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Preface

This AISC volume contains the papers presented at ICICT 2020: Fifth International Congress on Information and Communication Technology in concurrent with ICT Excellence Awards. The conference was held during February 20–21, 2020, London, UK, and collaborated by the Global Knowledge Research Foundation, City of Oxford College. The associated partners were Springer, InterYIT IFIP, Activate Learning. The conference was held at Brunel University, London. This conference was focused on e-business fields such as e-agriculture, e-education, e-mining. The objective of this conference was to provide a common platform for researchers, academicians, industry persons and students to create a conversational environment wherein topics related to future innovation, obstacles are to be resolved for new upcoming projects, exchange of views and ideas. The conference attracted immense experts from more than 45 countries, the conference was involved in deep discussion, and issues were intended to solve at the international level. New technologies were proposed, experiences were shared, and future solutions for design infrastructure for ICT were also discussed. Research Submissions in various advanced technology areas were received and then were reviewed by the committee members; 120 papers were accepted. The conference was overwhelmed by the presence of various members. Amit joshi, Organizing Secretary, ICICT 2020, gave the welcome speech on behalf of conference committee and editors. Our special invitee guest—Sean Holmes, Vice Dean, International College of Business, Arts and Social Sciences, Brunel University, London, UK, also addressed the conference by a speech. The conference was also addressed by our Inaugural Guest and Speakers—Mike Hinchey, President, International Federation for Information Processing (IFIP); Xin-She Yang, Professor, Middlesex University, UK; Jyoti Choudrie, Professor, University of Hertfordshire, UK; and Milan Tuba, Vice Rector for International Relations, Singidunum University, Serbia. There were 14 technical sessions in total, and talks on academic and industrial sector were focused on both the days. We are obliged to the Global Knowledge Research Foundation for their immense support to make this conference a successful one. A total of 105 papers were presented in technical sessions, and 120 were accepted with strategizing on ICT and intelligent systems.

At the closing ceremony, 10 Best Paper Awards by Springer were announced among the best selected and presented paper. On behalf of editors, we thank all the sponsors, press, print and electronic media for their excellent coverage of this conference.

London, UK	Xin-She Yang
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Kolkata, India	Nilanjan Dey
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Contents

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Xin-She Yang obtained his D.Phil. in Applied Mathematics from the University of Oxford, and subsequently worked at the Cambridge University and the National Physical Laboratory (UK) as a Senior Research Scientist. He is currently a Reader in Modelling and Optimization at Middlesex University London and an Adjunct Professor at Reykjavik University (Iceland). He is also an elected Bye-Fellow at the Cambridge University and the IEEE CIS Chair for the Task Force on Business Intelligence and Knowledge Management. He was included in the "2016 Thomson Reuters Highly Cited Researchers" list.

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Adaptive Cognitive Modeling of Electroconvulsive Treatment (ECT)

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Abstract. This paper presents a cognitive model on electroconvulsive treatment to reduce the stress level in body. The stress reduction is triggered by a cognitive electroconvulsive treatment that uses persistent manipulation of this treatment. The goal of this treatment is to decrease the strength between certain parts of the brain which are in charge of the stress. The proposed adaptive cognitive model aims to illustrate the effect of the therapy on different components of the brain. The model begins with a state of tough, powerful, and consistent stress within a post-traumatic disorder patient, and after following electroconvulsive treatment, the stress level starts to decrease from time to time according to each treatment session. The results show that, in the end, the disorder person will have a declined stress in contrast to not performing electroconvulsive treatment.

Keywords: Cognitive modeling · Extreme emotion · Electroconvulsive treatment · PTSD

1 Introduction

The need to understand human mental processes is an increasing trend in the designing of intelligent systems for facilitating behavioral and lifestyle changes. The reason for requiring this understanding is that this enables to more adequately help people improve their general well-being and support them in their daily life and activities.

Furthermore, developing intelligent systems capable of effecting supportive actions according to anticipated environmental and situational factors, as well as a person's mental states, must be robust and justifiable from a scientific perspective. In the design of dynamical models related to internal mental processes for intelligent human-supporting systems, the computational approach provides a good basis as it provides insight into behavioral changes and the related possibilities.

The crucial question in this instance is how such an intelligent support system can be designed, taking mental and environmental states into account, in a way that enables it to effectively support people in their daily lives.

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Usually, the heuristic is followed that a model should not be made at a too low level of abstraction for the accuracy required, as that would entail unnecessary complexity. However, what deviation is introduced by doing so is a serious question that needs analysis. Therefore, in this research area, models at different abstraction levels and their (interlevel) relations are being investigated.

