified representation state for connection weight $\omega_{\text{irr_birth_weight_AIC_det_underw_AIC}}$	
X65	W _{det_underw_AIC_refer_mom_ther_AIC}	Reified representation state for connection weight $\omega_{\text{det_underw_AIC_refer_mom_ther_AIC}}$	
X66	W _{det_underw_AIC_teach_dad_sup_mom_AIC}	Reified representation state for connection weight $\omega_{\text{det_underw_AIC_teach_dad_sup_mom_AIC}}$	
X67	W _{baby_born_AIC_type_com_AIC}	Reified representation state for connection weight $\omega_{\text{baby_born_AIC_type_com_AIC}}$	
X68	W _{type_mom_AIC_pre_birth_info_AIC}	Reified representation state for connection weight $\omega_{\text{type_mom_AIC_pre_birth_info_AIC}}$	
X69	W _{pre_birth_info_AIC_pre_birth_info}	Reified representation state for connection weight $\omega_{\text{pre_birth_info_AIC_pre_birth_info}}$	
X70	W _{calm_dad_AIC_acknowl_fat}	Reified representation state for connection weight $\omega_{\text{calm_dad_AIC_acknowl_fat}}$	
X71	W _{teach_dad_sup_mom_AIC_acknowl_fat}	Reified representation state for connection weight $\omega_{\text{teach_dad_sup_mom_AIC_acknowl_fat}}$	
X72	W _{calm_dad_AIC_com_sup_hcp}	Reified representation state for connection weight $\omega_{\text{calm_dad_AIC_com_sup_hcp}}$	
X73	W _{teach_dad_sup_mom_AIC_com_sup_hcp}	Reified representation state for connection weight $\omega_{\text{teach_dad_sup_mom_AIC_com_sup_hcp}}$	
X74	W _{calm_dad_AIC_post_info_com_par}	Reified representation state for connection weight $\omega_{\text{calm_dad_AIC_post_info_com_par}}$	
X75	W _{teach_dad_sup_mom_AIC_post_info_com_par}	Reified representation state for connection weight $\omega_{\text{teach_dad_sup_mom_AIC_post_info_com_par}}$	
X76	W _{encourage_mom_AIC_post_info_com_par}	Reified representation state for connection weight $\omega_{\text{encourage_mom_AIC_post_info_com_par}}$	
X77	W _{refer_mom_ther_AIC_refer_therapist}	Reified representation state for connection weight $\omega_{\text{refer_mom_ther_AIC_refer_therapist}}$	
X78	W _{calm_dad_AIC_mental_sup}	Reified representation state for connection weight $\omega_{\text{calm_dad_AIC_mental_sup}}$	
X79	W _{teach_dad_sup_mom_AIC_mental_sup}	Reified representation state for connection weight $\omega_{\text{teach_dad_sup_mom_AIC_mental_sup}}$	
X80	W _{encourage_mom_AIC_mental_sup}	Reified representation state for connection weight $\omega_{\text{encourage_mom_AIC_mental_sup}}$	
X81	W _{refer_mom_ther_AIC_mental_sup}	Reified representation state for connection weight $\omega_{\text{refer_mom_ther_AIC_mental_sup}}$	
X82	W _{type_com_AIC_type_com}	Reified representation state for connection weight $\omega_{\text{type_com_AIC_type_com}}$	
X83	monitor_pre_birth_info	State monitoring AIC mental model state <i>pre_birth_info_AIC</i> and world state <i>pre_birth_info</i>	
X84	monitor_acknowl_fat₁	State monitoring AIC mental model state <i>teach_dad_sup_mom_AIC</i> and world state <i>acknowl_fat</i>	
X85	monitor_acknowl_fat₂	State monitoring AIC mental model state <i>calm_dad_AIC</i> and world state <i>acknowl_fat</i>	
X86	monitor_com_sup_hcp₁	State monitoring AIC mental model state <i>calm_dad_AIC</i> and world state <i>com_sup_hcp</i>	
X87	monitor_com_sup_hcp₂	State monitoring AIC mental model state <i>teach_dad_sup_mom_AIC</i> and world state <i>com_sup_hcp</i>	
X88	monitor_post_info_com_par₁	State monitoring AIC mental model state <i>encourage_mom_AIC</i> and world state <i>post_info_com_par</i>	
X89	monitor_post_info_com_par₂	State monitoring AIC mental model state <i>calm_dad_AIC</i> and world state <i>post_info_com_par</i>	
X90	monitor_post_info_com_par₃	State monitoring AIC mental model state <i>teach_dad_sup_mom_AIC</i> and world state <i>post_info_com_par</i>	
X91	monitor_refer_therapist	State monitoring AIC mental model state <i>refer_mom_ther_AIC</i> and world state <i>refer_therapist</i>	
X92	monitor_mental_sup₁	State monitoring AIC mental model state <i>encourage_mom_AIC</i> and world state <i>mental_sup</i>	
X93	monitor_mental_sup₂	State monitoring AIC mental model state <i>refer_mom_ther_AIC</i> and world state <i>mental_sup</i>	
X94	monitor_mental_sup₃	State monitoring AIC mental model state <i>calm_dad_AIC</i> and world state <i>mental_sup</i>	
X95	monitor_mental_sup₄	State monitoring AIC mental model state <i>teach_dad_sup_mom_AIC</i> and world state <i>mental_sup</i>	
X96	monitor_type_com	State monitoring AIC mental model state <i>type_com_AIC</i> and world state <i>type_com</i>	

The mental model (light grey oval) of the HCP in the base level of the model shows which internal simulations a HCP can have during the childbirth process. There are four separate process models within the mental model, each with end states (bold), that connect to one of the communication actions and/or context states in the world states.

The baby is born, which affects the **type of communication** used. The type of mother, whether she is nulliparous or multiparous, determines whether any **special information has to be communicated before childbirth**. In the interest of space, type of mother is shortened to type of mom in the figures and tables. The HCP determines that there is a deviation in the childbirth process. They determine the risk level associated with this deviation and, in return, **encourage the mother while calming the father**. When the baby is born, especially if born prematurely, the HCP assumes the possibility of irregular birth weight of the child. Once the child is classified as being underweight, they **refer the mother to a therapist and teach the father how to support the mother**.

4.2. First-Order Self-Model level of the adaptive network model

In this section, we present the first-order adaptive network level for the base model designed in Section 4.1. First-order adaptive networks model plasticity; changes in brain structure for learning through ‘Hebbian Learning’ principle (Hebb, 1949). First, we will discuss how HCP

learns to communicate to the father by adding additional **W**-states on the first reification level, which determines the weight of the connection on the base level. Second, we present how a virtual safety coach (AIC) can facilitate communication using the shared mental models. Therefore, it has both **W**- and **H**-states on the first reification level. These states determine the weight of connections, and the speed factor of the connections on the base level, respectively. Third, we present how a virtual safety coach can monitor the communication during the procedure by adding both **W**-states and monitor states on the first reification level.

4.2.1. Healthcare practitioner learns to communicate

Additionally, to the base level described above (see Section 4.1), Fig. 2, has a middle level (red parallelogram), to represent the first level or the self-model of the base model using reification level states. This level contains eight **W**-states (red), which represent the weight of the connections within the HCP mental model on the base level. The detailed description of these states can be found in Table 3.

4.2.2. The Role of the Virtual safety Coach

This paper aims to model and determine the usability and effectiveness in having a virtual AI Coach (AIC) present. The main goal of the coach is to reduce the risk of maternal and paternal postpartum depression. This coach is aware of deviations in the process of the communication actions, and may intervene to provide support to the health practitioner(s) to correct them. Thus the related actions can be in

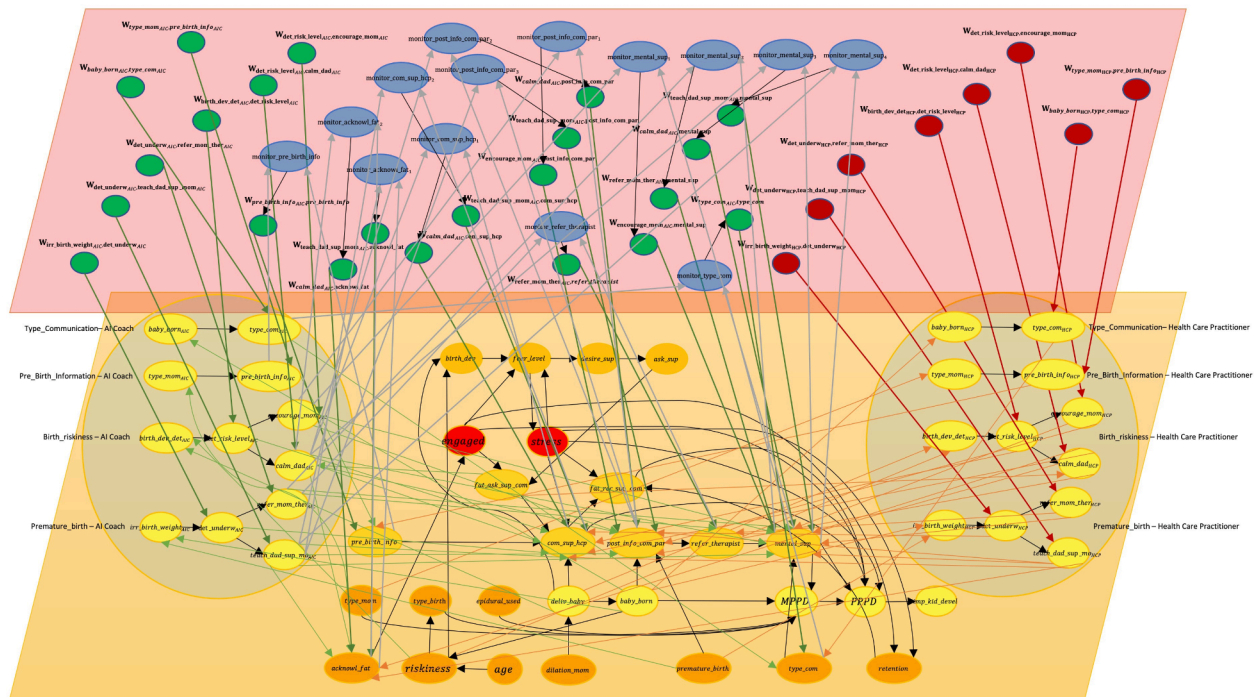


Fig. 4. Connectivity of First-Order Adaptive Network Model Case (c).

Table 5
First- and Second-Order Self-Model States (or First and Second Reification Level States).

State Number	State Name	Explanation	Level
X ₉₇	W _{W_AICW_HCP}	Reified representation state for connection weight $\omega_{W_AICW_HCP}$ for the connection between the reified representation states X ₉₁ -X ₉₈ and X ₅₁ -X ₆₀ , respectively	Second reification level
X ₉₈	con_feedback	Context state for learning of the HCP from the AIC	
X ₉₉	W _{birth_dev_det_E_det_risk_level_E}	Representation state for the experts knowledge about birth_dev_det_E_det_risk_level_E	First reification level
X ₁₀₀	W _{det_risk_level_E_encourage_mom_E}	Reified representation state for connection weight $\omega_{det_risk_level_E_encourage_mom_E}$	
X ₁₀₁	W _{det_risk_level_E_calm_dad_E}	Reified representation state for connection weight $\omega_{det_risk_level_E_calm_dad_E}$	
X ₁₀₂	W _{det_birth_weight_E_det_underw_E}	Reified representation state for connection weight $\omega_{det_birth_weight_E_det_underw_E}$	
X ₁₀₃	W _{det_underw_E_refer_mom_there_E}	Reified representation state for connection weight $\omega_{det_underw_E_refer_mom_there_E}$	
X ₁₀₄	W _{det_underw_E_teach_dad_sup_mom_E}	Reified representation state for connection weight $\omega_{det_underw_E_teach_dad_sup_mom_E}$	
X ₁₀₅	W _{baby_born_E_type_com_E}	Reified representation state for connection weight $\omega_{baby_born_E_type_com_E}$	
X ₁₀₆	W _{type_mom_E_pre_birth_info_E}	Reified representation state for connection weight $\omega_{type_mom_E_pre_birth_info_E}$	
X ₁₀₇	W _{W_E_W_AIC}	Reified representation state for connection weight $\omega_{W_E_W_AIC}$ for the connection between the reified representation states X ₉₉ -X ₁₀₆ and X ₆₁ -X ₆₈ , respectively	Second reification level
X ₁₀₈	con_feedforward	Context state for learning of the AIC from the E	

terms of altering the HCP of a forgotten action or communicating with the father itself (upon approval by an HCP). Thus, the Virtual AI Coach (AIC) will not only help the healthcare practitioner to monitor the process for communication, but also will facilitate them for communication, and in return avoiding adverse possible effects like PPPD and MPPD. Therefore, here, we present an extension to contain the Virtual AI Coach (Fig. 3) that intervenes when necessary in terms of communication with the father of the child. This was done by duplicating the mental model of the HCP for the Coach. The states, as well as all connections within the mental model and to the world states are identical.

The middle level was also duplicated, meaning eight W-states (green) were created to represent the weight of the connections within the Coach mental model. In addition, seven new states were added to this level. Six of these additional states are H-states (green), which have connections to one of each of the end states within the Coach mental model. The H-states represent time activation of the end states and are controlled by the seventh state (blue), a context state that activates the Coach at a particular time. A detailed explanation of the additional states is given in Table 4.

4.2.3. Dynamic monitoring by the Virtual Coach

To create a more dynamic Virtual Coach, a further model (Fig. 4) was created. The goal of this Coach is not to be activated by time; instead, we designed a ‘monitor’ function (see Table 1). This function is responsible for monitoring the communication and context states affected by the end

states of the mental models. Therefore, if insufficient activation of those states is detected (through a parameter called threshold - τ) by the Coach, then the Coach activates the corresponding part of its mental model, which results in the Coach performing the communication action instead of the HCP.

This model of monitoring role of the virtual AI Coach differs in the number of nodes in the middle level. The 16 W-states representing the weight of the connections for both mental models in the base level persist. However, the seven additional states mentioned in Section 4.2.2 were removed. Instead, 14 new W-states (green) that represent the weight of connections were added. These states represent the weight of connections between the end states of the mental model of the Virtual AI Coach and the world states affected by them. Moreover, 14 monitor states (blue), each with an outgoing connection to one of the new states mentioned earlier, were included that receive input from the base level and determine whether to activate their corresponding states based on the monitor combination function described in Table 1. A more in-depth explanation of the states in the middle level can be seen in Table 5.

4.3. Second-Order adaptive network model - organizational learning (feed forward and feedback)

The Second-Order Adaption Level adds another abstraction level of learning to the states modelled on first-order network using meta-plasticity principle. At this level, context states were added along with W-

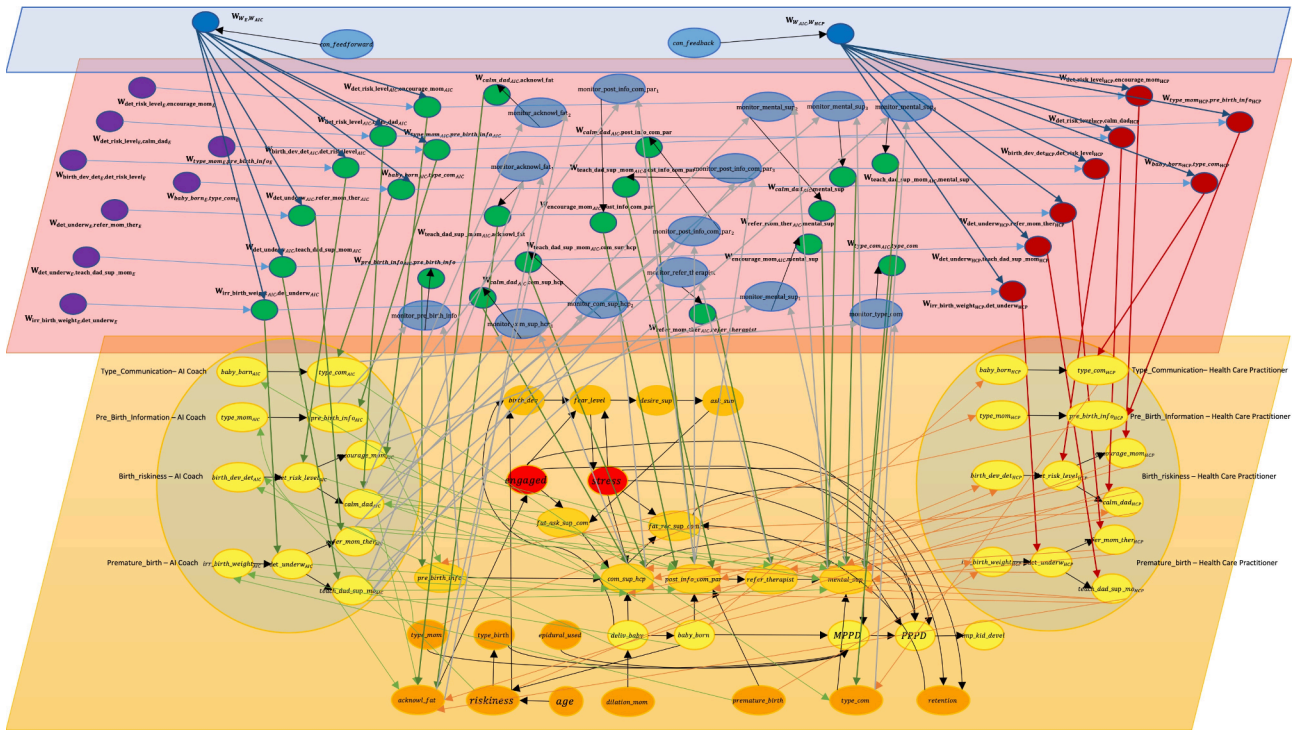


Fig. 5. Connectivity of Second-Order Adaptive Network Model Case (d).

states on the second reification level. It is to be noted that eight more W states are introduced on the first-order level in relation to organizational learning. This final addition to the model was done by incorporating an expert (Fig. 5) of the organization.

The goal with adding an expert (E) was to show the possibility of the Virtual AI Coach learning from a practitioner with a complete mental model. Moreover, the Coach, having acquired this knowledge, can then pass it on to the HCP. In this case the Coach’s mental model is interpreted as a shared mental model. This creates a more adaptive Virtual Coach, as it allows for the constant addition of information from an expert (as feed forward learning). This information is then relayed (feedback learning) to the HCPs after childbirth, making it an increasingly more valuable asset within a hospital setting and depicting organizational learning.

The set-up of the model is as follows. The base-level remains the same as in Section 4.2.2 and 4.2.3. The reason the expert is not being included in the actual process, is that he/she is a tool for teaching the Coach, while not being actively on the floor when the HCP and Coach work in cohesion. The middle level is the same as in 4.2.3, with the addition of eight W -states (purple) representing the knowledge of an expert. Each of these states has a link (light blue) from them to their counterpart of the eight original W -states corresponding to the Coach. Moreover, as the HCP can learn from the Coach, an additional eight links (light blue), with the same setup as mentioned before, were added from the Coach W -states to the HCP W -states.

In the second-order self-model level, two W_W -states (dark blue) were included, as well as two context states (blue). The W_W -states represent the horizontal connection weights (light blue) between the Expert (E) and the Coach, as well as between the Coach and Healthcare Practitioner (HCP). Therefore, the left most one has downward connections (dark blue) to the Coach W -states, and the right most one has downward connections (dark blue) to the HCP W -states. The context state *con_feedforward* creates an initial shared mental model of the knowledge necessary. The context state *con_feedback* updates the individual mental model, of the HCP in this case, with the information from the shared mental model. The detailed descriptions of the newly added states can be seen in the Appendices section.

5. Simulation results

This section presents the assumption made to simulate the model, along with the simulation results obtained from the designed model presented in Section 4.

5.1. Assumptions considered for simulation

While most states are dynamic, meaning they depend on the impact of other states, a handful of states within the models have manually chosen values given their binary nature.

1. The type of mother, either nulliparous or multiparous, was assigned a fixed value of 0, which corresponds to the mother being nulliparous.
2. The artificiality of birth, either being natural or caesarean section, was assigned a fixed value of 0, which corresponds to the mother having a natural birth.
3. The type of birth, either being no/little risk or high risk, was assigned a fixed value of 0, which corresponds to there being no risk.
4. The pre-birth information either being extra information is needed or not, was assigned a fixed value of 0, which corresponds to there being no need for additional information.
5. The age, either between the ages of 25–29 or not, was assigned a fixed value of 1, corresponding to the mother being between 25 and 29 years old.
6. Premature birth, either the birth being premature or not, was assigned a fixed value of 1, which corresponds to it being a premature birth.

Moreover, certain states had concrete specifications.

1. The starting value for maternal postpartum depression (MPPD) was set at 0.13, which is median of the probability of a woman developing postpartum depression (p. 526 - (Dennis, 2004))

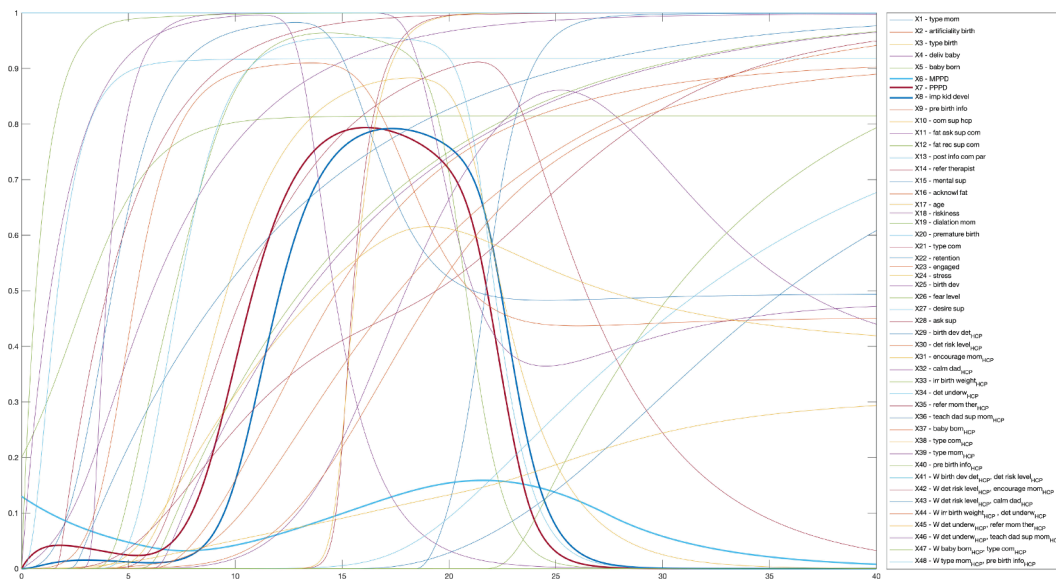


Fig. 6. Simulation Results for Successful Communication between HCP and Parents of the Child.

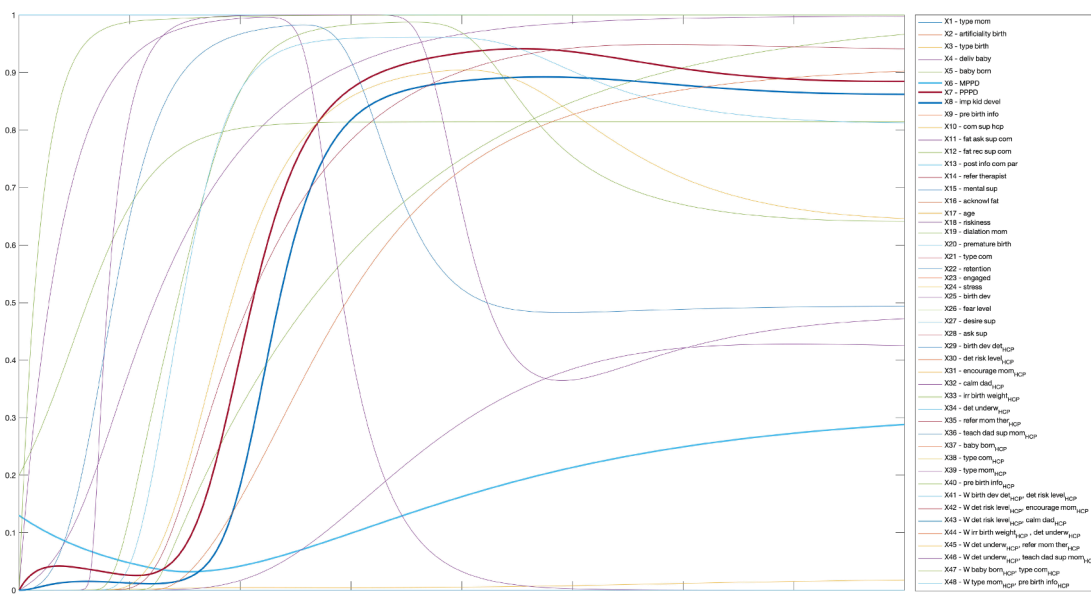


Fig. 7. Simulation Results for Poor Communication between the HCP and the Parents.

