**Healthy Child is a Happy Child: Designing an AI-based Coach for Psychological Safety and Mental Wellbeing**

**Abstract:** Ensuring patient healthcare and safety necessitates effective teamwork and collaboration, rooted in the concept of shared mental understanding or shared mental models. Different personal and professional factors among team members may influence patient diagnosis and decision-making, which can have long-lasting impact(s) on the patient (mental) wellbeing. Our work introduces the innovative concept of an Artificially Intelligent (AI) Coach, designed to enhance the shared understanding and communication among team members, to reduce the error expectancy in different medical fields (e.g., neonatology). This virtual assistant aims to cater the error related causes or factors for monitoring, so a related support can be provided to minimize these errors. The coach encompasses computational logic regarding user tasks and mental models, offering monitoring and communication through a graphical user interface. As a result, this coach can play role in better psychological safety of all the stakeholders like patients, medical practitioner or a neonate. During evaluation, our developer study indicates that participants, although having no prior knowledge of complex systems, were able to successfully design the computational models which can be designed for user-coach interaction. Furthermore, it was observed that user-coach interaction could be helpful in monitoring different causal factors and its related effects, i.e., it is effective in terms of achieving its goal.

# Introduction

Healthcare professionals work in a high-risk landscapes (like neonatology) where a minor medical error or unsafe incidents may lead to substantial hazards to patient safety (Panagos & Pearlman, 2017; Stavroudis et al., 2008). This challenge is often pronounced in intensive care units or operation theatres where this probability is quite elevated. Prevention of medical errors is widely acknowledged, given their potential repercussions on patient safety and mental wellbeing (Björkstén et al., 2016; Petrovic et al., 2022; Stavroudis et al., 2008). This requires cohesive teamwork among healthcare professionals emphasizing mutual understanding for diagnosis, the condition of patient and the plan of action (Panagos & Pearlman, 2017). Artificial Intelligence has emerged as a transformative force in the domain of healthcare, and can play an important role in improving healthcare.

AI has not only revolutionized the disease diagnostics (Ali et al., 2023), but also helped to improve mental and psychological health of an individual by different virtual assistants (Tsiouris et al., 2020). These assistants are goal oriented and usually designed for self-monitoring and self-rehabilitation of an individual (Tsiouris et al., 2020). Real-time monitoring and text or voice based assistance is offered to an individual for healthier life style (Fitzpatrick et al., 2017; Weizenbaum, 1983). However, none of the designed assistants were found to ensure safety and to avoid medical errors in neonatology, which may have life-lasting influence (Tsiouris et al., 2020). Also mostly AI-based technologies in healthcare relied on their performance and ignored the human factors (Choudhury, 2022), which are vital to develop complex societal solutions (Herrmann & Pfeiffer, 2023).

In this study, we propose an artificially intelligent assistant - AI Coach, which aims to interact with medical teams to ensure patient safety in the domain of neonatology. This coach is preliminary designed to work together with the medical team, who can intervene during child birth if safety of any of the stakeholders is desired. The stakeholders may include doctors, residents, neonate, and family of neonate. This innovative coach will be designed using living labs methodology in which all stakeholders collaborate to design a prototype addressing the complex phenomena in neonatology (Almirall et al., 2012; Leminen et al., 2012). Therefore, in this study, we address a) the framework design of AI Coach, b) how a user will interact with the coach, and c) the test results of generated after the pilot study.

The remainder of this paper is organized as follows. Section 2 explains the related work of AI Coach, while Section 3 explains the requirements and methodologies of the coach, while Section 4 presents the related interface design. Section 5 present the results for the coach evaluations, and the paper concludes in Section 7, after mentioning the limitations of the study in Section 6.

# Related work

This section lays the foundation for our study by exploring the interplay between neonatal care, medical errors, innovative methodologies, and virtual assistance in healthcare. First, we will explain the neonatal care and its inherent challenges, notably the medical errors associated to it. Secondly, we will explain the methodologies used for innovation. Lastly, we will explain the virtual assistance available in healthcare to improve healthcare.

## Medical Errors during Childbirth

Childbirth is a team work, in which different stakeholders work together as a team. These stakeholders may involve mother, family of a neonate, doctors and residents working on the floor, and the hospital management. The experience from all stakeholders, the ‘now’ moment of baby birth, and the conscious decisions made for the neonate are of prime importance, as they ensure the care and safety of an infant (Stavroudis et al., 2008), and the involved stakeholders (Profit et al., 2017). This may have short and long term impacts on the lives of individual stakeholders (Björkstén et al., 2016; Stavroudis et al., 2008).

Many departments are involved to ensure quality care during the child birth. For instance, maternity and gynae department who deal with pregnancy, labor, delivery and postnatal period (Petrovic et al., 2022), or neonatal care unity to ensure the safety of neonate (Profit et al., 2017). According to Profit et al. survey, few cases were reported with poor teamwork (Profit et al., 2017), resulting different medical errors (Stavroudis et al., 2008). This may have long-lasting impacts on a baby, and in severe cases, it might lead to fatality (Stavroudis et al., 2008). Therefore, on one side, it is essential to determine the state of the error to establish treatment plan is to be discussed if needed. While on the other side, preventive measures should be taken into account to ensure safety of all the stakeholders in healthcare (Björkstén et al., 2016; Petrovic et al., 2022; Stavroudis et al., 2008).

Stavroudis et al. also emphasize that a significant number of such errors are preventable by implementing a well-devised plan can mitigate the impact of these errors. In this context, consistent monitoring is regarded as playing a crucial role. Medical errors are not deliberately made, rather there are different factors mentioned by Björkstén et al. which may lead to a medical error. Forgetfulness and lack of attentiveness (399 cases among 772) was found to be the main cause for such inadvertent mistakes (See Table 3: (Björkstén et al., 2016)). Moreover, different related behaviors (e.g., speaking up behavior), can help to ensure the psychological safety of the individuals (Newman et al., 2017). Research shows that ‘patient safety’ and ‘just culture’ requires commitment and participation of all stakeholders including patient, healthcare team and the hospital management (Stavroudis et al., 2008).