The first part of this work involves inquiry about theories and knowledge from the fields of cognitive neuroscience. Based on this information, computational models were designed. The evaluation of these models was conducted by simulation. These computational models have been scientifically justified by various fundamental theories from the fields of neuroscience and cognitive science. This approach helped to facilitate a better understanding of the link between different human behaviors, mental states, and conditions, thereby providing a framework of knowledge for the design of intelligent support systems.

As it has been declared in [1], PTSD is a disorder that might play a role after exposure to exceptionally threatening or horrifying events. PTSD may be the outcome of a wide variety of causes ranging from a fight to car. Because of the fragile interaction between personality and circumstances in which the trauma has been developed, it is impossible to predict whether PTSD will develop. There are some treatments that have been used for years and have proven to be successful, such as the use of antidepressant drugs like fluoxetine, deep brain stimulation of different brain components like the amygdala and the hippocampus or much older therapies such as yoga or music therapy [2–12]. The mobile application of these works is presented in [13]. This work presents a cognitive modeling for electroconvulsive therapy. By providing a conceptual model based on the neuroscience literature, the effectiveness and results of aforementioned therapy for PTSD patients are demonstrated.

In this paper, the electroconvulsive therapy (ECT) which is used for decreasing extreme emotions in a patient with PTSD is presented. This is based on the neuroscientific and psychological literature review. This therapy can be applied when the limitation of other therapies, such as antidepressant drugs, are not allowed for example during pregnancy or when immediate treatment is needed, e.g., when patients experience high depression or have suicidal thoughts.

In Sect. 2, the findings in neuroscience, psychology, and biological research concerning the components of the brain are involved. In Sect. 3, network-oriented modeling is explained. In Sect. 4, we present the graphical results, and in the final section, the conclusion is presented.

2 Neurological Findings

Recent studies [14–16] show the effect of ECT in the hippocampus and amygdala and show that it enforces massive structural plasticity in humans. The process of the effect of the ECT on the brain components is mentioned in different research, and in the following part, the main outcomes are presented.

Also, it has been mentioned that the neurogenesis of the amygdala may be enhanced by performing ECT, and the feedforward cortical-subcortical connection from FFA to amygdala will be improved. However, by using ECT, the general global connectivity in the left dorsolateral prefrontal cortex is decreased. In [17], the correlation between sad faces and the amygdala has been investigated. There is a remarkable negative interconnectivity between alters in the activity of amygdala to safe faces and symptoms of using ECT. Moreover, analysis depicted that the reactivity degree of the amygdala to negative emotional stimuli was accompanied by clinical results.

Also, in [18], the effect of ECT on dentate gyrus of the hippocampus has been shown. It has been stated that the volume of the bilateral hippocampus and amygdala has been increased by performing ECT, and this change is more visible in young adults.

The reason for increased volume in the hippocampus is based on the increase of neurons in the dentate gyrus, and this increase is maintained for three months. Furthermore, it has been shown that electroconvulsive shock is faster and stronger than antidepressant drugs [15]. It increases cell proliferation 2.5-4-fold compared with 1.5-fold using antidepressant drugs. ECT enforces an increase in proliferation of glial progenitor (NG2-positive cells) and enhances the number of glial cells and also alters the activation of glial cells and elevates the maturation of dendritic spines. These alterations also remodeled the neural circuits which intervened with the therapeutic impact of ECT. Deep into the molecular layer, it has been noted that ECT increased endothelial cell numbers by up to 30% and the length of the vessel by 16% in the dentate gyrus. The metabolism and perfusion are increased in the medial temporal lobe which contains para-hippocampal gyrus and hippocampus after doing ECT [19].

In the major depressive disorder, the density of total glia and oligodendrocytes in the amygdala and subgenual cingulate cortex is declined. However, using ECT increases the glial cells in the amygdala [20].

Also, in [21], changes in BDNF and its receptor, trkB, are discussed. Acute ECT increases BDNF mRNA almost twofold; however, the impacts of chronic ECT on the hippocampus varies. Stress-induced atrophy and in the worst case, cell death, cause to the loss of hippocampal control of the hypothalamic-adrenal axis (HPA) and exhibition in hypercortisolism in a depressive period.

In [22], different indications of ECS therapy has been mentioned. The result of a proton magnetic resonance spectroscopy shows that by having ECT treatment, the occipital cortex GABA concentrations are increased in depressed patients. In addition to the effect of ECT in increasing the level of glutamate plasma and normalizing the reduced level of glutamate/glutamine in the left cingulum in PTSD, it also plays a role in glutamate and an excitatory neurotransmitter.

However, this dysregulation normalizes based on the therapeutic effect of ECT.

As it has been discussed in [22], ECT is involved in increasing the neuron formation in the hippocampus, and this depends on doses of using ECT on neurogenesis. It has been also found that CBF in frontal areas of the brain after depression declines.

