A Second-Order Adaptive Network Model for Exam-Related Anxiety Regulation

Barradas, Isabel; Kloc, Agnieszka; Weng, Nina; Treur, Jan

published in
Biologically Inspired Cognitive Architectures 2021
2022

DOI (link to publisher)
10.1007/978-3-030-96993-6_4

document version
Publisher's PDF, also known as Version of record

document license
Article 25fa Dutch Copyright Act

A Second-Order Adaptive Network Model for Exam-Related Anxiety Regulation

Isabel Barradas[1], Agnieszka Kloc[2], Nina Weng[3], and Jan Treur[4(✉)]

[1] Faculty of Science and Technology, Free University of Bozen-Bolzano, Bolzano, Italy
isabel.barradas@unibz.it
[2] Department of Technology and Operations Management, Erasmus University Rotterdam, Rotterdam, The Netherlands
kloc@rsm.com
[3] Technical University of Denmark, DTU Compute, Kongens Lyngby, Denmark
s202997@student.dtu.dk
[4] Department of Computer Science, Social AI Group, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands
j.treur@vu.nl

Abstract. A common type of performance anxiety is the so-called "exam anxiety", in which students can experience physical and emotional reactions before or during the exam due to the testing situation. If exam anxiety was already quite prevalent in students' lives, one could expect that this condition got even worse due to the COVID-19 pandemic. Besides all the worrying factors that COVID-19 brought to the general population, students had to rapidly adapt to the reality of online exam modalities – introducing extra sources of stress. Therefore, our aim is to model the differences between online and offline modalities in the emotion regulation processes to overcome exam anxiety. To model these processes, we used a second-order adaptive network model. We employed reappraisal, since it is considered the most effective emotion regulation strategy to deal with this type of anxiety. We showed that, even though the reappraisal processes take place and the exam anxiety is regulated, the exam anxiety levels are higher in the online exams than in the offline exams.

Keywords: Second-order adaptive · Network model · Exam anxiety · Emotion regulation · Reappraisal

1 Introduction

Anxiety is an emotion that accompanies everyone throughout their lives, in different moments and to different extents, and by some psychologists is considered as "being at the root of what it means to be human" [1, 2]. It can be triggered by distinct current, upcoming or also past events. Researchers distinguish between various types of anxiety

I. Barradas, A. Kloc and N. Weng—The first three authors contributed equally to this research and the writing of the paper.

V. V. Klimov and D. J. Kelley (Eds.): BICA 2021, SCI 1032, pp. 42–53, 2022.
https://doi.org/10.1007/978-3-030-96993-6_4

depending on the context it refers to, for example classroom anxiety, public speaking anxiety, workplace-related anxiety, exam anxiety. In this work, we focus on the latter one and examine how the specifics of the context – online or offline examination mode – could affect the experienced levels of anxiety.

The experienced levels of anxiety depend additionally on whether an individual is able to employ processes that can help decrease his/her/their emotion levels. In the psychological literature, such processes are referred to as *emotion regulation* [3].

Examples of the most widely discussed emotion regulation strategies are acceptance, avoidance, problem solving or reappraisal. These emotion regulation strategies are extremely important for human mental functioning as it is often argued that the impairment or lack of ability to employ them when faced with stressful situations can explain the existence of the so-called distress disorders – generalized anxiety disorder or depression [4]. Typically, these strategies are used on a daily basis by everyone at least to a certain extent, consciously or subconsciously, in each anxiety-inducing situation. To the best of our knowledge, however, emotion regulation models have not been used in the context of modeling the differences between anxiety levels in online and offline exams and thus we aim to fill this gap by addressing these processes in our research.

To study the anxiety-related mental processes in the online and offline exams context, we construct a computational model which takes into account the differences between anxiety-related states that become activated in a specific (online or offline exam) context. We also model the emotion regulation process in regard to two anxiety conditions: concerning having a stable examination environment and concerning the new exam formula with a different type of questions. Finally, we add two adaptation levels to the model, what helps us make the model more realistic by making the connection strength between anxiety and emotion regulation control states, as well as the speed of its development, adaptive.