2. The state for dilation of the mother increases and reaches a maximum at 0.8, which represents full dilation of 10 cm (NHS, 2020).
3. Once the dilation of the mother reaches 0.8, the state ‘baby_born’ is activated and increases quickly to 1 (Hueston, 1998).

The time points (t) are referred to as unit time and have a value range between 0 and 80. This range for t is selected for an impression. However, it can also have a different range, and can be interpreted in minutes or hours. Moreover, the choice that a deviation occurs during childbirth, as well as the birth being premature, was deliberate, to show the effects of proper communication in a scenario where complications arise. In addition, the mother was set up with the best conditions to not develop MPPD. This can be seen by a slower increase of the line in the simulations compared to PPPD.

Furthermore, an active mental model is defined by the end states of the four mental processes specified earlier (See Section 4). Meaning all

states, except the end states, may be active, as there is internal knowledge of what is occurring in front of them. However, this does not result in further communication actions. For example, the HCP is aware of there being a birth deviation but does not follow through with the further steps that then elicit the communication action.

Lastly, since the goal of this paper is to observe and show how to reduce the risk of maternal (light blue) and paternal (red) postpartum depression and in return reducing the risk of impeding child development (dark blue), their corresponding lines were made bold.

5.2. Communication with the parents

5.2.1. Adequate communication between healthcare practitioners and parents

Here, we present a scenario of successful communication between parents and Healthcare Practitioner (HCP) during the childbirth process. The time duration is from 0 to 40 (t -axis) with a step size of $\Delta t = 0.1$.

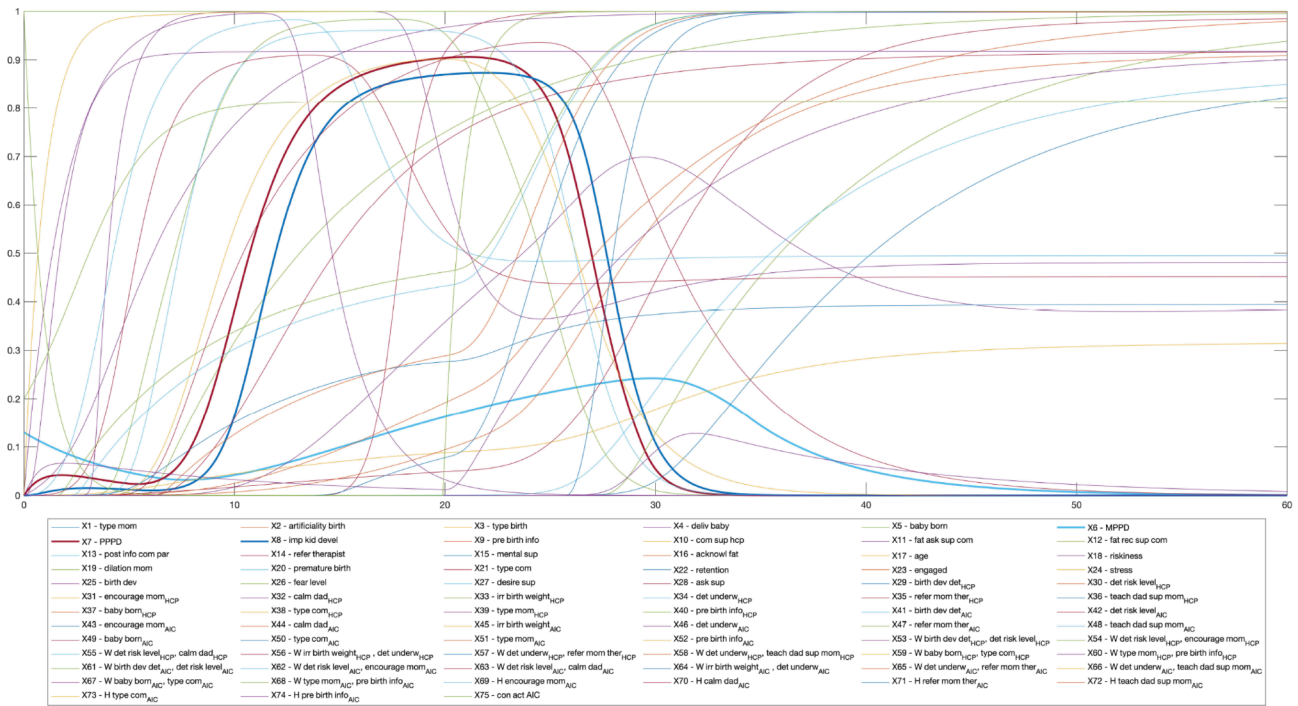


Fig. 8. Simulation Results for Case (b) – AIC Intervenes.

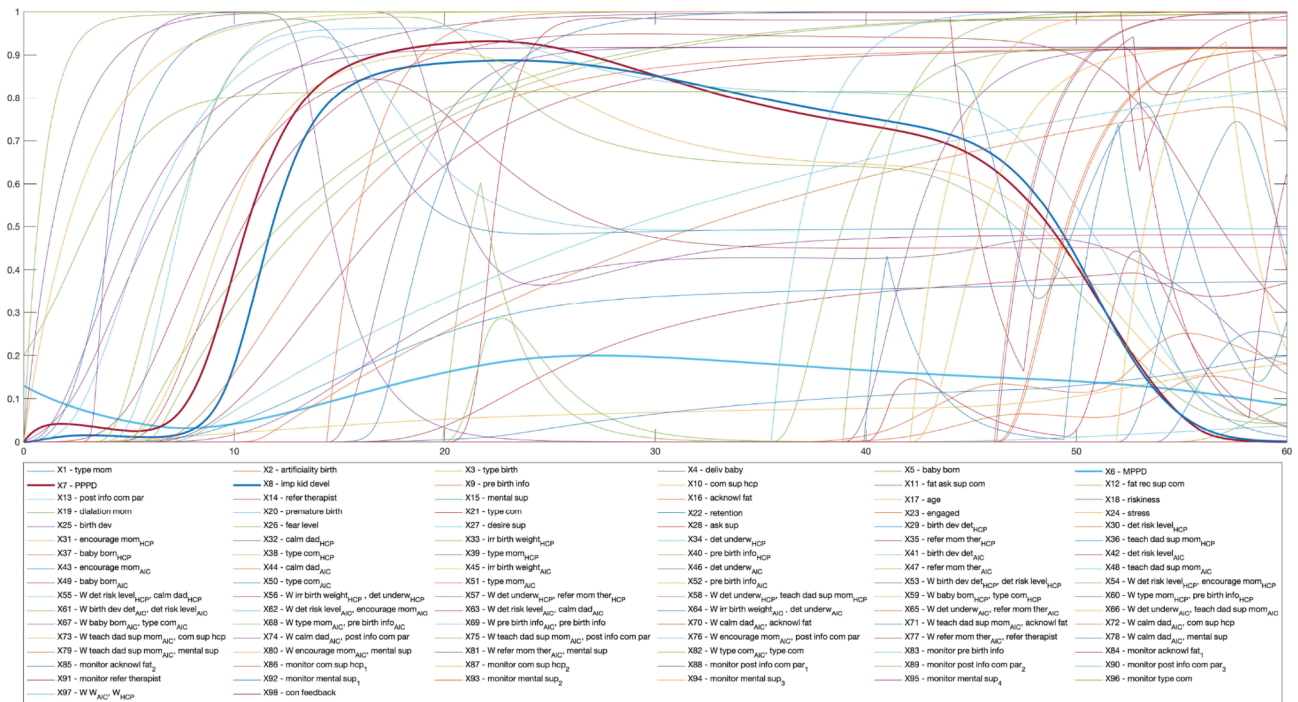


Fig. 9. Simulation Results for Case (c) – AIC Monitors.

The low step size results in smoother curves in the simulation graphs. At first, the healthcare practitioner is set to have a perfect mental model (all HCP’s W-states are constant 1). The simulation shown in Fig. 6 depicts this scenario. The trend lines of the three bold states first increase since a deviation occurs, and risk and fear persist. However, once adequate support from the HCP to the father sets in, there is a fast decrease, eventually reaching 0. MPPD also decreases, as a result of the risk of PPD decreasing, since the father being healthy allows for adequate support of the mother.

5.2.2. Ineffective communication between HealthCare practitioners and parents

In comparison to the simulation above, a further scenario was simulated (Fig. 7) to show the effects of imperfect communication of the HCP. When performing this simulation, all values were kept the same, except for the values of states in the mental model of the HCP. In this simulation, the HCP does not have an active mental model that facilitates proper communication (all HCP’s W-states are constant 0).

When comparing Fig. 6 and Fig. 7, one can clearly see the effects of a

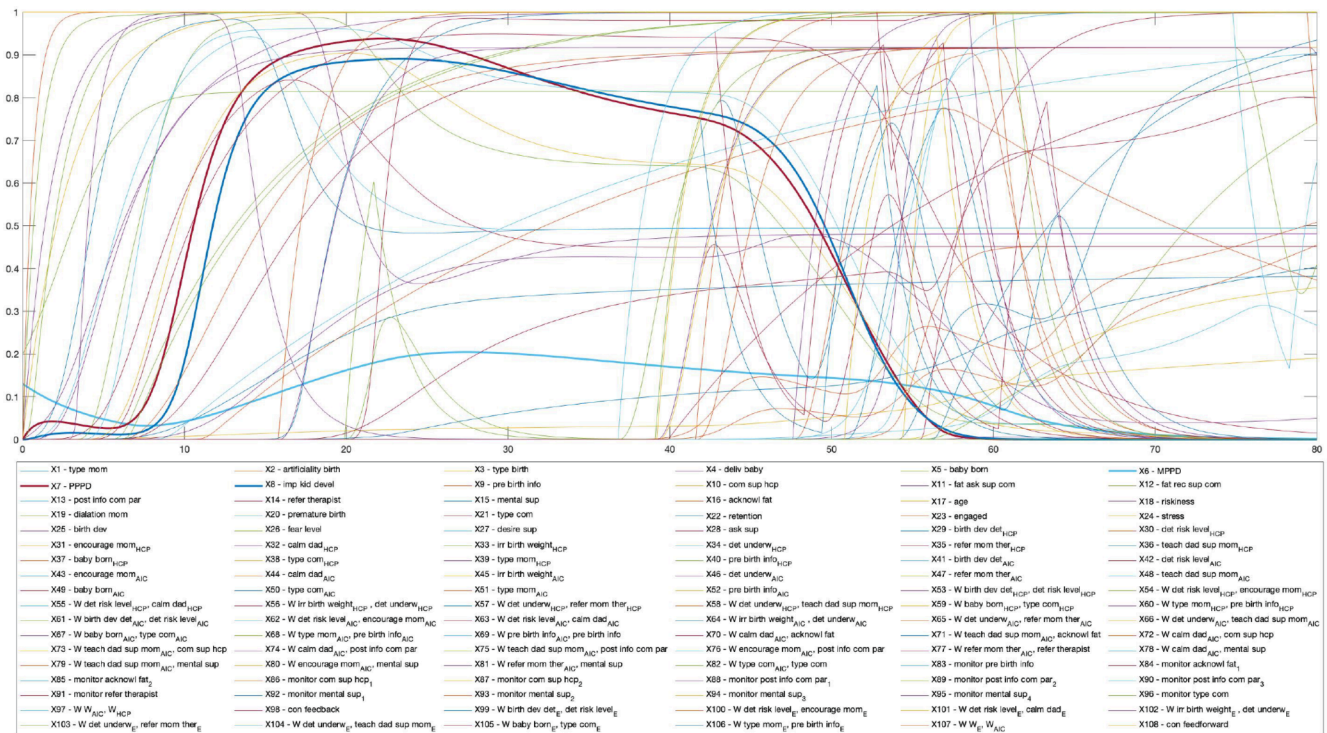


Fig. 10. Simulation Results for Case (d) – Expert Teaches AIC, AIC Monitors, AIC teaches, HCP.

lack of communication support from the HCP to the parents. While in Fig. 6, all risk-representing bold states increase, but promptly decrease again to reach 0, in Fig. 7, they all depict only an increase. At roughly $t = 25$, PPPD and imp_kid_devel correct themselves once the risk factor has subsided but remain high until the end of the time span. Moreover, MPPD has a steadily increasing trend, with no indication of decreasing whatsoever.

5.3. The Role of the Virtual Coach

In this scenario, the virtual AI Coach (AIC) steps in to communicate when a healthcare practitioner doesn't attend to the father and mother appropriately during childbirth. The simulation (Fig. 8) has a time duration from 0 to 60 (t -axis) with a step size of $\Delta t = 0.1$. An increase of the time duration, in comparison to previous simulation (see Section 5.2), compensates for the late activation of the communication actions.

The end states of the HCP never get activated and remain at 0, which results in no communication taking place from the HCP's side. This is due to the fact that the W -states are at 0 for the HCP. There exists an exception to this rule, as the $calm_dad_HCP$ state gets activated briefly upon the $fat_ask_sup_com$ state. Given the father approaching a HCP to ask for support, the HCP will act on being approached, even if their own initiative isn't there. This is visible by the two purple lines that reach their maximum at around $t = 30$.

On the other hand, the W -states for the AIC are at 1, meaning the respective mental model is active. The intervention (con_act_AIC) of the AIC starts at $t = 20$ (red line). The rapid change from 0 to 1 of this state, consequently, affects the communication action mental model states of the AIC. Before $t = 20$ these states had a slow increasing trend with little effect on the PPPD, MPPD and imp_kid_devel states. Promptly after the intervention, a rapid growth of the trend lines of the AIC mental model end states can be observed. This is a result of the H -states (purple line). This activation of the mental model translates into real-world support, which prompts, amongst others, the $desire_sup$ state to decrease. The effects of this intervention can be observed by the three bold trend lines, which change course to decrease at around $t = 24$. Simultaneously to

the end states of the AIC mental model reaching 1, the risk of PPPD and the risk of imp_kid_devel reach 0, followed by the risk of MPPD shortly after.

6. Dynamic Context-Sensitive Monitoring by the Virtual Coach

This is a similar scenario where a healthcare practitioner doesn't attend to the father and mother appropriately during the childbirth process. However, here, the Coach acts in a more context-sensitive manner. It is actively monitoring the relevant world states and intervenes only when it doesn't detect enough activation. The simulation (Fig. 9) has a time duration from 0 to 60 (t -axis) with a step size of $\Delta t = 0.1$.

Similarly to the role of the coach (discussed in Section 4.2.2 and 5.3), the HCP mental model does not get activated for the same reasons (W -states constant 0). Moreover, the W -states for AIC are also the same (constant 1). The reason for them being 1 is because the AI Coach is supposed to have perfect knowledge from the beginning. The mental model of the AIC is active starting between $t = 0$ to $t = 12$. The interesting aspect about this model are the monitoring states. These activate in the range of $t = 15$ to $t = 20$, as well as from $t = 35$ to $t = 48$.

Taking $type_com$ (red line at $t = 20$) as an example state, the sequences of how the monitors activate will be explained. State $type_com_AIC$ (blue line at $t = 17$), which is the mental model state of the AIC for the type of communication, activates first, since the AI Coach has a perfect mental model. This is followed by the $monitor_type_com$ (green high spike at $t = 20$) state, which in return activates $W_type_com_AIC$, $type_com$ (green low spike at $t = 20$) to effectuate the communication intended by AIC. The process that occurs here is that the monitor state observes the $type_com$ and $type_com_AIC$ states and, by applying the monitor function (see Table 1), determines whether it must act to compensate for missing actions in the real world. This occurs by strengthening the $W_type_com_AIC$, $type_com$ connection weight state. As a result of the strengthening, the $type_com$ context state gets activated, which means it is being translated into a real-world action: the communication from the AIC actually takes place.

Table 6
Role Matrix for Best Case (a) for **mb** – Base Connectivity.

mb - base connectivity		1	2	3	4	5	6	7	8
X ₁	type_mom	X ₁							
X ₂	artificiality_birth	X ₂	X ₁₈						
X ₃	epidural_used	X ₃							
X ₄	deliv_baby	X ₄	X ₁₉						
X ₅	baby_born	X ₄							
X ₆	MPPD	X ₁	X ₂	X ₃	X ₅	X ₁₅			
X ₇	PPPD	X ₆	X ₁₀	X ₁₂	X ₁₅	X ₂₃	X ₂₄		
X ₈	imp_kid_devel	X ₇							
X ₉	pre_birth_info	X ₉	X ₄₀						
X ₁₀	com_sup_hcp	X ₄	X ₉	X ₁₁	X ₂₄	X ₃₀	X ₃₂	X ₃₄	X ₃₆
X ₁₁	fat_ask_sup_com	X ₂₃	X ₂₈						
X ₁₂	fat_rec_sup_com	X ₁₀	X ₂₂	X ₂₄					
X ₁₃	post_info_com_par	X ₅	X ₂₀	X ₃₁	X ₃₂	X ₃₆			
X ₁₄	refer_therapist	X ₁₃	X ₃₅						
X ₁₅	mental_sup	X ₁₄	X ₂₁	X ₃₁	X ₃₂	X ₃₅	X ₃₆		
X ₁₆	acknowl_fat	X ₉	X ₃₂	X ₃₆					
X ₁₇	age	X ₁₇							
X ₁₈	riskiness	X ₅	X ₁₇						
X ₁₉	dilation_mom	X ₁₉							
X ₂₀	premature_birth	X ₂₀							
X ₂₁	type_com	X ₂₁	X ₃₈						
X ₂₂	retention	X ₂₃	X ₂₄						
X ₂₃	engaged	X ₁₆							
X ₂₄	stress	X ₂₆							
X ₂₅	birth_dev	X ₄	X ₁₈						
X ₂₆	fear_level	X ₂₃	X ₂₄	X ₂₅					
X ₂₇	desire_sup	X ₂₆							
X ₂₈	ask_sup	X ₂₇							
X ₂₉	birth_dev_det _{HCP}	X ₄	X ₁₈						
X ₃₀	det_risk_level _{HCP}	X ₂₉							
X ₃₁	encourage_mom _{HCP}	X ₃₀							
X ₃₂	calm_dad _{HCP}	X ₁₁	X ₃₀						
X ₃₃	irr_birth_weight _{HCP}	X ₅	X ₂₀						
X ₃₄	det_underw _{HCP}	X ₃₃							
X ₃₅	refer_mom_ther _{HCP}	X ₃₄							
X ₃₆	teach_dad_sup_mom _{HCP}	X ₃₄							
X ₃₇	baby_born _{HCP}	X ₅							
X ₃₈	type_com _{HCP}	X ₃₇							
X ₃₉	type_mom _{HCP}	X ₁							
X ₄₀	pre_birth_info _{HCP}	X ₃₉							
X ₄₁	W_{birth_dev_det_HCP, det_risk_level_HCP}	X ₄₁							
X ₄₂	W_{det_risk_level_HCP, encourage_mom_HCP}	X ₄₂							
X ₄₃	W_{det_risk_level_HCP, calm_dad_HCP}	X ₄₃							
X ₄₄	W_{irr_birth_weight_HCP, det_underw_HCP}	X ₄₄							
X ₄₅	W_{det_underw_HCP, refer_mom_ther_HCP}	X ₄₅							
X ₄₆	W_{det_underw_HCP, teach_dad_sup_mom_HCP}	X ₄₆							
X ₄₇	W_{baby_born_HCP, type_com_HCP}	X ₄₇							
X ₄₈	W_{type_mom_HCP, pre_birth_info_HCP}	X ₄₈							

The overall time-span for the bold lines to decrease and eventually reach zero is higher than in the previous two cases, however the same outcome is eventually reached. This is a result of the increased duration due to the monitoring having to take place before the AIC can act. The speed factors for the AIC were chosen this way to make it not too fast, as it would be a disadvantage if the HCP didn't have time to start acting, before the AIC stepped in.

6.1. The role of organizational learning

In this scenario, a healthcare practitioner initially has no knowledge

for the appropriate mental model and doesn't attend to the father and mother appropriately during the childbirth process. However, in this case, we present the process of organizational learning by which HCP would improve its mental model, by acquiring shared knowledge. In this case, the AI Coach get on the role of maintaining the organization's shared mental knowledge. It acquires it first by feed forward learning. This is based on an expert teaching the AI Coach, thus creating a shared mental model. Then later in the process feedback learning takes place: this shared mental model is transferred to HCP (after the childbirth process). In this way, this simulation depicts organizational learning. The timing was a deliberate choice, as teaching the HCP during

Table 7
Role Matrix for Best Case (a) for **mcw** – Connection Weights.

mcw - connection weights		1	2	3	4	5	6	7	8
X ₁	type_mom	1							
X ₂	artificiality_birth	1	-1						
X ₃	epidural_used	1							
X ₄	deliv_baby	1	1						
X ₅	baby_born	1							
X ₆	MPPD	0.25	0.25	0.25	0.25	-1			
X ₇	PPPD	1	-0.5	-0.5	-0.5	-0.5	1		
X ₈	kid_devel	1							
X ₉	pre_birth_info	1	1						
X ₁₀	com_sup_hcp	1	1	1	-1	1	1	1	1
X ₁₁	fat_ask_sup_com	1	1						
X ₁₂	fat_rec_sup_com	1	1	-1					
X ₁₃	post_info_com_par	1	1	1	1	1			
X ₁₄	refer_therapist	1	1						
X ₁₅	mental_sup	1	1	1	1	1	1		
X ₁₆	acknowl_fat	1	1	1					
X ₁₇	age	1							
X ₁₈	riskiness	-1	1						
X ₁₉	dilation_mom	1							
X ₂₀	premature_birth	1							
X ₂₁	type_com	1	1						
X ₂₂	retention	2	-1						
X ₂₃	engaged	1							
X ₂₄	stress	1							
X ₂₅	birth_dev	1	1						
X ₂₆	fear_level	-1	1	1					
X ₂₇	desire_sup	1							
X ₂₈	ask_sup	1							
X ₂₉	birth_dev_det _{HCP}	1	1						
X ₃₀	det_risk_level _{HCP}	X ₄₁							
X ₃₁	encourage_mom _{HCP}	X ₄₂							
X ₃₂	calm_dad _{HCP}	1	X ₄₃						
X ₃₃	irr_birth_weight _{HCP}	1	2						
X ₃₄	det_underw _{HCP}	X ₄₄							
X ₃₅	refer_mom_ther _{HCP}	X ₄₅							
X ₃₆	teach_dad_sup_mom _{HCP}	X ₄₆							
X ₃₇	baby_born _{HCP}	1							
X ₃₈	type_com _{HCP}	X ₄₇							
X ₃₉	type_mom _{HCP}	1							
X ₄₀	pre_birth_info _{HCP}	X ₄₈							
X ₄₁	W_{birth_dev_det_{HCP}, det_risk_level_{HCP}}	1							
X ₄₂	W_{det_risk_level_{HCP}, encourage_mom_{HCP}}	1							
X ₄₃	W_{det_risk_level_{HCP}, calm_dad_{HCP}}	1							
X ₄₄	W_{irr_birth_weight_{HCP}, det_underw_{HCP}}	1							
X ₄₅	W_{det_underw_{HCP}, refer_mom_ther_{HCP}}	1							
X ₄₆	W_{det_underw_{HCP}, teach_dad_sup_mom_{HCP}}	1							
X ₄₇	W_{baby_born_{HCP}, type_com_{HCP}}	1							
X ₄₈	W_{type_mom_{HCP}, pre_birth_info_{HCP}}	1							

childbirth could result in increased stress levels and, in return, possibly have an adverse effect on the communication actions. Similar to our previous simulation results (Section 5.4), the AI Coach uses monitors to determine if or when to take an action. The simulation (Fig. 10) has a time duration from 0 to 80 (*t*-axis) with a step size of $\Delta t = 0.1$. The increased time duration is to have a full illustration of the learning phase of the HCP after the childbirth process.

This scenario follows a similar trend as dynamic monitoring (Section 5.4), given that the HCP has a non-active mental model. Meaning the actions that take place to reduce the three bold line states are identical to what is described above. The notable difference is the learning of the AIC

from the expert. The left most line represents the **W_W**-states of the expert to the AIC (light red), which strengthens the connection weights, meaning the AIC acquires all the information and a shared mental model has been established. Moreover, the learning of the HCP from the AIC is activated by the con_feedback state (purple) at *t* = 40. At around *t* = 48, the **W_W**-states (light blue) of the AIC to the HCP begin to increase. This activates the **W**-states of the HCP and in return strengthens the mental model connection weights. The HCP learns between *t* = 50 and *t* = 60.