Also, in [22, p. 107], different brain parts involved during ECT have been mentioned. After using ECT, in many other areas in the brain such as frontal and parietal cortex, and in anterior and posterior cingulate gyrus of PTSD, a decreased regional glucose metabolism happened. This might also consider as a therapeutic impact of ECT.

The usage of ECT can be considered when the high risk of depression and severe psychological issue and suicide noticed. Moreover, in the case of mania and depression during pregnancy and other therapeutic options such as antidepressant drugs are useless, ECT can play an important role [23]. The success rate (remission) for ECT therapy is close to 90%, and the resting time for relief is within 10–14 days.

In [24], the influence of electroconvulsive on hippocampus has been described more precisely. Another result of using ECT on the hippocampus is discussed in [24] which it states that cell proliferation of ECT on the hippocampus is increased twice in three days.

In [25], the privilege of using of electroconvulsive therapy comparing to other therapies and antidepressant drugs has been explained. Although there are many improvements in variant pharmacological agents which are patient-friendly and used in many aspects of disorders such as catatonia, treatment-resistant schizophrenia, and acute manic episode, ECT still is more useful in mood-stabilizing property than pharmacotherapy [25]. Another reason for using ECT is quicker response comparing to other existing psychotropic medications.

3 The Network-Oriented Modeling

In this part, we discuss the principle and description of network-oriented modeling approach [24, Chap. 2, 25, 1]. This approach is basically adopted from the foundations and principles of neuroscience, psychology and social sciences.

This kind of modeling can be described on two different levels called conceptual representation and numerical representation. A conceptual representation consists of all states (nodes) and connections between them as can be interpreted as the causal impacts of the nodes on each other. We have considered 26 states to represent the brain components in neuroscience, biological components such as hormones and cognitive components such as the goal of using ECT and preparation of doing that, and stress stimuli.

In the next phase, a mathematical representation of the model needs to be considered. This representation consists of three important parts such as *strength of a connection, aggregate multiple causal impacts, and speed of change.* The former represents the strength of the connection among states. The middle one noted the aggregation of multiple connection weights when there are more than one causal relation impacts other states. Finally, *speed of change* shows the speed of the changes among nodes and how fast they change.

- $\boldsymbol{\omega}_{X,Y}$: illustrates the strength of the connection from a state X to state Y, and it is between -1 (negative effect) and 1(positive effect).
- **state** $\mathbf{c}_Y(\ldots)$: represents an aggregation function for combining the causal effects on state Y.
- $\boldsymbol{\eta}_Y$: represents a speed of change, and it varies between 0 and 1.

There are multiple combination functions which are used in different causal relations, but the most used ones are identity function, one entering connection, scale sum function, and the advanced logistic function for more than one. The advanced logistic function is mostly used when there are some changes during the time.

Figure 1 shows the proposed cognitive model. $\mathrm{ps}_{\mathrm{ECS}}$ is the preparation state of doing electroconvulsive therapy. $\mathrm{es}_{\mathrm{ECS}}$ is the state of using electroconvulsive therapy. The other states link to the components in the brain (anterior insula, bilateral inferior frontal gyrus, putamen, thalamus, bilateral parietal, occipital cortex, ACTH, cortisol, adrenal cortex, HPA, amygdala, hippocampus, bilateral cingulate gyrus, the left dorsal cortex, LC, and NA) which are involved in stress regulation.