AI has revolutionized the way we approach healthcare, many analytical tools are being used by healthcare professionals to provide healthcare facilities to their patients. However, mostly tools can only help to detect the errors(or deviations) through data analysis. So, they might miss the ‘now moment’ that should be also considered for a conscious choice (Stavroudis et al., 2008). In the following sections, we will discuss state of the art methodologies to design such systems that be helpful to understand and analyze the ‘now moment’, and analyzing how such systems can be helpful to overcome the medical errors in neonatology.

## Methodologies for Innovation in Healthcare

Innovative healthcare solutions use certain methodologies for diagnostics and patient healthcare. Few well-known examples are user-centered design, in which users are engaged to design and evaluate a (user-intuitive) technology (Giacomin, 2014); or agile development, in which iterative and incremental development is focused among different team members (Manifesto, 2001). These methodologies are merged with clinical trials and studies to ensure the safety and efficacy of new technologies (Stepke, 2012).

Furthermore, several research-based methodologies are also addressed where research and technical innovations are integrated to provide solutions. These methodologies ensure that technical advancements are developed in tandem with the insights of researchers to produce effective solutions. For example, design science research (DSR) where technology-based solutions (or other artifacts) are created to solve some specific problem and thus evaluated in a controlled environment (Hevner et al., 2008). Another example is ethnographic research, where user behavior and needs are considered to design the relevant technological solution (Hammersley & Atkinson, 2007). Co-Creation allows different stakeholders to ideate and design an artifact (Sanders & Stappers, 2008). Living labs is a methodology closer to co-creation, where end-users and researchers cooperate to prototype and validate solutions in real-life contexts (Almirall et al., 2012; Leminen et al., 2012). As they rely on designing and validating co-created concepts, this methodology offers to test innovations (while analyzing users’ behaviors), which can address the context of ‘now moment’ in a much better way.

## Virtual Assistance in Healthcare

From many years, pressure on healthcare have been increasing due to reduced availability or accessibility of healthcare professionals. To address this challenge, intelligent conversational agents or virtual assistants were developed. For example, Eliza was the first conversational agent ever designed (Weizenbaum, 1983), or Woebot, who helped as therapy chatbots (Fitzpatrick et al., 2017), and proven themselves for behavioral change. Ever since, there is a huge trend on using them with healthcare and improving their capabilities. Therefore, not only they focus on human understanding (through natural language processing), but also aim to understand the context of conversation through machine learning and artificial intelligence.

Unlike conventional agents virtual coaching system are known for healthcare interventions. They not only offer an opportunity for mental wellbeing but it also allows the individuals to self-track and e-coach for their goals (Tsiouris et al., 2020). A system-human interaction can be possible by a conscious choice of users (by clicking certain option) or by monitoring sensors. For instance, in home coaches data maybe gathered by different sensory devices (e.g., Fitbit, Samsung, Polar, etc.), or in hospital where data maybe gathered by Virtual Reality (e.g., Microsoft Kinect, Nintendo, sensing gloves) or by medical equipment (e.g., ECG, vitals monitor, or accelerometers, etc.) (Tsiouris et al., 2020). Serious gaming has been used to strengthen the learning methodology for the childbirth in neonatology (Bardelli et al., 2022; Hu et al., 2021). Similarly, root cause analysis can help to identify the errors and improve the action plans (Panagos & Pearlman, 2017). Treatment analysis and drug interactions have already been studied in clinical care (Panagos & Pearlman, 2017), however, the role of virtual assistants in neonatology is not studied so far (Tsiouris et al., 2020).

Moreover, conversational agents are designed to provide a textual interface to interact with its users. This which may need some time and attention to build the rapport and to achieve the goals, as it intends to understand the natural language. Similarly, Tsiouris et al. mentioned that different virtual coaches were designed to interact with a single individual (See Table 1 in (Tsiouris et al., 2020)), to overcome phobias and cognitive impairments (See Table 2 in (Tsiouris et al., 2020)). Also, in literature many related different corpora have often been also explored to provide an improved human computer interaction (Serban et al., 2018). These interactions can be in terms of text (Serban et al., 2018) or audio (Henderson & Jurčíček, 2012). Such agents are user-centered which are designed to fulfil certain user requirement and goals. However, in our knowledge, there is no virtual coach or assistant designed to avoid possible medical errors in neonatology, in particular to a team-based interactions in neonatology (See Section 2.1. and 2.2). Following section discusses the requirements and methodologies used in the study.

# Requirements and Methodologies of AI Coach

This section presents the whole process that lays the foundation for the development of AI Coach. Initially, we will discuss the design requirements for AI Coach, then its framework design, and then we present how coach interacts with its stakeholders.

## Design Requirements

Identifying the design requirements is a key to make a successful product design. This may include understanding the user requirements or analyzing existing systems in term of use-cases (Rosson & Carroll, 2002). Following are the fundamental concepts which were considered while designing and implementing AI Coach. The aim of AI Coach is to provide assistance during childbirth while acting as a team member. For Design following approaches were considered.

### Formulation of Design Outline

Living Labs thrives on engagement and collaboration to align the system design with the real-world requirements (Almirall et al., 2012; Leminen et al., 2012). Interviewing and iterative discussions can be a useful tool used for system design, as they allow a direct interaction with the involved stakeholders. Also, It helps to gain a deeper understanding of the needs and expectations of the users (Almirall et al., 2012).

The interviews were conducted in a (semi-)structured way, where narration of critical events (like child birth) was considered to extract scenarios (See (Doornkamp et al., 2022; Weigl et al., 2022; Xu et al., 2022)), and to formulate the use-cases (Rosson & Carroll, 2002) that were used as the basis of the design. It is to be noted, that the focus of these interview sessions was a) what are the possible situations that can lead to such medical errors (termed as scenarios), and b) how can we design a system that can ensure proper execution of protocol. The aim was to avoid the errors that can be caused by forgetfulness or inability to perform an action (Björkstén et al., 2016).