Table 8
Role Matrix for Best Case (a) for **mcfw** – Combination Function Weights.

mcfw - combination function weights		1	
		Alogistic	
X ₁	type_mom	1	
X ₂	artificiality_birth	1	
X ₃	epidural_used	1	
X ₄	deliv_baby	1	
X ₅	baby_born	1	
X ₆	MPPD	1	
X ₇	PPPD	1	
X ₈	kid_devel	1	
X ₉	pre_birth_info	1	
X ₁₀	com_sup_hcp	1	
X ₁₁	fat_ask_sup_com	1	
X ₁₂	fat_rec_sup_com	1	
X ₁₃	post_info_com_par	1	
X ₁₄	refer_therapist	1	
X ₁₅	mental_sup	1	
X ₁₆	acknowl_fat	1	
X ₁₇	age	1	
X ₁₈	riskiness	1	
X ₁₉	dilation_mom	1	
X ₂₀	premature_birth	1	
X ₂₁	type_com	1	
X ₂₂	retention	1	
X ₂₃	engaged	1	
X ₂₄	stress	1	
X ₂₅	birth_dev	1	
X ₂₆	fear_level	1	
X ₂₇	desire_sup	1	
X ₂₈	ask_sup	1	
X ₂₉	birth_dev_det _{HCP}	1	
X ₃₀	det_risk_level _{HCP}	1	
X ₃₁	encourage_mom _{HCP}	1	
X ₃₂	calm_dad _{HCP}	1	
X ₃₃	irr_birth_weight _{HCP}	1	
X ₃₄	det_underw _{HCP}	1	
X ₃₅	refer_mom_ther _{HCP}	1	
X ₃₆	teach_dad_sup_mom _{HCP}	1	
X ₃₇	baby_born _{HCP}	1	
X ₃₈	type_com _{HCP}	1	
X ₃₉	type_mom _{HCP}	1	
X ₄₀	pre_birth_info _{HCP}	1	
X ₄₁	W _{birth_dev_det_HCP, det_risk_level_HCP}	1	
X ₄₂	W _{det_risk_level_HCP, encourage_mom_HCP}	1	
X ₄₃	W _{det_risk_level_HCP, calm_dad_HCP}	1	
X ₄₄	W _{irr_birth_weight_HCP, det_underw_HCP}	1	
X ₄₅	W _{det_underw_HCP, refer_mom_ther_HCP}	1	
X ₄₆	W _{det_underw_HCP, teach_dad_sup_mom_HCP}	1	
X ₄₇	W _{baby_born_HCP, type_com_HCP}	1	
X ₄₈	W _{type_mom_HCP, pre_birth_info_HCP}	1	

Table 9
Role Matrix for Best Case (a) for **mcfp** – Combination Function Parameters.

mcfp - combination function parameters		1 Alogistic	
		Steepness	Threshold
X ₁	type_mom	50	0.5
X ₂	artificiality_birth	50	0.5
X ₃	epidural_used	50	0.5
X ₄	deliv_baby	5	0.5
X ₅	baby_born	50	0.5
X ₆	MPPD	5	0.3
X ₇	PPPD	5	0.5
X ₈	kid_devel	5	0.5
X ₉	pre_birth_info	50	0.5
X ₁₀	com_sup_hcp	0.5	6
X ₁₁	fat_ask_sup_com	5	1
X ₁₂	fat_rec_sup_com	5	0.5
X ₁₃	post_info_com_par	5	4
X ₁₄	refer_therapist	5	1
X ₁₅	mental_sup	5	5
X ₁₆	acknowl_fat	5	0.8
X ₁₇	age	5	0.5
X ₁₈	riskiness	50	0.5
X ₁₉	dilation_mom	2.8	0
X ₂₀	premature_birth	5	0.5
X ₂₁	type_com	5	0.1
X ₂₂	retention	5	0.3
X ₂₃	engaged	5	0.5
X ₂₄	stress	5	0.5
X ₂₅	birth_dev	50	1
X ₂₆	fear_level	5	1
X ₂₇	desire_sup	5	0.3
X ₂₈	ask_sup	5	0.2
X ₂₉	birth_dev_det _{HCP}	5	1
X ₃₀	det_risk_level _{HCP}	5	0.5
X ₃₁	encourage_mom _{HCP}	5	0.5
X ₃₂	calm_dad _{HCP}	50	0.7
X ₃₃	irr_birth_weight _{HCP}	5	1
X ₃₄	det_underw _{HCP}	5	0.5
X ₃₅	refer_mom_ther _{HCP}	50	0.5
X ₃₆	teach_dad_sup_mom _{HCP}	50	0.7
X ₃₇	baby_born _{HCP}	5	0.5
X ₃₈	type_com _{HCP}	50	0.5
X ₃₉	type_mom _{HCP}	5	0.5
X ₄₀	pre_birth_info _{HCP}	50	0.5
X ₄₁	W _{birth_dev_det_HCP, det_risk_level_HCP}	5	0.5
X ₄₂	W _{det_risk_level_HCP, encourage_mom_HCP}	5	0.5
X ₄₃	W _{det_risk_level_HCP, calm_dad_HCP}	5	0.5
X ₄₄	W _{irr_birth_weight_HCP, det_underw_HCP}	5	0.5
X ₄₅	W _{det_underw_HCP, refer_mom_ther_HCP}	5	0.5
X ₄₆	W _{det_underw_HCP, teach_dad_sup_mom_HCP}	5	0.5
X ₄₇	W _{baby_born_HCP, type_com_HCP}	5	0.5
X ₄₈	W _{type_mom_HCP, pre_birth_info_HCP}	5	0.5

7. An environment for the Virtual safety Coach

The models designed and simulated in this study explain how using a Virtual Safety Coach can improve communication among healthcare practitioner and father. The Virtual AI Coach will be designed to use these models, with the aim to facilitate the medical practitioners to achieve their goals without any possible omission or other error. In other words, the Safety Coach would mainly rely on similar mental models to facilitate the healthcare practitioners.

Table 10
Role Matrix for Best Case (a) for iv – Initial Values.

ms - speed factors		1
X ₁	type_mom	1
X ₂	artificiality_birth	1
X ₃	epidural_used	1
X ₄	deliv_baby	0.2
X ₅	baby_born	0.1
X ₆	MPPD	0.2
X ₇	PPPD	1
X ₈	kid_devel	1
X ₉	pre_birth_info	0.1
X ₁₀	com_sup_hcp	0.1
X ₁₁	fat_ask_sup_com	0.3
X ₁₂	fat_rec_sup_com	0.1
X ₁₃	post_info_com_par	0.1
X ₁₄	refer_therapist	0.3
X ₁₅	mental_sup	0.1
X ₁₆	acknowl_fat	0.1
X ₁₇	age	0
X ₁₈	riskiness	0.5
X ₁₉	dilation_mom	1
X ₂₀	premature_birth	0
X ₂₁	type_com	1
X ₂₂	retention	1
X ₂₃	engaged	1
X ₂₄	stress	0.4
X ₂₅	birth_dev	1
X ₂₆	fear_level	1
X ₂₇	desire_sup	1
X ₂₈	ask_sup	0.2
X ₂₉	birth_dev_det _{HCP}	1
X ₃₀	det_risk_level _{HCP}	1
X ₃₁	encourage_mom _{HCP}	0.1
X ₃₂	calm_dad _{HCP}	0.1
X ₃₃	irr_birth_weight _{HCP}	1
X ₃₄	det_underw _{HCP}	1
X ₃₅	refer_mom_ther _{HCP}	0.3
X ₃₆	teach_dad_sup_mom _{HCP}	0.1
X ₃₇	baby_born _{HCP}	1
X ₃₈	type_com _{HCP}	1
X ₃₉	type_mom _{HCP}	1
X ₄₀	pre_birth_info _{HCP}	1
X ₄₁	W _{birth_dev_det_HCP, det_risk_level_HCP}	0
X ₄₂	W _{det_risk_level_HCP, encourage_mom_HCP}	0
X ₄₃	W _{det_risk_level_HCP, calm_dad_HCP}	0
X ₄₄	W _{irr_birth_weight_HCP, det_underw_HCP}	0
X ₄₅	W _{det_underw_HCP, refer_mom_ther_HCP}	0
X ₄₆	W _{det_underw_HCP, teach_dad_sup_mom_HCP}	0
X ₄₇	W _{baby_born_HCP, type_com_HCP}	0
X ₄₈	W _{type_mom_HCP, pre_birth_info_HCP}	0

Table 11
Role Matrix for Best Case (a) for ms – Speed Factors.

iv - initial values		1
X ₁	type_mom	0
X ₂	artificiality_birth	0
X ₃	epidural_used	0
X ₄	deliv_baby	0
X ₅	baby_born	0
X ₆	MPPD	0.13
X ₇	PPPD	0
X ₈	kid_devel	0
X ₉	pre_birth_info	0
X ₁₀	com_sup_hcp	0
X ₁₁	fat_ask_sup_com	0
X ₁₂	fat_rec_sup_com	0
X ₁₃	post_info_com_par	0
X ₁₄	refer_therapist	0
X ₁₅	mental_sup	0
X ₁₆	acknowl_fat	0
X ₁₇	age	1
X ₁₈	riskiness	0
X ₁₉	dilation_mom	0.2
X ₂₀	premature_birth	1
X ₂₁	type_com	0
X ₂₂	retention	0
X ₂₃	engaged	0
X ₂₄	stress	0
X ₂₅	birth_dev	0
X ₂₆	fear_level	0
X ₂₇	desire_sup	0
X ₂₈	ask_sup	0
X ₂₉	birth_dev_det _{HCP}	0
X ₃₀	det_risk_level _{HCP}	0
X ₃₁	encourage_mom _{HCP}	0
X ₃₂	calm_dad _{HCP}	0
X ₃₃	irr_birth_weight _{HCP}	0
X ₃₄	det_underw _{HCP}	0
X ₃₅	refer_mom_ther _{HCP}	0
X ₃₆	teach_dad_sup_mom _{HCP}	0
X ₃₇	baby_born _{HCP}	0
X ₃₈	type_com _{HCP}	0
X ₃₉	type_mom _{HCP}	0
X ₄₀	pre_birth_info _{HCP}	0
X ₄₁	W _{birth_dev_det_HCP, det_risk_level_HCP}	1
X ₄₂	W _{det_risk_level_HCP, encourage_mom_HCP}	1
X ₄₃	W _{det_risk_level_HCP, calm_dad_HCP}	1
X ₄₄	W _{irr_birth_weight_HCP, det_underw_HCP}	1
X ₄₅	W _{det_underw_HCP, refer_mom_ther_HCP}	1
X ₄₆	W _{det_underw_HCP, teach_dad_sup_mom_HCP}	1
X ₄₇	W _{baby_born_HCP, type_com_HCP}	1
X ₄₈	W _{type_mom_HCP, pre_birth_info_HCP}	1

Table 12
Role Matrix for Worst Case (a) for **mb** – Base Connectivity.

mb - base connectivity		1	2	3	4	5	6	7	8
X ₁	type_mom	X ₁							
X ₂	artificiality_birth	X ₂	X ₁₈						
X ₃	epidural_used	X ₃							
X ₄	deliv_baby	X ₄	X ₁₉						
X ₅	baby_born	X ₄							
X ₆	MPPD	X ₁	X ₂	X ₃	X ₅	X ₁₅			
X ₇	PPPD	X ₆	X ₁₀	X ₁₂	X ₁₅	X ₂₃	X ₂₄		
X ₈	imp_kid_devel	X ₇							
X ₉	pre_birth_info	X ₉	X ₄₀						
X ₁₀	com_sup_hcp	X ₄	X ₉	X ₁₁	X ₂₄	X ₃₀	X ₃₂	X ₃₄	X ₃₆
X ₁₁	fat_ask_sup_com	X ₂₃	X ₂₈						
X ₁₂	fat_rec_sup_com	X ₁₀	X ₂₂	X ₂₄					
X ₁₃	post_info_com_par	X ₅	X ₂₀	X ₃₁	X ₃₂	X ₃₆			
X ₁₄	refer_therapist	X ₁₃	X ₃₅						
X ₁₅	mental_sup	X ₁₄	X ₂₁	X ₃₁	X ₃₂	X ₃₅	X ₃₆		
X ₁₆	acknowl_fat	X ₉	X ₃₂	X ₃₆					
X ₁₇	age	X ₁₇							
X ₁₈	riskiness	X ₅	X ₁₇						
X ₁₉	dilation_mom	X ₁₉							
X ₂₀	premature_birth	X ₃₀							
X ₂₁	type_com	X ₂₁	X ₃₈						
X ₂₂	retention	X ₂₃	X ₂₄						
X ₂₃	engaged	X ₁₆							
X ₂₄	stress	X ₂₆							
X ₂₅	birth_dev	X ₄	X ₁₈						
X ₂₆	fear_level	X ₂₃	X ₂₄	X ₂₅					
X ₂₇	desire_sup	X ₂₆							
X ₂₈	ask_sup	X ₂₇							
X ₂₉	birth_dev_det _{HCP}	X ₄	X ₁₈						
X ₃₀	det_risk_level _{HCP}	X ₂₉							
X ₃₁	encourage_mom _{HCP}	X ₃₀							
X ₃₂	calm_dad _{HCP}	X ₁₁	X ₃₀						
X ₃₃	irr_birth_weight _{HCP}	X ₅	X ₂₀						
X ₃₄	det_underw _{HCP}	X ₃₃							
X ₃₅	refer_mom_ther _{HCP}	X ₃₄							
X ₃₆	teach_dad_sup_mom _{HCP}	X ₃₄							
X ₃₇	baby_born _{HCP}	X ₅							
X ₃₈	type_com _{HCP}	X ₃₇							
X ₃₉	type_mom _{HCP}	X ₁							
X ₄₀	pre_birth_info _{HCP}	X ₃₉							
X ₄₁	W _{birth_dev_det_{HCP}, det_risk_level_{HCP}}	X ₄₁							
X ₄₂	W _{det_risk_level_{HCP}, encourage_mom_{HCP}}	X ₄₂							
X ₄₃	W _{det_risk_level_{HCP}, calm_dad_{HCP}}	X ₄₃							
X ₄₄	W _{irr_birth_weight_{HCP}, det_underw_{HCP}}	X ₄₄							
X ₄₅	W _{det_underw_{HCP}, refer_mom_ther_{HCP}}	X ₄₅							
X ₄₆	W _{det_underw_{HCP}, teach_dad_sup_mom_{HCP}}	X ₄₆							
X ₄₇	W _{baby_born_{HCP}, type_com_{HCP}}	X ₄₇							
X ₄₈	W _{type_mom_{HCP}, pre_birth_info_{HCP}}	X ₄₈							

In network models, states and their causal relations are declarative by nature and can be represented by some connection weight, speed, and a combination function values (see Section 3.3 and 3.4). These values are used to compute the impact of a state by the incoming states. In particular, a combination function is responsible to compute the effect of the incoming states(s), which may vary as per the nature of the combination function used for them. To reflect various behaviors different functions ranging from simple standard functions like Euclidian (i.e., eucl(..)) to more complex ones like homophily (i.e., slhomo(V₁, V₂, W)) were designed (Treur, 2016, 2020). A library was created, that offers these combination functions at one place. This library can be extended further, to reflect more behaviors, which have not been addressed before. Thus the library can be considered as a collection of various functions along with information describing them, for example:

```
Library{
  id, // unique identifier of the combination function
  (continued on next column)
```

(continued)

```
name, // the name of the function
numberOfParams, // number of possible parameters
params, // names of the parameters
}
```

The combination functions included in the library follows a template

$$cf_i(i, (p_1, p_2, \dots, p_j), (V_1, \dots, V_k))$$

In principle, a state may have a number $k \geq 0$ of incoming causal connections. Also, a combination function in the library may have j parameters ($j = 0 \dots m$). For instance, the identity function does not take any parameter. However, a logistic homophily function takes three parameters. Detailed information related to combination function is available online (Treur, 2019). Moreover, a state is considered as a

Table 13
Role Matrix for Worst Case (a) for **mcw** – Connection Weights.

mcw - connection weights		1	2	3	4	5	6	7	8
X ₁	type_mom	1							
X ₂	artificiality_birth	1	-1						
X ₃	epidural_used	1							
X ₄	deliv_baby	1	1						
X ₅	baby_born	1							
X ₆	MPPD	0.25	0.25	0.25	0.25	-1			
X ₇	PPPD	1	-0.5	-0.5	-0.5	-0.5	1		
X ₈	kid_devel	1							
X ₉	pre_birth_info	1	1						
X ₁₀	com_sup_hcp	1	1	1	-1	1	1	1	1
X ₁₁	fat_ask_sup_com	1	1						
X ₁₂	fat_rec_sup_com	1	1	-1					
X ₁₃	post_info_com_par	1	1	1	1	1			
X ₁₄	refer_therapist	1	1						
X ₁₅	mental_sup	1	1	1	1	1	1		
X ₁₆	acknowl_fat	1	1	1					
X ₁₇	age	1							
X ₁₈	riskiness	-1	1						
X ₁₉	dilation_mom	1							
X ₂₀	premature_birth	1							
X ₂₁	type_com	1	1						
X ₂₂	retention	2	-1						
X ₂₃	engaged	1							
X ₂₄	stress	1							
X ₂₅	birth_dev	1	1						
X ₂₆	fear_level	-1	1	1					
X ₂₇	desire_sup	1							
X ₂₈	ask_sup	1							
X ₂₉	birth_dev_det _{HCP}	1	1						
X ₃₀	det_risk_level _{HCP}	X ₄₁							
X ₃₁	encourage_mom _{HCP}	X ₄₂							
X ₃₂	calm_dad _{HCP}	1	X ₄₃						
X ₃₃	irr_birth_weight _{HCP}	1	2						
X ₃₄	det_underw _{HCP}	X ₄₄							
X ₃₅	refer_mom_ther _{HCP}	X ₄₅							
X ₃₆	teach_dad_sup_mom _{HCP}	X ₄₆							
X ₃₇	baby_born _{HCP}	1							
X ₃₈	type_com _{HCP}	X ₄₇							
X ₃₉	type_mom _{HCP}	1							
X ₄₀	pre_birth_info _{HCP}	X ₄₈							
X ₄₁	W _{birth_dev_det_HCP, det_risk_level_HCP}	1							
X ₄₂	W _{det_risk_level_HCP, encourage_mom_HCP}	1							
X ₄₃	W _{det_risk_level_HCP, calm_dad_HCP}	1							
X ₄₄	W _{irr_birth_weight_HCP, det_underw_HCP}	1							
X ₄₅	W _{det_underw_HCP, refer_mom_ther_HCP}	1							
X ₄₆	W _{det_underw_HCP, teach_dad_sup_mom_HCP}	1							
X ₄₇	W _{baby_born_HCP, type_com_HCP}	1							
X ₄₈	W _{type_mom_HCP, pre_birth_info_HCP}	1							

specification that can be defined as:

```

State{
  initialValue,
  speedFactor,
  connectionWeight,
  output,
  cfData
}
    
```

For all state data (e.g., initialValue, speedFactor, weights), values range from 0 to 1, while output reflects the output of a state, that varies

according to the causal impact of input states with respect to the time *t*. This output is computed using a combination function structured under the variable called 'cfData'. This consists of:

- **ImpactWeight:** How strong a specific combination function influences a state.
- **Parameters:** This contains the values of the parameters for the combination function used.

It is to be noted, that ImpactWeight facilitates the modelers to use different combination functions to study behaviors that are hybrid by

Table 14
Role Matrix for Worst Case (a) for **mcfw** – Combination Function Weights.

mcfw - combination function weights		1
		Alogistic
X ₁	type_mom	1
X ₂	artificiality_birth	1
X ₃	epidural_used	1
X ₄	deliv_baby	1
X ₅	baby_born	1
X ₆	MPPD	1
X ₇	PPPD	1
X ₈	kid_devel	1
X ₉	pre_birth_info	1
X ₁₀	com_sup_hcp	1
X ₁₁	fat_ask_sup_com	1
X ₁₂	fat_rec_sup_com	1
X ₁₃	post_info_com_par	1
X ₁₄	refer_therapist	1
X ₁₅	mental_sup	1
X ₁₆	acknowl_fat	1
X ₁₇	age	1
X ₁₈	riskiness	1
X ₁₉	dilation_mom	1
X ₂₀	premature_birth	1
X ₂₁	type_com	1
X ₂₂	retention	1
X ₂₃	engaged	1
X ₂₄	stress	1
X ₂₅	birth_dev	1
X ₂₆	fear_level	1
X ₂₇	desire_sup	1
X ₂₈	ask_sup	1
X ₂₉	birth_dev_det _{HCP}	1
X ₃₀	det_risk_level _{HCP}	1
X ₃₁	encourage_mom _{HCP}	1
X ₃₂	calm_dad _{HCP}	1
X ₃₃	irr_birth_weight _{HCP}	1
X ₃₄	det_underw _{HCP}	1
X ₃₅	refer_mom_ther _{HCP}	1
X ₃₆	teach_dad_sup_mom _{HCP}	1
X ₃₇	baby_born _{HCP}	1
X ₃₈	type_com _{HCP}	1
X ₃₉	type_mom _{HCP}	1
X ₄₀	pre_birth_info _{HCP}	1
X ₄₁	W _{birth_dev_det_HCP, det_risk_level_HCP}	1
X ₄₂	W _{det_risk_level_HCP, encourage_mom_HCP}	1
X ₄₃	W _{det_risk_level_HCP, calm_dad_HCP}	1
X ₄₄	W _{irr_birth_weight_HCP, det_underw_HCP}	1
X ₄₅	W _{det_underw_HCP, refer_mom_ther_HCP}	1
X ₄₆	W _{det_underw_HCP, teach_dad_sup_mom_HCP}	1
X ₄₇	W _{baby_born_HCP, type_com_HCP}	1
X ₄₈	W _{type_mom_HCP, pre_birth_info_HCP}	1

Table 15
Role Matrix for Worst Case (a) for **mcfp** – Combination Function Parameters.

mcfp - combination function parameters		1 Alogistic	
		Steepness	Threshold
X ₁	type_mom	50	0.5
X ₂	artificiality_birth	50	0.5
X ₃	epidural_used	50	0.5
X ₄	deliv_baby	5	0.5
X ₅	baby_born	50	0.5
X ₆	MPPD	5	0.3
X ₇	PPPD	5	0.5
X ₈	kid_devel	5	0.5
X ₉	pre_birth_info	50	0.5
X ₁₀	com_sup_hcp	0.5	6
X ₁₁	fat_ask_sup_com	5	1
X ₁₂	fat_rec_sup_com	5	0.5
X ₁₃	post_info_com_par	5	4
X ₁₄	refer_therapist	5	1
X ₁₅	mental_sup	5	5
X ₁₆	acknowl_fat	5	0.8
X ₁₇	age	5	0.5
X ₁₈	riskiness	50	0.5
X ₁₉	dilation_mom	2.8	0
X ₂₀	premature_birth	5	0.5
X ₂₁	type_com	5	0.1
X ₂₂	retention	5	0.3
X ₂₃	engaged	5	0.5
X ₂₄	stress	5	0.5
X ₂₅	birth_dev	50	1
X ₂₆	fear_level	5	1
X ₂₇	desire_sup	5	0.3
X ₂₈	ask_sup	5	0.2
X ₂₉	birth_dev_det _{HCP}	5	1
X ₃₀	det_risk_level _{HCP}	5	0.5
X ₃₁	encourage_mom _{HCP}	5	0.5
X ₃₂	calm_dad _{HCP}	50	0.7
X ₃₃	irr_birth_weight _{HCP}	5	1
X ₃₄	det_underw _{HCP}	5	0.5
X ₃₅	refer_mom_ther _{HCP}	50	0.5
X ₃₆	teach_dad_sup_mom _{HCP}	50	0.7
X ₃₇	baby_born _{HCP}	5	0.5
X ₃₈	type_com _{HCP}	50	0.5
X ₃₉	type_mom _{HCP}	5	0.5
X ₄₀	pre_birth_info _{HCP}	50	0.5
X ₄₁	W _{birth_dev_det_HCP, det_risk_level_HCP}	5	0.5
X ₄₂	W _{det_risk_level_HCP, encourage_mom_HCP}	5	0.5
X ₄₃	W _{det_risk_level_HCP, calm_dad_HCP}	5	0.5
X ₄₄	W _{irr_birth_weight_HCP, det_underw_HCP}	5	0.5
X ₄₅	W _{det_underw_HCP, refer_mom_ther_HCP}	5	0.5
X ₄₆	W _{det_underw_HCP, teach_dad_sup_mom_HCP}	5	0.5
X ₄₇	W _{baby_born_HCP, type_com_HCP}	5	0.5
X ₄₈	W _{type_mom_HCP, pre_birth_info_HCP}	5	0.5

nature. An example can be a state *X* which gets activated after a certain period of time, and show the behavior through **allogistic** function. In this case, a modeler can use **step** functions to reflect the period along with the allogistic function, with different impact weights for both functions (where the sum of impact weights should be 1). Parameters contain the value for the parameters used with respect to a combination function during the simulation, which is also addressed in the literature (Treur, 2019). Please note, parameters may vary as per combination function used for a state. The simulation environment takes input with respect to

Table 16
Role Matrix for Worst Case (a) for **iv** – Initial Values.