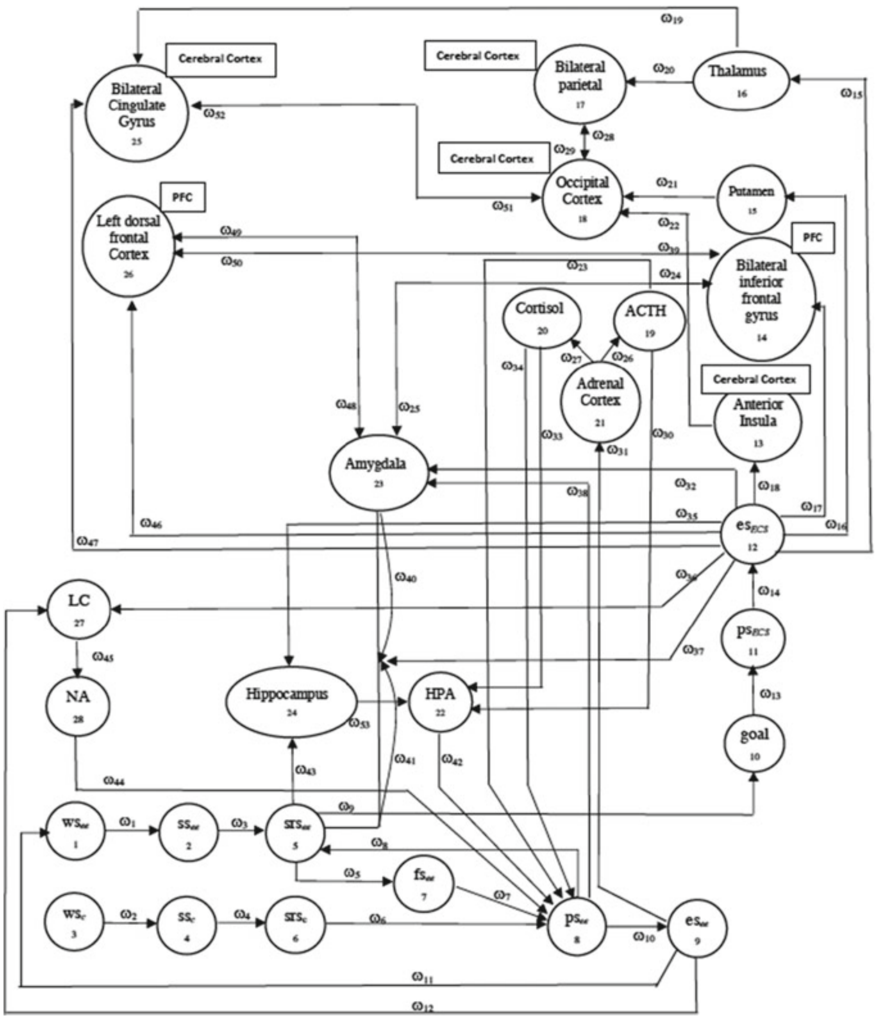

Fig. 1. Proposed cognitive model of ECT

The connection weights ω_i in Fig. 1 are based on the findings presented in Sect. 2. First, the cognitive part of the model is described: the beginning part of the explanation is based on Damasio theory about cognitive theory of mind [26]. Firstly, the cognitive part of the model and secondly the biological processes of the brain are described in this part (Table 1).

Table 1. Cognitive model explanation

X_1	ws_{ee}	World state
X_2	ss_{ee}	Sensor state of extreme emotion *ee*
X_3	ws_c	World state
X_4	ss_c	Sensor state for context *c*
X_5	srs_{ee}	Sensory representation
X_6	srs_c	Sensory representation
X_7	fs_{ee}	Feeling state
X_8	ps_{ee}	Preparation state
X_9	es_{ee}	Execution state
X_{10}	goal	Goal of using therapy
X_{11}	ps_{ECS}	Preparation state of using electroconvulsive therapy
X_{12}	es_{ECS}	Execution of using electroconvulsive therapy
X_{13}	Anterior insula (part of cerebral cortex)	Part of the brain
X_{14}	Bilateral inferior frontal gyrus (part of PFC)	Part of the brain
X_{15}	Putamen	Part of the brain
X_{16}	Thalamus	Part of the brain
X_{17}	Bilateral parietal (part of cerebral cortex)	Part of the brain
X_{18}	Occipital cortex (part of cerebral cortex)	Part of the brain
X_{19}	ACTH	Hormone
X_{20}	Cortisol	Hormone
X_{21}	Adrenal cortex	Brain part
X_{22}	HPA	Hypothalamic pituitary adrenal axis
X_{23}	Amygdala	Part of the brain
X_{24}	Hippocampus	Part of the brain
X_{25}	Bilateral cingulate gyrus (part of cerebral cortex)	Part of the brain
X_{26}	Left frontal cortex (part of PFC)	Part of the brain

The model contains a biological part as well. The state anterior insula has weight ω_{18} from es_{ECS}, and weight ω_{22} toward the cccipital cortex as it has been mentioned in Sect. 2 [27]. The bilateral inferior frontal gyrus part of the brain has three arriving connection weights ω_{17}, ω_{39}, and ω_{24} from es_{ECS}, left dorsal frontal cortex [22]. Putamen part of the brain has an incoming connection, ω_{16}, from es_{ECS}. It is worth mentioning that the connection between the amygdala and srs_{ee} is changing, and by using Hebbian learning, this will change (ω_{40}, ω_{41}). Thalamus has an arriving weight from es_{ECS} (ω_{15}). Bilateral parietal state has an arriving weight from thalamus with ω_{16} and an outgoing connection to occipital cortex, ω_{28}. The state occipital cortex has four incoming weights from bilateral parietal, bilateral cingulate gyrus, anterior insula, putamen with ω_{29}, ω_{51}, ω_{22}, ω_{21}, respectively. The state ACTH has two leaving connection weights to HPA, ps_{ee} named ω_{30}, ω_{23}, respectively. Furthermore, cortisol has leaving weights to HPA, ps_{ee} named ω_{33}, ω_{34}, respectively. The state HPA has three connection weights from cortisol, ACTH, and hippocampus (ω_{53}). amygdala has five incoming connection weights from srs_{ee}, ps_{ee}, es_{ECS}, bilateral inferior frontal gyrus, left frontal cortex named ω_{41}, ω_{38}, ω_{32}, ω_{25}, and ω_{48}, respectively. Hippocampus has two incoming connection weights from es_{ECS}, srs_{ee} named ω_{43}, ω_{35}, respectively. The brain part bilateral cingulate gyrus has three incoming connections from thalamus, occipital cortex, and es_{ECS} named ω_{19}, ω_{51}, ω_{47}, respectively. The state, left dorsal frontal cortex, has three arriving connections from bilateral inferior frontal gyrus, amygdala, es_{ECS} named ω_{50}, ω_{49}, ω_{46}.