### Attachment Theory and Human Emotions

According to attachment theory, the human coach interaction should be based on different (human-based) factors. For instance, virtual system should already be aware of the desires and goals of its user(s). Similarly, to make certain decisions, the system should be aware of the human emotions and the related environment. Over the period of time, such a system should learn to be ‘like-minded’, so that a relationship can be maintained with the user (Roelofsma, 2013).

While discussing about Neonatology, this theory of secure attachment can be extended to the emotional bonds among the team members, where team members are comfortable with interdependence and trusting each other's abilities, leading to effective communication, cooperation, and problem-solving. To have this harmony and just culture, all of the team members should have adequate ‘shared mental models’, to observe and communicate each other’s actions.

### Shared Mental Models and Human Behaviors

Neonatology department has necessary and sufficient content complexity, where all team members interact as a team during the whole procedure. Due to multiple factors involved in its processes, this collaboration could result in medical errors (See Section 2.1). To ensure patient safety, all the team members must have a shared understanding of diagnosis to develop any mutual plan of action. In other words, they should have ‘shared mental models’ (SMM) to communicate, deicide and follow a certain plan of action. They explain how individuals in a group develop their specialized knowledge (through mental models) and rely on each other’s expertise to interact and learn to share and enhance their mental and cognitive abilities, thus enhancing the team coordination and performance (Mathieu et al., 2000).

Computational logic is well known in Artificial Intelligence as an attempt to program to reflect human intelligence (Kowalski, 2011). Computational models allows to infer the cognitive states (or levels) of an individual, which can predict user(s) or team(s) behaviors (Treur, 2020; van Ments et al., 2021). Van Ments et al, have explained how doctor and nurse can interact together as a team to perform the related medical task (i.e., tracheal intubation of a patient) through shared mental models. Similar behaviors are also addressed in other studies (Doornkamp et al., 2022; Weigl et al., 2022; Xu et al., 2022). These behaviors can be studied and facilitated by trivial secondary tasks like pressing a button, or answering in a specific way, e.g., through questionnaires (Clark & Maguire, 2020) which can help in better understanding of human behaviors, interactions, and tendencies, which is usually ignored while AI-based systems are considered (Choudhury, 2022).

Shared mental models allows effective team collaboration, which can improve decision-making regarding a task. Also, when combined with Living Labs, it emphasizes the importance of collaborative understanding among the participants’ behaviors and preferences. This can also help to design a supportive system. So, our goal was to design an interactive virtual assistant who could interact as a ‘virtual team member’, i.e., AI Coach, who can help to avoid medical errors due to forgetfulness (Björkstén et al., 2016). This may represent a visualization tool that can act as a teamwork facilitator (Redlich et al., 2017). That is, it can address different reasoning mechanisms (e.g., human factors) to interact with the users in relevance with the medical protocol, and its execution.

## Framework Design of AI Coach

In IT, a framework refers to a structure that consist of many phases or components working together to act as a foundation for the software design and implementation. Here, we address a novel Human-AI based framework to support medical teams in different healthcare settings. The designed is based on a **M**odel**-V**iew**-C**ontroller based architecture. It has ability to offer assistance to a variety of end users, while incorporating their behaviors, the culture(s) of an organization (like medical healthcare) or its organizational hierarchy. The framework of system has two components, i.e., AI Coach and the stakeholders of a system (See Figure XXX).

A diagram of a server

Description automatically generated

**Figure** **XXX**: Block Diagram of AI Coach system

### Stakeholders

AI Coach system is a software application that aims to interact and serve two type of stakeholders in particular, i.e., end users and experts.

**End users** are the stake holders who interact directly with the system to achieve their goals, learn and have an pleasant experience via usage of technology. AI Coach is designed to serve neonatology in Erasmus MC, for example during baby delivery/care, or intensive care unit. Therefore, it not only has the capability to adhere proper neonatal protocol execution but it can also foster emotional and social wellbeing of the people who are actually on the floor, e.g., patient, their family, or the medical team working together in neonatal care. Understanding the time constraint the coach is designed to fulfil its objective through minimum user engagement. These users are further discussed in Section 3.2.

While **experts** are the stakeholders which work in different domains and interact to provide support in a meaningful activity. They can from different domains like psychology, artificial intelligence, health and safety sciences, who interacted with each other to ensure patient safety and just culture. The main focus of experts is to brainstorm and develop the algorithm of the coach. As a result, the behavior of AI Coach behavior is adaptive by nature. This is accomplished by developing (shared) mental models (van Ments et al., 2021). Further details can be found in Section 3.2.

Current role of AI Coach is to serve neonatology department in Erasmus MC, Rotterdam. So, it can provide support for neonatal care and wellbeing of patient(s) and medical team, where the possible end users are; baby, patient, their family and the staff on the floor.

### AI Coach System

AI Coach is an AI based virtual assistant whose design is inspired by the principles of sociotechnical systems (i.e., with the focus on social systems and technical systems in healthcare). Therefore, primarily it is human centered and have a social impact on its users. Still, it is quite flexible to address any changes in the social landscape over the time (within an organization). Therefore, all the stakeholders are considered for human interaction with the AI Coach.

AI Coach is designed with a deep understanding of needs of the medical team who is working on the floor in the neonatology department (See Section 3.1.1). This can address different social situations/aspects, capabilities and behaviors in different situations like child birth. For instance, if a baby is not breathing, AI Coach will assist to achieve the particular goal of helping the baby to breath (Xu et al., 2022). Similarly, if a resident wants to speak up during any medical process the coach will help him/her to speak up in a certain situation (Doornkamp et al., 2022). Therefore, end user interaction is adaptive which follows through the series of choices which may have been (un)consciously made by the end users.

Similarly, the design of AI Coach is quite flexible, which means that an organization (like Erasmus MC) can design the usage of AI Coach as per needs (via their expert users). This may address changes in environment, technology or organization, which may evolve over time. In other words, the stakeholders can become an architect of AI Coach. As a result, this may not only effect the assistance process of the coach, but it may also affect the roles of the involved stakeholders and the coach itself. In the section below, we describe the components and functionality of AI Coach.