2 Background

Exam anxiety is a type of performance anxiety [5, 6] that is defined by Zeidner in his book as a "set of phenomenological, physiological, and behavioral responses that accompany concern about possible negative consequences or loss of competence on an exam or similar evaluative situation" [7]. This type of anxiety is experienced by many students and it tends to happen when the student perceives either the test performance or the testing situation as a threat [8]. As a consequence, the student believes that his/her/their intellectual, motivational, and social capabilities are not enough to cope with the test [7]. Exam anxiety has also been referred to as test anxiety, exam stress or test stress.

There are different factors that impact exam anxiety, such as fear of failure, lack of preparation, poor test history, high pressure, and perfectionism. Besides all of this, the COVID-19 pandemic brought more stressful factors that are added to the ones just mentioned. Not just people increased their level of anxiety due to concerns related to their health and economic situation, students have classes and are assessed in a novel scenario to which they are not used. Moreover, adjusting to the new required routine can be challenging. Even before the COVID-19 pandemic, online assessment has been gaining followers. In fact, it can be more convenient to schedule, it saves time grading and entering grades (can even be automatic), and it costs less than paper and pencil exams [9]. Moreover, Stowell & Bennett (2010) [10] reported that students that normally had high levels of exam anxiety in the classroom had reduced exam anxiety during online exams, while students with low classroom anxiety had higher anxiety during online exams. Nonetheless, changing the paradigm from offline exams (exams in the classroom) to online exams requires time and resources for adaptation – which was something not possible to achieve during the COVID-19 pandemic. In many cases, online exams became mandatory and the process of converting the assessment methodologies was accelerated. To cope with this new reality, both students and instructors had to learn fast how to use these platforms, which introduced an extra source of stress.

A low level of test-related anxiety is beneficial to students, since it makes them more aware and alert. However, an overall state of anxiety has negative consequences on the well-being of students and also on their performance. Exam anxiety has a mental and physical impact, that can be reflected in many symptoms, such as: loss of sleep, appetite and hair, nervousness, fear, irritability, headaches, inability to concentrate, and craving for food (before the exam); as well as confusion, panic, mental blocks, fainting, and feeling too hot or too cold (during the exam) [5]. Also, Akinsola & Nwajei (2013) [11] reported a coexistence of exam anxiety with depression. This further affects students exam performance and their grades, as established by Putwain (2008) [12] and Segool *et al.* (2013) [13]. These examples of consequences are already enough to understand that strategies are needed to reduce the anxiety level to a state in which it can be healthy and positively-stimulating.

Many strategies to reduce exam anxiety that can be adopted and combined can be found in Mashayekh & Hashemi (2011) [5]. Improving self-image and motivation, keeping a healthy lifestyle, and taking test samples are good examples of practices that can be performed to help students to decrease their felt exam anxiety. Even though these strategies are general and not specific to the COVID-19 situation, they can be helpful in that context too. Nonetheless, since COVID-19 forced the implementation of online assessments, our goal here is to assess the differences in exam anxiety for online and offline exams. Therefore, the emotion regulation strategies adopted in this work will take the differences between these two modalities into consideration and these general strategies will not be considered.

Emotion regulation refers to the ability to effectively control which emotions individuals have, when they have them, and how they experience or express these emotions [14]. Processes to regulate emotions are either automatic or controlled, conscious or unconscious, and can affect different parts in the emotion process. Although the definition of emotion is ambiguous, here we consider that emotions can be the abbreviation for "emotional episodes" since they are multicomponential processes that evolve in time. Therefore, emotion regulation mechanisms cause changes in the emotion dynamics. With this in mind, there is the need to adopt models that are able to reflect these dynamical changes.

According to Gross (2013) [3], emotion regulation has three core features: the *goal* (what the individual is trying to accomplish), the *strategy* (which processes are engaged to achieve that goal), and the *outcome* (the consequences of trying to reach that goal using that strategy). In this work, we are focused on the strategies to regulate emotions. Whatever the goal is, there are different ways to achieve it and can be categorized as adaptive (associated with greater wellbeing or fewer symptoms) or maladaptive (associated with psychological symptoms and other negative outcomes) [15].