This representation of the proposed cognitive model can be represented as a mathematical depiction [24, Chap. 2, 25, 1]:

- The *aggregated impact:*

$$\begin{aligned}\textbf{aggimpact}_Y(t) &= c_Y\big(\textbf{impact}_{X_1,Y}(t),\ \ldots,\ \textbf{impact}_{Xk,Y}(t)\big)\\ &= c_Y\big(\omega_{X_1,Y}X_1(t),\ \ldots, \omega_{Xk,Y}X_k(t)\big)\end{aligned}$$

- Difference/differential equations for the cognitive mmodel:

$$\begin{aligned}&Y(t+\Delta t) = Y(t) + \eta_Y\big[\textbf{aggimpact}_Y(t) - Y(t)\big]\Delta t\\ &Y(t+\Delta t) = Y(t) + \eta_Y\big[\mathbf{c}_Y\big((\omega_{X_1,Y}X_1(t),\ \ldots, \omega_{Xk,Y}X_k(t)\big) - Y(t)\big]\end{aligned}$$

For getting more insight of these combination functions, see [24].

$$\textbf{ssum}_\lambda(V_1,\ \ldots,\ V_k) = (V_1 + \cdots + V_k)/\lambda$$

$$\textbf{alogistic}_{\sigma,\tau}(V_1,\ \ldots, V_k) = \Big[(1/(1+e^{-\sigma(V1+\ldots+Vk-t)})) - 1/(1+e^{\sigma t})\Big]\big(1+e^{-\sigma t}\big)$$

Hebbian learning is described as follows [21]:

$$\begin{aligned}d\omega(t)/dt &= \eta[X_1(t)X_2(t)(1-\omega(t) - (1-\mu)\omega(t)]\\ \omega(t+\Delta t) &= \omega(t)+\eta[X_1(t)X_2(t)(1-\omega(t)) - (1-\mu)\omega(t)]\Delta t\end{aligned}$$

4 Graphical Result

The graphical results of the model are depicted in Fig. 2. The figure bears qualitative information. [27].

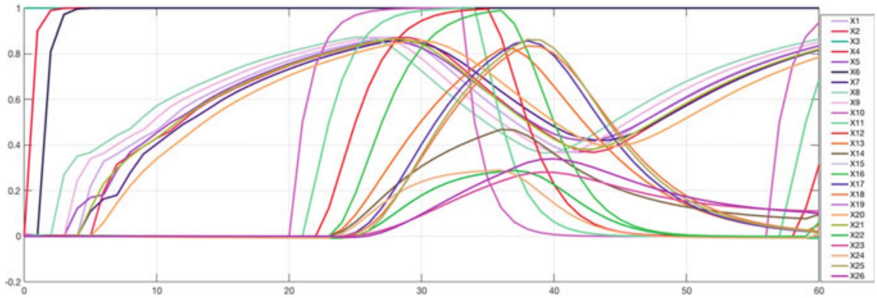

Fig. 2. Results of a simulation for the proposed cognitive model of the electroconvulsive therapy

We used MATLAB program in [2]. This program allowed us to use all differential equations that were needed for simulation, and also it contained adaptivity feature which we had in our proposed algorithm. With using appropriate connections, we make the model mathematical and well-fitted to the information gathered from the neuroscientific research findings. The time step for the graphical representation was equal to 1. Table 2 shows the λ_i for the nodes with more than one entering weight. Firstly, the context stress becomes active, and consequently, it makes the stress level of the body to be increased gradually. Consequently, the stressed individual senses the stress, and therefore, as a next phase, the goal comes to play a role to reduce this by using ECT at about 25. The weights between most of the states are 1 except the following weights with their following weight's representation. ω_{18}: −0.7, ω_{20}: 0.7, ω_{23}: 0.4, ω_{24}: 0.4, ω_{35}: −0.9, ω_{47}: −0.9.

Table 2. Scaling factors for the proposed cognitive model

State	X_5	X_8	X_{14}	X_{15}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}
λ_i	2	3	3.4	3	1.4	2	2	2	2

Based on the simulation results, it is possible to show that the best solution for decreasing the stress is taken, performing of electroconvulsive treatment. The objective and the performing electroconvulsive treatment influence other brain components to decrease the activation at time 35. However, this influence is not permanent, and after some time, the stress up rises, which guides to activation of the objective and performing of another need of performing electroconvulsive therapy, and repeatedly until the patient resolves to stop executing electroconvulsive therapy. Thus, the results illustrate that the proposed cognitive model for the electroconvulsive treatment works well.