ms - speed factors		1
X ₁	type_mom	1
X ₂	artificiality_birth	1
X ₃	epidural_used	1
X ₄	deliv_baby	0.2
X ₅	baby_born	0.1
X ₆	MPPD	0.2
X ₇	PPPD	1
X ₈	kid_devel	1
X ₉	pre_birth_info	0.1
X ₁₀	com_sup_hcp	0.1
X ₁₁	fat_ask_sup_com	0.3
X ₁₂	fat_rec_sup_com	0.1
X ₁₃	post_info_com_par	0.1
X ₁₄	refer_therapist	0.3
X ₁₅	mental_sup	0.1
X ₁₆	acknowl_fat	0.1
X ₁₇	age	0
X ₁₈	riskiness	0.5
X ₁₉	dilation_mom	1
X ₂₀	premature_birth	0
X ₂₁	type_com	1
X ₂₂	retention	1
X ₂₃	engaged	1
X ₂₄	stress	0.4
X ₂₅	birth_dev	1
X ₂₆	fear_level	1
X ₂₇	desire_sup	1
X ₂₈	ask_sup	0.2
X ₂₉	birth_dev_det _{HCP}	1
X ₃₀	det_risk_level _{HCP}	1
X ₃₁	encourage_mom _{HCP}	0.1
X ₃₂	calm_dad _{HCP}	0.1
X ₃₃	irr_birth_weight _{HCP}	1
X ₃₄	det_underw _{HCP}	1
X ₃₅	refer_mom_ther _{HCP}	0.3
X ₃₆	teach_dad_sup_mom _{HCP}	0.1
X ₃₇	baby_born _{HCP}	1
X ₃₈	type_com _{HCP}	1
X ₃₉	type_mom _{HCP}	1
X ₄₀	pre_birth_info _{HCP}	1
X ₄₁	W _{birth_dev_det_HCP, det_risk_level_HCP}	0
X ₄₂	W _{det_risk_level_HCP, encourage_mom_HCP}	0
X ₄₃	W _{det_risk_level_HCP, calm_dad_HCP}	0
X ₄₄	W _{irr_birth_weight_HCP, det_underw_HCP}	0
X ₄₅	W _{det_underw_HCP, refer_mom_ther_HCP}	0
X ₄₆	W _{det_underw_HCP, teach_dad_sup_mom_HCP}	0
X ₄₇	W _{baby_born_HCP, type_com_HCP}	0
X ₄₈	W _{type_mom_HCP, pre_birth_info_HCP}	0

Table 17
Role Matrix for Worst Case (a) for **ms** – Speed Factors.

iv - initial values		1
X ₁	type_mom	0
X ₂	artificiality_birth	0
X ₃	epidural_used	0
X ₄	deliv_baby	0
X ₅	baby_born	0
X ₆	MPPD	0.13
X ₇	PPPD	0
X ₈	kid_devel	0
X ₉	pre_birth_info	0
X ₁₀	com_sup_hcp	0
X ₁₁	fat_ask_sup_com	0
X ₁₂	fat_rec_sup_com	0
X ₁₃	post_info_com_par	0
X ₁₄	refer_therapist	0
X ₁₅	mental_sup	0
X ₁₆	acknowl_fat	0
X ₁₇	age	1
X ₁₈	riskiness	0
X ₁₉	dilation_mom	0.2
X ₂₀	premature_birth	1
X ₂₁	type_com	0
X ₂₂	retention	0
X ₂₃	engaged	0
X ₂₄	stress	0
X ₂₅	birth_dev	0
X ₂₆	fear_level	0
X ₂₇	desire_sup	0
X ₂₈	ask_sup	0
X ₂₉	birth_dev_det _{HCP}	0
X ₃₀	det_risk_level _{HCP}	0
X ₃₁	encourage_mom _{HCP}	0
X ₃₂	calm_dad _{HCP}	0
X ₃₃	irr_birth_weight _{HCP}	0
X ₃₄	det_underw _{HCP}	0
X ₃₅	refer_mom_ther _{HCP}	0
X ₃₆	teach_dad_sup_mom _{HCP}	0
X ₃₇	baby_born _{HCP}	0
X ₃₈	type_com _{HCP}	0
X ₃₉	type_mom _{HCP}	0
X ₄₀	pre_birth_info _{HCP}	0
X ₄₁	W _{birth_dev_det_HCP, det_risk_level_HCP}	0
X ₄₂	W _{det_risk_level_HCP, encourage_mom_HCP}	0
X ₄₃	W _{det_risk_level_HCP, calm_dad_HCP}	0
X ₄₄	W _{irr_birth_weight_HCP, det_underw_HCP}	0
X ₄₅	W _{det_underw_HCP, refer_mom_ther_HCP}	0
X ₄₆	W _{det_underw_HCP, teach_dad_sup_mom_HCP}	0
X ₄₇	W _{baby_born_HCP, type_com_HCP}	0
X ₄₈	W _{type_mom_HCP, pre_birth_info_HCP}	0

Table 18
Role Matrix for Case (b) for **mb** – Base Connectivity.

mb- base connectivity		1	2	3	4	5	6	7	8	9	10	11	12
X ₁	type_mom	X ₁											
X ₂	artificiality_birth	X ₂	X ₁₈										
X ₃	epidural_used	X ₃											
X ₄	deliv_baby	X ₄	X ₁₉										
X ₅	baby_born	X ₅											
X ₆	MPPD	X ₁	X ₂	X ₃	X ₅	X ₁₅							
X ₇	PPPD	X ₆	X ₁₀	X ₁₂	X ₁₅	X ₂₃	X ₂₄						
X ₈	imp_kid_devel	X ₇											
X ₉	pre_birth_info	X ₉	X ₃₀	X ₅₂									
X ₁₀	com_sup_hcp	X ₄	X ₉	X ₁₁	X ₃₄	X ₃₀	X ₃₂	X ₃₄	X ₃₆	X ₄₂	X ₄₄	X ₄₆	X ₄₈
X ₁₁	fat_ask_sup_com	X ₂₃	X ₂₈										
X ₁₂	fat_rec_sup_com	X ₁₀	X ₂₂	X ₂₄									
X ₁₃	post_info_com_par	X ₅	X ₂₀	X ₃₁	X ₃₂	X ₃₆	X ₄₃	X ₄₄	X ₄₈				
X ₁₄	refer_therapist	X ₁₃	X ₃₅	X ₄₇									
X ₁₅	mental_sup	X ₁₄	X ₂₁	X ₃₁	X ₃₂	X ₃₅	X ₃₆	X ₄₃	X ₄₄	X ₄₇	X ₄₈		
X ₁₆	acknowl_fat	X ₉	X ₃₂	X ₃₆	X ₄₄	X ₄₈							
X ₁₇	age	X ₁₇											
X ₁₈	riskiness	X ₅	X ₁₇										
X ₁₉	dilation_mom	X ₁₉											
X ₂₀	premature_birth	X ₂₀											
X ₂₁	type_com	X ₂₁	X ₃₈	X ₅₀									
X ₂₂	retention	X ₂₃	X ₂₄										
X ₂₃	engaged	X ₁₆											
X ₂₄	stress	X ₂₆											
X ₂₅	birth_dev	X ₄	X ₁₈										
X ₂₆	fear_level	X ₂₃	X ₂₄	X ₃₅									
X ₂₇	desire_sup	X ₂₆											
X ₂₈	ask_sup	X ₂₇											
X ₂₉	birth_dev_det _{HCP}	X ₄	X ₁₈										
X ₃₀	det_risk_level _{HCP}	X ₂₉											
X ₃₁	encourage_mom _{HCP}	X ₃₀											
X ₃₂	calm_dad _{HCP}	X ₁₁	X ₃₀										
X ₃₃	irr_birth_weight _{HCP}	X ₅	X ₂₀										
X ₃₄	det_underw _{HCP}	X ₃₃											
X ₃₅	refer_mom_ther _{HCP}	X ₃₄											
X ₃₆	teach_dad_sup_mom _{HCP}	X ₃₄											
X ₃₇	baby_born _{HCP}	X ₅											
X ₃₈	type_com _{HCP}	X ₃₇											
X ₃₉	type_mom _{HCP}	X ₁											
X ₄₀	pre_birth_info _{HCP}	X ₃₉											
X ₄₁	birth_dev_det _{AIC}	X ₄	X ₁₈										
X ₄₂	det_risk_level _{AIC}	X ₄₁											
X ₄₃	encourage_mom _{AIC}	X ₄₂											
X ₄₄	calm_dad _{AIC}	X ₁₁	X ₄₂										
X ₄₅	irr_birth_weight _{AIC}	X ₅	X ₂₀										
X ₄₆	det_underw _{AIC}	X ₄₅											
X ₄₇	refer_mom_ther _{AIC}	X ₄₆											
X ₄₈	teach_dad_sup_mom _{AIC}	X ₄₆											
X ₄₉	baby_born _{AIC}	X ₅											
X ₅₀	type_com _{AIC}	X ₄₉											
X ₅₁	type_mom _{AIC}	X ₁											
X ₅₂	pre_birth_info _{AIC}	X ₅₁											
X ₅₃	W _{birth_dev_det_HCP, det_risk_level_HCP}	X ₅₃											
X ₅₄	W _{det_risk_level_HCP, encourage_mom_HCP}	X ₅₄											
X ₅₅	W _{det_risk_level_HCP, calm_dad_HCP}	X ₅₅											
X ₅₆	W _{irr_birth_weight_HCP, det_underw_HCP}	X ₅₆											
X ₅₇	W _{det_underw_HCP, refer_mom_ther_HCP}	X ₅₇											
X ₅₈	W _{det_underw_HCP, teach_dad_sup_mom_HCP}	X ₅₈											
X ₅₉	W _{baby_born_HCP, type_com_HCP}	X ₅₉											
X ₆₀	W _{type_mom_HCP, pre_birth_info_HCP}	X ₆₀											
X ₆₁	W _{birth_dev_det_AIC, det_risk_level_AIC}	X ₆₁											
X ₆₂	W _{det_risk_level_AIC, encourage_mom_AIC}	X ₆₂											
X ₆₃	W _{det_risk_level_AIC, calm_dad_AIC}	X ₆₃											
X ₆₄	W _{irr_birth_weight_AIC, det_underw_AIC}	X ₆₄											
X ₆₅	W _{det_underw_AIC, refer_mom_ther_AIC}	X ₆₅											
X ₆₆	W _{det_underw_AIC, teach_dad_sup_mom_AIC}	X ₆₆											
X ₆₇	W _{baby_born_AIC, type_com_AIC}	X ₆₇											
X ₆₈	W _{type_mom_AIC, pre_birth_info_AIC}	X ₆₈											
X ₆₉	H _{encourage_mom_AIC}	X ₇₅											
X ₇₀	H _{calm_dad_AIC}	X ₇₅											
X ₇₁	H _{refer_mom_ther_AIC}	X ₇₅											
X ₇₂	H _{teach_dad_sup_mom_AIC}	X ₇₅											
X ₇₃	H _{type_com_AIC}	X ₇₅											
X ₇₄	H _{pre_birth_info_AIC}	X ₇₅											
X ₇₅	con_act_AIC	X ₇₅											

each state. Therefore, for simulation, we provide the state specification. For instance, each state Y will have.

- list of incoming connections to state Y (e.g., states X_1, X_2, \dots, X_n)
- the connection weight of each incoming state (e.g., from state X_1, X_2, \dots, X_n)

- the speed of influence of the incoming states (termed as η_Y)
- initial value (iv_Y)
- cfData (cf_Y)

This input is processed to generate the simulation output. For each state, this output is computed by the formula mentioned in equation (1).

Table 19
Role Matrix for Case (b) for **mcw** – Connection Weights.

mcw - connection weights		1	2	3	4	5	6	7	8	9	10	11	12
X ₁	type_mom	1											
X ₂	artificiality_birth	1	-1										
X ₃	epidural_used	1											
X ₄	deliv_baby	1	1										
X ₅	baby_born	1											
X ₆	MPPD	0.25	0.25	0.25	0.25	-1							
X ₇	PPPD	1	-0.5	-0.5	-0.5	-0.5	1						
X ₈	kid_devel	1											
X ₉	pre_birth_info	1	1	1									
X ₁₀	com_sup_hcp	1	1	1	-1	1	1	1	1	1	1	1	1
X ₁₁	fat_ask_sup_com	1	1										
X ₁₂	fat_rec_sup_com	1	1	-1									
X ₁₃	post_info_com_par	1	1	1	1	1	1	1					
X ₁₄	refer_therapist	1	1	1									
X ₁₅	mental_sup	1	1	1	1	1	1	1	1	1			
X ₁₆	acknowl_fat	1	1	1	1	1							
X ₁₇	age	1											
X ₁₈	riskiness	-1	1										
X ₁₉	dilation_mom	1											
X ₂₀	premature_birth	1											
X ₂₁	type_com	1	1	1									
X ₂₂	retention	2	-1										
X ₂₃	engaged	1											
X ₂₄	stress	1											
X ₂₅	birth_dev	1	1										
X ₂₆	fear_level	-1	1	1									
X ₂₇	desire_sup	1											
X ₂₈	ask_sup	1											
X ₂₉	birth_dev_det _{HCP}	1	1										
X ₃₀	det_risk_level _{HCP}	X ₅₃											
X ₃₁	encourage_mom _{HCP}	X ₅₄											
X ₃₂	calm_dad _{HCP}	1	X ₅₅										
X ₃₃	irr_birth_weight _{HCP}	1	2										
X ₃₄	det_underw _{HCP}	X ₅₆											
X ₃₅	refer_mom_ther _{HCP}	X ₅₇											
X ₃₆	teach_dad_sup_mom _{HCP}	X ₅₈											
X ₃₇	baby_born _{HCP}	1											
X ₃₈	type_com _{HCP}	X ₅₉											
X ₃₉	type_mom _{HCP}	1											
X ₄₀	pre_birth_info _{HCP}	X ₆₀											
X ₄₁	birth_dev_det _{AIC}	1	1										
X ₄₂	det_risk_level _{AIC}	X ₆₁											
X ₄₃	encourage_mom _{AIC}	X ₆₂											
X ₄₄	calm_dad _{AIC}	1	X ₆₃										
X ₄₅	irr_birth_weight _{AIC}	1	2										
X ₄₆	det_underw _{AIC}	X ₆₄											
X ₄₇	refer_mom_ther _{AIC}	X ₆₅											
X ₄₈	teach_dad_sup_mom _{AIC}	X ₆₆											
X ₄₉	baby_born _{AIC}	1											
X ₅₀	type_com _{AIC}	X ₆₇											
X ₅₁	type_mom _{AIC}	1											
X ₅₂	pre_birth_info _{AIC}	X ₆₈											
X ₅₃	W _{birth_dev_det_HCP_det_risk_level_HCP}	1											
X ₅₄	W _{det_risk_level_HCP_encourage_mom_HCP}	1											
X ₅₅	W _{det_risk_level_HCP_calm_dad_HCP}	1											
X ₅₆	W _{irr_birth_weight_HCP_det_underw_HCP}	1											
X ₅₇	W _{det_underw_HCP_refer_mom_ther_HCP}	1											
X ₅₈	W _{det_underw_HCP_teach_dad_sup_mom_HCP}	1											
X ₅₉	W _{baby_born_HCP_type_com_HCP}	1											
X ₆₀	W _{type_mom_HCP_pre_birth_info_HCP}	1											
X ₆₁	W _{birth_dev_det_AIC_det_risk_level_AIC}	1											
X ₆₂	W _{det_risk_level_AIC_encourage_mom_AIC}	1											
X ₆₃	W _{det_risk_level_AIC_calm_dad_AIC}	1											
X ₆₄	W _{irr_birth_weight_AIC_det_underw_AIC}	1											
X ₆₅	W _{det_underw_AIC_refer_mom_ther_AIC}	1											
X ₆₆	W _{det_underw_AIC_teach_dad_sup_mom_AIC}	1											
X ₆₇	W _{baby_born_AIC_type_com_AIC}	1											
X ₆₈	W _{type_mom_AIC_pre_birth_info_AIC}	1											
X ₆₉	H _{encourage_mom_AIC}	1											
X ₇₀	H _{calm_dad_AIC}	1											
X ₇₁	H _{refer_mom_ther_AIC}	1											
X ₇₂	H _{teach_dad_sup_mom_AIC}	1											
X ₇₃	H _{type_com_AIC}	1											
X ₇₄	H _{pre_birth_info_AIC}	1											
X ₇₅	con_act_AIC	1											

Therefore, ‘output’ is a matrix containing timestamps and values for all the states of a model with their respective timestamps. Therefore, *output* not only reflects the state value at a certain time, but it also provide reasoning for the causal interaction between the states, which can be viewed by different plotting methods. Built-in plot methods were used to

generate the simulation results of the designed model, which can be viewed in Appendix B.

Table 20
Role Matrix for Case (b) for **mcfw** – Combination Function Weights.

mcfw - combination function weights		1	
		Allogistic	Steponce
X ₁	type_mom	1	
X ₂	artificiality_birth	1	
X ₃	epidural_used	1	
X ₄	deliv_baby	1	
X ₅	baby_born	1	
X ₆	MPPD	1	
X ₇	PPPD	1	
X ₈	kid_devel	1	
X ₉	pre_birth_info	1	
X ₁₀	com_sup_hcp	1	
X ₁₁	fat_ask_sup_com	1	
X ₁₂	fat_rec_sup_com	1	
X ₁₃	post_info_com_par	1	
X ₁₄	refer_therapist	1	
X ₁₅	mental_sup	1	
X ₁₆	acknowl_fat	1	
X ₁₇	age	1	
X ₁₈	riskiness	1	
X ₁₉	dilation_mom	1	
X ₂₀	premature_birth	1	
X ₂₁	type_com	1	
X ₂₂	retention	1	
X ₂₃	engaged	1	
X ₂₄	stress	1	
X ₂₅	birth_dev	1	
X ₂₆	fear_level	1	
X ₂₇	desire_sup	1	
X ₂₈	ask_sup	1	
X ₂₉	birth_dev_det _{HCP}	1	
X ₃₀	det_risk_level _{HCP}	1	
X ₃₁	encourage_mom _{HCP}	1	
X ₃₂	calm_dad _{HCP}	1	
X ₃₃	irr_birth_weight _{HCP}	1	
X ₃₄	det_underw _{HCP}	1	
X ₃₅	refer_mom_ther _{HCP}	1	
X ₃₆	teach_dad_sup_mom _{HCP}	1	
X ₃₇	baby_born _{HCP}	1	
X ₃₈	type_com _{HCP}	1	
X ₃₉	type_mom _{HCP}	1	
X ₄₀	pre_birth_info _{HCP}	1	
X ₄₁	birth_dev_det _{AIC}	1	
X ₄₂	det_risk_level _{AIC}	1	
X ₄₃	encourage_mom _{AIC}	1	
X ₄₄	calm_dad _{AIC}	1	
X ₄₅	irr_birth_weight _{AIC}	1	
X ₄₆	det_underw _{AIC}	1	
X ₄₇	refer_mom_ther _{AIC}	1	
X ₄₈	teach_dad_sup_mom _{AIC}	1	
X ₄₉	baby_born _{AIC}	1	
X ₅₀	type_com _{AIC}	1	
X ₅₁	type_mom _{AIC}	1	
X ₅₂	pre_birth_info _{AIC}	1	
X ₅₃	W _{birth_dev_det_HCP, det_risk_level_HCP}	1	
X ₅₄	W _{det_risk_level_HCP, encourage_mom_HCP}	1	
X ₅₅	W _{det_risk_level_HCP, calm_dad_HCP}	1	
X ₅₆	W _{irr_birth_weight_HCP, det_underw_HCP}	1	
X ₅₇	W _{det_underw_HCP, refer_mom_ther_HCP}	1	
X ₅₈	W _{det_underw_HCP, teach_dad_sup_mom_HCP}	1	
X ₅₉	W _{baby_born_HCP, type_com_HCP}	1	
X ₆₀	W _{type_mom_HCP, pre_birth_info_HCP}	1	
X ₆₁	W _{birth_dev_det_AIC, det_risk_level_AIC}	1	
X ₆₂	W _{det_risk_level_AIC, encourage_mom_AIC}	1	
X ₆₃	W _{det_risk_level_AIC, calm_dad_AIC}	1	
X ₆₄	W _{irr_birth_weight_AIC, det_underw_AIC}	1	
X ₆₅	W _{det_underw_AIC, refer_mom_ther_AIC}	1	
X ₆₆	W _{det_underw_AIC, teach_dad_sup_mom_AIC}	1	
X ₆₇	W _{baby_born_AIC, type_com_AIC}	1	
X ₆₈	W _{type_mom_AIC, pre_birth_info_AIC}	1	
X ₆₉	H _{encourage_mom_AIC}	1	
X ₇₀	H _{calm_dad_AIC}	1	
X ₇₁	H _{refer_mom_ther_AIC}	1	
X ₇₂	H _{teach_dad_sup_mom_AIC}	1	
X ₇₃	H _{type_com_AIC}	1	
X ₇₄	H _{pre_birth_info_AIC}	1	
X ₇₅	con_act_AIC		1

Table 21
Role Matrix for Case (b) for **mcfp** – Combination Function Parameters.

mcfp - combination function parameters		1 Allogistic		2 Steponce	
		Steepness	Threshold	Start Time	End Time
X ₁	type_mom	50	0.5		
X ₂	artificiality_birth	50	0.5		
X ₃	epidural_used	50	0.5		
X ₄	deliv_baby	5	0.5		
X ₅	baby_born	50	0.5		
X ₆	MPPD	5	0.3		
X ₇	PPPD	5	0.5		
X ₈	kid_devel	5	0.5		
X ₉	pre_birth_info	50	0.5		
X ₁₀	com_sup_hcp	0.5	6		
X ₁₁	fat_ask_sup_com	5	1		
X ₁₂	fat_rec_sup_com	5	0.5		
X ₁₃	post_info_com_par	5	4		
X ₁₄	refer_therapist	5	1		
X ₁₅	mental_sup	5	5		
X ₁₆	acknowl_fat	5	0.8		
X ₁₇	age	5	0.5		
X ₁₈	riskiness	50	0.5		
X ₁₉	dilation_mom	2.8	0		
X ₂₀	premature_birth	5	0.5		
X ₂₁	type_com	5	0.1		
X ₂₂	retention	5	0.3		
X ₂₃	engaged	5	0.5		
X ₂₄	stress	5	0.5		
X ₂₅	birth_dev	50	1		
X ₂₆	fear_level	5	1		
X ₂₇	desire_sup	5	0.3		
X ₂₈	ask_sup	5	0.2		
X ₂₉	birth_dev_det _{HCP}	5	1		
X ₃₀	det_risk_level _{HCP}	5	0.5		
X ₃₁	encourage_mom _{HCP}	5	0.5		
X ₃₂	calm_dad _{HCP}	50	0.7		
X ₃₃	irr_birth_weight _{HCP}	5	1		
X ₃₄	det_underw _{HCP}	5	0.5		
X ₃₅	refer_mom_ther _{HCP}	50	0.5		
X ₃₆	teach_dad_sup_mom _{HCP}	50	0.7		
X ₃₇	baby_born _{HCP}	5	0.5		
X ₃₈	type_com _{HCP}	50	0.5		
X ₃₉	type_mom _{HCP}	5	0.5		
X ₄₀	pre_birth_info _{HCP}	50	0.5		
X ₄₁	birth_dev_det _{AIC}	5	1		
X ₄₂	det_risk_level _{AIC}	5	0.5		
X ₄₃	encourage_mom _{AIC}	5	0.5		
X ₄₄	calm_dad _{AIC}	50	0.7		
X ₄₅	irr_birth_weight _{AIC}	5	1		
X ₄₆	det_underw _{AIC}	5	0.5		
X ₄₇	refer_mom_ther _{AIC}	50	0.5		
X ₄₈	teach_dad_sup_mom _{AIC}	50	0.7		
X ₄₉	baby_born _{AIC}	5	0.5		
X ₅₀	type_com _{AIC}	50	0.5		
X ₅₁	type_mom _{AIC}	5	0.5		
X ₅₂	pre_birth_info _{AIC}	50	0.5		
X ₅₃	W _{birth_dev_det_HCP, det_risk_level_HCP}	5	0.5		
X ₅₄	W _{det_risk_level_HCP, encourage_mom_HCP}	5	0.5		
X ₅₅	W _{det_risk_level_HCP, calm_dad_HCP}	5	0.5		
X ₅₆	W _{irr_birth_weight_HCP, det_underw_HCP}	5	0.5		
X ₅₇	W _{det_underw_HCP, refer_mom_ther_HCP}	5	0.5		
X ₅₈	W _{det_underw_HCP, teach_dad_sup_mom_HCP}	5	0.5		
X ₅₉	W _{baby_born_HCP, type_com_HCP}	5	0.5		
X ₆₀	W _{type_mom_HCP, pre_birth_info_HCP}	5	0.5		
X ₆₁	W _{birth_dev_det_AIC, det_risk_level_AIC}	5	0.5		
X ₆₂	W _{det_risk_level_AIC, encourage_mom_AIC}	5	0.5		
X ₆₃	W _{det_risk_level_AIC, calm_dad_AIC}	5	0.5		
X ₆₄	W _{irr_birth_weight_AIC, det_underw_AIC}	5	0.5		
X ₆₅	W _{det_underw_AIC, refer_mom_ther_AIC}	5	0.5		
X ₆₆	W _{det_underw_AIC, teach_dad_sup_mom_AIC}	5	0.5		
X ₆₇	W _{baby_born_AIC, type_com_AIC}	5	0.5		
X ₆₈	W _{type_mom_AIC, pre_birth_info_AIC}	5	0.5		
X ₆₉	H _{encourage_mom_AIC}	5	0.5		
X ₇₀	H _{calm_dad_AIC}	5	0.5		
X ₇₁	H _{refer_mom_ther_AIC}	5	0.5		
X ₇₂	H _{teach_dad_sup_mom_AIC}	5	0.5		
X ₇₃	H _{type_com_AIC}	5	0.5		
X ₇₄	H _{pre_birth_info_AIC}	5	0.5		
X ₇₅	con_act_AIC			20	60