#### Components of AI Coach System

In this section, we will describe technical aspect of AI Coach system, i.e., how it was designed to offer functionality to its end users. AI Coach is a server based virtual assistant, that is designed based on requirements were formulated through the outlines from the staff of neonatology department in Erasmus MC. Few important considerations were taken into account during the design time, i.e.,:

1. Job is physically demanding, which may lead to forgetfulness, stress or influence on the personal skills of a resident or a doctor
2. Job has a time constraint, they have to respond in a quick and timely manner
3. Baby birth is a team work, and safe execution of protocol ensures no errors in the procedure
4. Different situations may lead to protocol deviations (medical errors) which may lead to poor mental wellbeing, and sufficient support is desired in this.

Key stakeholders were identified and invited to take part in the developmental process of AI Coach for neonatal care. Different stakeholder groups were identified through scoping interviews, therefore, human-computer interaction mainly involved two types of actors, i.e., the residents or the doctors. AI Coach had to considered the rest of the stakeholders for assistance, i.e., the neonate, mother, father (or a family member). To offer a deeper analysis, we undertook formal stakeholder analysis, where individual behaviors and related support was modeled along with relevance to the organization and available resources.

Interviews reflected that, shared contribution of all stakeholders ensure better performance and improved safety in neonatology department. We also considered different kind of data (e.g., protocols, user information) to dive into the possible situations that may cause poor adherence of protocol. As a first step, the protocols were investigated along with the interviews, to see the possible deviations in the healthcare protocol of neonatal care (Madar, Roehr, Ainsworth, Ersda, et al., 2021), which helped us to extract use-cases. *Use-case* is a term that describes the functional requirements and explain how stakeholders can interact with the system. Table usecases mention few examples in which each use-case is addressed through possible scenarios. i.e., a success scenario and when AI Coach predicts that support is desired or intervention is necessary.

Table usecases: Scenarios (use cases) in neonatal care

|  |  |  |  |
| --- | --- | --- | --- |
| **Use-case (step)** | **Success Scenario** | **Possible Intervention desired** | |
| **When** | **Possible Causes of Failure** |
| Access neonate breathing and tone | Neonate is breathing adequately and tone is good | Baby is not breathing or needs ventilation support | Mask is not appropriate  Sufficient FiO2 levels are not provided |
| Communication Behaviors | Members of medical team can communicate properly | Poor Communication due to different possible factors | Residents/team members can’t communicate |
| Family of Neonate may get affected | Delivery makes everyone happy | Development of postpartum depression in parents | Adequate support isn’t provided |

Once the requirements and expectations of the stakeholders collected, we designed the basic layout of AI Coach System that can support these use cases. The system layout is divided in two parts, server and a controller. Expert users are allowed to access and design the knowledgebase for AI Coach, that play role in the computational logic of the AI Coach, whereas, end users (i.e., medical team) interact through terminals to monitor and achieve these goals.

##### Knowledgebase for AI Coach

For every conversational agent or virtual assistants a related knowledgebase is vital, as it provides a basis for human computer interaction (Serban et al., 2018). Section 2.3 indicate how assistants or conversational agents may use domain knowledge to interact with its users. Here, the knowledgebase of system consist of ‘Support Knowledgebase’ and ‘Protocol Knowledgebase’ (See Figure XXX).

To generate knowledgebase, we modeled the collected requirements through shared mental models approach (van Ments et al., 2021). The formulated requirements and the modeled scenarios reflected how different stakeholders can interact with the coach to achieve a success scenario. For instance, Xu et al. explains how team should interact to ensure baby can breathe normally (Xu et al., 2022), or how mother can face postpartum depression (Weigl et al., 2022), or how can speaking up behavior of a resident can ensure risk free environment and help in proper execution of protocol (Doornkamp et al., 2022). For this, we also explored when AI Coach needs to intervene and ensure the patient safety and mental wellbeing by different causal inference and the support related messages. The modeled interaction and the support related messages are considered as knowledgebase resource for the human coach interaction.

The above mentioned studies explore how social elements can be integrated into the design of AI Coach. For example, we studied how a healthcare practitioner may respond in case of development of postpartum depression among parents for a behavioral change. A similar design methodology was considered for the interaction of AI Coach, which aims to reflect the similar behavior towards a family member(s), i.e., to provide support to avoid postpartum depression (Weigl et al., 2022). Thus, the AI Coach interacts to avoid postpartum depression or help if it is developed in father (or a family member). If certain factor is found AI Coach notify the support messages from the support knowledgebase using visual and audio support. The aim of support knowledgebase is to use support messages to make users aware of what is happening or about to happen. Few example some support messages can be seen in Table supmsgs. Therefore, these models not only ensures that system meets its intended goals (adherence of protocol and mental wellbeing by monitoring), but they also manifest the possible behaviors of AI Coach, which may vary as per scenarios. The dynamic behaviors of coach are discussed below, while the related interfaces will be discussed in Section 3.2.

Table supmsgs: Example Support messages that can be used for human coach interaction

|  |  |  |
| --- | --- | --- |
| **State** | **Meaning and Context** | **Example Support Messages** |
| epidural\_used | If epidural is administered: It might increase the chances of depression | * If epidural is used, then there are more chances of development of postpartum depression |
| birth\_dev | Deviation from actual birth plan: This may elevate the fears regarding the deviation, which may lead to stress | * As there is a deviation in birth protocol, an elevated fear or stress levels is expected * you know if there is a deviation in birth, this can increase the fear levels in the patient and can lead to stress too * Support is desired as there is a deviation in normal birth protocol |
| stress | Stress: This may lead to postpartum depression and father needs support | * In stressful environment, there are more chances to develop postpartum depression. * Father needs support too, as there are high chances of developing postpartum depression. |

##### Processing Logic

###### Causal Inference

A basic human-coach interaction enables medical professionals to monitor their progress and avoid any possible medical errors. So, AI Coach helps to avoid forgetfulness or ensure mental well-being of the people on the floor. For processing, we considered not only the input from a user, but also considered protocol knowledgebase. Thus AI Coach analyzes a scenario based on user input and responds as per causal inference deduced from the designed shared mental models (e.g., see Table usecases). This response can benefit the team in different ways, for instance, for protocol monitoring, action impact assessment, future proposals and reminder notification (See Figure plogic).

