A Computational Network Model for Shared Mental Models in Hospital Operation Rooms

Laila van Ments[1], Jan Treur[2(✉)], Jan Klein[3], and Peter Roelofsma[3]

[1] AutoLeadStar, Jerusalem, Israel
laila@autoleadstar.com
[2] Social AI Group, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands
j.treur@vu.nl
[3] Delft University of Technology Section Safety and Security Science, Delft, The Netherlands
{j.klein,p.h.m.p.roelofsma}@tudelft.nl

Abstract. This paper describes a network model for mental processes making use of shared mental models (SMM) of team performance. The paper illustrates the value of adequate SMM's for safe and efficient team performance. The addressed application context is that of a medical team performing a tracheal intubation executed by a nurse and a medical specialist. Simulations of successful and unsuccessful team performance have been performed, some of which are presented. The paper discusses potential further elaborations for future research as well as implications for other domains of team performance.

Keywords: Shared mental model · Network model · Hospital · Team performance · Healthcare safety

1 Introduction

A crucial aspect of the efficiency, effectiveness and safety of team performance concerns the adequacy of the shared mental model of the team members. The notion of shared mental model (SMM) - also called 'team mental model' – concerns a specific common knowledge structure held by members of a team or a group. More specifically, it refers to the alignment of the internal representations of the members concerning explanations on how reality works, or should work [6, 11, 12]. The aim of this paper is to present how a network-oriented modeling approach [18] can be used to model mental processes of team members using shared mental models. Besides representing the shared mental models themselves in a network-oriented manner, this also involves processing within the network model for the use of the mental model for internal (mental) simulations and using the outcomes of such internal simulations for decisions to undertake actions in the world via action ownership states mediating between the mental model and action execution. Thus, the paper contributes a first network model for the dynamics of the use of internal simulations of mental models and action ownership states to decide about actions to be undertaken.

M. Mahmud et al. (Eds.): BI 2021, LNAI 12960, pp. 67–78, 2021.
https://doi.org/10.1007/978-3-030-86993-9_7

First, in Sect. 2 some background for this is described. Section 2 also introduces the domain of the example scenario (use case) that is addressed, a team performance of a nurse and a medical specialist performing a tracheal intubation. In Sect. 3 the design of the network model using a shared mental model is presented. Section 4 presents some of the simulation examples. In this section a presentation of a successful team performance is given, and it is pointed out how a failure can be simulated. Section 5 summarizes the main conclusions and provides a discussion for further extensions of the obtained network model for shared mental models to support team performance.

2 Background

The network model introduced here is based on knowledge from a number of domains: mental models from psychology, team mental models from social sciences, hospital protocols from medical- and safety sciences and the domain of network-oriented modeling.

Mental Models. For the history of the mental models area, often Kenneth Craik is mentioned as a central person. Craik [3] describes a mental model as a *small-scale model* that is carried by an organism within its head as follows; see also [28]:

> 'If the organism carries a "small-scale model" of external reality and of its own possible actions within its head, it is able to try out various alternatives, conclude which is the best of them, react to future situations before they arise, utilize the knowledge of past events in dealing with the present and future, and in every way to react in a much fuller, safer, and more competent manner to the emergencies which face it.' ([3], p. 61)

Other authors also have formulated what mental models are. For example, with an emphasis on causal relations, Shih and Alessi ([16], p. 157) explain that.

> 'By a mental model we mean a person's understanding of the environment. It can represent different states of the problem and the causal relationships among states.'

De Kleer and Brown [4] describe a mental model as the envisioning of a system, including a topological representation of the system components, the possible states of each of the components, and the structural relations between these components, the running or execution of the causal model based on basic operational rules and on general scientific principles.

Shared Mental Models. A shared mental model consists of knowledge structures that overlap in contextual information and procedures. The lack of an adequate SMM in teams have been often been related to the occurrence of team errors [6, 11]. It is suggested that SSM play a major role in the effectiveness, efficiency of the group decision process and performance in a variety of domains, e.g., aviation decision making and medical team decision making and command and control [2, 8, 9, 12, 17, 29, 30]. Among others the adequacy of SSM have been related to patent safety in the operation room, e.g., open heart operation and tracheal intubation [10, 15].