8. Discussion and conclusion

This study presents adaptive computational network models covering (shared) mental models of the father and healthcare practitioner, which illustrates how they can communicate during childbirth. These models are designed using multidisciplinary literature. Therefore, first, the benefits of the HCP having a mental model for communication is presented. Then it shows the utility of a Virtual Safety Coach (AIC)

Table 22
Role Matrix for Case (b) for **ms** – Speed Factors.

ms - speed factors		1
X ₁	type_mom	1
X ₂	artificiality_birth	1
X ₃	epidural_used	1
X ₄	deliv_baby	0.2
X ₅	baby_born	0.1
X ₆	MPPD	0.2
X ₇	PPPD	1
X ₈	kid_devel	1
X ₉	pre_birth_info	0.1
X ₁₀	com_sup_hcp	0.1
X ₁₁	fat_ask_sup_com	0.3
X ₁₂	fat_rec_sup_com	0.1
X ₁₃	post_info_com_par	0.1
X ₁₄	refer_therapist	0.3
X ₁₅	mental_sup	0.1
X ₁₆	acknowl_fat	0.1
X ₁₇	age	0
X ₁₈	riskiness	0.5
X ₁₉	dilation_mom	1
X ₂₀	premature_birth	0
X ₂₁	type_com	1
X ₂₂	retention	1
X ₂₃	engaged	1
X ₂₄	stress	0.4
X ₂₅	birth_dev	1
X ₂₆	fear_level	1
X ₂₇	desire_sup	1
X ₂₈	ask_sup	0.2
X ₂₉	birth_dev_det _{HCP}	1
X ₃₀	det_risk_level _{HCP}	1
X ₃₁	encourage_mom _{HCP}	0.1
X ₃₂	calm_dad _{HCP}	0.1
X ₃₃	irr_birth_weight _{HCP}	1
X ₃₄	det_underw _{HCP}	1
X ₃₅	refer_mom_ther _{HCP}	0.3
X ₃₆	teach_dad_sup_mom _{HCP}	0.1
X ₃₇	baby_born _{HCP}	1
X ₃₈	type_com _{HCP}	1
X ₃₉	type_mom _{HCP}	1
X ₄₀	pre_birth_info _{HCP}	1
X ₄₁	birth_dev_det _{AIC}	1
X ₄₂	det_risk_level _{AIC}	1
X ₄₃	encourage_mom _{AIC}	X ₆₉
X ₄₄	calm_dad _{AIC}	X ₇₀
X ₄₅	irr_birth_weight _{AIC}	1
X ₄₆	det_underw _{AIC}	1
X ₄₇	refer_mom_ther _{AIC}	X ₇₁
X ₄₈	teach_dad_sup_mom _{AIC}	X ₇₂
X ₄₉	baby_born _{AIC}	1
X ₅₀	type_com _{AIC}	X ₇₃
X ₅₁	type_mom _{AIC}	1
X ₅₂	pre_birth_info _{AIC}	X ₇₄
X ₅₃	W birth_dev_det _{HCP} , det_risk_level _{HCP}	0
X ₅₄	W det_risk_level _{HCP} , encourage_mom _{HCP}	0
X ₅₅	W det_risk_level _{HCP} , calm_dad _{HCP}	0
X ₅₆	W irr_birth_weight _{HCP} , det_underw _{HCP}	0
X ₅₇	W det_underw _{HCP} , refer_mom_ther _{HCP}	0
X ₅₈	W det_underw _{HCP} , teach_dad_sup_mom _{HCP}	0
X ₅₉	W baby_born _{HCP} , type_com _{HCP}	0
X ₆₀	W type_mom _{HCP} , pre_birth_info _{HCP}	0
X ₆₁	W birth_dev_det _{AIC} , det_risk_level _{AIC}	0
X ₆₂	W det_risk_level _{AIC} , encourage_mom _{AIC}	0
X ₆₃	W det_risk_level _{AIC} , calm_dad _{AIC}	0
X ₆₄	W irr_birth_weight _{AIC} , det_underw _{AIC}	0
X ₆₅	W det_underw _{AIC} , refer_mom_ther _{AIC}	0
X ₆₆	W det_underw _{AIC} , teach_dad_sup_mom _{AIC}	0
X ₆₇	W baby_born _{AIC} , type_com _{AIC}	0
X ₆₈	W type_mom _{AIC} , pre_birth_info _{AIC}	0
X ₆₉	H encourage_mom _{AIC}	0.1
X ₇₀	H calm_dad _{AIC}	0.1
X ₇₁	H refer_mom_ther _{AIC}	0.1
X ₇₂	H teach_dad_sup_mom _{AIC}	0.1
X ₇₃	H type_com _{AIC}	0.1
X ₇₄	H pre_birth_info _{AIC}	0.1
X ₇₅	con_act _{AIC}	1

Table 23
Role Matrix for Case (b) for **iv** – Initial Values.

iv - initial values		1
X ₁	type_mom	0
X ₂	artificiality_birth	0
X ₃	epidural_used	0
X ₄	deliv_baby	0
X ₅	baby_born	0
X ₆	MPPD	0.13
X ₇	PPPD	0
X ₈	kid_devel	0
X ₉	pre_birth_info	0
X ₁₀	com_sup_hcp	0
X ₁₁	fat_ask_sup_com	0
X ₁₂	fat_rec_sup_com	0
X ₁₃	post_info_com_par	0
X ₁₄	refer_therapist	0
X ₁₅	mental_sup	0
X ₁₆	acknowl_fat	0
X ₁₇	age	1
X ₁₈	riskiness	0
X ₁₉	dilation_mom	0.2
X ₂₀	premature_birth	1
X ₂₁	type_com	0
X ₂₂	retention	0
X ₂₃	engaged	0
X ₂₄	stress	0
X ₂₅	birth_dev	0
X ₂₆	fear_level	0
X ₂₇	desire_sup	0
X ₂₈	ask_sup	0
X ₂₉	birth_dev_det _{HCP}	0
X ₃₀	det_risk_level _{HCP}	0
X ₃₁	encourage_mom _{HCP}	0
X ₃₂	calm_dad _{HCP}	0
X ₃₃	irr_birth_weight _{HCP}	0
X ₃₄	det_underw _{HCP}	0
X ₃₅	refer_mom_ther _{HCP}	0
X ₃₆	teach_dad_sup_mom _{HCP}	0
X ₃₇	baby_born _{HCP}	0
X ₃₈	type_com _{HCP}	0
X ₃₉	type_mom _{HCP}	0
X ₄₀	pre_birth_info _{HCP}	0
X ₄₁	birth_dev_det _{AIC}	0
X ₄₂	det_risk_level _{AIC}	0
X ₄₃	encourage_mom _{AIC}	0
X ₄₄	calm_dad _{AIC}	0
X ₄₅	irr_birth_weight _{AIC}	0
X ₄₆	det_underw _{AIC}	0
X ₄₇	refer_mom_ther _{AIC}	0
X ₄₈	teach_dad_sup_mom _{AIC}	0
X ₄₉	baby_born _{AIC}	0
X ₅₀	type_com _{AIC}	0
X ₅₁	type_mom _{AIC}	0
X ₅₂	pre_birth_info _{AIC}	0
X ₅₃	W birth_dev_det _{HCP} , det_risk_level _{HCP}	0
X ₅₄	W det_risk_level _{HCP} , encourage_mom _{HCP}	0
X ₅₅	W det_risk_level _{HCP} , calm_dad _{HCP}	0
X ₅₆	W irr_birth_weight _{HCP} , det_underw _{HCP}	0
X ₅₇	W det_underw _{HCP} , refer_mom_ther _{HCP}	0
X ₅₈	W det_underw _{HCP} , teach_dad_sup_mom _{HCP}	0
X ₅₉	W baby_born _{HCP} , type_com _{HCP}	0
X ₆₀	W type_mom _{HCP} , pre_birth_info _{HCP}	0
X ₆₁	W birth_dev_det _{AIC} , det_risk_level _{AIC}	1
X ₆₂	W det_risk_level _{AIC} , encourage_mom _{AIC}	1
X ₆₃	W det_risk_level _{AIC} , calm_dad _{AIC}	1
X ₆₄	W irr_birth_weight _{AIC} , det_underw _{AIC}	1
X ₆₅	W det_underw _{AIC} , refer_mom_ther _{AIC}	1
X ₆₆	W det_underw _{AIC} , teach_dad_sup_mom _{AIC}	1
X ₆₇	W baby_born _{AIC} , type_com _{AIC}	1
X ₆₈	W type_mom _{AIC} , pre_birth_info _{AIC}	1
X ₆₉	H encourage_mom _{AIC}	0
X ₇₀	H calm_dad _{AIC}	0
X ₇₁	H refer_mom_ther _{AIC}	0
X ₇₂	H teach_dad_sup_mom _{AIC}	0
X ₇₃	H type_com _{AIC}	0
X ₇₄	H pre_birth_info _{AIC}	0
X ₇₅	con_act _{AIC}	1

Table 24
Role Matrix for Case (c) for mb – Base Connectivity.

mb - base connectivity		1	2	3	4	5	6	7	8	9	10	11	12
X1	type_mom	X1											
X2	artificiality_birth	X2	X18										
X3	epidural_used	X3											
X4	deliv_baby	X4	X19										
X5	baby_born	X4											
X6	MPPD	X1	X2	X1	X5	X15							
X7	PPPD	X6	X10	X12	X15	X23	X24						
X8	imp_kid_devel	X7											
X9	pre_birth_info	X9	X40	X52									
X10	com_sup_hcp	X4	X9	X11	X14	X30	X32	X34	X36	X42	X44	X46	X48
X11	fat_ask_sup_com	X23	X28										
X12	fat_rec_sup_com	X10	X22	X24									
X13	post_info_com_par	X5	X30	X31	X32	X36	X43	X44	X48				
X14	refer_therapist	X13	X15	X47									
X15	mental_sup	X14	X21	X31	X32	X35	X36	X43	X44	X47	X48		
X16	acknow_fat	X9	X32	X36	X44	X48							
X17	age	X17											
X18	riskiness	X5	X17										
X19	dilation_mom	X19											
X20	premature_birth	X20											
X21	type_com	X21	X38	X50									
X22	retention	X23	X24										
X23	engaged	X16											
X24	stress	X26											
X25	birth_dev	X4	X18										
X26	fear_level	X23	X24	X25									
X27	desire_sup	X26											
X28	ask_sup	X27											
X29	birth_dev_det _{HCP}	X4	X18										
X30	det_risk_level _{HCP}	X29											
X31	encourage_mom _{HCP}	X30											
X32	calm_dad _{HCP}	X11	X30										
X33	irr_birth_weight _{HCP}	X5	X30										
X34	det_underw _{HCP}	X33											
X35	refer_mom_ther _{HCP}	X34											
X36	teach_dad_sup_mom _{HCP}	X34											
X37	baby_born _{HCP}	X5											
X38	type_com _{HCP}	X37											
X39	type_mom _{HCP}	X1											
X40	pre_birth_info _{HCP}	X39											
X41	birth_dev_det _{AIC}	X4	X18										
X42	det_risk_level _{AIC}	X41											
X43	encourage_mom _{AIC}	X42											
X44	calm_dad _{AIC}	X11	X42										
X45	irr_birth_weight _{AIC}	X5	X30										
X46	det_underw _{AIC}	X45											
X47	refer_mom_ther _{AIC}	X46											
X48	teach_dad_sup_mom _{AIC}	X46											
X49	baby_born _{AIC}	X5											
X50	type_com _{AIC}	X49											
X51	type_mom _{AIC}	X1											
X52	pre_birth_info _{AIC}	X51											
X53	W _{birth_dev_det_{HCP}}	X53											
X54	W _{det_risk_level_{HCP}}	X54											
X55	W _{det_risk_level_{HCP}}	X55											
X56	W _{irr_birth_weight_{HCP}}	X56											
X57	W _{det_underw_{HCP}}	X57											
X58	W _{det_underw_{HCP}}	X58											
X59	W _{baby_born_{HCP}}	X59											
X60	W _{type_mom_{HCP}}	X60											
X61	W _{birth_dev_det_{AIC}}	X61											
X62	W _{det_risk_level_{AIC}}	X62											
X63	W _{det_risk_level_{AIC}}	X63											
X64	W _{irr_birth_weight_{AIC}}	X64											
X65	W _{det_underw_{AIC}}	X65											
X66	W _{det_underw_{AIC}}	X66											
X67	W _{baby_born_{AIC}}	X67											
X68	W _{type_mom_{AIC}}	X68											
X69	W _{pre_birth_info_{AIC}}	X69											
X70	W _{acknow_fat_{AIC}}	X70											
X71	W _{acknow_fat_{AIC}}	X71											
X72	W _{com_sup_hcp_{AIC}}	X72											
X73	W _{com_sup_hcp_{AIC}}	X73											
X74	W _{post_info_com_{AIC}}	X74											
X75	W _{post_info_com_{AIC}}	X75											
X76	W _{post_info_com_{AIC}}	X76											
X77	W _{refer_therapist_{AIC}}	X77											
X78	W _{mental_sup_{AIC}}	X78											
X79	W _{mental_sup_{AIC}}	X79											
X80	W _{mental_sup_{AIC}}	X80											
X81	W _{mental_sup_{AIC}}	X81											
X82	W _{type_com_{AIC}}	X82											
X83	monitor_pre_birth_info	X52	X9										
X84	monitor_acknow_fat ₁	X48	X16										
X85	monitor_acknow_fat ₂	X44	X16										
X86	monitor_com_sup_hcp ₁	X44	X10										
X87	monitor_com_sup_hcp ₂	X48	X10										
X88	monitor_post_info_com _{par₁}	X43	X13										
X89	monitor_post_info_com _{par₂}	X44	X13										
X90	monitor_post_info_com _{par₃}	X48	X13										
X91	monitor_refer_therapist	X47	X14										
X92	monitor_mental_sup ₁	X43	X15										
X93	monitor_mental_sup ₂	X47	X15										
X94	monitor_mental_sup ₃	X44	X15										
X95	monitor_mental_sup ₄	X48	X15										
X96	monitor_type_com	X50	X21										

intervening after a given amount of time, to compensate for actions not being taken by the healthcare practitioner. This study also presents an advanced version of the Coach, illustrating a more complex system using monitoring for determining whether the Coach performs communication or not. Simulation results indicate that integrating the partners into the childbirth process and viewing them as active actors, as well as

opening up communication lines between HCP and parents’, aids in decreasing the risk of postpartum depression and in return ensuring positive child development. Moreover, both communication actions by AIC and HCP carry the same weight. This indicates that both are equally as effective in reaching the same end goal of having no risk of the father developing PPD.

Table 25
Role Matrix for Case (c) for mcw – Connection Weights.

mcw - connection weights		1	2	3	4	5	6	7	8	9	10	11	12
X ₁	type_mom	1											
X ₂	artificiality_birth	1	-1										
X ₃	epidural_used	1											
X ₄	deliv_baby	1											
X ₅	baby_born	1											
X ₆	MPPD	0.25	0.25	0.25	0.25	-1							
X ₇	PPPD	1	-0.5	-0.5	-0.5	-0.5	1						
X ₈	kid_devel	1											
X ₉	pre_birth_info	1	1	X ₅₉									
X ₁₀	com_sup_hcp	1	1	1	-1	1	1	1	1	1	X ₇₂	1	X ₇₃
X ₁₁	fat_ask_sup_com	1	1										
X ₁₂	fat_rec_sup_com	1	1	-1									
X ₁₃	post_info_com_par	1	1	1	1	1	X ₇₆	X ₇₄	X ₇₅				
X ₁₄	refer_therapist	1	1	X ₇₇									
X ₁₅	mental_sup	1	1	1	1	1	X ₈₀	X ₇₈	X ₈₁	X ₇₉			
X ₁₆	acknowl_fat	1	1	1	X ₇₀	X ₇₁							
X ₁₇	age	1											
X ₁₈	riskiness	-1	1										
X ₁₉	dilation_mom	1											
X ₂₀	premature_birth	1											
X ₂₁	type_com	1	1	X ₈₂									
X ₂₂	retention	2	-1										
X ₂₃	engaged	1											
X ₂₄	stress	1											
X ₂₅	birth_dev	1	1										
X ₂₆	fear_level	-1	1	1									
X ₂₇	desire_sup	1											
X ₂₈	ask_sup	1											
X ₂₉	birth_dev_det _{HCP}	1	1										
X ₃₀	det_risk_level _{HCP}	X ₅₃											
X ₃₁	encourage_mom _{HCP}	X ₅₄											
X ₃₂	calm_dad _{HCP}	1	X ₅₅										
X ₃₃	irr_birth_weight _{HCP}	1	2										
X ₃₄	det_underw _{HCP}	X ₅₆											
X ₃₅	refer_mom_ther _{HCP}	X ₅₇											
X ₃₆	teach_dad_sup_mom _{HCP}	X ₅₈											
X ₃₇	baby_born _{HCP}	1											
X ₃₈	type_com _{HCP}	X ₅₉											
X ₃₉	type_mom _{HCP}	1											
X ₄₀	pre_birth_info _{HCP}	X ₆₀											
X ₄₁	birth_dev_det _{AIC}	1	1										
X ₄₂	det_risk_level _{AIC}	X ₆₁											
X ₄₃	encourage_mom _{AIC}	X ₆₂											
X ₄₄	calm_dad _{AIC}	1	X ₆₃										
X ₄₅	irr_birth_weight _{AIC}	1	2										
X ₄₆	det_underw _{AIC}	X ₆₄											
X ₄₇	refer_mom_ther _{AIC}	X ₆₅											
X ₄₈	teach_dad_sup_mom _{AIC}	X ₆₆											
X ₄₉	baby_born _{AIC}	1											
X ₅₀	type_com _{AIC}	X ₆₇											
X ₅₁	type_mom _{AIC}	1											
X ₅₂	pre_birth_info _{AIC}	X ₆₈											
X ₅₃	W _{birth_dev_det_HCP_det_risk_level_HCP}	1											
X ₅₄	W _{det_risk_level_HCP_encourage_mom_HCP}	1											
X ₅₅	W _{det_risk_level_HCP_calm_dad_HCP}	1											
X ₅₆	W _{irr_birth_weight_HCP_det_underw_HCP}	1											
X ₅₇	W _{det_underw_HCP_refer_mom_ther_HCP}	1											
X ₅₈	W _{det_underw_HCP_teach_dad_sup_mom_HCP}	1											
X ₅₉	W _{baby_born_HCP_type_com_HCP}	1											
X ₆₀	W _{type_mom_HCP_pre_birth_info_HCP}	1											
X ₆₁	W _{birth_dev_det_AIC_det_risk_level_AIC}	1											
X ₆₂	W _{det_risk_level_AIC_encourage_mom_AIC}	1											
X ₆₃	W _{det_risk_level_AIC_calm_dad_AIC}	1											
X ₆₄	W _{irr_birth_weight_AIC_det_underw_AIC}	1											
X ₆₅	W _{det_underw_AIC_refer_mom_ther_AIC}	1											
X ₆₆	W _{det_underw_AIC_teach_dad_sup_mom_AIC}	1											
X ₆₇	W _{baby_born_AIC_type_com_AIC}	1											
X ₆₈	W _{type_mom_AIC_pre_birth_info_AIC}	1											
X ₆₉	W _{pre_birth_info_AIC_pre_birth_info}	1											
X ₇₀	W _{calm_dad_AIC_acknowl_fat}	1											
X ₇₁	W _{teach_dad_sup_mom_AIC_acknowl_fat}	1											
X ₇₂	W _{calm_dad_AIC_com_sup_hcp}	1											
X ₇₃	W _{teach_dad_sup_mom_AIC_com_sup_hcp}	1											
X ₇₄	W _{calm_dad_AIC_post_info_com_par}	1											
X ₇₅	W _{teach_dad_sup_mom_AIC_post_info_com_par}	1											
X ₇₆	W _{encourage_mom_AIC_post_info_com_par}	1											
X ₇₇	W _{refer_mom_ther_AIC_refer_therapist}	1											
X ₇₈	W _{calm_dad_AIC_mental_sup}	1											
X ₇₉	W _{teach_dad_sup_mom_AIC_mental_sup}	1											
X ₈₀	W _{encourage_mom_AIC_mental_sup}	1											
X ₈₁	W _{refer_mom_ther_AIC_mental_sup}	1											
X ₈₂	W _{type_com_AIC_type_com}	1											
X ₈₃	monitor_pre_birth_info	1	1										
X ₈₄	monitor_acknowl_fat ₁	1	1										
X ₈₅	monitor_acknowl_fat ₂	1	1										
X ₈₆	monitor_com_sup_hcp ₁	1	1										
X ₈₇	monitor_com_sup_hcp ₂	1	1										
X ₈₈	monitor_post_info_com_par ₁	1	1										
X ₈₉	monitor_post_info_com_par ₂	1	1										
X ₉₀	monitor_post_info_com_par ₃	1	1										
X ₉₁	monitor_refer_therapist	1	1										
X ₉₂	monitor_mental_sup ₁	1	1										
X ₉₃	monitor_mental_sup ₂	1	1										
X ₉₄	monitor_mental_sup ₃	1	1										
X ₉₅	monitor_mental_sup ₄	1	1										
X ₉₆	monitor_type_com	1	1										

Table 26
Role Matrix for Case (c) for **mcfw** – Combination Function Weights.

mcfw - combination function weights	1	
	1 Allogistic	2 Monitor
X ₁ type_mom	1	
X ₂ artificiality_birth	1	
X ₃ epidural_used	1	
X ₄ deliv_baby	1	
X ₅ baby_born	1	
X ₆ MPPD	1	
X ₇ PPPD	1	
X ₈ kid_devel	1	
X ₉ pre_birth_info	1	
X ₁₀ com_sup_hcp	1	
X ₁₁ fat_ask_sup_com	1	
X ₁₂ fat_rec_sup_com	1	
X ₁₃ post_info_com_par	1	
X ₁₄ refer_therapist	1	
X ₁₅ mental_sup	1	
X ₁₆ acknowl_fat	1	
X ₁₇ age	1	
X ₁₈ riskiness	1	
X ₁₉ dilation_mom	1	
X ₂₀ premature_birth	1	
X ₂₁ type_com	1	
X ₂₂ retention	1	
X ₂₃ engaged	1	
X ₂₄ stress	1	
X ₂₅ birth_dev	1	
X ₂₆ fear_level	1	
X ₂₇ desire_sup	1	
X ₂₈ ask_sup	1	
X ₂₉ birth_dev_det _{HCP}	1	
X ₃₀ det_risk_level _{HCP}	1	
X ₃₁ encourage_mom _{HCP}	1	
X ₃₂ calm_dad _{HCP}	1	
X ₃₃ irr_birth_weight _{HCP}	1	
X ₃₄ det_underw _{HCP}	1	
X ₃₅ refer_mom_ther _{HCP}	1	
X ₃₆ teach_dad_sup_mom _{HCP}	1	
X ₃₇ baby_born _{HCP}	1	
X ₃₈ type_com _{HCP}	1	
X ₃₉ type_mom _{HCP}	1	
X ₄₀ pre_birth_info _{HCP}	1	
X ₄₁ birth_dev_det _{AIC}	1	
X ₄₂ det_risk_level _{AIC}	1	
X ₄₃ encourage_mom _{AIC}	1	
X ₄₄ calm_dad _{AIC}	1	
X ₄₅ irr_birth_weight _{AIC}	1	
X ₄₆ det_underw _{AIC}	1	
X ₄₇ refer_mom_ther _{AIC}	1	
X ₄₈ teach_dad_sup_mom _{AIC}	1	
X ₄₉ baby_born _{AIC}	1	
X ₅₀ type_com _{AIC}	1	
X ₅₁ type_mom _{AIC}	1	
X ₅₂ pre_birth_info _{AIC}	1	
X ₅₃ W _{birth_dev_det_HCP} , det_risk_level_HCP	1	
X ₅₄ W _{det_risk_level_HCP} , encourage_mom_HCP	1	
X ₅₅ W _{det_risk_level_HCP} , calm_dad_HCP	1	
X ₅₆ W _{irr_birth_weight_HCP} , det_underw_HCP	1	
X ₅₇ W _{det_underw_HCP} , refer_mom_ther_HCP	1	
X ₅₈ W _{det_underw_HCP} , teach_dad_sup_mom_HCP	1	
X ₅₉ W _{baby_born_HCP} , type_com_HCP	1	
X ₆₀ W _{type_mom_HCP} , pre_birth_info_HCP	1	
X ₆₁ W _{birth_dev_det_AIC} , det_risk_level_AIC	1	
X ₆₂ W _{det_risk_level_AIC} , encourage_mom_AIC	1	
X ₆₃ W _{det_risk_level_AIC} , calm_dad_AIC	1	
X ₆₄ W _{irr_birth_weight_AIC} , det_underw_AIC	1	
X ₆₅ W _{det_underw_AIC} , refer_mom_ther_AIC	1	
X ₆₆ W _{det_underw_AIC} , teach_dad_sup_mom_AIC	1	
X ₆₇ W _{baby_born_AIC} , type_com_AIC	1	
X ₆₈ W _{type_mom_AIC} , pre_birth_info_AIC	1	
X ₆₉ W _{pre_birth_info_AIC} , pre_birth_info	1	
X ₇₀ W _{calm_dad_AIC} , acknowl_fat	1	
X ₇₁ W _{teach_dad_sup_mom_AIC} , acknowl_fat	1	
X ₇₂ W _{calm_dad_AIC} , com_sup_hcp	1	
X ₇₃ W _{teach_dad_sup_mom_AIC} , com_sup_hcp	1	
X ₇₄ W _{calm_dad_AIC} , post_info_com_par	1	
X ₇₅ W _{teach_dad_sup_mom_AIC} , post_info_com_par	1	
X ₇₆ W _{encourage_mom_AIC} , post_info_com_par	1	
X ₇₇ W _{refer_mom_ther_AIC} , refer_therapist	1	
X ₇₈ W _{calm_dad_AIC} , mental_sup	1	
X ₇₉ W _{teach_dad_sup_mom_AIC} , mental_sup	1	
X ₈₀ W _{encourage_mom_AIC} , mental_sup	1	
X ₈₁ W _{refer_mom_ther_AIC} , mental_sup	1	
X ₈₂ W _{type_com_AIC} , type_com	1	
X ₈₃ monitor_pre_birth_info		1
X ₈₄ monitor_acknowl_fat ₁		1
X ₈₅ monitor_acknowl_fat ₂		1
X ₈₆ monitor_com_sup_hcp ₁		1
X ₈₇ monitor_com_sup_hcp ₂		1
X ₈₈ monitor_post_info_com_par ₁		1
X ₈₉ monitor_post_info_com_par ₂		1
X ₉₀ monitor_post_info_com_par ₃		1
X ₉₁ monitor_refer_therapist		1
X ₉₂ monitor_mental_sup ₁		1
X ₉₃ monitor_mental_sup ₂		1
X ₉₄ monitor_mental_sup ₃		1
X ₉₅ monitor_mental_sup ₄		1
X ₉₆ monitor_type_com		1