Maladaptive strategies include, for instance, suppression (the attempt to hide, inhibit or reduce ongoing emotion-expressive behavior [16, 17] which happens once an emotion is already taking place [18]) and rumination (the repetitive thinking about the thoughts and feelings about the event [19]. Both processes give the individual the feeling that they are solving the process, but actually trigger more negative emotions [20]. On the other hand, adaptive strategies can include, for instance, putting an event into perspective: diminishing the meaning of the event [19] or reappraisal (the attempt to reinterpret an emotion-eliciting situation, altering its meaning and its emotional impact [17]). Reappraisal can be employed even before the emotion takes place and therefore is able to modify the entire dynamics of the emotional process before the response has been completely generated [18]. In fact, individuals can change their exam anxiety through reappraisal. Brady *et al.* (2018) [21] suggested that a way to do it would be to reinterpret the role of anxiety – instead of considering this state as harmful, students should try to see it as neutral or beneficial. Due to the believed effect of reappraisal in controlling exam anxiety, this emotion regulation technique is commonly employed during cognitive therapy [22, 23]. Strain & D'Mello (2011) [24] concluded that reappraisal is an effective strategy for emotion regulation during learning, which was also beneficial for the learning process.

Moreover, it can be argued that even though certain strategies, such as distraction, can be effective in high-intensity negative situations [25], they cannot be effective in the learning context, especially if it is the only strategy used. For instance, if students exclusively apply the strategy (distraction) *before* the exam, it can happen that they will not have enough time to study everything and, once they realize this, they get too anxious to study more (worsening the process) and they will be even more anxious during the exam. If students decide to exclusively apply the strategy *during* the exam, it is easy to understand that either they do not finish the exam in time, or at a certain point they will realize that they do not have enough time to finish it, affecting their performance at the rest of the exam. For these reasons, reappraisal is the only strategy that is going to be considered here. It is important to note that reappraisal can be cognitively demanding and therefore, to be effective, it should not happen too late in the emotional process.

3 The Adaptive Network Modeling Approach Used

In this work, the adaptive modeling approach from [26] is applied for designing and simulating a dynamic process of multiple orders of adaptation. By extracting states and causal relationships between them for a certain mental or social process, the network model is built. The linkages could be manipulated further by adding extra states to the network, which are called *self-model states* or *reification states*. Given the initial value for all states, the states activations will change with time. The network structure characteristics for this approach are described as follows:

Connectivity characteristics: a connection weight $\boldsymbol{\omega}_{X,Y}$ represents the connection strength from state X to state Y.
Aggregation characteristics: for each state Y a combination function $\mathbf{c}_Y(..)$ is used to aggregate the multiple incoming impacts.
Timing characteristics: $\boldsymbol{\eta}_Y$ represents the speed factor of state Y which controls the timing of the impact on Y.

These three types of network characteristics provide the standard numerical representation of the network model in difference equation format:

$$Y(t + \Delta t) = Y(t) + \boldsymbol{\eta}_Y[\mathbf{c}_Y(\boldsymbol{\omega}_{X_1,Y}X_k(t), \ldots, \boldsymbol{\omega}_{X_k,Y}X_k(t)) - Y(t)]\Delta t \quad (1)$$

where Y is any given state that has incoming connections from states $X_1,\ldots, X_k$. The characteristics for all states are specified in a standard table format called role matrices, which allows us to simulate the process automatically in the software environment.

Using the notion of *self-modeling network* (also called *reified network*) introduced in [26], any network characteristic can be made adaptive by adding a (self-model) state to the network that represents the value of this characteristic. This will be applied here to obtain a second-order adaptive network in which for some states X and Y: (1) first-order self-model states $\mathbf{W}_{X,Y}$ are included in the network that represent the value of connection weight $\boldsymbol{\omega}_{X,Y}$, and (2) second-order self-model states $\mathbf{H}_{\mathbf{W}X,Y}$ are included in the network that represent the value of the speed factor of $\mathbf{W}_{X,Y}$ (learning rate).