Case Description. The setting of the addressed case is an emergency department where an emergency team is coming together for preparing to intubate a critically ill patient with deteriorating conscious state. The airway has been assessed as being normal and there is no expectation that there are going to be any difficulties with intubation. A doctor (D) is called to perform a tracheal intubation in collaboration with a nurse (N). In general, a tracheal intubation induces stress for D and A. The call of the doctor triggers the activation of the initial state of a shared mental model with separate roles and activities for the tracheal intubation for the D and N. The roles and activities are unique for D and N. The roles for the doctor are: team leader, prepare team, prepare for difficulties and the role of intubator. The roles for the nurse are: intubator's assistant, prepare patient, prepare equipment, prepare drugs, give drugs, monitoring patient, cricoid force, and the role of runner for help and/or additional equipment. In addition to the allocation of roles, the shared mental model contains the corresponding (temporal) sequence of activities for D and N. This consists of the following sequence. The nurse prepares the patient and performs the preparation of the equipment; then the nurse performs the preparation of the drugs. Doctor executes pre oxygenation and starts with the preparation of the team and the preparation for difficulties. The nurse listens and observes to the doctor's team preparation. The nurse give drugs to the patient and applies cricoid to the patient. Then the doctor initiates the executing of plan A Larynscopy and starts the first intubation attempt. The nurse assists the doctor in the intubation attempt. The nurse monitors the patient When the first attempt is finished the nurse seeks confirmation of its success by monitoring the capnograph. If this is OK, the attempt has succeeded.

Network-Oriented Modeling. The Network-Oriented Modelling approach based on temporal-causal networks from [18, 19] has been used to represent causal relations between mental and other states and to simulate the mental processes based on them, as needed for the use of mental models. Therefore, this approach was used to design a network model for using shared mental models in a team member's mental processing and acting. Network nodes X have state values indicated by real numbers $X(t)$ that vary over time t; nodes are also called states. The characteristics defining a network model are:

- **Connectivity characteristics**: *connections* from states X to Y, having *connection weights* $\boldsymbol{\omega}_{X,Y}$ specifying their strengths
- **Aggregation characteristics**: each state Y has a *combination function* $\mathbf{c}_Y$ that specifies how impact from all incoming connections on Y is aggregated
- **Timing characteristics**: each state Y has a *speed factor* $\boldsymbol{\eta}_Y$ specifying how fast Y changes

The numerical representation created by the available dedicated software environment is based on the following equations based on the above network characteristics (where $X_1, \ldots, X_k$ are the states from which state Y gets incoming connections):

$$\mathbf{impact}_{X,Y}(t) = \boldsymbol{\omega}_{X,Y} X(t) \tag{1}$$

$$\mathbf{aggimpact}_Y(t) = \mathbf{c}_Y(\mathbf{impact}_{X_1 Y}(t), \ldots, \mathbf{impact}_{X_k Y}(t)) = \mathbf{c}_Y(\boldsymbol{\omega}_{X_1,Y} X_1(t), \ldots, \boldsymbol{\omega}_{X_k,Y} X_k(t)) \tag{2}$$

$$
\begin{aligned}
Y(t + \Delta t) &= Y(t) + \boldsymbol{\eta}_Y \left[\mathbf{aggimpact}_Y(t) - Y(t) \right] \Delta t \\
&= Y(t) + \boldsymbol{\eta}_Y [\mathbf{c}_Y (\boldsymbol{\omega}_{X_1,Y} X_1(t), \; \ldots, \boldsymbol{\omega}_{X_k,Y} X_k(t)) - Y(t)] \Delta t
\end{aligned}
\tag{3}
$$

Within this software environment based on the generic equations (3) the processing of all network states takes place, thereby using the network characteristics.

3 Design of the Network Model Using a Shared Mental Model

The introduced temporal-causal network model design for the scenario described in Sect. 2 has connectivity as depicted in Fig. 1. See Tables 1 and 2 for an explanation of the main states. The scenario describes a sequence of actions with actors performing them and their temporal order, according to the example scenario as described in Sect. 2.