To draw causal inference, the coach monitors all states. If a state is marked as completed/monitored, the related causal effects are estimated, using the computational logic (Treur, 2020), which results in displayed the affected states. These affected states allows the users to interact with the coach further. As an example, let’s consider the example discussed earlier, i.e., development of postpartum depression (Weigl et al., 2022). For protocol monitoring, there are many factors that can cause depression e.g., deviation in normal delivery (represented by state birth\_dev), or stress (stress). To monitor depression (mppd; pppd), AI Coach has to estimate these factors (Kowalski, 2011; Treur, 2020). If these factors are observed, then Coach is allowed to proceed to monitor depression and provide the related support.

However, if these factors are not observed and mppd is marked as observed, the coach will intervene that the related states are not observed (through computational logic), and the related support will be provided. Another example can be consideration of state birth deviation (birth\_dev). AI Coach will monitor it if mother is in labor (baby\_deliv) and if there was riskiness involved during birth (riskiness). If both of the factors (states) are observed, then AI Coach will enable the users to monitor the deviation in birth (if any). Therefore, a related monitoring message can be ‘Please make sure that mother is in labor and there is a risk of giving birth’. Similarly, when mental support is monitored (mental\_supp), then AI Coach ensures that the therapist has been referred (refer\_therapist). So, a related support message can be ‘Please make sure that therapist is referred’.

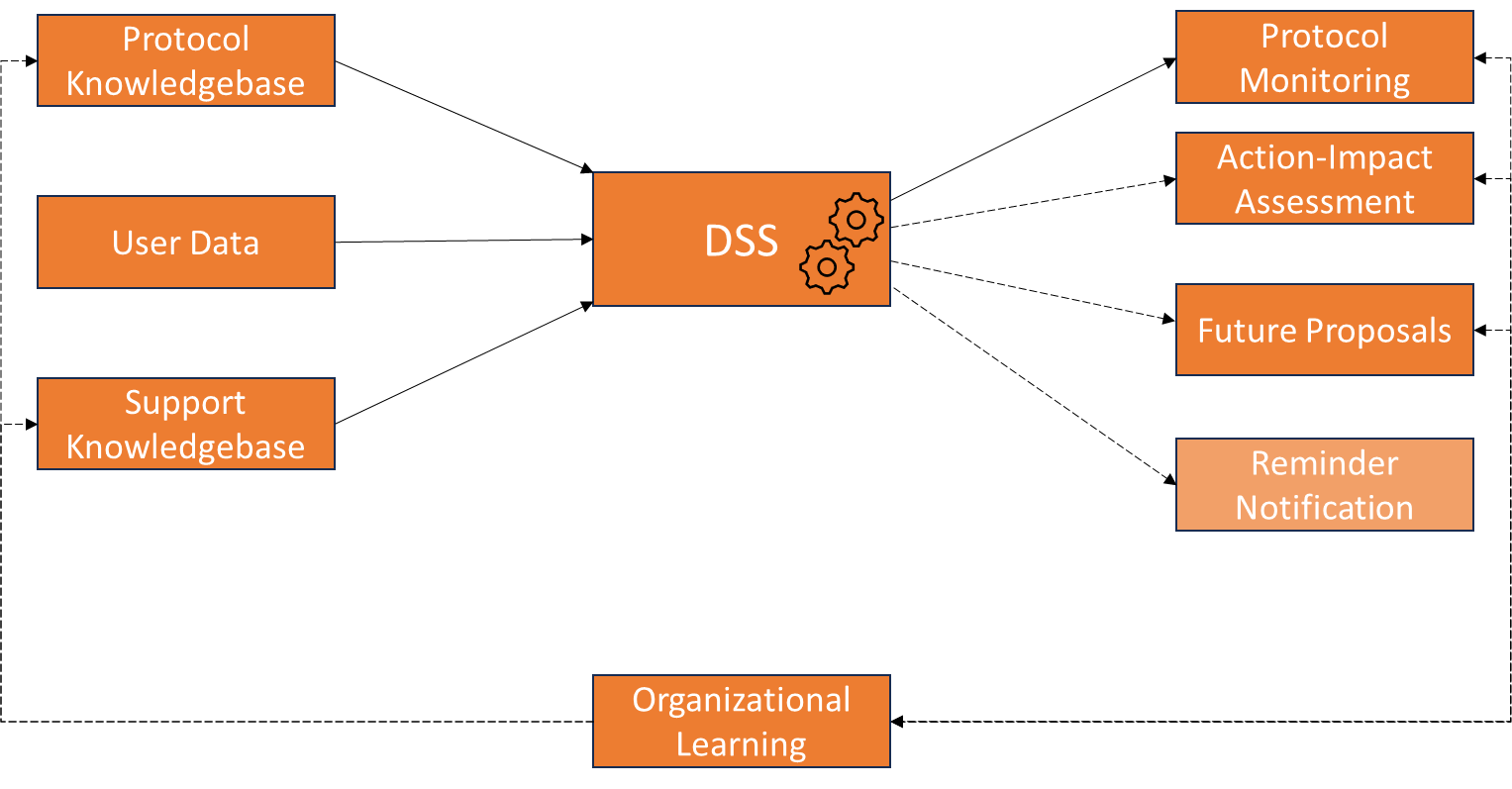


Figure plogic: Processing Logic of AI Coach

In other words, human coach interaction acts as a decision support system that manages and help the medical team to make decisions an follow protocol about the current situation(s) which cannot be easily specified beforehand. These support messages are designed by the expert users. Moreover, we have implemented the functionality of ‘Protocol Monitoring’, however, further research is needed to implement the rest of the functionality of the coach. Our framework allows to view, extend/edit the human-coach interaction, this can be done after analyzing the impacts of user coach interaction, however, as the interaction is purely based on computational logic, it is advisable to do research in this regard. Open source code is available online[[1]](#footnote-1).