4 The Second-Order Adaptive Network Model

The knowledge from the background literature (Sect. 2) and the modeling approach from Sect. 3 were combined into an adaptive mental network model for exam-related anxiety regulation. The connectivity of the multi-levelled model is 3D-visualized in Fig. 1 with the detailed explanation of states in the Table 1.

This model simulates the process of activating and regulating the anxiety before and during the exam. In the base level, the two exam states are introduced (X_1 – on_ex, X_2 – off_ex) for specifying the two modalities of exam: online and offline. Each modality causes different issues/problems and then leads to different levels of anxiety. The states from X_3 to X_9 states are potential issues that students might encounter before the exam, while the during-exam issues are represented by the states from X_{10} to X_{16}. Some of these potential problems might be triggered only by online or offline exam (*e.g.*, the Internet problem during the exam X_{10} can only be caused by an online exam) or by both (*e.g.*, the difficulty of checking course materials before the exam X_3 would be introduced by both online and offline settings with different levels of impact).

After the “issues states”, four states about the way students feel are created, which are the expected difficulties for exam performance (X_{17}), the expected difficulties for technical performance (X_{18}), the feeling of being demoralized (X_{19}) and the difficulties to be focused (X_{20}). It is necessary to mention that the first two states would affect the latter two due to the fact that the mental states before the exam influence the feelings during the exam, especially in the early stage of the exam. Finally, the exam anxiety level (X_{21}) is integrated based on these four states.

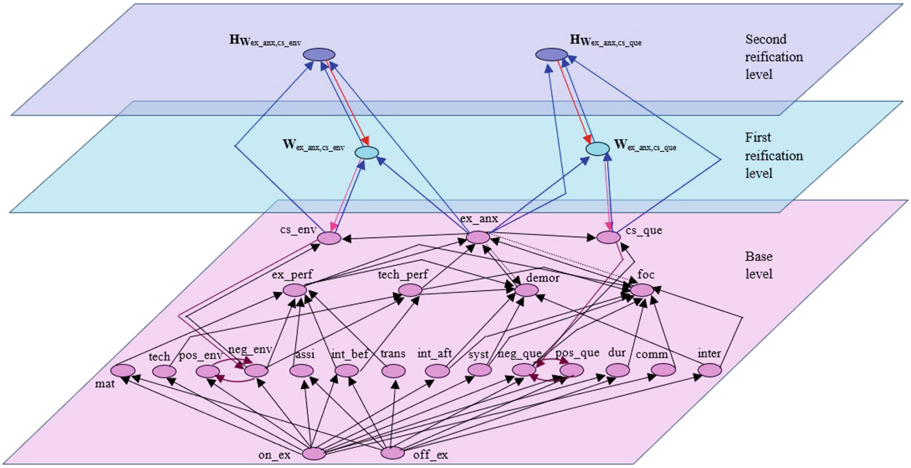

Fig. 1. Overview of the self-modeling network architecture for exam-related anxiety regulation with the base level (lower plane, pink), the first reification level (middle plane, blue), and the second reification level (upper plane, purple).

Since we are applying reappraisal as a strategy of emotion regulation (as mentioned before in Sect. 2.2), there are two pairs of states that are belief states – X_5 and X_6, X_{12} and X_{13} – indicating two opposite beliefs about the environment and the type of questions, respectively. The negative states in each pair will be influenced (suppressed) by the corresponding control states (X_{22} and X_{23}), so that the student is able to regulate the emotion by reappraisal. These two control states are triggered by the level of exam anxiety (X_{21}). The states were chosen based on a conducted survey that reported the views and difficulties of students during online exam modalities as consequence of the COVID-19 pandemic [27]. We took this study into consideration, but grouped some difficulties that were related to each other (about technical difficulties, for instance). To make the comparison possible, we also added states that are just influenced by offline modalities and therefore were not included in the referred survey.