The world states representing the steps in the world for this scenario are depicted in Fig. 1 by the blue nodes in the middle area with their connections. The green node on the left represents a contextual stress factor. The actor is indicated within a world state name by D for doctor or N for nurse. The mental models of the doctor and the nurse reflect this ordered structure (as discussed in the first part of Sect. 2); they are depicted by the red nodes and yellow nodes and their mutual connections, respectively (as indicated globally by the long red oval, and by the long yellow oval). The states within the mental models correspond to the world states and accordingly they also specify an actor, indicated by D for doctor or N for nurse. The two individual mental models are two instances of an overall team mental model addressing the course of actions and the roles of the different team members for these actions. As often not all team members will possess one and the same perfect team mental model, these individual instances of the team mental model can have differences. By each of the two team members, their own mental model is used to determine their actions in the world.

This goes through the members' action ownership states (indicated in light red for the doctor and in light yellow for the nurse). These ownership states are mental states but are not part of the mental models. Instead, they receive input from some of the mental model states and based on that initiate the execution of the indicated actions, which leads to affecting the related world states. By these causal pathways, the mental models affect the actions changing the world states. Connections from world states to corresponding mental model states are (at some points) used to generate information about the world as input for the mental models.

The combination functions from the combination function library available within the software environment used here are shown in Table 3.

4 Simulation for the Example Scenario

The network characteristics defining the network model introduced above have been specified in a standard table format (called role matrices) that can be used as input for the available dedicated software environment; see also the Appendix as Linked Data at URL https://www.researchgate.net/publication/350873959. When transferred to this software environment, they are automatically used by the incorporated differential equations (3)

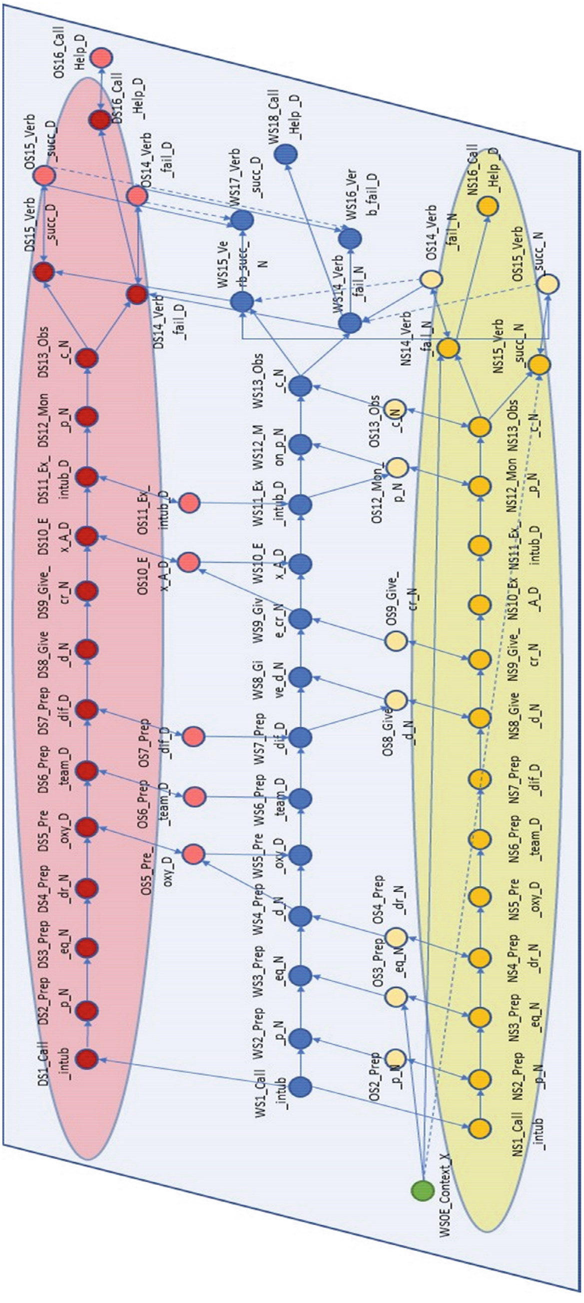

Fig. 1. Connectivity of the designed temporal-causal network model including the two mental models of the nurse (long yellow oval) and of the doctor (long red oval) (Color figure online)