Table 27
Role Matrix for Case (c) for **mcfp** – Combination Function Parameters.

mcfp - combination function parameters	1 Allogistic		2 Monitor	
	Steepness	Threshold	Threshold	
X ₁ type_mom	50	0.5		
X ₂ artificiality_birth	50	0.5		
X ₃ epidural_used	50	0.5		
X ₄ deliv_baby	5	0.5		
X ₅ baby_born	50	0.5		
X ₆ MPPD	5	0.3		
X ₇ PPPD	5	0.5		
X ₈ kid_devel	5	0.5		
X ₉ pre_birth_info	50	0.5		
X ₁₀ com_sup_hcp	0.5	6		
X ₁₁ fat_ask_sup_com	5	1		
X ₁₂ fat_rec_sup_com	5	0.5		
X ₁₃ post_info_com_par	5	4		
X ₁₄ refer_therapist	5	1		
X ₁₅ mental_sup	5	5		
X ₁₆ acknowl_fat	5	0.8		
X ₁₇ age	5	0.5		
X ₁₈ riskiness	50	0.5		
X ₁₉ dilation_mom	2.8	0		
X ₂₀ premature_birth	5	0.5		
X ₂₁ type_com	5	0.1		
X ₂₂ retention	5	0.3		
X ₂₃ engaged	5	0.5		
X ₂₄ stress	5	0.5		
X ₂₅ birth_dev	50	1		
X ₂₆ fear_level	5	1		
X ₂₇ desire_sup	5	0.3		
X ₂₈ ask_sup	5	0.2		
X ₂₉ birth_dev_det _{HCP}	5	1		
X ₃₀ det_risk_level _{HCP}	5	0.5		
X ₃₁ encourage_mom _{HCP}	5	0.5		
X ₃₂ calm_dad _{HCP}	50	0.7		
X ₃₃ irr_birth_weight _{HCP}	5	1		
X ₃₄ det_underw _{HCP}	5	0.5		
X ₃₅ refer_mom_ther _{HCP}	50	0.5		
X ₃₆ teach_dad_sup_mom _{HCP}	50	0.7		
X ₃₇ baby_born _{HCP}	5	0.5		
X ₃₈ type_com _{HCP}	50	0.5		
X ₃₉ type_mom _{HCP}	5	0.5		
X ₄₀ pre_birth_info _{HCP}	50	0.5		
X ₄₁ birth_dev_det _{AIC}	5	1		
X ₄₂ det_risk_level _{AIC}	5	0.5		
X ₄₃ encourage_mom _{AIC}	5	0.5		
X ₄₄ calm_dad _{AIC}	50	0.7		
X ₄₅ irr_birth_weight _{AIC}	5	1		
X ₄₆ det_underw _{AIC}	5	0.5		
X ₄₇ refer_mom_ther _{AIC}	50	0.5		
X ₄₈ teach_dad_sup_mom _{AIC}	50	0.7		
X ₄₉ baby_born _{AIC}	5	0.5		
X ₅₀ type_com _{AIC}	50	0.5		
X ₅₁ type_mom _{AIC}	5	0.5		
X ₅₂ pre_birth_info _{AIC}	50	0.5		
X ₅₃ W _{birth_dev_det_HCP} , det_risk_level_HCP	5	0.5		
X ₅₄ W _{det_risk_level_HCP} , encourage_mom_HCP	5	0.5		
X ₅₅ W _{det_risk_level_HCP} , calm_dad_HCP	5	0.5		
X ₅₆ W _{irr_birth_weight_HCP} , det_underw_HCP	5	0.5		
X ₅₇ W _{det_underw_HCP} , refer_mom_ther_HCP	5	0.5		
X ₅₈ W _{det_underw_HCP} , teach_dad_sup_mom_HCP	5	0.5		
X ₅₉ W _{baby_born_HCP} , type_com_HCP	5	0.5		
X ₆₀ W _{type_mom_HCP} , pre_birth_info_HCP	5	0.5		
X ₆₁ W _{birth_dev_det_AIC} , det_risk_level_AIC	5	0.5		
X ₆₂ W _{det_risk_level_AIC} , encourage_mom_AIC	5	0.5		
X ₆₃ W _{det_risk_level_AIC} , calm_dad_AIC	5	0.5		
X ₆₄ W _{irr_birth_weight_AIC} , det_underw_AIC	5	0.5		
X ₆₅ W _{det_underw_AIC} , refer_mom_ther_AIC	5	0.5		
X ₆₆ W _{det_underw_AIC} , teach_dad_sup_mom_AIC	5	0.5		
X ₆₇ W _{baby_born_AIC} , type_com_AIC	5	0.5		
X ₆₈ W _{type_mom_AIC} , pre_birth_info_AIC	5	0.5		
X ₆₉ W _{pre_birth_info_AIC} , pre_birth_info	5	0.5		
X ₇₀ W _{calm_dad_AIC} , acknowl_fat	5	0.5		
X ₇₁ W _{teach_dad_sup_mom_AIC} , acknowl_fat	5	0.5		
X ₇₂ W _{calm_dad_AIC} , com_sup_hcp	5	0.5		
X ₇₃ W _{teach_dad_sup_mom_AIC} , com_sup_hcp	5	0.5		
X ₇₄ W _{calm_dad_AIC} , post_info_com_par	5	0.5		
X ₇₅ W _{teach_dad_sup_mom_AIC} , post_info_com_par	5	0.5		
X ₇₆ W _{encourage_mom_AIC} , post_info_com_par	5	0.5		
X ₇₇ W _{refer_mom_ther_AIC} , refer_therapist	5	0.5		
X ₇₈ W _{calm_dad_AIC} , mental_sup	5	0.5		
X ₇₉ W _{teach_dad_sup_mom_AIC} , mental_sup	5	0.5		
X ₈₀ W _{encourage_mom_AIC} , mental_sup	5	0.5		
X ₈₁ W _{refer_mom_ther_AIC} , mental_sup	5	0.5		
X ₈₂ W _{type_com_AIC} , type_com	5	0.5		
X ₈₃ monitor_pre_birth_info				0.6
X ₈₄ monitor_acknowl_fat ₁				0.6
X ₈₅ monitor_acknowl_fat ₂				0.6
X ₈₆ monitor_com_sup_hcp ₁				0.6
X ₈₇ monitor_com_sup_hcp ₂				0.6
X ₈₈ monitor_post_info_com_par ₁				0.6
X ₈₉ monitor_post_info_com_par ₂				0.6
X ₉₀ monitor_post_info_com_par ₃				0.6
X ₉₁ monitor_refer_therapist				0.6
X ₉₂ monitor_mental_sup ₁				0.6
X ₉₃ monitor_mental_sup ₂				0.6
X ₉₄ monitor_mental_sup ₃				0.6
X ₉₅ monitor_mental_sup ₄				0.6
X ₉₆ monitor_type_com				0.6

Table 28
Role Matrix for Case (c) for **iv** – Initial Values.

ms - speed factors		1
X ₁	type_mom	1
X ₂	artificiality_birth	1
X ₃	epidural_used	1
X ₄	deliv_baby	0.2
X ₅	baby_born	0.1
X ₆	MPPD	0.2
X ₇	PPPD	1
X ₈	kid_devel	1
X ₉	pre_birth_info	0.1
X ₁₀	com_sup_hcp	0.1
X ₁₁	fat_ask_sup_com	0.3
X ₁₂	fat_rec_sup_com	0.1
X ₁₃	post_info_com_par	0.1
X ₁₄	refer_therapist	0.3
X ₁₅	mental_sup	0.1
X ₁₆	acknowl_fat	0.1
X ₁₇	age	0
X ₁₈	riskiness	0.5
X ₁₉	dilation_mom	1
X ₂₀	premature_birth	0
X ₂₁	type_com	1
X ₂₂	retention	1
X ₂₃	engaged	1
X ₂₄	stress	0.4
X ₂₅	birth_dev	1
X ₂₆	fear_level	1
X ₂₇	desire_sup	1
X ₂₈	ask_sup	0.2
X ₂₉	birth_dev_det _{HCP}	1
X ₃₀	det_risk_level _{HCP}	1
X ₃₁	encourage_mom _{HCP}	0.1
X ₃₂	calm_dad _{HCP}	0.1
X ₃₃	irr_birth_weight _{HCP}	1
X ₃₄	det_underw _{HCP}	1
X ₃₅	refer_mom_ther _{HCP}	0.3
X ₃₆	teach_dad_sup_mom _{HCP}	0.1
X ₃₇	baby_born _{HCP}	1
X ₃₈	type_com _{HCP}	1
X ₃₉	type_mom _{HCP}	1
X ₄₀	pre_birth_info _{HCP}	1
X ₄₁	birth_dev_det _{AIC}	0.33
X ₄₂	det_risk_level _{AIC}	0.33
X ₄₃	encourage_mom _{AIC}	0.033
X ₄₄	calm_dad _{AIC}	0.033
X ₄₅	irr_birth_weight _{AIC}	0.33
X ₄₆	det_underw _{AIC}	0.33
X ₄₇	refer_mom_ther _{AIC}	0.1
X ₄₈	teach_dad_sup_mom _{AIC}	0.033
X ₄₉	baby_born _{AIC}	0.33
X ₅₀	type_com _{AIC}	0.33
X ₅₁	type_mom _{AIC}	0.33
X ₅₂	pre_birth_info _{AIC}	0.33
X ₅₃	W _{birth_dev_det_{HCP}, det_risk_level_{HCP}}	0
X ₅₄	W _{det_risk_level_{HCP}, encourage_mom_{HCP}}	0
X ₅₅	W _{det_risk_level_{HCP}, calm_dad_{HCP}}	0
X ₅₆	W _{irr_birth_weight_{HCP}, det_underw_{HCP}}	0
X ₅₇	W _{det_underw_{HCP}, refer_mom_ther_{HCP}}	0
X ₅₈	W _{det_underw_{HCP}, teach_dad_sup_mom_{HCP}}	0
X ₅₉	W _{baby_born_{HCP}, type_com_{HCP}}	0
X ₆₀	W _{type_mom_{HCP}, pre_birth_info_{HCP}}	0
X ₆₁	W _{birth_dev_det_{AIC}, det_risk_level_{AIC}}	0
X ₆₂	W _{det_risk_level_{AIC}, encourage_mom_{AIC}}	0
X ₆₃	W _{det_risk_level_{AIC}, calm_dad_{AIC}}	0
X ₆₄	W _{irr_birth_weight_{AIC}, det_underw_{AIC}}	0
X ₆₅	W _{det_underw_{AIC}, refer_mom_ther_{AIC}}	0
X ₆₆	W _{det_underw_{AIC}, teach_dad_sup_mom_{AIC}}	0
X ₆₇	W _{baby_born_{AIC}, type_com_{AIC}}	0
X ₆₈	W _{type_mom_{AIC}, pre_birth_info_{AIC}}	0
X ₆₉	W _{pre_birth_info_{AIC}, pre_birth_info}	0
X ₇₀	W _{calm_dad_{AIC}, acknowl_fat}	0.5
X ₇₁	W _{teach_dad_sup_mom_{AIC}, acknowl_fat}	0.5
X ₇₂	W _{calm_dad_{AIC}, com_sup_hcp}	0.5
X ₇₃	W _{teach_dad_sup_mom_{AIC}, com_sup_hcp}	0.5
X ₇₄	W _{calm_dad_{AIC}, post_info_com_par}	0.5
X ₇₅	W _{teach_dad_sup_mom_{AIC}, post_info_com_par}	0.5
X ₇₆	W _{encourage_mom_{AIC}, post_info_com_par}	0.5
X ₇₇	W _{refer_mom_ther_{AIC}, refer_therapist}	0.5
X ₇₈	W _{calm_dad_{AIC}, mental_sup}	0.5
X ₇₉	W _{teach_dad_sup_mom_{AIC}, mental_sup}	0.5
X ₈₀	W _{encourage_mom_{AIC}, mental_sup}	0.5
X ₈₁	W _{refer_mom_ther_{AIC}, mental_sup}	0.5
X ₈₂	W _{type_com_{AIC}, type_com}	0.5
X ₈₃	monitor_pre_birth_info	0.5
X ₈₄	monitor_acknowl_fat ₁	0.5
X ₈₅	monitor_acknowl_fat ₂	0.5
X ₈₆	monitor_com_sup_hcp ₁	0.5
X ₈₇	monitor_com_sup_hcp ₂	0.5
X ₈₈	monitor_post_info_com_par ₁	0.5
X ₈₉	monitor_post_info_com_par ₂	0.5
X ₉₀	monitor_post_info_com_par ₃	0.5
X ₉₁	monitor_refer_therapist	0.5
X ₉₂	monitor_mental_sup ₁	0.5
X ₉₃	monitor_mental_sup ₂	0.5
X ₉₄	monitor_mental_sup ₃	0.5
X ₉₅	monitor_mental_sup ₄	0.5
X ₉₆	monitor_type_com	0.5

Table 29
Role Matrix for Case (c) for **ms** – Speed Factors.

iv - initial values		1
X ₁	type_mom	0
X ₂	artificiality_birth	0
X ₃	epidural_used	0
X ₄	deliv_baby	0
X ₅	baby_born	0
X ₆	MPPD	0.13
X ₇	PPPD	0
X ₈	kid_devel	0
X ₉	pre_birth_info	0
X ₁₀	com_sup_hcp	0
X ₁₁	fat_ask_sup_com	0
X ₁₂	fat_rec_sup_com	0
X ₁₃	post_info_com_par	0
X ₁₄	refer_therapist	0
X ₁₅	mental_sup	0
X ₁₆	acknowl_fat	0
X ₁₇	age	1
X ₁₈	riskiness	0
X ₁₉	dilation_mom	0.2
X ₂₀	premature_birth	1
X ₂₁	type_com	0
X ₂₂	retention	0
X ₂₃	engaged	0
X ₂₄	stress	0
X ₂₅	birth_dev	0
X ₂₆	fear_level	0
X ₂₇	desire_sup	0
X ₂₈	ask_sup	0
X ₂₉	birth_dev_det _{HCP}	0
X ₃₀	det_risk_level _{HCP}	0
X ₃₁	encourage_mom _{HCP}	0
X ₃₂	calm_dad _{HCP}	0
X ₃₃	irr_birth_weight _{HCP}	0
X ₃₄	det_underw _{HCP}	0
X ₃₅	refer_mom_ther _{HCP}	0
X ₃₆	teach_dad_sup_mom _{HCP}	0
X ₃₇	baby_born _{HCP}	0
X ₃₈	type_com _{HCP}	0
X ₃₉	type_mom _{HCP}	0
X ₄₀	pre_birth_info _{HCP}	0
X ₄₁	birth_dev_det _{AIC}	0
X ₄₂	det_risk_level _{AIC}	0
X ₄₃	encourage_mom _{AIC}	0
X ₄₄	calm_dad _{AIC}	0
X ₄₅	irr_birth_weight _{AIC}	0
X ₄₆	det_underw _{AIC}	0
X ₄₇	refer_mom_ther _{AIC}	0
X ₄₈	teach_dad_sup_mom _{AIC}	0
X ₄₉	baby_born _{AIC}	0
X ₅₀	type_com _{AIC}	0
X ₅₁	type_mom _{AIC}	0
X ₅₂	pre_birth_info _{AIC}	0
X ₅₃	W _{birth_dev_det_{HCP}, det_risk_level_{HCP}}	0
X ₅₄	W _{det_risk_level_{HCP}, encourage_mom_{HCP}}	0
X ₅₅	W _{det_risk_level_{HCP}, calm_dad_{HCP}}	0
X ₅₆	W _{irr_birth_weight_{HCP}, det_underw_{HCP}}	0
X ₅₇	W _{det_underw_{HCP}, refer_mom_ther_{HCP}}	0
X ₅₈	W _{det_underw_{HCP}, teach_dad_sup_mom_{HCP}}	0
X ₅₉	W _{baby_born_{HCP}, type_com_{HCP}}	0
X ₆₀	W _{type_mom_{HCP}, pre_birth_info_{HCP}}	0
X ₆₁	W _{birth_dev_det_{AIC}, det_risk_level_{AIC}}	1
X ₆₂	W _{det_risk_level_{AIC}, encourage_mom_{AIC}}	1
X ₆₃	W _{det_risk_level_{AIC}, calm_dad_{AIC}}	1
X ₆₄	W _{irr_birth_weight_{AIC}, det_underw_{AIC}}	1
X ₆₅	W _{det_underw_{AIC}, refer_mom_ther_{AIC}}	1
X ₆₆	W _{det_underw_{AIC}, teach_dad_sup_mom_{AIC}}	1
X ₆₇	W _{baby_born_{AIC}, type_com_{AIC}}	1
X ₆₈	W _{type_mom_{AIC}, pre_birth_info_{AIC}}	1
X ₆₉	W _{pre_birth_info_{AIC}, pre_birth_info}	0
X ₇₀	W _{calm_dad_{AIC}, acknowl_fat}	0
X ₇₁	W _{teach_dad_sup_mom_{AIC}, acknowl_fat}	0
X ₇₂	W _{calm_dad_{AIC}, com_sup_hcp}	0
X ₇₃	W _{teach_dad_sup_mom_{AIC}, com_sup_hcp}	0
X ₇₄	W _{calm_dad_{AIC}, post_info_com_par}	0
X ₇₅	W _{teach_dad_sup_mom_{AIC}, post_info_com_par}	0
X ₇₆	W _{encourage_mom_{AIC}, post_info_com_par}	0
X ₇₇	W _{refer_mom_ther_{AIC}, refer_therapist}	0
X ₇₈	W _{calm_dad_{AIC}, mental_sup}	0
X ₇₉	W _{teach_dad_sup_mom_{AIC}, mental_sup}	0
X ₈₀	W _{encourage_mom_{AIC}, mental_sup}	0
X ₈₁	W _{refer_mom_ther_{AIC}, mental_sup}	0
X ₈₂	W _{type_com_{AIC}, type_com}	0
X ₈₃	monitor_pre_birth_info	0
X ₈₄	monitor_acknowl_fat ₁	0
X ₈₅	monitor_acknowl_fat ₂	0
X ₈₆	monitor_com_sup_hcp ₁	0
X ₈₇	monitor_com_sup_hcp ₂	0
X ₈₈	monitor_post_info_com_par ₁	0
X ₈₉	monitor_post_info_com_par ₂	0
X ₉₀	monitor_post_info_com_par ₃	0
X ₉₁	monitor_refer_therapist	0
X ₉₂	monitor_mental_sup ₁	0
X ₉₃	monitor_mental_sup ₂	0
X ₉₄	monitor_mental_sup ₃	0
X ₉₅	monitor_mental_sup ₄	0
X ₉₆	monitor_type_com	0

Table 30
Role Matrix for Case (d) for **mb** – Base Connectivity.