The second level describes first-order network adaptation at the first reification level, which demonstrates the Hebbian learning process for anxiety regulation taking place before and during the exam. By changing the **W**-states, which provides the self-model representation for the connection weights in the base level, the student learns the ability of switching from negative to positive interpretation over time.

The third level describes a second-order adaptation, which controls the speed of the first-order learning at the first reification level. **H**-states are used for these self-model states. Here, by adapting the speed factor for the first-order adaptation, the student could further gain the ability of reappraisal by adjusting the speed.

Some connections in this model have negative values, indicating that the source state negatively impacts the target state. Those connections are colored as dark-red in Fig. 1. The combination functions used in this model are listed in Table 2. When only one incoming connection exists, the identity function is used. By contrast, the advanced logistic function **alogistic** was chosen to combine multiple effects for the nodes. There are two parameters for **alogistic**: the steepness **σ** and the threshold **τ**. With the application of Hebbian learning, Hebbian learning function **hebb** is used in this work with the persistence factor **μ** accordingly.

Figure 2 demonstrates the role matrices of this multi-leveled network model. Matrix **mb** represents the incoming base connections, which are either between states at the same level, or from lower states to higher states. Notice that even though arrows from higher states to lower states exist in Fig. 1 (*e.g.*, the pink/red arrows from **H**-states to **W**-states), those arrows do not indicate the base connectivity but the connectivity based on reification for a specific role; they are specified in the matrix for that role instead.

Table 1. Overview of the states of the multi-level network model.

State nr	State name	Explanation	Level
X_1	on_ex	Online exam	
X_2	off_ex	Offline exam	
Pre-exam states			
X_3	mat	Difficulty in checking course materials	
X_4	tech	Checking technological tools to be used during the exam	
X_5	pos_env	Belief of a stable and comfortable environment	
X_6	neg_env	Belief of an unstable and uncomfortable environment	
X_7	assi	Difficulty in getting assistance	
X_8	int_bef	Internet problems during the preparation of the exam	
X_9	trans	Worry about arriving on time to the exam (due to transports, for instance)	
During exam states			
X_{10}	int_aft	Internet problems during the exam	
X_{11}	syst	Problems related to the system (entering, visualizing questions, etc.)	Base Level
X_{12}	neg_que	Negative belief about the type of questions of the exam	
X_{13}	pos_que	Positive belief about the type of questions of the exam	
X_{14}	dur	Duration of the exam	
X_{15}	comm	Communication with the instructor	
X_{16}	inter	Social and physical interaction with colleagues	
X_{17}	ex_perf	Expected difficulties for exam performance	
X_{18}	tech_perf	Expected difficulties for technical performance	
X_{19}	demor	Feeling demoralized	
X_{20}	foc	Difficulties in getting focused	
X_{21}	ex_anx	Level of exam anxiety	
X_{22}	cs_env	Reappraisal control state for the environment	
X_{23}	cs_que	Reappraisal control state for the type of questions	
X_{24}	$\mathbf{W}_{ex\_anx,cs\_env}$	Reified representation state for connection weight ω_{ex_anx,cs_env}	First reification level
X_{25}	$\mathbf{W}_{ex\_anx,cs\_que}$	Reified representation state for connection weight ω_{ex_anx,cs_que}	
X_{26}	$\mathbf{H}_{\mathbf{W}ex\_anx,cs\_env}$	Reified representation state for speed factor $\eta_{\mathbf{W}ex\_anx,cs\_env}$ for reified representation state $\mathbf{W}_{ex\_anx,cs\_env}$	Second reification level
X_{27}	$\mathbf{H}_{\mathbf{W}ex\_anx,cs\_que}$	Reified representation state for speed factor $\eta_{\mathbf{W}ex\_anx,cs\_que}$ for reified representation state $\mathbf{W}_{ex\_anx,cs\_que}$	