Table 1. Overview of the world states (WS) and the mental model states for the doctor (DS) and nurse (NS) reflecting these world states

World, Doctor and Nurse				Explanation
WS0			Context	Contextual stress factor
WS1	DS1	NS1	Call_intub	External call for intubation
WS2	DS2	NS2	Prep_p_N	Preparation of the patient by the nurse
WS3	DS3	NS3	Prep_eq_N	Preparation of the intubation equipment by the nurse
WS4	DS4	NS4	Prep_d_N	Nurse prepares drugs for the patient
WS5	DS5	NS5	Pre_oy_D	Doctor executes pre oxygenation
WS6	DS6	NS6	Prep_team_D	Doctor prepares the team for intubation
WS7	DS7	NS7	Prep_dif_D	Doctor prepares the team for difficulties
WS8	DS8	NS8	Give_d_N	Nurse gives the patient drugs
WS9	DS9	NS9	Give_cr_N	Nurse applies cricoid to the patient
WS10	DS10	NS10	E_A_D	Doctor executes plan A Laryngoscopy
WS11	DS11	NS11	E_intub_D	Doctor intubates the patient
WS12	DS12	NS12	Mon_p_N	Nurse monitors patient
WS13	DS13	NS13	Obs_c_N	Nurse observes capnograph

when running simulations. The example simulation discussed here was run over a time interval of 0 to 80 with step size $\Delta t = 0.5$. This provides us with graphs of simulations based on the values chosen for the network characteristics. In Figs. 2 (world states), 3 (doctor's mental model) and 4 (nurse's mental model) a successful intubation process is shown. In all three figures the stress context has been set low (zero). For reasons of clarity, the figures have split the world states (Fig. 2) and the nurse's (Fig. 3) and doctor's (Fig. 4) mental model states visually, but they all happen in the same simulation at the indicated time points.

Figure 2 shows the simulation output for the world states. This shows how the actual process in the world proceeds. From $t = 10$–30 a call for intubation takes place, which sets in motion the intubation sequence described in Sect. 2. A bit after the call for intubation the Nurse starts preparing the patient (the light green line), the equipment and drugs (the lines starting around $t = 18$). After that, the doctor pre-oxygenates the patient (orange line), prepares the team and prepares for difficulties (blue and purple line after the orange one). Then, the nurse starts giving the patient drugs (around $t = 27$) and applies cricoid (around $t = 28$). This triggers the doctor to start the first attempt laryngoscopy (around $t = 33$) and to start to intubate after that (around $t = 37$). This triggers the nurse to monitor the patient, see the light blue line starting around $t = 37$, and to observe the capnograph. After this, the nurse will verbalize the success of the intubation (slowly starting at $t = 37$), and the doctor will then formally verbalize the success of the intubation (after $t = 47$).

Table 2. Overview of the ownership states for the doctor and nurse

Name		Explanation
DOS6	DOS for Pre_oxy_D	Ownership state for the action of preoxygenation
DOS7	DOS for Prep_team_D	Ownership state for the action of preparing the team
DOS8	DOS for Prep_dif_D	Ownership state for the action of preparing the team for difficulties
DOS11	DOS for E_A_D	Ownership state for the action of plan A Laryngoscopy by doctor
DOS12	DOS for E_intub_D	Ownership state for the action of intubating first attempt by doctor
DOS15	DOS for verb_fail_D	Ownership state for the action of verbalizing that attempt has failed by doctor
DOS16	DOS for Verb_succ_D	Ownership state for the action of verbalizing that attempt has succeeded by doctor
DOS17	DOS for Call_help_D	Ownership state for the action of call for help, by doctor
NOS3	NOS for Prep_N	Nurse Ownership State for Preparation patient
NOS4	NOS for Prep_eq_N	Nurse Ownership State for Preparation equipment
NOS5	NOS for Prep_dr_N	Nurse Ownership State for preparing drugs
NOS9	NOS for Give_d_N	Nurse Ownership State for Nurse gives drugs
NOS10	NOS for Give_cr_N	Nurse Ownership State for Nurse gives cricoid
NOS13	NOS for Mon_p_N	Nurse Ownership State for Nurse monitors patient
NOS14	NOS for Obs_c_N	Nurse Ownership State for observing capnograph
NOS15	NOS for Verb_fail_N	Nurse Ownership State for verbalizing that attempt has failed
NOS16	NOS for Verb_succ_N	Nurse Ownership State for verbalizing that attempt has succeeded