In Fig. 3, the stable condition is illustrated.

The suppression of connection and adaptivity among above-mentioned brain components; srs_{ee} (cognitive) and amygdala is shown in Fig. 4. As it has been illustrated, grasp to tolerate with high level of stress, and declining begins at time around 30 and the following time until time 60 to remain stable.

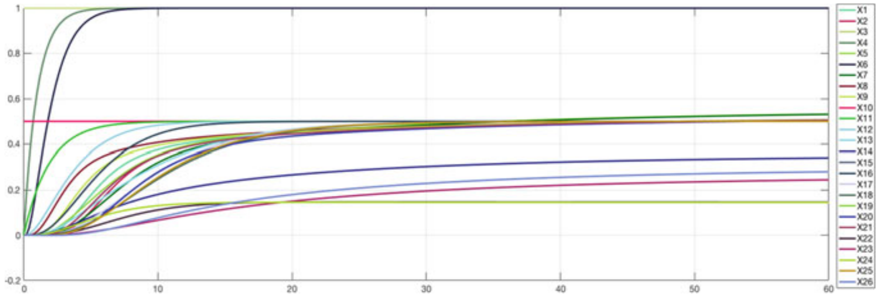

Fig. 3. Graphical representation for stable state for non-electroconvulsive treatment

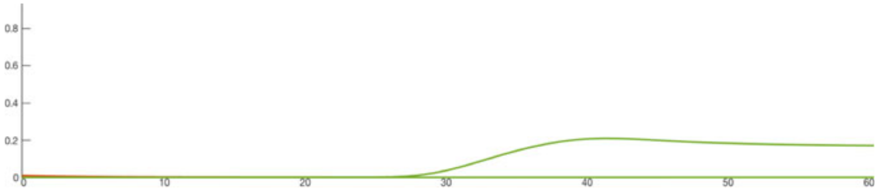

Fig. 4. Graphical representation for checking the adaptivity between amygdala and srs_{ee}, suppressed by electroconvulsive treatment es_{ECS}

5 Discussion

This work introduced a cognitive model of electroconvulsive treatment for post-traumatic disorder. This model can be used in order to evaluate various neurological patterns about the impact on the brain, and the influences that several brain components have on the stress reduction.

One important limitation of this work might concern the assumptions made while designing the computational models. However, by involving the right literature, those assumptions should be in line with underlying background in neuroscience according to real-world phenomenon. For instance, in this research, some assumptions regarding the extreme emotion responses and controlling of that were made. Connecting research from neuroscience to cognition can be tricky. We have considered mind processes which are based on the findings from neuroscience. For instance, sensory representation state that we have considered in our computational models is related to the perception happening in the human's mind, and we connect that to the real-world phenomenon which was stress in our case.

Various graphical representations have been performed, and one of which was illustrated in detail in this work. The presented cognitive model might be considered as the foundation of a greater model of the brain for having more insight in the processes inside the brain and to propose a possible treatment of different persons with disorders to do the treatments of extreme emotions. Future work of this model can be exploring the effect of different emotions on the brain and finding the physical effect of that in different brain components and biological processes.

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Digital Transformation in Swiss Hospitals: A Reference Modeling Approach

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Abstract. Through various approaches such as the eHealth Switzerland 2.0 strategy, the Swiss healthcare system aims to digitally catch up with other industries and drive the industry into the digital future. To enable hospitals to transform their business model and prepare for the future, this paper presents an approach for the implementation of the digital transformation in Swiss hospitals. Thus, a metamodel consisting of nine elements was created as a base. The focus of the metamodel and the later reference model lay on the central activity elements, which are each embedded in a phase and are directly or indirectly connected to all the other elements in the metamodel. For the reference modeling, the metamodel serves as a structural template, while an existing roadmap from the literature on the digital transformation was used as a content-based starting point. The final reference model consists of 30 activities within six different phases.

Keywords: Healthcare · Transformation · Model

1 Introduction

The digital transformation in the healthcare industry is gaining momentum, and new digital transformation trends are continuously emerging and are slowly establishing themselves. These trends include progresses in several areas of health services and innovations such as an increase in patient engagement through technology, artificial intelligence in health, health apps, big data and 3D printing [15]. To unleash the enormous potential behind these technologies and allow them to prosper, a solid digitized base is required [6, 26]. Compared to other business sectors, healthcare organizations remain at a significantly lower degree of digitization and record far lower investments in their digital future [2, 10, 24]. A positive indicator of the digitization in healthcare is a proportionate increase in investments compared to previous years [24].