Table 2. The combination functions used in the introduced network model

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

On the right-top corner of Fig. 2, matrix **mcw** shows the connection weights which has values within [−1, 1]. Two weights here are not fixed numbers but considered as adaptive – the two states we adapt through Hebbian learning; this is where the related downward connections are specified. In matrix **mcfw**, the combination functions weights are shown, with only **W**-states applying the **hebb** function. Matrix **mcfp** presents the combination function parameters for all states, where the two negative belief states are applied with lower thresholds than others to model the reappraisal process. Besides, the steepness for X_{19} (feeling demoralized), X_{20} (difficulty of being focused) and X_{21} (exam anxiety) are down-adjusted to imitate the gradually increasing progress of anxiety level during the exam stages. In the right-bottom corner, the matrices of speed factors (matrix **msv**) and the initial values (**iv**) are displayed. The current values are given under the online setting. To switch to offline setting, the initial value of X_1 should be set as 0, and X_2 set as 1.

5 Simulation Results

In this section, we present some of the simulation results for the introduced model of context-dependent exam anxiety. We show separate simulations for offline and online exams and discuss the differences in anxiety-inducing processes in these two contexts.

mb	base connectivity	1	2	3	4	5	6	7	8	9
X1	on_ex	X1								
X2	off_ex	X2								
X3	mat	X1	X2							
X4	tech	X1								
X5	pos_env	X1	X6							
X6	neg_env	X1	X5	X22						
X7	assi	X1	X2							
X8	int_bef	X1	X2							
X9	trans	X2								
X10	int_aft	X1								
X11	syst	X1								
X12	neg_que	X1	X2	X13	X23					
X13	pos_que	X1	X2	X12						
X14	dur	X1	X2							
X15	comm	X1								
X16	inter	X2								
X17	ex_perf	X3	X6	X7	X8	X9				
X18	tech_perf	X4	X6	X8						
X19	demor	X10	X11	X16	X17	X18	X21			
X20	foc	X10	X11	X12	X14	X15	X16	X17	X18	X21
X21	ex_anx	X17	X18	X19	X20					
X22	cs_env	X6	X21							
X23	cs_que	X12	X21							
X24	W(ex_anx,cs_env)	X21	X22	X24						
X25	W(ex_anx,cs_que)	X21	X23	X25						
X26	H(ex_anx,cs_env)	X21	X22	X24	X26					
X27	H(ex_anx,cs_que)	X21	X23	X25	X27					

mcwv	connection weights	1	2	3	4	5	6	7	8	9
X1	on_ex	1								
X2	off_ex	1								
X3	mat	0.5	0.8							
X4	tech	0.5								
X5	pos_env	0.8	-0.8							
X6	neg_env	0.8	-0.8	-0.6						
X7	assi	0.8	0.5							
X8	int_bef	0.8	0.5							
X9	trans	0.5								
X10	int_aft	1								
X11	syst	0.8								
X12	neg_que	0.8	0.5	-0.8	-0.6					
X13	pos_que	0.8	0.5	-0.8						
X14	dur	0.9	0.5							
X15	comm	0.7								
X16	inter	0.7								
X17	ex_perf	0.7	0.7	0.7	0.7	0.7				
X18	tech_perf	0.7	0.7	0.7						
X19	demor	0.3	0.3	0.3	0.7	0.7	0.7			
X20	foc	0.3	0.3	0.7	0.3	0.3	0.3	0.7	0.7	0.7
X21	ex_anx	0.8	0.8	0.8	0.8					
X22	cs_env	0.7	X24							
X23	cs_que	0.7	X25							
X24	W(ex_anx,cs_env)	1	1	1						
X25	W(ex_anx,cs_que)	1	1	1						
X26	H(ex_anx,cs_env)	1	1	-0.1	1					
X27	H(ex_anx,cs_que)	1	1	-0.1	1					