Table 3. Combination functions from the library used in the introduced network model

	Notation	Formula	Parameters
Steponce	**steponce**(V)	1 if $\boldsymbol{\alpha} \leq t \leq \boldsymbol{\beta}$, else 0	$\boldsymbol{\alpha}$ start, $\boldsymbol{\beta}$ end time
Advanced logistic sum	$\mathbf{alogistic}_{\boldsymbol{\sigma},\boldsymbol{\tau}}(V_1, \ldots, V_k)$	$[\frac{1}{1+e^{-\sigma(V_1+\cdots+V_k-\tau)}} - \frac{1}{1+e^{\sigma\tau})}](1 + e^{-\boldsymbol{\sigma\tau}})$	Steepness $\boldsymbol{\sigma} > 0$ Excitability threshold $\boldsymbol{\tau}$

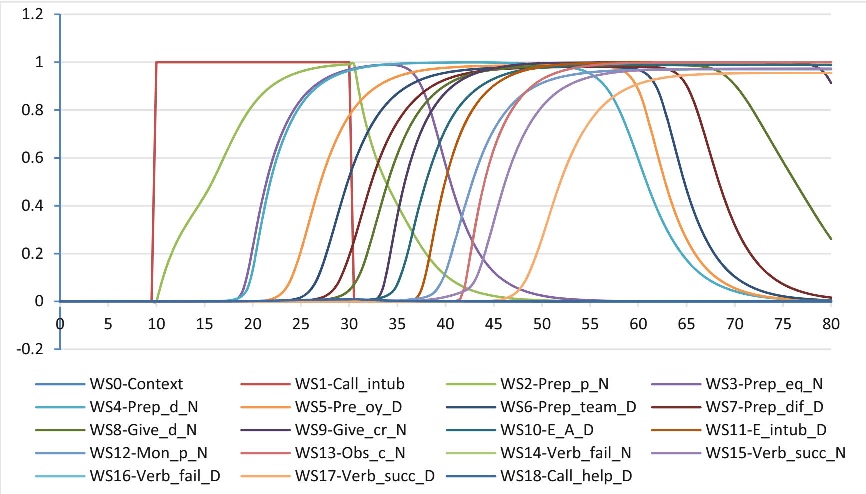

Fig. 2. World states of a successful intubation process (Color figure online)

Figures 3 and 4 show the successful intubation scenario described above, but for what precedes the world state activations described above: respectively the internal simulations by the doctor and nurse of their own mental model and activating accordingly their ownership states.

In Fig. 3, at $t = 10$ the world state for a call for intubation activates. This subsequently triggers the doctor's internal simulation of her mental model states for actions the nurse does, i.e., preparing the patient, equipment and drugs. When this sequence is finished, this internal simulation activates the doctor's mental model states for actions she has to do herself, which in turn activate her ownership states for these actions (dotted lines for pre oxygenating the patient, preparing the team and preparing for difficulties around $t = 18$–22). These actions trigger to subsequent mental model states that the nurse then makes her deciding for actions via the corresponding ownership states, giving the drugs and applying cricoid, which then activates the doctors mental model states and thus ownership states for his own next actions, starting to actually intubate (around $t = 28$). Around $t = 38$, the nurse's verbalization in the world states triggers the doctor's mental model state and ownership state of verbalization of a successful intubation.

Figure 4 shows a very similar pattern, just substituting the doctor's mental model states for the nurse's mental model states, and showing the nurse's ownership states instead of the doctor's ownership states.

The network model is also able to show a failed attempt, as illustrated in the Appendix by a scenario with a high contextual stress factor that was simulated. The high stress level leads to missing steps in the intubation scenario, leading to a failing intubation process.