###### Input and Output

We aimed for a meaningful and limited interaction, so minimal attention and understanding is required from the medical team with a complete functionality (see formulated requirements in Section 3.2.2.1).

For input, we considered click-based input from a user. Thus a user has to click what is monitored in the procedure room. The user can be any of the stakeholder’s representative. In future, we aim to extend the user input from different devices (e.g., temperature monitor, or cardiac- and oxi-meters).

The coach analyzes and responds to user in terms of text and audio. (See Figure plogic). There are different type of outputs generated, i.e., a) real-time status, and b) process log. The former is a log that helps the end users to identify if they are forgetting any task or observation during the procedure (see Section 4.2), while the latter contains a JSON file, that has a trace of the process carried out during a procedure. This log can be used in various ways. For instance, team can use it for protocol tracing or monitoring, action impact assessment, future proposals (See Fig plogic). A sample JSON file is shown in Figure jsonoutput, which can also be altered as per further requirements. It contains the state specification and the time stamp at which certain task or state was monitored.

Figure jsonoutput: JSON Output for protocol monitoring

[{"iteration":0,"date":"2023-08-28T08:38:12.575Z"},  
{"id":"X17","name":"age","user\_name":"age between 25-29","completed":true,"time\_stamp":"2023-09-01T11:36:04.012Z "},  
{"id":"X3","name":"epidural\_used","user\_name":"Epidural used","completed":false ,"time\_stamp":""},  
{"id":"X1","name":"type\_mom","user\_name":"nulliparous mother","completed":false,"time\_stamp": "2023-09-01T11:37:04.722Z"},  
{" id":"X19","name":"dilation\_mom","user\_name":"dilation of mother","completed":false,"time\_stamp":""},{"id":"X20","name ":"premature\_birth","user\_name":"premature birth","completed":false,"time\_stamp":""}]

###### Sentiment Models

Sentiment models are natural language models that are designed to analyze and classify the sentiment or emotional tone of a text. It can play an important role in developing an ambient coach (Roelofsma, 2013). We used sentiment models from huggingface library[[2]](#footnote-2), which enables sentiment analysis for multiple languages. Therefore, to change the tone of coach as per situation(s), we performed sentiment analysis of the text (e.g., state name, or the related message specification). For instance, if a negative state (e.g., stress) is observed by user, the audio tone of coach is high (pitch = 0.9) and rate = 0.7), while a positive tone is bit low (pitch = 0.8) and rate = 0.85). The implementation details of the coach can be found in appendices and online.

# User Interface and Interaction

This section presents the user interfaces for the AI Coach system. Preliminary, there are two type of stakeholders who may use interface of AI Coach system, i.e., the expert users who design the functionality of the coach and end users who will interact with the coach. Each user has to login to the AI Coach system to use the related functionality. The considered constraint was that the interaction was intended mainly for the baby birth. It is to be noted that the related requirements were identified by the invited interviews which involved the stakeholders from the organization, AI experts and experts from psychology.

## Expert User Interface

This interface is meant to model the behaviors of the involved stakeholders and the role of AI Coach in assisting them. Therefore, the main aim is to design and reflect the adaptive behavior of AI Coach which varies as per scenarios.

It is to be noted, that all the models are based on the shared mental models which are subjected to preliminary analysis and simulation by AI experts and researchers in the same domain. For example, in neonatal care, the work from Doornkamp et al. which specifies the communication behavior among the medical team to ensure patient safety (Doornkamp et al., 2022). Another example can be postpartum depression which identifies the factors that can play role in its development (Weigl et al., 2022). However, in this section, we take a simple model to provide an essence of how it can be designed as an expert user. In this model *X*1 and *X*2 are the states that influence a state *Y*, which can be estimated mathematically (Treur, 2020).

To start with the design, a logical name for the model should be specified (See Figure statenames - a). The name should be self-explanatory so that model search can be made easy. Moreover, the modeler has to specify the number of actors who would be interacting as a team. This kind of information helps in selecting the model for the human coach interaction. Once the users information is there, he can design the model using the states specifications mentioned below.

|  |
| --- |
| A screenshot of a chat  Description automatically generated |
| (a) |
| A screenshot of a computer  Description automatically generated |
| (b) |

Figure statenames: a) specifies the name of the conceptual model. b) Specifying the related state names

#### Incoming Connections

Figure statenames – b indicates the incoming states at the base level. For example, here we consider that Y has two incoming connections that is from states Input X1, and Input X2 (See (Treur, 2020), and Section 3.1.3 for further details). User has to specify different details related to a state, i.e., state name, the user name or the friendly user name, the type of the state (internal or mental state/actionable state) and then the respective incoming state. An ‘internal state’ is a state which does not need user monitoring and will not be shown to the end users, but, they are part of predicting certain behavior of a state. While, an ‘actionable / observation state’ is a state that needs input from the user and thus involved in the monitoring process. First column id is auto generated, it is unique and is used for further specification of any state (see below).

In Figure statenames – b, it can also be seen that X1 has one incoming connection i.e., X1, so if a state (like X1) has an incoming connection from the state itself, the aim is to maintain the state value over the period of time (for further details see (Treur, 2020)). A similar pattern is developed for the adaption layers, i.e., first order level and the second order level (See Appendix A). However, the states on these levels can only be the internal states.

#### Connection weight, Speed and Initial Value of a state

Figure specs indicates the connection weights for the incoming states for the complete model specified in Figure statenames. These weights can be either a number ranging between 0 – 1 or a state specified by id. A state having parameter as a state id (e.g., X1, or X2), indicates that the behavior of the a state will vary as per values of the state with that id.

|  |  |
| --- | --- |
|  |  |
| (a) | (b) |

Figure specs: a) Connection weights b) Initial values and Speed factor for the incoming states

#### Impact Computation of a state

Figure combfunc indicates how can a modeler choose the combination function (For theory Section 2.1). By default Euclidean function is selected, however, user can modify the function by choosing it through dropdown list. After choosing the combination function, the modeler has to choose the respective parameters. Modeler can also add or remove another combination function by choosing ‘+’ or ‘-’ respectively. Once the modeler specifies these specifications, (s)he can save them. A similar interface is provided to specify the message specification for a state. This specification can help to set the tone of AI Coach when certain state is monitored (See Appendix A). Once the designed model is saved, it is ready to be used for a human coach interaction.