mb - base connectivity		1	2	3	4	5	6	7	8	9	10	11	12
X ₁	type_mom	X ₁											
X ₂	artificiality_birth	X ₂	X ₁₈										
X ₃	epidural_used	X ₃											
X ₄	deliv_baby	X ₄	X ₁₉										
X ₅	baby_born	X ₄											
X ₆	MPPD	X ₁	X ₂	X ₁	X ₅	X ₁₅							
X ₇	PPPD	X ₆	X ₁₀	X ₁₂	X ₁₅	X ₂₃	X ₂₄						
X ₈	imp_kid_devel	X ₇											
X ₉	pre_birth_info	X ₉	X ₄₀	X ₅₂									
X ₁₀	com_sup_hcp	X ₄	X ₉	X ₁₁	X ₂₄	X ₃₀	X ₃₂	X ₃₄	X ₃₅	X ₄₂	X ₄₄	X ₄₆	X ₄₈
X ₁₁	fat_ask_sup_com	X ₂₃	X ₂₈										
X ₁₂	fat_rec_sup_com	X ₁₀	X ₂₂	X ₂₄									
X ₁₃	post_info_com_par	X ₅	X ₂₀	X ₁₁	X ₁₂	X ₃₆	X ₄₃	X ₄₄	X ₄₈				
X ₁₄	refer_therapist	X ₁₃	X ₃₅	X ₄₇									
X ₁₅	mental_sup	X ₁₄	X ₂₁	X ₁₁	X ₁₂	X ₃₅	X ₃₆	X ₄₃	X ₄₄	X ₄₇	X ₄₈		
X ₁₆	acknowl_fat	X ₉	X ₃₂	X ₃₆	X ₄₄	X ₄₈							
X ₁₇	age	X ₁₇											
X ₁₈	riskiness	X ₅	X ₁₇										
X ₁₉	dilation_mom	X ₁₉											
X ₂₀	premature_birth	X ₂₀											
X ₂₁	type_com	X ₂₁	X ₃₈	X ₅₀									
X ₂₂	retention	X ₂₃	X ₂₄										
X ₂₃	engaged	X ₁₆											
X ₂₄	stress	X ₂₆											
X ₂₅	birth_dev	X ₄	X ₁₈										
X ₂₆	fear_level	X ₂₃	X ₂₄	X ₁₅									
X ₂₇	desire_sup	X ₂₆											
X ₂₈	ask_sup	X ₂₇											
X ₂₉	birth_dev_det _{HCP}	X ₄	X ₁₈										
X ₃₀	det_risk_level _{HCP}	X ₂₉											
X ₃₁	encourage_mom _{HCP}	X ₃₀											
X ₃₂	calm_dad _{HCP}	X ₁₁	X ₃₀										
X ₃₃	irr_birth_weight _{HCP}	X ₅	X ₂₀										
X ₃₄	det_underw _{HCP}	X ₃₃											
X ₃₅	refer_mom_ther _{HCP}	X ₃₄											
X ₃₆	teach_dad_sup_mom _{HCP}	X ₃₄											
X ₃₇	baby_born _{HCP}	X ₅											
X ₃₈	type_com _{HCP}	X ₃₇											
X ₃₉	type_mom _{HCP}	X ₁											
X ₄₀	pre_birth_info _{HCP}	X ₉											
X ₄₁	birth_dev_det _{AIC}	X ₄	X ₁₈										
X ₄₂	det_risk_level _{AIC}	X ₄₁											
X ₄₃	encourage_mom _{AIC}	X ₄₂											
X ₄₄	calm_dad _{AIC}	X ₁₁	X ₃₂										
X ₄₅	irr_birth_weight _{AIC}	X ₅	X ₂₀										
X ₄₆	det_underw _{AIC}	X ₄₅											
X ₄₇	refer_mom_ther _{AIC}	X ₄₆											
X ₄₈	teach_dad_sup_mom _{AIC}	X ₄₆											
X ₄₉	baby_born _{AIC}	X ₅											
X ₅₀	type_com _{AIC}	X ₄₀											
X ₅₁	type_mom _{AIC}	X ₁											
X ₅₂	pre_birth_info _{AIC}	X ₉											
X ₅₃	W _{birth_dev_det_HCP_det_risk_level_HCP}	X ₁₃	X ₆₁										
X ₅₄	W _{det_risk_level_HCP_encourage_mom_HCP}	X ₁₄	X ₆₂										
X ₅₅	W _{det_risk_level_HCP_calm_dad_HCP}	X ₁₅	X ₆₃										
X ₅₆	W _{irr_birth_weight_HCP_det_underw_HCP}	X ₁₆	X ₆₄										
X ₅₇	W _{det_underw_HCP_refer_mom_ther_HCP}	X ₁₇	X ₆₅										
X ₅₈	W _{det_underw_HCP_teach_dad_sup_mom_HCP}	X ₁₈	X ₆₆										
X ₅₉	W _{baby_born_HCP_type_com_HCP}	X ₁₉	X ₆₇										
X ₆₀	W _{type_mom_HCP_pre_birth_info_HCP}	X ₂₀	X ₆₈										
X ₆₁	W _{birth_dev_det_AIC_det_risk_level_AIC}	X ₂₁	X ₆₉										
X ₆₂	W _{det_risk_level_AIC_encourage_mom_AIC}	X ₂₂	X ₁₀₀										
X ₆₃	W _{det_risk_level_AIC_calm_dad_AIC}	X ₂₃	X ₁₀₁										
X ₆₄	W _{irr_birth_weight_AIC_det_underw_AIC}	X ₂₄	X ₁₀₂										
X ₆₅	W _{det_underw_AIC_refer_mom_ther_AIC}	X ₂₅	X ₁₀₃										
X ₆₆	W _{det_underw_AIC_teach_dad_sup_mom_AIC}	X ₂₆	X ₁₀₄										
X ₆₇	W _{baby_born_AIC_type_com_AIC}	X ₂₇	X ₁₀₅										
X ₆₈	W _{type_mom_AIC_pre_birth_info_AIC}	X ₂₈	X ₁₀₆										
X ₆₉	W _{pre_birth_info_AIC_pre_birth_info}	X ₂₉	X ₈₃										
X ₇₀	W _{adm_dad_AIC_acknowl_fat}	X ₃₀	X ₈₅										
X ₇₁	W _{teach_dad_sup_mom_AIC_acknowl_fat}	X ₃₁	X ₈₄										
X ₇₂	W _{adm_dad_AIC_com_sup_hcp}	X ₃₂	X ₈₆										
X ₇₃	W _{teach_dad_sup_mom_AIC_com_sup_hcp}	X ₃₃	X ₈₇										
X ₇₄	W _{adm_dad_AIC_post_info_com_par}	X ₃₄	X ₈₉										
X ₇₅	W _{teach_dad_sup_mom_AIC_post_info_com_par}	X ₃₅	X ₉₀										
X ₇₆	W _{encourage_mom_AIC_post_info_com_par}	X ₃₆	X ₈₈										
X ₇₇	W _{refer_mom_ther_AIC_refer_therapist}	X ₃₇	X ₉₁										
X ₇₈	W _{adm_dad_AIC_mental_sup}	X ₃₈	X ₉₄										
X ₇₉	W _{teach_dad_sup_mom_AIC_mental_sup}	X ₃₉	X ₉₅										
X ₈₀	W _{encourage_mom_AIC_mental_sup}	X ₄₀	X ₉₂										
X ₈₁	W _{refer_mom_ther_AIC_mental_sup}	X ₄₁	X ₉₃										
X ₈₂	W _{type_com_AIC_type_com}	X ₄₂	X ₉₆										
X ₈₃	monitor_pre_birth_info	X ₅₂	X ₉										
X ₈₄	monitor_acknowl_fat ₁	X ₄₈	X ₁₆										
X ₈₅	monitor_acknowl_fat ₂	X ₄₄	X ₁₆										
X ₈₆	monitor_com_sup_hcp ₁	X ₄₄	X ₁₀										
X ₈₇	monitor_com_sup_hcp ₂	X ₄₈	X ₁₀										
X ₈₈	monitor_post_info_com_par ₁	X ₄₃	X ₁₃										
X ₈₉	monitor_post_info_com_par ₂	X ₄₄	X ₁₃										
X ₉₀	monitor_post_info_com_par ₃	X ₄₈	X ₁₃										
X ₉₁	monitor_refer_therapist	X ₄₇	X ₁₄										
X ₉₂	monitor_mental_sup ₁	X ₄₃	X ₁₅										
X ₉₃	monitor_mental_sup ₂	X ₄₇	X ₁₅										
X ₉₄	monitor_mental_sup ₃	X ₄₄	X ₁₅										
X ₉₅	monitor_mental_sup ₄	X ₄₈	X ₁₅										
X ₉₆	monitor_type_com	X ₅₀	X ₃₁										
X ₉₇	W _{W_AIC_W_HCP}	X ₉₈											
X ₉₈	con.feedback	X ₉₈											
X ₉₉	W _{birth_dev_det_E_det_risk_level_E}												
X ₁₀₀	W _{det_risk_level_E_encourage_mom_E}												
X ₁₀₁	W _{det_risk_level_E_calm_dad_E}												
X ₁₀₂	W _{irr_birth_weight_E_det_underw_E}												
X ₁₀₃	W _{det_underw_E_refer_mom_ther_E}												
X ₁₀₄	W _{det_underw_E_teach_dad_sup_mom_E}												
X ₁₀₅	W _{baby_born_E_type_com_E}												
X ₁₀₆	W _{type_mom_E_pre_birth_info_E}												
X ₁₀₇	W _{W_E_W_AIC}	X ₁₀₈											
X ₁₀₈	con.feedforward	X ₁₀₈											

Table 31
Role Matrix for Case (d) for mcw – Connection Weights.

mcw - connection weights		1	2	3	4	5	6	7	8	9	10	11	12
X ₁	type_mom	1											
X ₂	artificiality_birth	1	-1										
X ₃	epidural_used	1											
X ₄	deliv_baby	1											
X ₅	baby_born	1											
X ₆	MPPD	0.25	0.25	0.25	0.25	-1							
X ₇	PPPD	1	-0.5	-0.5	-0.5	-0.5	1						
X ₈	kid_devel	1											
X ₉	pre_birth_info	1		X ₉₉									
X ₁₀	com_sup_hcp	1	1	1	-1	1	1	1	1	1	X ₁₀₂	1	X ₁₀₃
X ₁₁	fat_ask_sup_com	1	1										
X ₁₂	fat_rec_sup_com	1	1	-1									
X ₁₃	post_info_com_par	1	1	1	1	1	X ₁₀₆	X ₁₀₄	X ₁₀₅				
X ₁₄	refer_therapist	1	1	X ₁₀₇									
X ₁₅	mental_sup	1	1	1	1	1	1	X ₁₀₈	X ₁₀₈	X ₁₀₁	X ₁₀₉		
X ₁₆	acknow_fat	1	1	1	X ₁₀₀	X ₁₀₁							
X ₁₇	age	1											
X ₁₈	riskness	-1	1										
X ₁₉	dilation_mom	1											
X ₂₀	premature_birth	1											
X ₂₁	type_com	1	1	X ₁₀₂									
X ₂₂	retention	2	-1										
X ₂₃	engaged	1											
X ₂₄	stress	1											
X ₂₅	birth_dev	1	1										
X ₂₆	fear_level	-1	1	1									
X ₂₇	desire_sup	1											
X ₂₈	ask_sup	1											
X ₂₉	birth_dev_det _{HCP}	1	1										
X ₃₀	det_risk_level _{HCP}	X ₁₀₃											
X ₃₁	encourage_mom _{HCP}	X ₁₀₄											
X ₃₂	calm_dad _{HCP}	1	X ₁₀₅										
X ₃₃	irf_birth_weight _{HCP}	1	2										
X ₃₄	det_underw _{HCP}	X ₁₀₆											
X ₃₅	refer_mom_the _{HCP}	X ₁₀₇											
X ₃₆	teach_dad_sup_mom _{HCP}	X ₁₀₈											
X ₃₇	baby_born _{HCP}	1											
X ₃₈	type_com _{HCP}	X ₁₀₉											
X ₃₉	type_mom _{HCP}	1											
X ₄₀	pre_birth_info _{HCP}	X ₁₁₀											
X ₄₁	birth_dev_det _{AIC}	1	1										
X ₄₂	det_risk_level _{AIC}	X ₁₀₃											
X ₄₃	encourage_mom _{AIC}	X ₁₀₄											
X ₄₄	calm_dad _{AIC}	1	X ₁₀₅										
X ₄₅	irf_birth_weight _{AIC}	1	2										
X ₄₆	det_underw _{AIC}	X ₁₀₆											
X ₄₇	refer_mom_the _{AIC}	X ₁₀₇											
X ₄₈	teach_dad_sup_mom _{AIC}	X ₁₀₈											
X ₄₉	baby_born _{AIC}	1											
X ₅₀	type_com _{AIC}	X ₁₀₉											
X ₅₁	type_mom _{AIC}	1											
X ₅₂	pre_birth_info _{AIC}	X ₁₁₀											
X ₅₃	W _{birth_dev_det_HCP_det_risk_level_HCP}	1	X ₁₀₇										
X ₅₄	W _{det_risk_level_HCP_encourage_mom_HCP}	1	X ₁₀₇										
X ₅₅	W _{det_risk_level_HCP_calm_dad_HCP}	1	X ₁₀₇										
X ₅₆	W _{irf_birth_weight_HCP_det_underw_HCP}	1	X ₁₀₇										
X ₅₇	W _{det_underw_HCP_refer_mom_the_HCP}	1	X ₁₀₇										
X ₅₈	W _{det_underw_HCP_teach_dad_sup_mom_HCP}	1	X ₁₀₇										
X ₅₉	W _{baby_born_HCP_type_com_HCP}	1	X ₁₀₇										
X ₆₀	W _{type_mom_HCP_pre_birth_info_HCP}	1	X ₁₀₇										
X ₆₁	W _{birth_dev_det_AIC_det_risk_level_AIC}	1	X ₁₀₇										
X ₆₂	W _{det_risk_level_AIC_encourage_mom_AIC}	1	X ₁₀₇										
X ₆₃	W _{det_risk_level_AIC_calm_dad_AIC}	1	X ₁₀₇										
X ₆₄	W _{irf_birth_weight_AIC_det_underw_AIC}	1	X ₁₀₇										
X ₆₅	W _{det_underw_AIC_refer_mom_the_AIC}	1	X ₁₀₇										
X ₆₆	W _{det_underw_AIC_teach_dad_sup_mom_AIC}	1	X ₁₀₇										
X ₆₇	W _{baby_born_AIC_type_com_AIC}	1	X ₁₀₇										
X ₆₈	W _{type_mom_AIC_pre_birth_info_AIC}	1	X ₁₀₇										
X ₆₉	W _{pre_birth_info_AIC_pre_birth_info}	1											
X ₇₀	W _{calm_dad_AIC_acknow_fat}	1											
X ₇₁	W _{refer_mom_the_AIC_acknow_fat}	1											
X ₇₂	W _{calm_dad_AIC_com_sup_hcp}	1											
X ₇₃	W _{teach_dad_sup_mom_AIC_com_sup_hcp}	1											
X ₇₄	W _{calm_dad_AIC_post_info_com_par}	1											
X ₇₅	W _{teach_dad_sup_mom_AIC_post_info_com_par}	1											
X ₇₆	W _{encourage_mom_AIC_post_info_com_par}	1											
X ₇₇	W _{refer_mom_the_AIC_refer_therapist}	1											
X ₇₈	W _{calm_dad_AIC_mental_sup}	1											
X ₇₉	W _{teach_dad_sup_mom_AIC_mental_sup}	1											
X ₈₀	W _{encourage_mom_AIC_mental_sup}	1											
X ₈₁	W _{refer_mom_the_AIC_mental_sup}	1											
X ₈₂	W _{type_com_AIC_type_com}	1											
X ₈₃	monitor_pre_birth_info	1	1										
X ₈₄	monitor_acknow_fat	1	1										
X ₈₅	monitor_acknow_fat ₂	1	1										
X ₈₆	monitor_com_sup_hcp ₁	1	1										
X ₈₇	monitor_com_sup_hcp ₂	1	1										
X ₈₈	monitor_post_info_com_par ₁	1	1										
X ₈₉	monitor_post_info_com_par ₂	1	1										
X ₉₀	monitor_post_info_com_par ₃	1	1										
X ₉₁	monitor_refer_therapist	1	1										
X ₉₂	monitor_mental_sup ₁	1	1										
X ₉₃	monitor_mental_sup ₂	1	1										
X ₉₄	monitor_mental_sup ₃	1	1										
X ₉₅	monitor_mental_sup ₄	1	1										
X ₉₆	monitor_type_com	1	1										
X ₉₇	W _{W_AIC_W_HCP}	1											
X ₉₈	con_feedback	1											
X ₉₉	W _{birth_dev_det_E_det_risk_level_E}												
X ₁₀₀	W _{det_risk_level_E_encourage_mom_E}												
X ₁₀₁	W _{det_risk_level_E_calm_dad_E}												
X ₁₀₂	W _{irf_birth_weight_E_det_underw_E}												
X ₁₀₃	W _{det_underw_E_refer_mom_the_E}												
X ₁₀₄	W _{det_underw_E_teach_dad_sup_mom_E}												
X ₁₀₅	W _{baby_born_E_type_com_E}												
X ₁₀₆	W _{type_mom_E_pre_birth_info_E}												
X ₁₀₇	W _{W_E_W_AIC}	1											
X ₁₀₈	con_feedforward	1											

Although the father is considered an actor, the mental model of the father was not included, as the AI Coach is a tool for HCP's and therefore, the father's internal model would have added no additional useful information to the simulations and in return, to the real-life application.

However, in monitoring action of the safety coach, the willingness of the father to speak up alone, elicited a reaction in the mental model of the HCP. Therefore, promoting and applying a just safety culture into hospital organizations, where all parties involved feel welcome to speak up,

Table 32
Role Matrix for Case (d) for **mcfw** – Combination Function Weights.

mcfw - combination function weights	1			2			3		
	Allogistic	Monitor	Steponce	Allogistic	Monitor	Steponce	Allogistic	Monitor	Steponce
X1 type_mom	1								
X2 artificiality_birth	1								
X3 epidural_used	1								
X4 deliv_baby	1								
X5 baby_born	1								
X6 MPPD	1								
X7 PPPD	1								
X8 kid_devel	1								
X9 pre_birth_info	1								
X10 com_sup_hcp	1								
X11 fat_ask_sup_com	1								
X12 fat_rec_sup_com	1								
X13 post_info_com_par	1								
X14 refer_therapist	1								
X15 mental_sup	1								
X16 acknowl_fat	1								
X17 age	1								
X18 riskiness	1								
X19 dilation_mom	1								
X20 premature_birth	1								
X21 type_com	1								
X22 retention	1								
X23 engaged	1								
X24 stress	1								
X25 birth_dev	1								
X26 fear_level	1								
X27 desire_sup	1								
X28 ask_sup	1								
X29 birth_dev_detHCP	1								
X30 det_risk_levelHCP	1								
X31 encourage_momHCP	1								
X32 calm_dadHCP	1								
X33 irr_birth_weightHCP	1								
X34 det_underwHCP	1								
X35 refer_mom_therHCP	1								
X36 teach_dad_sup_momHCP	1								
X37 baby_bornHCP	1								
X38 type_comHCP	1								
X39 type_momHCP	1								
X40 pre_birth_infoHCP	1								
X41 birth_dev_detAIC	1								
X42 det_risk_levelAIC	1								
X43 encourage_momAIC	1								
X44 calm_dadAIC	1								
X45 irr_birth_weightAIC	1								
X46 det_underwAIC	1								
X47 refer_mom_therAIC	1								
X48 teach_dad_sup_momAIC	1								
X49 baby_bornAIC	1								
X50 type_comAIC	1								
X51 type_momAIC	1								
X52 pre_birth_infoAIC	1								
X53 Wbirth_dev_det_HCP, det_risk_level_HCP	1								
X54 Wdet_risk_level_HCP, encourage_mom_HCP	1								
X55 Wdet_risk_level_HCP, calm_dad_HCP	1								
X56 Wirr_birth_weight_HCP, det_underw_HCP	1								
X57 Wdet_underw_HCP, refer_mom_ther_HCP	1								
X58 Wdet_underw_HCP, teach_dad_sup_mom_HCP	1								
X59 Wbaby_born_HCP, type_com_HCP	1								
X60 Wtype_mom_HCP, pre_birth_info_HCP	1								
X61 Wbirth_dev_det_AIC, det_risk_level_AIC	1								
X62 Wdet_risk_level_AIC, encourage_mom_AIC	1								
X63 Wdet_risk_level_AIC, calm_dad_AIC	1								
X64 Wirr_birth_weight_AIC, det_underw_AIC	1								
X65 Wdet_underw_AIC, refer_mom_ther_AIC	1								
X66 Wdet_underw_AIC, teach_dad_sup_mom_AIC	1								
X67 Wbaby_born_AIC, type_com_AIC	1								
X68 Wtype_mom_AIC, pre_birth_info_AIC	1								
X69 Wpre_birth_info_AIC, pre_birth_info	1								
X70 Wcalm_dad_AIC, acknowl_fat	1								
X71 Wteach_dad_sup_mom_AIC, acknowl_fat	1								
X72 Wcalm_dad_AIC, com_sup_hcp	1								
X73 Wteach_dad_sup_mom_AIC, com_sup_hcp	1								
X74 Wcalm_dad_AIC, post_info_com_par	1								
X75 Wteach_dad_sup_mom_AIC, post_info_com_par	1								
X76 Wencourage_mom_AIC, post_info_com_par	1								
X77 Wrefer_mom_ther_AIC, refer_therapist	1								
X78 Wcalm_dad_AIC, mental_sup	1								
X79 Wteach_dad_sup_mom_AIC, mental_sup	1								
X80 Wencourage_mom_AIC, mental_sup	1								
X81 Wrefer_mom_ther_AIC, mental_sup	1								
X82 Wtype_com_AIC, type_com	1								
X83 monitor_pre_birth_info		1							
X84 monitor_acknowl_fat1			1						
X85 monitor_acknowl_fat2				1					
X86 monitor_com_sup_hcp1					1				
X87 monitor_com_sup_hcp2						1			
X88 monitor_post_info_com_par1							1		
X89 monitor_post_info_com_par2								1	
X90 monitor_post_info_com_par3									1
X91 monitor_refer_therapist									1
X92 monitor_mental_sup1									1
X93 monitor_mental_sup2									1
X94 monitor_mental_sup3									1
X95 monitor_mental_sup4									1
X96 monitor_type_com									1
X97 WW_AICW_HCP	1								
X98 con_feedback									1
X99 Wbirth_dev_det_E, det_risk_level_E	1								
X100 Wdet_risk_level_E, encourage_mom_E	1								
X101 Wdet_risk_level_E, calm_dad_E	1								
X102 Wirr_birth_weight_E, det_underw_E	1								
X103 Wdet_underw_E, refer_mom_ther_E	1								
X104 Wdet_underw_E, teach_dad_sup_mom_E	1								
X105 Wbaby_born_E, type_com_E	1								
X106 Wtype_mom_E, pre_birth_info_E	1								
X107 WW_EWAIC	1								
X108 con_feedforward									1

Table 33
Role Matrix for Case (d) for **mcfp** – Combination Function Parameters.

mcfp - combination function parameters	1 Allogistic		2 Monitor		3 Steponce	
	Steepness	Threshold	Threshold		Start Time	End Time
X1 type_mom	50	0.5				
X2 artificiality_birth	50	0.5				
X3 epidural_used	50	0.5				
X4 deliv_baby	5	0.5				
X5 baby_born	50	0.5				
X6 MPPD	5	0.3				
X7 PPPD	5	0.5				
X8 kid_devel	5	0.5				
X9 pre_birth_info	50	0.5				
X10 com_sup_hcp	0.5	8				
X11 fat_ask_sup_com	5	1				
X12 fat_rec_sup_com	5	0.5				
X13 post_info_com_par	5	4				
X14 refer_therapist	5	1				
X15 mental_sup	0.5	5				
X16 acknowl_fat	5	0.8				
X17 age	5	0.5				
X18 riskiness	5.0	0.5				
X19 dilation_mom	2.8	0				
X20 premature_birth	5	0.5				
X21 type_com	5	0.1				
X22 retention	5	0.3				
X23 engaged	5	0.5				
X24 stress	5	0.5				
X25 birth_dev	50	1				
X26 fear_level	5	1				
X27 desire_sup	5	0.3				
X28 ask_sup	5	0.2				
X29 birth_dev_detHCP	5	1				
X30 det_risk_levelHCP	5	0.5				
X31 encourage_momHCP	5	0.5				
X32 calm_dadHCP	50	0.7				
X33 irr_birth_weightHCP	5	1				
X34 det_underwHCP	5	0.5				
X35 refer_mom_therHCP	50	0.5				
X36 teach_dad_sup_momHCP	50	0.7				
X37 baby_bornHCP	5	0.5				
X38 type_comHCP	50	0.5				
X39 type_momHCP	5	0.5				
X40 pre_birth_infoHCP	50	0.5				
X41 birth_dev_detAIC	5	1				
X42 det_risk_levelAIC	5	0.5				
X43 encourage_momAIC	5	0.5				
X44 calm_dadAIC	50	0.7				
X45 irr_birth_weightAIC	5	1				
X46 det_underwAIC	5	0.5				
X47 refer_mom_therAIC	50	0.5				
X48 teach_dad_sup_momAIC	50	0.7				
X49 baby_bornAIC	5	0.5				
X50 type_comAIC	50	0.5				
X51 type_momAIC	5	0.5				
X52 pre_birth_infoAIC	50	0.5				
X53 WW_AICW_HCP, det_risk_level_HCP	5	0.5				
X54 WWdet_risk_level_HCP, encourage_mom_HCP	5	0.5				
X55 WWdet_risk_level_HCP, calm_dad_HCP	5	0.5				
X56 WWirr_birth_weight_HCP, det_underw_HCP	5	0.5				
X57 WWdet_underw_HCP, refer_mom_ther_HCP	5	0.5				
X58 WWdet_underw_HCP, teach_dad_sup_mom_HCP	5	0.5				
X59 WWbaby_born_HCP, type_com_HCP	5	0.5				
X60 WWtype_mom_HCP, pre_birth_info_HCP	5	0.5				
X61 WWbirth_dev_det_AIC, det_risk_level_AIC	5	0.5				
X62 WWdet_risk_level_AIC, encourage_mom_AIC	5	0.5				
X63 WWdet_risk_level_AIC, calm_dad_AIC	5	0.5				
X64 WWirr_birth_weight_AIC, det_underw_AIC	5	0.5				
X65 WWdet_underw_AIC, refer_mom_ther_AIC	5	0.5				
X66 WWdet_underw_AIC, teach_dad_sup_mom_AIC	5	0.5				
X67 WWbaby_born_AIC, type_com_AIC	5	0.5				
X68 WWtype_mom_AIC, pre_birth_info_AIC	5	0.5				
X69 WWpre_birth_info_AIC, pre_birth_info	5	0.5				
X70 WWcalm_dad_AIC, acknowl_fat	5	0.5				
X71 WWteach_dad_sup_mom_AIC, acknowl_fat	5	0.5				
X72 WWcalm_dad_AIC, com_sup_hcp	5	0.5				
X73 WWteach_dad_sup_mom_AIC, com_sup_hcp	5	0.5				
X74 WWcalm_dad_AIC, post_info_com_par	5	0.5				
X75 WWteach_dad_sup_mom_AIC, post_info_com_par	5	0.5				
X76 WWencourage_mom_AIC, post_info_com_par	5	0.5				
X77 WWrefer_mom_ther_AIC, refer_therapist	5	0.5				
X78 WWcalm_dad_AIC, mental_sup	5	0.5				
X79 WWteach_dad_sup_mom_AIC, mental_sup	5	0.5				
X80 WWencourage_mom_AIC, mental_sup	5	0.5				
X81 WWrefer_mom_ther_AIC, mental_sup	5	0.5				
X82 WWtype_com_AIC, type_com	5	0.5				
X83 monitor_pre_birth_info			0.6			
X84 monitor_acknowl_fat1				0.6		
X85 monitor_acknowl_fat2					0.6	
X86 monitor_com_sup_hcp1						0.6
X87 monitor_com_sup_hcp2						0.6
X88 monitor_post_info_com_par1						0.6
X89 monitor_post_info_com_par2						0.6
X90 monitor_post_info_com_par3						0.6
X91 monitor_refer_therapist						0.6
X92 monitor_mental_sup1						0.6
X93 monitor_mental_sup2						0.6
X94 monitor_mental_sup3						0.6
X95 monitor_mental_sup4						0.6
X96 monitor_type_com						0.6
X97 WW_AICW_HCP	30	0.5				
X98 con_feedback					40	80
X99 Wbirth_dev_det_E, det_risk_level_E	50	0.5				
X100 Wdet_risk_level_E, encourage_mom_E	50	0.5				
X101 Wdet_risk_level_E, calm_dad_E	50	0.5				
X102 Wirr_birth_weight_E, det_underw_E	50	0.5				
X103 Wdet_underw_E, refer_mom_ther_E	50	0.5				
X104 Wdet_underw_E, teach_dad_sup_mom_E	50	0.5				
X105 Wbaby_born_E, type_com_E	50	0.5				
X106 Wtype_mom_E, pre_birth_info_E	50	0.5				
X107 WW_EWAIC	50	0.5				
X108 con_feedforward	5	0.5				

has a lasting effect on the overall learning. This stems from the fact, that repeated and increasing exposure to the stimulus of the HCP being asked for support communication accelerates adaptation and can lead to long-term learning (Robinson et al., 2016). Similar to the safety culture, organizational learning allows for an ever-evolving growth of knowledge and creates stronger foundations for new and current HCPs in the medical field. This was reflected by using the notion of feedforward and feedback in the study. Applying the Virtual Safety Coach into the field and treating it as an individual reaps the benefits of using it to create a shared mental model based on the mental models existing within experts and, through this further education and improvement in medical practices. The combination of various mental models to create a shared