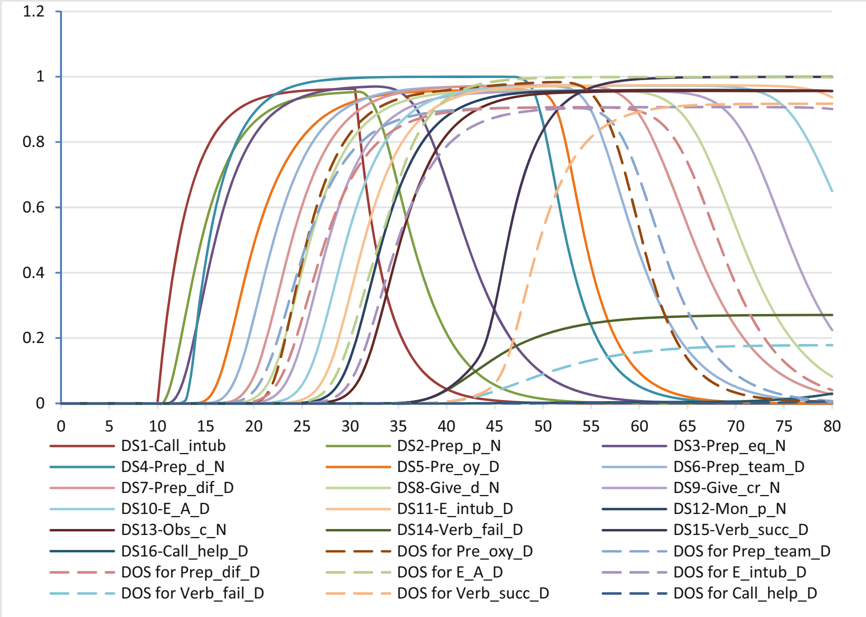

Fig. 3. The doctor's mental model and ownership states of a successful intubation process

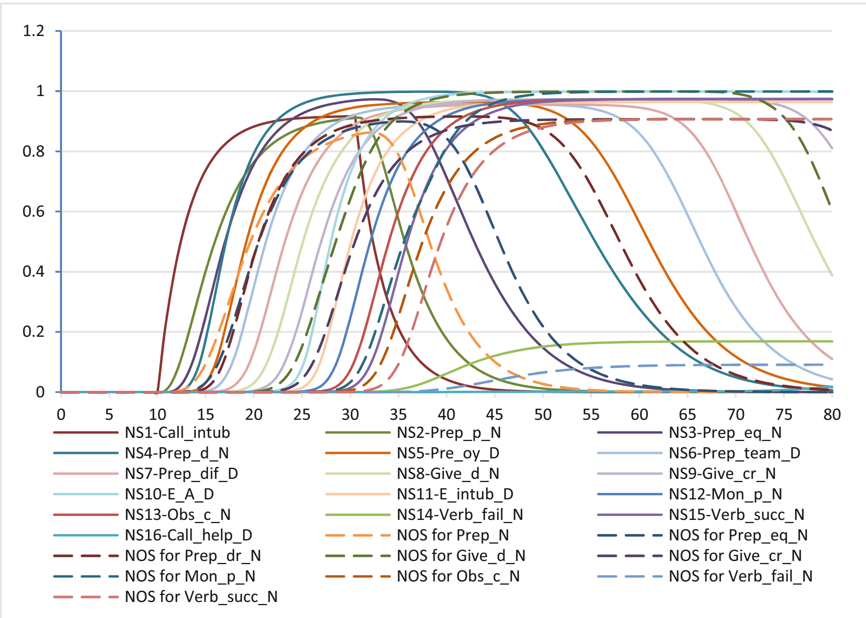

Fig. 4. The nurse's mental model and ownership states of a successful intubation process

5 Discussion

In the work described here, a computational network model was developed to allow for simulation of mental processes involving a shared mental model for a doctor and a nurse performing tracheal intubation of a patient. The model incorporates representation and processing of the actions in the world, the required internal simulation of the two mental models of the nurse and doctor, and the dynamics via the ownership states to represent how the actors actually perform the intubation actions. A contextual stress factor was introduced that determines whether an intubation process is successful or not. Accordingly, in simulation experiments, a successful and failed intubation process were addressed.