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| Figure combfunc: Combination Function Specification of the model states. |

## End User Interface

End users can interact with AI Coach through an interactive interface, with a visual and audio support. AI Coach selects a scenario based interaction, which depends on multiple factors, for example, number of participants, current use case and so on. As a precondition an end user should be aware of how to interact with AI Coach. The interface of the coach is kept simple, and is designed to handle real-time monitoring with the minimum involvement of a user. An visual and audio support is also added, so that if a user is not able to track a predictable state, the coach assists the user to ensure that the particular state is also monitored. Figure monitoring shows the interface of AI Coach, responsible for monitoring of neonatal care protocols, where each step is represented by a state (rectangle).

AI coach is a AI-based coach, so it interacts as per modeled behaviors of the individuals in the team. These behaviors are dynamic in nature and therefore doesn’t have to be the predefined steps except the initial factors in the main protocol. Figure monitoring illustrates how AI Coach provides interaction based on the causal model designed by Weigel et al. The interaction starts by showing some initial states of the main protocol. Figure monitoring a indicates the initial factors (shown by grey rectangles – e.g., nulliparous mother, epidural used) that might be observed by the medical team. If these states are observed during the process, these states need to be marked as ‘monitored’ or ‘observed’ (marked as green). Marking these states will enable the end users to keep the track. Moreover, when a user clicks any state state, the coach shows further states known as ‘predictable states’ (grey rectangles – e.g., risk and mppd), which need to be monitored to follow the protocol further. If medical team somehow misses these steps, this may cause an error in the protocol. AI Coach plays its role to avoid missing this step by ensuring that they are also monitored (for modeling details please see (Weigl et al., 2022)).

|  |  |
| --- | --- |
|  |  |
| Figure monitoring: a) initial states of model by Weigl et al (Weigl et al., 2022). b) Observed states are shown as green, while initial/predicted states are shown as grey states | |

To maintain the rapport and to help avoid forgetfulness, the users are reminded if they are missing a task. This reminder is a highlighted state (in yellow) which allows user to ensure if they have performed the task or certain state is observed. An information slider and audio support in terms of status and log to increase the visibility of the tasks to be performed and allowing users not to miss a single task. Figure forgetfulness shows how a state is highlighted, and a related status is shown to the user(s), if they click a state. To explain it further, state MPPD can’t be observed or monitored if there the related things are not observed or performed (i.e., epidural used, cesarean, baby is born and mental support). In other words, the human coach interaction lies on how coach understands (the human behaviors) to estimate the current situation (Tauber & Ackermann, 2013). This intervention is also shown in terms of a status, which is played back by AI Coach (Figure forgetfulness – b) with certain tone. As a result, a user may feel the ambience, and the task may not be missed in case of lesser eye contact. However, the user is also facilitated to terminate the process by an end button at any time. A process log is maintained when procedure is complete to provide a trace of actions monitored over time (see in Figure jsonoutput).

|  |  |
| --- | --- |
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| **Figure forgetfulness:** If mppd is observed, then a) a visual interaction for the related unobserved states are highlighted. b) status displayed (along with audio support) to provide a better understanding of the missing tasks. | |

# System Evaluation and Discussion

Preliminary discussions also helped us to clarify the system boundaries and the basic objectives of AI Coach (See Section 3). We considered them to design the basis for system evaluation. Therefore, system evaluation was based on, e.g., a) how well AI Coach interaction can be designed by the system, b) how far it can meet the consumers’ needs, and c) what is the usability of the system and AI Coach to assist the medical team. Table feedback mentions the feedback and related score of the questions that were asked from 5 participants (applied psychologist = 1; software developers = 2; AI researchers = 2) to evaluate the system.

It is to be noted that, the knowledgebase (models used by AI Coach) has to be designed, simulated and verified mathematically before using AI Coach. However, to evaluate as an expert user, we explained a test model to be designed. Similarly, to act as an end user, we used a sample model for a dynamic human coach interaction. This was a brief walk-through tutorial which included a) the goals of the AI Coach system, b) the knowledgebase creation of AI Coach, c) interaction with the AI-Coach, d) feedback questions, and e) an informal session about the coach. This session not only helped us to study the look and feel of the users (expert + end users) for the system, but it also helped the participant to understand how AI Coach will interact with the end users. Following we explain the results of using the AI Coach system.

## Designing a Sample Model

A sample model was designed by AI Coach system, to see how far it is easy to design the model using the AI Coach system. This model is inspired from newborn life support (Madar, Roehr, Ainsworth, Ersdal, et al., 2021), and uses adaptive network modelling technique (Treur, 2020). The model designed in this phase is used for protocol monitoring and the results mentioned in Section 4.2 are compiled accordingly.

Therefore, the participants of the study had to play the role of a) an expert users and b) an end users. This is because, our focus is investigate how easy is to use the system to design the coach and using it. Moreover, following this will develop a deeper understanding of the system and algorithm for protocol monitoring. The example model is mentioned in Figure samplemodel, where each state specifies actions to be monitored by AI Coach. These actions are similar to the actions, which are to be performed by medical staff. Here state XXX

Figure samplemodel: Sample model inspired from life support neonatal care (Madar, Roehr, Ainsworth, Ersdal, et al., 2021)

## Results and Discussion

All the participants were explained the purpose to design a model, and all the participants were successful to design the model (in average time = 25 mins). Participants found the framework quite easy and useful to develop a human coach interaction, which will serve in a dynamic manner. All users commented that the interactive visualization could help and save time to develop such coaches. They were delighted to see that an assistant was not only capable of providing human computer interaction to reflect human behaviors, but also can be designed/customized to be used for different purposes.

A participant also mentioned that he used to develop rule based chatbots, which rely on structures like decision trees, however, this system can enable users to develop a human-bot interaction to address graph based structures, which seems more liberty. Moreover, writing support messages were also found good to provide human-bot interaction. Overall, positive user experience was noticed for the coach design.