mcfwv	combination function weights	1 identity	2 alogistic	3 hebb
X1	on_ex	1	0	0
X2	off_ex	1	0	0
X3	mat	0	1	0
X4	tech	1	0	0
X5	pos_env	0	1	0
X6	neg_env	0	1	0
X7	assi	0	1	0
X8	int_bef	0	1	0
X9	trans	1	0	0
X10	int_aft	1	0	0
X11	syst	1	0	0
X12	neg_que	0	1	0
X13	pos_que	0	1	0
X14	dur	0	1	0
X15	comm	1	0	0
X16	inter	1	0	0
X17	ex_perf	0	1	0
X18	tech_perf	0	1	0
X19	demor	0	1	0
X20	foc	0	1	0
X21	ex_anx	0	1	0
X22	cs_env	0	1	0
X23	cs_que	0	1	0
X24	W(ex_anx,cs_env)	0	0	1
X25	W(ex_anx,cs_que)	0	0	1
X26	H(ex_anx,cs_env)	0	1	0
X27	H(ex_anx,cs_que)	0	1	0

mcfpv	combination function parameters	1 identity		2 alogistic		3 hebb	
				σ	τ	μ	
X1	on_ex	NaN	NaN				
X2	off_ex	NaN	NaN				
X3	mat			5	1		
X4	tech	NaN	NaN				
X5	pos_env			5	0.5		
X6	neg_env			5	0.3		
X7	assi			5	1		
X8	int_bef			5	1		
X9	trans	NaN	NaN				
X10	int_aft	NaN	NaN				
X11	syst	NaN	NaN				
X12	neg_que			5	0.3		
X13	pos_que			5	0.5		
X14	dur			5	1		
X15	comm	NaN	NaN				
X16	inter	NaN	NaN				
X17	ex_perf			5	0.5		
X18	tech_perf			5	0.5		
X19	demor			1	1.5		
X20	foc			1	1.5		
X21	ex_anx			2	1		
X22	cs_env			5	0.5		
X23	cs_que			5	0.5		
X24	W(ex_anx,cs_env)					1	NaN
X25	W(ex_anx,cs_que)					1	NaN
X26	H(ex_anx,cs_env)			5	1		
X27	H(ex_anx,cs_que)			5	1		

msv	speed factors	1
X1	on_ex	0
X2	off_ex	0
X3	mat	0.8
X4	tech	0.8
X5	pos_env	0.8
X6	neg_env	0.8
X7	assi	0.8
X8	int_bef	0.8
X9	trans	0.8
X10	int_aft	0.05
X11	syst	0.05
X12	neg_que	0.05
X13	pos_que	0.05
X14	dur	0.05
X15	comm	0.05
X16	inter	0.05
X17	ex_perf	0.5
X18	tech_perf	0.5
X19	demor	0.5
X20	foc	0.5
X21	ex_anx	0.5
X22	cs_env	0.5
X23	cs_que	0.5
X24	W(ex_anx,cs_env)	X26
X25	W(ex_anx,cs_que)	X27
X26	H(ex_anx,cs_env)	0.5
X27	H(ex_anx,cs_que)	0.5

iv	initial values	1
X1	on_ex	1
X2	off_ex	0
X3	mat	0
X4	tech	0
X5	pos_env	0
X6	neg_env	0
X7	assi	0
X8	int_bef	0
X9	trans	0
X10	int_aft	0
X11	syst	0
X12	neg_que	0
X13	pos_que	0
X14	dur	0
X15	comm	0
X16	inter	0
X17	ex_perf	0
X18	tech_perf	0
X19	demor	0
X20	foc	0
X21	ex_anx	0
X22	cs_env	0
X23	cs_que	0
X24	W(ex_anx,cs_env)	0.1
X25	W(ex_anx,cs_que)	0.1
X26	H(ex_anx,cs_env)	0
X27	H(ex_anx,cs_que)	0

Fig. 2. Role matrices for connectivity, aggregation and timing characteristics of the network model.

Figure 3 and Fig. 4 show the simulations with two adaptation levels for online and offline exams, respectively. For the online modality (Fig. 3), the values of the control state for emotional regulation related to environment reaches a maximum value of 0.74. The speed modification makes the values of self-model state X_{24} grow slower than if we consider a model without the speed adaptation. The anxiety level reaches a maximum value of 0.87. When it comes to the second emotion regulation process, again the values of the control state X_{23} grow slow at first. However, the growth picks up speed.