The computational model was developed based on the network-oriented modeling approach described in [18, 19] and its dedicated software environment described in [19], Ch 9. In earlier work it has been shown how this modeling approach enables modeling of different types of mental models, for example, for mental models representing flashback experiences in PTSD [21], for joint decision making based on certain metaphors [22], and for how a mental God-model can affect empathic and disempathic human behaviour [25–27]. Other computational approaches such as described in [5, 13, 14], use agent-based models (which usually brings more added complexity), dynamical system models or program code (which lacks a description at a modelling level). In contrast to all this, the current paper describes at a modelling level a first computational network model addressing hospital processes and shared mental models for teamwork for them. Neural correlates of mental models are discussed in more detail in [20] with several neuroscience references such as [1, 7].

The network model developed in this paper can be extended to include multiple intubation attempts, different types of failures in the intubation process, and adaptivity showing learning (and forgetting) by the doctor and nurse. A next step would be to model the occurrence of errors and incidents - and their solutions - that are specific for team and group performance. Examples of topics for further research are: false consensus, group think, escalation of commitment and group polarization [11]. Another interesting topic is to examine the effect of group dynamics depending on the team size. Sometimes it is claimed that increasing the team, will lead to more safety and efficiency [10] but an increasing group size also leads to new group dynamics which may introduce new potential problems.

A limitation of the presented network model that it does not address adaptation of the mental model (learning, refining, revising or forgetting it). For the further development of models it is important to incorporate adaptive learning and higher-order components into the model as is described, for example, by a generic multilevel cognitive architecture in [23]. Such adaptation and control are relevant not only for the study of shared mental models in medical teams [10], but also for team decision making in other contexts. In the meantime, after submission of the current paper a first step in this direction has been taken; see [24]. As mentioned, shared mental models are often used in safety-related situations such as aviation, firefighting teams, dealing rooms, shipping control, etc. An important line for future research is to analyse the validity of the introduced network model and further extensions of it for such domains.

References

1. Alfred, K.L., Connolly, A.C., Cetron, J.S., et al.: Mental models use common neural spatial structure for spatial and abstract content. Commun. Biol. **3**, 17 (2020)
2. Burtscher, M.J., Manser, T.: Team mental models and their potential to improve teamwork and safety: a review and implications for future research in healthcare. Saf. Sci. **50**(5), 1344–1354 (2012)
3. Craik, K.J.W.: The Nature of Explanation. University Press, Cambridge (1943)
4. De Kleer, J., Brown, J.: Assumptions and ambiguities in mechanistic mental models. In: Gentner, D., Stevens, A. (eds.) Mental models, pp. 155–190. Lawrence Erlbaum Associates, Hillsdale (1983)
5. Dionne, S.D., Sayama, H., Hao, C., Bush, B.J.: The role of leadership in shared mental model convergence and team performance improvement: an agent-based computational model. Leadersh. Q. **21**, 1035–1049 (2010)
6. Fischhof, B., Johnson, S.: Organisational Decision Making. Cambridge University Press, Cambridge (1997)
7. Garvert, M., Dolan, R., Behrens, T.: A map of abstract relational knowledge in the human hippocampal–entorhinal cortex. eLife. **6**, e17086 (2017)
8. Gehlert, S.: Developing a shared mental model of team functioning in the context of research. J. Psychiatry Psychiatr. Disord. **4**(3), 74–81 (2020)
9. Gisick, L.M., et al.: Measuring shared mental models in healthcare. J. Patient Saf. Risk Manag. **23**(5), 207–219 (2018)
10. Higgs, A., et al.: Guidelines for the management of tracheal intubation of critically ill adults. Br. J. Anaesth. **120**(2), 323–352 (2018)
11. Jones, P.E., Roelofsma, P.H.M.P.: The potential for social contextual and group biases in team decision making: biases, conditions and psychological mechanisms. Ergonomics **43**(8), 1129–1152 (2000)
12. Mathieu, J.E., Hefner, T.S., Goodwin, G.F., Salas, E., Cannon-Bowers, J.A.: The influence of shared mental models on team process and performance. J. Appl. Psychol. **85**(2), 273–283 (2000)
13. Outland, N.B.: A Computational Cognitive Architecture for Exploring Team Mental Models. College of Science and Health Theses and Dissertations. 289 (2019). https://via.library.depaul.edu/csh_etd/289
14. Scheutz, M.: Computational mechanisms for mental models in human-robot interaction. In: Shumaker, R. (ed.) Virtual Augmented and Mixed Reality. Designing and Developing Augmented and Virtual Environments. LNCS, vol. 8021, pp. 304–312. Springer, Heidelberg (2013). https://doi.org/10.1007/978-3-642-39405-8_34
15. Seo, S., Kennedy-Metz, L.R., Zenati, M.A., Shah, J.A., Dias, R.D., Unhelkar, V.V.: Towards an AI coach to infer team mental model alignment in healthcare. Department of Computer Science, Rice University Houston TX, USA (2021)
16. Shih, Y.F., Alessi, S.M.: Mental models and transfer of learning in computer programming. J. Res. Comput. Educ. **26**(2), 154–175 (1993)
17. Todd, J.: Audit of compliance with WHO surgical safety checklist and building a shared mental model in the operating theatre. BJM Leader **2**(1), 32–135 (2018)
18. Treur, J.: Network-Oriented Modeling: Addressing Complexity of Cognitive Affective and Social Interactions. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-45213-5
19. Treur, J.: Network-Oriented Modeling for Adaptive Networks: Designing Higher-Order Adaptive Biological, Mental and Social Network Models. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-31445-3