Table 34
Role Matrix for Case (d) for *iv* – Initial Values.

ms – speed factors		1
X ₁	type_mom	1
X ₂	artificiality_birth	1
X ₃	epidural_used	1
X ₄	deliv_baby	0.2
X ₅	baby_born	0.1
X ₆	MPPD	0.2
X ₇	PPPD	1
X ₈	kid_devel	1
X ₉	pre_birth_info	0.1
X ₁₀	com_sup_hcp	0.1
X ₁₁	fat_ask_sup_com	0.3
X ₁₂	fat_rec_sup_com	0.1
X ₁₃	post_info_com_par	0.1
X ₁₄	refer_therapist	0.3
X ₁₅	mental_sup	0.1
X ₁₆	acknowl_fat	0.1
X ₁₇	age	0
X ₁₈	riskiness	0.5
X ₁₉	dilation_mom	1
X ₂₀	premature_birth	0
X ₂₁	type_com	1
X ₂₂	retention	1
X ₂₃	engaged	1
X ₂₄	stress	0.4
X ₂₅	birth_dev	1
X ₂₆	fear_level	1
X ₂₇	desire_sup	1
X ₂₈	ask_sup	0.2
X ₂₉	birth_dev_det _{HCP}	1
X ₃₀	det_risk_level _{HCP}	1
X ₃₁	encourage_mom _{HCP}	0.1
X ₃₂	calm_dad _{HCP}	0.1
X ₃₃	irr_birth_weight _{HCP}	1
X ₃₄	det_underw _{HCP}	1
X ₃₅	refer_mom_ther _{HCP}	0.3
X ₃₆	teach_dad_sup_mom _{HCP}	0.1
X ₃₇	baby_born _{HCP}	1
X ₃₈	type_com _{HCP}	1
X ₃₉	type_mom _{HCP}	1
X ₄₀	pre_birth_info _{HCP}	1
X ₄₁	birth_dev_det _{AIC}	0.33
X ₄₂	det_risk_level _{AIC}	0.33
X ₄₃	encourage_mom _{AIC}	0.033
X ₄₄	calm_dad _{AIC}	0.033
X ₄₅	irr_birth_weight _{AIC}	0.33
X ₄₆	det_underw _{AIC}	0.33
X ₄₇	refer_mom_ther _{AIC}	0.1
X ₄₈	teach_dad_sup_mom _{AIC}	0.033
X ₄₉	baby_born _{AIC}	0.33
X ₅₀	type_com _{AIC}	0.33
X ₅₁	type_mom _{AIC}	0.33
X ₅₂	pre_birth_info _{AIC}	0.33
X ₅₃	W _{birth_dev_det_HCP}	1
X ₅₄	W _{det_risk_level_HCP}	1
X ₅₅	W _{det_risk_level_HCP}	1
X ₅₆	W _{irr_birth_weight_HCP}	1
X ₅₇	W _{det_underw_HCP}	1
X ₅₈	W _{det_underw_HCP}	1
X ₅₉	W _{baby_born_HCP}	1
X ₆₀	W _{type_mom_HCP}	1
X ₆₁	W _{birth_dev_det_AIC}	0.5
X ₆₂	W _{det_risk_level_AIC}	0.5
X ₆₃	W _{det_risk_level_AIC}	0.5
X ₆₄	W _{irr_birth_weight_AIC}	0.5
X ₆₅	W _{det_underw_AIC}	0.5
X ₆₆	W _{det_underw_AIC}	0.5
X ₆₇	W _{baby_born_AIC}	0.5
X ₆₈	W _{type_mom_AIC}	0.5
X ₆₉	W _{pre_birth_info_AIC}	0.5
X ₇₀	W _{calm_dad_AIC}	0.5
X ₇₁	W _{teach_dad_sup_mom_AIC}	0.5
X ₇₂	W _{calm_dad_AIC}	0.5
X ₇₃	W _{teach_dad_sup_mom_AIC}	0.5
X ₇₄	W _{calm_dad_AIC}	0.5
X ₇₅	W _{teach_dad_sup_mom_AIC}	0.5
X ₇₆	W _{encourage_mom_AIC}	0.5
X ₇₇	W _{refer_mom_ther_AIC}	0.5
X ₇₈	W _{calm_dad_AIC}	0.5
X ₇₉	W _{teach_dad_sup_mom_AIC}	0.5
X ₈₀	W _{encourage_mom_AIC}	0.5
X ₈₁	W _{refer_mom_ther_AIC}	0.5
X ₈₂	W _{type_com_AIC}	0.5
X ₈₃	monitor_pre_birth_info	0.5
X ₈₄	monitor_acknowl_fat ₁	0.5
X ₈₅	monitor_acknowl_fat ₂	0.5
X ₈₆	monitor_com_sup_hcp ₁	0.5
X ₈₇	monitor_com_sup_hcp ₂	0.5
X ₈₈	monitor_post_info_com_par ₁	0.5
X ₈₉	monitor_post_info_com_par ₂	0.5
X ₉₀	monitor_post_info_com_par ₃	0.5
X ₉₁	monitor_refer_therapist	0.5
X ₉₂	monitor_mental_sup ₁	0.5
X ₉₃	monitor_mental_sup ₂	0.5
X ₉₄	monitor_mental_sup ₃	0.5
X ₉₅	monitor_mental_sup ₄	0.5
X ₉₆	monitor_type_com	0.5
X ₉₇	W _{W_AIC_W_HCP}	1
X ₉₈	con_feedback	0.05
X ₉₉	W _{birth_dev_det_E}	0
X ₁₀₀	W _{det_risk_level_E}	0
X ₁₀₁	W _{det_risk_level_E}	0
X ₁₀₂	W _{irr_birth_weight_E}	0
X ₁₀₃	W _{det_underw_E}	0
X ₁₀₄	W _{det_underw_E}	0
X ₁₀₅	W _{baby_born_E}	0
X ₁₀₆	W _{type_mom_E}	0
X ₁₀₇	W _{W_E_W_AIC}	1.5
X ₁₀₈	con_feedforward	0

Table 35
Role Matrix for Case (d) for *ms* – Speed Factors.

iv – Initial values		1
X ₁	type_mom	0
X ₂	artificiality_birth	0
X ₃	epidural_used	0
X ₄	deliv_baby	0
X ₅	baby_born	0
X ₆	MPPD	0.13
X ₇	PPPD	0
X ₈	kid_devel	0
X ₉	pre_birth_info	0
X ₁₀	com_sup_hcp	0
X ₁₁	fat_ask_sup_com	0
X ₁₂	fat_rec_sup_com	0
X ₁₃	post_info_com_par	0
X ₁₄	refer_therapist	0
X ₁₅	mental_sup	0
X ₁₆	acknowl_fat	1
X ₁₇	age	1
X ₁₈	riskiness	0
X ₁₉	dilation_mom	0.2
X ₂₀	premature_birth	1
X ₂₁	type_com	0
X ₂₂	retention	0
X ₂₃	engaged	0
X ₂₄	stress	0
X ₂₅	birth_dev	0
X ₂₆	fear_level	0
X ₂₇	desire_sup	0
X ₂₈	ask_sup	0
X ₂₉	birth_dev_det _{HCP}	0
X ₃₀	det_risk_level _{HCP}	0
X ₃₁	encourage_mom _{HCP}	0
X ₃₂	calm_dad _{HCP}	0
X ₃₃	irr_birth_weight _{HCP}	0
X ₃₄	det_underw _{HCP}	0
X ₃₅	refer_mom_ther _{HCP}	0
X ₃₆	teach_dad_sup_mom _{HCP}	0
X ₃₇	baby_born _{HCP}	0
X ₃₈	type_com _{HCP}	0
X ₃₉	type_mom _{HCP}	0
X ₄₀	pre_birth_info _{HCP}	0
X ₄₁	birth_dev_det _{AIC}	0
X ₄₂	det_risk_level _{AIC}	0
X ₄₃	encourage_mom _{AIC}	0
X ₄₄	calm_dad _{AIC}	0
X ₄₅	irr_birth_weight _{AIC}	0
X ₄₆	det_underw _{AIC}	0
X ₄₇	refer_mom_ther _{AIC}	0
X ₄₈	teach_dad_sup_mom _{AIC}	0
X ₄₉	baby_born _{AIC}	0
X ₅₀	type_com _{AIC}	0
X ₅₁	type_mom _{AIC}	0
X ₅₂	pre_birth_info _{AIC}	0
X ₅₃	W _{birth_dev_det_HCP}	0
X ₅₄	W _{det_risk_level_HCP}	0
X ₅₅	W _{det_risk_level_HCP}	0
X ₅₆	W _{irr_birth_weight_HCP}	0
X ₅₇	W _{det_underw_HCP}	0
X ₅₈	W _{det_underw_HCP}	0
X ₅₉	W _{baby_born_HCP}	0
X ₆₀	W _{type_mom_HCP}	0
X ₆₁	W _{birth_dev_det_AIC}	0
X ₆₂	W _{det_risk_level_AIC}	0
X ₆₃	W _{det_risk_level_AIC}	0
X ₆₄	W _{irr_birth_weight_AIC}	0
X ₆₅	W _{det_underw_AIC}	0
X ₆₆	W _{det_underw_AIC}	0
X ₆₇	W _{baby_born_AIC}	0
X ₆₈	W _{type_mom_AIC}	0
X ₆₉	W _{pre_birth_info_AIC}	0
X ₇₀	W _{calm_dad_AIC}	0
X ₇₁	W _{teach_dad_sup_mom_AIC}	0
X ₇₂	W _{calm_dad_AIC}	0
X ₇₃	W _{teach_dad_sup_mom_AIC}	0
X ₇₄	W _{calm_dad_AIC}	0
X ₇₅	W _{teach_dad_sup_mom_AIC}	0
X ₇₆	W _{encourage_mom_AIC}	0
X ₇₇	W _{refer_mom_ther_AIC}	0
X ₇₈	W _{calm_dad_AIC}	0
X ₇₉	W _{teach_dad_sup_mom_AIC}	0
X ₈₀	W _{encourage_mom_AIC}	0
X ₈₁	W _{refer_mom_ther_AIC}	0
X ₈₂	W _{type_com_AIC}	0
X ₈₃	monitor_pre_birth_info	0
X ₈₄	monitor_acknowl_fat ₁	0
X ₈₅	monitor_acknowl_fat ₂	0
X ₈₆	monitor_com_sup_hcp ₁	0
X ₈₇	monitor_com_sup_hcp ₂	0
X ₈₈	monitor_post_info_com_par ₁	0
X ₈₉	monitor_post_info_com_par ₂	0
X ₉₀	monitor_post_info_com_par ₃	0
X ₉₁	monitor_refer_therapist	0
X ₉₂	monitor_mental_sup ₁	0
X ₉₃	monitor_mental_sup ₂	0
X ₉₄	monitor_mental_sup ₃	0
X ₉₅	monitor_mental_sup ₄	0
X ₉₆	monitor_type_com	0
X ₉₇	W _{W_AIC_W_HCP}	0
X ₉₈	con_feedback	1
X ₉₉	W _{birth_dev_det_E}	1
X ₁₀₀	W _{det_risk_level_E}	1
X ₁₀₁	W _{det_risk_level_E}	1
X ₁₀₂	W _{irr_birth_weight_E}	1
X ₁₀₃	W _{det_underw_E}	1
X ₁₀₄	W _{det_underw_E}	1
X ₁₀₅	W _{baby_born_E}	1
X ₁₀₆	W _{type_mom_E}	1
X ₁₀₇	W _{W_E_W_AIC}	0
X ₁₀₈	con_feedforward	1

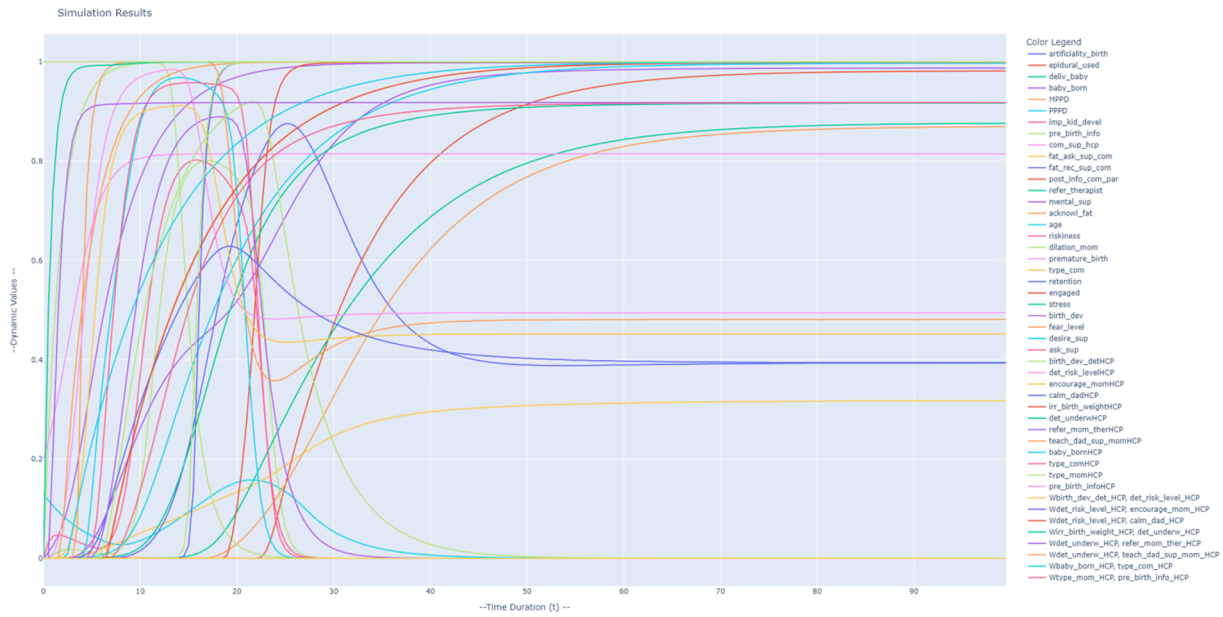


Fig. B1. Adequate Communication.

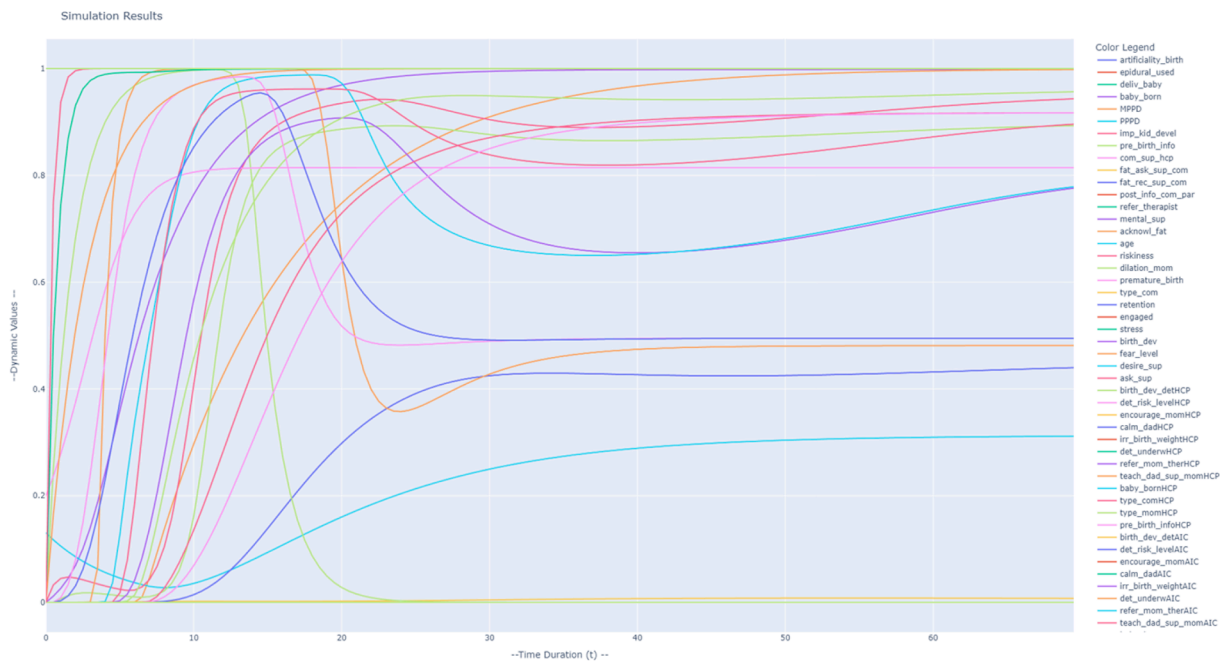


Fig. B2. Ineffective Communication.

mental model, results in optimal current knowledge.

Lastly, the strong influence of proper communication depicted in the models is not limited to the potential they depict of communication within the childbirth process. The perspective can be extended to other medical practices, which increasingly facilitates a safety culture, where open communication lies at the center.

9. Limitations and further work

This research has potential limitations. Given the nature of the research focusing mainly on actions that can be taken to reduce paternal postpartum depression, overcompensation may be a factor. Specifically, the bias of centering the model around necessary communication for father, may have restricted the realistic scope of the communication

actions for the mother while assigning too much emphasis on those actions for the father only.

During modeling, various aspects were not discussed, for instance, how communication may influence the stress or engagement levels, while considering all the actors. Similarly, how communication can play its role in overcoming the related fears is not addressed. During simulation we only presented for a certain time duration, but, it would be interesting to investigate the impacts of communication for a longer time, i.e., when parents leave the hospital. Moreover, how equilibrium for certain states (e.g., stress or asking for support), may influence states of postpartum depression for longer time is not presented in this study.

The available literature on risk factors and intervention methods to combat paternal postpartum depression is not very extensive. Some states selected for the model are based on desires that fathers have

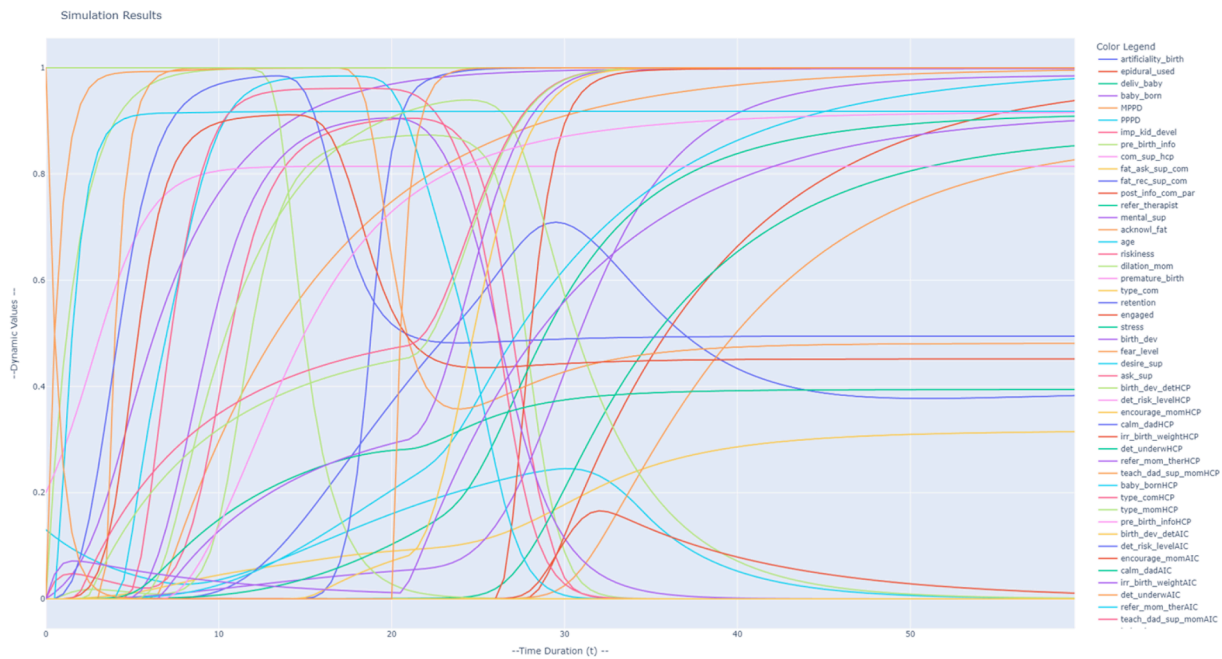


Fig. B3. Role of Virtual Coach.

expressed without their effectiveness being studied scientifically and determined to be successful. In future, we aim to collect more multi-disciplinary information, which may help researchers to provide some analytical grounds to study the effectiveness of the modeled states. A possible improvement on this, could be conducting a study based on the Edinburgh Postpartum Depressive Scale (EPDS) and applying the values to the model created. The model is created in such a way, that does not depend on a precise definition, and it is not limited to one notion. This allows for a large application scope within the AI Coach Project.

Also, we aim to extend our model, in terms of responses of healthcare practitioners toward father and toward the virtual safety coach. In the future, we also would like to study multiple factors (e.g., culture, family structure or affiliations) regarding communication during the childbirth process (Dunkel Schetter et al., 2016; Goodman, 2004). Moreover, an extension including the support during the prepartum period, would add to the effectiveness of communication in reducing the risk of postpartum depression. This stems from the fact, that developing depression is not limited to after giving birth. In addition, a relevant point that was not discussed in the scope of this paper, is it could help parents who previously suffer from depressive episodes.

We also aim to extend the monitoring. Some world states had incoming connections from multiple mental model end states. In the models, this may have resulted in only one of these end states being activated, as one may be sufficient to pass the chosen threshold determining activation, which allows for some but not the maximum possible support.

Learning is a time-consuming task not only for individuals but also for the HCP and AIC. Therefore, in a real-world setting, this would allow for emphasis to be applied on having certain mental process over others. For example, having only post-birth communication may be as effective in decreasing the risk of PPPD as all the other states combined. This would allow for an adequate learning pace for practitioners in the field without overwhelming them regarding vast additional knowledge. Similarly, this could be applied to the AIC teaching the HCP in steps (based on importance), rather than all at once. By doing so, the level of retention of the information could be higher. Moreover, studying the aspect of trust towards AIC can also add a value while discussing the levels of communication.

In this study, the Coach (AIC) is modeled to be activated without a

permission from the actors on the floor. To implement it with the current mental model into a healthcare setting, one would have to ensure high specificity and high sensitivity of the AIC. This would avoid eliciting negative emotions in the father with a false positive of, for example, a deviation occurring. A trigger initiated from the HCP could activate the Coach would be beneficial.

In the real-world, the virtual AI Coach can be considered a facility to assist healthcare practitioners. Therefore, the coach could have a different model (i.e., not similar to HCP). In this study, the virtual AI Coach is trying to monitor if communication is needed. That might be possible by analyzing the conversations or through some sensors. However, then the coach should be empathetic enough to provide support to the father. Moreover, without a trigger, it would be still questionable if the coach receives enough input to decide on whether to communicate or not in terms of accuracy and time. Lastly, how communication provided by Virtual Safety Coach will be evaluated by all the actors, is also to be considered as a future work for this research study.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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This research is part of the SAFECOach Project, which aims to create an AI based coach to serve hospital organization. The main aim of this coach is to assist healthcare practitioner while considering mental models and shared mental models for its implementation.

Appendix A. Role matrices for all model variants

Role matrices are the numerical representations of the simulations.

They provide full information about the network characteristics of the model variants. Below all role matrices for the models are visible, with each state having its own row, on which each incoming connections, as well as their impact, is specified. Moreover, they are color coordinated based on the level that the states lie on. See below.

A1 Healthcare Practitioner communicates with Father

For full specification see:

Tables 6, 7, 8, 9, 10 and 11

A2 Lack of Communication with Father

For full specification see:

Tables 12, 13, 14, 15, 16 and 17

A3 Role of Virtual Safety Coach

For full specification see:

Tables 18, 19, 20, 21, 22 and 23

A4 Dynamic Monitoring of Virtual Safety Coach

For full specification see:

Tables 24, 25, 26, 27, 28 and 29

A5 Organizational Learning and its Influence

For full specification see:

Table 30, 31, 32, 33, 34 and 35

Appendix B. Simulation results in the software designed for the Virtual Coach

As the coach is implemented by the Python environment, the Matlab-generated simulation results have been reproduced; see examples below. They are exactly similar to the simulations by the Matlab software, which provides additional verification.

B1 Adequate Communication

See Fig. B1.

B2 Ineffective Communication

See Fig. B2.

B3 Role of Virtual Coach

See Fig. B3.

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