As a next step, participants were briefed, that the models they designed so far can also be used for monitoring a neonate. For simplicity, a pre-designed model was considered for monitoring through human coach interaction. Table feedback mentions the results of the experience of participants about the human coach interaction. Overall, all the participants were quite impressed how AI Coach system can be used to generate a human coach interaction. One of the participants liked the possibility of using such complex phenomenon in practical fields like healthcare. Also, a participant mentioned ‘it was a nice experience, coach especially when seeing how the model came to an end to ensure a good operation’.

However, a participant mentioned that it can indeed provide a real time interaction in neonatal care, but how the users will be trained to use this type of agent in stressful situations. Similarly, another concern was that the steps were not shown earlier, so how could a user know what to click. But, this was an intentional choice, so that the users don’t click a step mistakenly or unintentionally, but to ensure that (s)he has performed/observed that particular task. A participant mentioned that user engagement has been always very challenging, and users might hesitate to use it, so it needs to be more compelling and valuable enough to encourage regular usage. Moreover, another participant mentioned that how can an end-user interact with the coach in such a limited time, and how voice interaction is possible under stress. The limitations and future work of the study is mentioned below.

Table feedback: Participants feedback on usefulness and usability of AI Coach (5 point Likert Scale)

|  |  |  |
| --- | --- | --- |
| **Statement** | **Mean** | **S.D** |
| The system is easy to use | 3.8 | 0.81 |
| I find the system design is helpful to develop the human coach interaction | 2.9 | 0.58 |
| The system helped me to understand the flow of AI Coach which will interact with the people | 3.8 | 0.5 |
| AI Coach can help to achieve the goal, i.e., reduction of medical errors | 3.9 | 0.68 |
| The interaction of AI Coach was useful | 3.1 | 0.48 |
| The reminder prompts dynamically generated are useful. | 4.0 | 0.88 |
| Audio utterances were helpful to keep the flow of AI Coach | 2.9 | 0.66 |
| I enjoyed real-time interaction with AI Coach | 3.2 | 0.40 |
| I am satisfied with my experience using the system and its coach | 3.0 | 0.70 |
| I would use the system to design my coach. | 3.9 | 0.73 |

# Limitations and Future Work

In this section, we would like to present the limitations of our study. We designed AI Coach to provide visual and audio assistance to follow and monitor healthcare protocols in neonatal care. The Coach provides real-time assistance and intervenes if needed. For example, if a team member forgets (or is unable) to perform a step in a medical procedure or protocol, the coach intervenes to help him complete it. User requirements were taken as a primary objective during the design, however, some requirements still need to be incorporated. For instance, rapport building, which can be provided by using (advanced) language processing (Henderson & Jurčíček, 2012; Kowalski, 2011). The coach relies on the temporal causal network, which can be helpful in explaining many related phenomenon and human behaviors. However, this interaction has to be improved by including the ambiance during the interactions (Roelofsma, 2013).

Although the designed AI Coach incorporates complex human behaviors and provides a meaningful interaction with medical practitioners (Choudhury, 2022), but there is a need to develop human trust. This can be done by having personalized or adaptive responses of AI Coach over the time (Roelofsma, 2013), and may vary with the need of its users to provide elaborated assistance. For instance, incorporating images with certain specifications (Zmugg et al., 2015), or providing some additional related information that can also be helpful to follow the protocol can help gain trust in the coach, or show the processed information from visualizations (Guo et al., 2022) . This can be helpful to not only to understand the user affinity to an environment and his requirements (Zmugg et al., 2015), but also provides an effective way to build an image of the coach (Guo et al., 2022). However, this might require a stronger knowledgebase as it needs to incorporate previous interactions, user preferences, and situational information to deliver such responses (Narasimhan & Schwing, 2018). Such techniques can help to cater users with different levels of expertise, have reasoning and to improve long-term user-coach relationship (Yang et al., 2023).

The current interaction design of AI Coach is based on how the coach is modeled (Treur, 2020). In other words it may also interact similar to the preprogrammed chatbots at some points. However, using these models as a knowledgebase and developing conversational design on top of these models may help in enhancing the interaction to be more naturalistic and helpful to build trust (Choudhury, 2022; Guo et al., 2022; Zmugg et al., 2015). This may require extending knowledgebase (Narasimhan & Schwing, 2018) of AI Coach containing information regarding each modeled state.

Unlike many other chatbots, AI Coach takes user input through button click, however, framework also allows to integrate sensors, which can improve the human experience by better understanding of environmental factors to predict an action. For example, one example can be integrating sensors for taking baby vitals’ data, to predict if the baby is breathing normally, and predicting the related outcomes which can be helpful in assisting the healthcare professionals working on the floor. Another example, can be predicting stress from sensors. As a result, stress can be reduced by music, so AI Coach interprets the stress levels through the environmental sensors, and may propose users to play a comforting music (Trappe, 2012). Similarly, adding few question answer sessions via sensors can improve the human-level understanding and intuition, which can improve human coach interaction.

# Conclusion

In this study, we presented an AI-based coach to interact with the medical team in neonatology department. The aim of this coach is to enhance the shared understanding of the medical team to reduce the medical errors. The coach caters error related causes and monitor them to avoid the errors. A pilot study was conducted which showed that the coach is easy to use and can be helpful to avoid the errors. In future we aim to extend the functionality of coach by incorporating sensors. We also aim to improve our knowledgebase to improve the human user interaction.

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Doctors

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# Appendices

1. **Interface of AI Coach**

**Creating Model**

While considering work from Weigel et al., this interface shows how can a model be specified

A screenshot of a computer

Description automatically generated

A screenshot of a computer

Description automatically generated

Moreover, the modeler has to specify the number of actors who would be interacting as a team. This in

1. **Implementing AI Coach**

1. https://github.com/MsFakhra/AI\_in\_Healthcare [↑](#footnote-ref-1)
2. <https://huggingface.co/transformers/usage.html> [↑](#footnote-ref-2)