Despite that, Switzerland, among other north European countries, scored highest in the digital evaluation index in 2017 [8]. Harvard Business Review created this index to analyze the digital evolution of 60 countries. Among other things, the index analyses the countries' pattern of digital evolution, evaluates the digital competitiveness and assesses the changes since the last publication. Even though Switzerland, Denmark, Sweden, and

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Norway lead the digital evolution index, they score below two of a maximum of four points regarding their rate of change in digital evolution between 2008 and 2015 [8]. This result reflects the challenges of sustaining growth and offers chances to facilitate existing maturity, scale and network effects to advance the digitization. A study published by PricewaterhouseCoopers, and Google Switzerland analyzed the degree of digitization in various industries [12]. The degree of digitization is based on a self-assessment of participating companies. The survey evaluates the digital maturity in four areas: process and infrastructure, digital sales, customer involvement and people and culture. The questions were answered on a four-point scale. The industries energy and utilities (1.78) and healthcare (1.84) lag the furthest behind. However, [12] mentions that the implementation of the eHealth Switzerland 2.0 strategy could advance the digital maturity in Swiss healthcare. This strategy was introduced in 2018 by the Swiss Confederacy and cantons to increase the digitization within the healthcare sector [11]. One of the suggested reasons for the lagging digitization in the healthcare industry is the focus for human interaction that often stands in the way of digital advancements [12]. Additionally, [12] states the strict regulations as another reason for the slow-progressing digitization in healthcare.

Several technology and consulting companies published reports with various views and explanations about the current state of digitization in the healthcare industry in Switzerland [16]. Barriers obstruct the digital transformation from the inside (e.g. the absence of relevant knowledge) and outside (e.g. strict regulations) of an organization. These impediments have led to the current digital deficit compared to other industries. Therefore, special attention must be given to the barriers when approaching future digitization projects.

As a result of the above-described slow digital transformation and the identified factors supporting it, this paper presents a reference model for the digital transformation of Swiss hospitals that address the mentioned issues and allow a simplified and guided transformation process. In the next chapter, the metamodel will be elaborated, and the deduction of the reference model described. Chapter 4 presents the outcome of the reference modeling approach and provides examples showing how the model is applied in practice. The fifth chapter reflects the results, discusses the findings, and describes the limitations. The final chapter concludes the paper, provides an outlook, and proposes approaches to reduce the impact of the previously discussed limitations.

2 Problem Statement

Medical institutions, specifically hospitals, face various challenges in connection with the digital transformation. Continuous pressure to decrease costs and increase efficiency is forcing hospitals to promptly address the digital transformation. However, the hospitals are diverse, and tailor-made solutions do not yet exist or are too specific. Therefore, they do not fit the specific organizational needs [16]. Hence, a reference model is defined to exploit these industry-specific drivers and barriers. The goal of the model is to create a generic approach where organizational characteristics are not considered, and the drivers are used to support the specific strengths of a company while at the same time removing and overcoming barriers. The result is a reference model, which is instanced based on an organizations unique characteristics and requirements. Therefore, the model uses only generic elements which are adopted by the management or project lead to specific entities within the target organization. This approach addresses the different organizational settings of the various players within the hospital system. This paper will answer the following primary research question:

- What does an ideal approach for implementing the digital transformation in the Swiss healthcare system look like?

In order to answer this main research question, the following subordinate research questions are approached first:

- Which framework serves as a suitable foundation for the reference model?
- Which elements, components, and the corresponding relationships between them have to be taken into account in a reference model for digital transformation in Swiss hospitals?

The answers given in this paper only consider the hospital organizations within the Swiss healthcare industry. In case, the same sector in a different geographic region has similar drivers and barriers, and the reference model may be suitable as well. The reference model is a generic guideline and needs to be instantiated upon utilization according to an organization's specific requirements.

3 Metamodeling

In order to answer the previously defined research questions, a reference modeling approach was selected. This approach was applied on the base of a previously created metamodel. Below, the details of this research design are explained and where necessary, more profound statements are delivered in order to present a conclusive procedure.

3.1 Metamodel

The first step of creating a reference model for the implementation of the digital transformation in Swiss hospitals is establishing and defining the applicability of the reference model in the targeted domain using a metamodel as a blueprint. In the metamodeling process the overall depth, scale as well as the syntax and structure of the reference model are determined by charting its elements, components, and the corresponding relationships between them [13, 23, 27]. Hence, the metamodel facilitates the conceptual modeling and allows a more intuitive and practical view on the model based on it [13]. This helps users and implementors to better understand its complexity and extent when evaluating or making use of it.