20. Treur, J.: Mental models in the brain: on context-dependent neural correlates of mental models. Cogn. Syst. Res. **79**, 83–90 (2021)
21. van Ments, L., Treur, J.: A higher-order adaptive network model to simulate development of and recovery from PTSD. In: Paszynski, M., Kranzlmüller, D., Krzhizhanovskaya, V.V., Dongarra, J.J., Sloot, P.M.A. (eds.) Computational Science – ICCS 2021. LNCS, vol. 12743, pp. 154–166. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-77964-1_13
22. Van Ments, L., Treur, J.: Modeling adaptive cooperative and competitive metaphors as mental models for joint decision making. Cogn. Syst. Res. **69**, 67–82 (2021)
23. Van Ments, L., Treur, J.: Reflections on dynamics, adaptation and control: a cognitive architecture for mental models. Cogn. Syst. Res. **70**, 1–9 (2021)
24. Van Ments, L., Treur, J., Klein, J., Roelofsma, P.H.M.P.: A second-order adaptive network model for shared mental models in hospital teamwork. In: Nguyen, N.T., et al. (eds.) Proceedings of the 13th International Conference on Computational Collective Intelligence, ICCCI 2021, Lecture Notes in AI, Springer, Heidelberg (2021). To appear
25. Van Ments, L., Treur, J., Roelofsma, P.H.M.P.: A temporal-causal network model for the relation between religion and human empathy. In: Cherifi, H., Gaito, S., Quattrociocchi, W., Sala, A. (eds.) Proceedings of the 5th International Workshop on Complex Networks and Their Applications V. Lecture Notes in Computer Science, vol. 693, pp. 55–67. Springer, Heidelberg (2016)
26. Van Ments, L., Treur, J., Roelofsma, P.H.M.P.: Modeling the effect of religion on human empathy based on an adaptive temporal-causal network model. Comput. Soc. Netw. **5**(1), 1–23 (2018). https://doi.org/10.1186/s40649-017-0049-z
27. Van Ments, L., Treur, J., Roelofsma, P.H.M.P.: An adaptive network model for formation and use of a mental god-model and its effect on human empathy. In: Treur, J., van Ments, L. (eds.) Mental Models and their Dynamics, Adaptation, and Control: a Self-Modeling Network Modeling Approach. Springer, Heidelberg (2022)
28. Williams, D.: The Mind as a Predictive Modelling Engine: Generative Models, Structural Similarity, and Mental Representation. Ph. D. Thesis, University of Cambridge, UK (2018)
29. Wilson, A.: Creating and applying shared mental models in the operating room. J. Perioper. Nurs. **32**(3), 33–36 (2019)
30. Wise, S., Duffield, C., Fry, M., Roche, M.: A team mental model approach to understanding team effectiveness in an emergency department: a qualitative study. J. Health Serv. Res. Policy (2021). https://doi.org/10.1177/13558196211031285