The previous description shows that various modeling levels and abstractions exist. The guidelines followed in this research regarding multi-level modeling are presented in the paper by [14] and further described in [23]. As shown in Fig. 1, the mentioned guidelines are differentiated into four hierarchies. Apart from M0, each layer conforms to or is implemented according to the adjoining layer above it and additionally (except M3) defines or abstracts the layer underneath it [14, 23]. Therefore, the metamodel describes the notation of the metamodel, while the metamodel describes the structure of the model. This research only includes the M1 and M2 layers. The first layer (M0) is not formally carried out and thereby is only briefly described in the following paragraph. In the final layer, the reference model is adapted to a Swiss hospital (layer M2) and consequently takes place in practice.

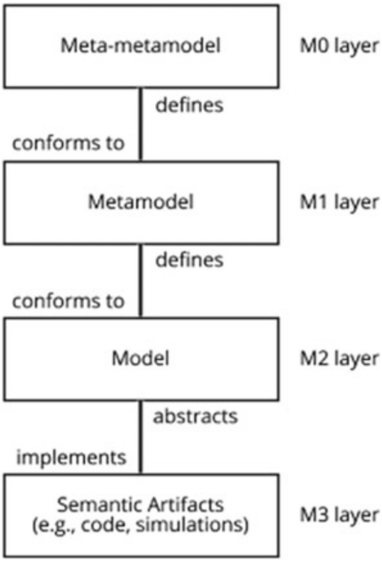

Fig. 1. Four-layer metamodeling architecture as described by [1]

The metamodel in this project was created using a simplified adoption of the UML class diagram notation. This notation, along with its elements, was chosen because it represents and aligns well with the main purpose of the metamodel, which is the listing of the allowed and necessary constructs within the reference model [13]. The mentioned simplification contributes to a better understanding by non-experts and increases the clarity of the model. Moreover, since the metamodel is not a model to a software artifact, using the notation to the full extent is not feasible and would not be appropriate. The following elements were used in the metamodeling process: the class element, the navigability, the multiplicity, and the generalization. The class element is used to model the single components that make up the reference model. Displayed with a rectangular outline, these components stand in an associative navigability to one another [19, 22]. The navigability gives additional information to the association and can either be unspecified, navigable or not navigable in both directions of the associated components [19, 22]. Additionally, the multiplicity or cardinality of the associations specifies the allowable number of instances of the described component in nonnegative integers [19, 22]. Lastly, associations can also occur in the form of a generalization. This form of association structures classes into hierarchies of inheritance, where the subclasses specify the parent in a more detailed manner but are essentially already covered in the parent class. To allow the creation of a complete metamodel, the metamodeling process was not undertaken completely uncoupled from the reference modeling process. Rather, the first version of the original metamodel was used as a base for designing the reference model. Elements of one or the other model where then added or removed if necessary, in order to perfectly match the models to the targeted domain. This iteration between the meta- and reference modeling process resulted in complete and well-aligned models.

3.2 Reference Model

After completing the metamodel, the reference model was created according to the prior defined elements and relations discussed above. A definition that is universally accepted for "reference model" cannot be found. Consequently, to use a broadly accepted definition of the term in the context of this paper, common denominators in different definitions by [5, 7, 18, 21, 25] were combined. For example, [25] describes reference models as a universal tool using "recommendation character" to construct and derivate other (enterprise-specific) models while [5, 7] call it a "normalized description of key concepts of a given domain" and [21] describes a reference model as a construction with recommended universal elements and relationships that create a point of reference. Resulting from the combination of the mentioned definitions, a reference model in this paper is defined as a universally applicable and reusable best practice framework for a certain domain, which in this case are Swiss hospitals.

As displayed in the metamodel (Fig. 2), the reference model (and its phases) was derived from an existing roadmap. This serves as a solid base to ensure the completeness of the approach presented in this paper. Thereby, it offers a fully accompanying guideline using established and proven methods to better address the hospitals lagging regarding digitization, when compared to organizations of other industries [4, 9]. However, the single activities and phases as well as other elements of the underlying roadmap were modified, adjusted, removed, replaced or extended to fit the specific application domain of this research when necessary.

For this purpose, the model by [20] was selected. Schallmo and colleagues present in their book a high-level, comprehensive roadmap with five phases starting with the digital reality phase and ending with the implementation phase. The roadmap by [14] met several key factors to serve as a template, which is why it was selected. Firstly, their model not only shows a certain procedure, but is also a well-documented roadmap for the digital transformation and business model innovation. The second key factor is the combination of the objectives "digital transformation" and "business model innovation." This allows to keep a customer-oriented view during the major digital changes. In addition, the roadmap by [20] is based on existing "digital transformation" and "business model innovation" approaches as well as on best practices and therefore suggests an established procedure. Lastly, the roadmap is divided into five phases, where the implementation does not take place until the last step. Thus, this ensures a solid base with a thoroughly developed framework, inclusion of all stakeholders, and organizational characteristics plus a carefully designed organizational fit.