For offline exams (Fig. 4), just the control state X_{23} takes place. This because students are used to the classroom environment and, since the negative belief X_6 never reaches high values, the control state X_{22} does not need to happen. The anxiety level (X_{21}) is much lower than in the online scenario.

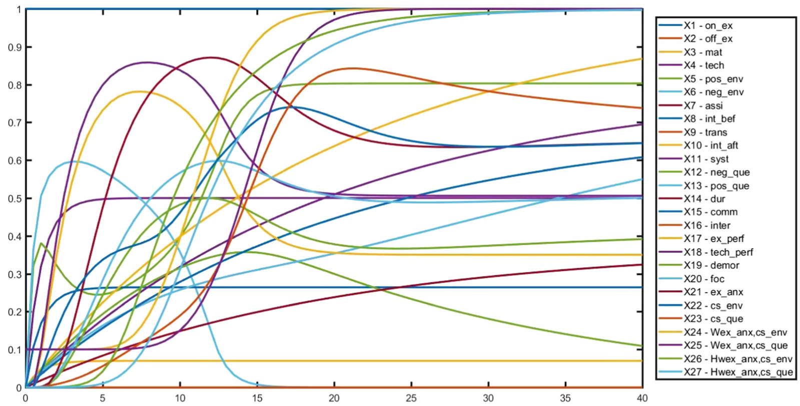

Fig. 3. Simulation results for online exam using emotion regulation processes.

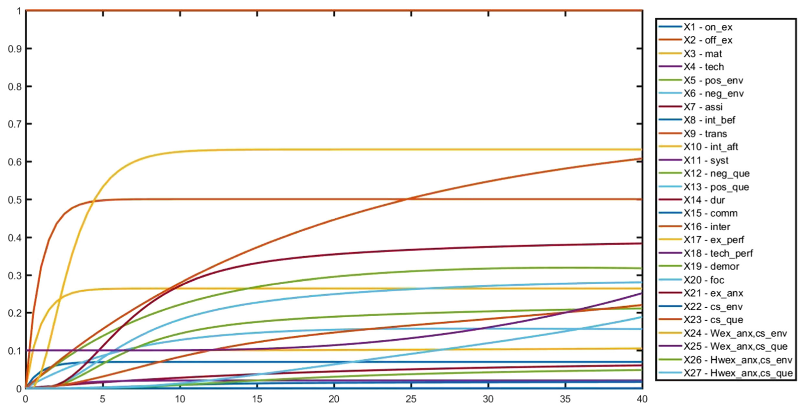

Fig. 4. Simulation results for offline exam using emotion regulation processes.

6 Conclusion and Future Directions

This work uses a multi-order adaptive network model to study the differences in emotion regulation for exam-related anxiety between two modalities of exams – online and offline. As an emotion regulation strategy, we applied reappraisal processes, since they represent a commonly employed strategy to deal with learning-related anxiety [21]. In here, our general comparisons were conducted in a way in which the timeline did not represent the exact moments in which the different states happened. The chronological order is correct, but the pre-exam period is "compressed". For the purpose of this paper and comparison, we considered this approach to be satisfactory. However, if we would like to precisely define the time intervals in which the pre-exam states and the during exam states happen and understand how that affects the overall exam anxiety, we can add two extra context states – *pre exam* (X_{28}) and *during exam* (X_{29}) – that just are activated during the time periods in which they occur. We checked this (for a non-adaptive scenario) and that seems to work well.

If one compares our models with non-adaptive models, it might seem that the adaptive models should achieve lower values of exam anxiety (X_{21}). Nonetheless, the two adaptation levels were not added with this purpose, but to make the model resemble a real-life situation more closely. This is because the learning speed of reappraisal is not constant. As expected, we could see that the emotion regulation processes promoted by the control states X_{22} and X_{23} were influenced by the introduction of the two reification levels, also affecting the beliefs related to the way students perceived the exam environment (X_5 and X_6) and the difficulties related to the type of questions (X_{12} and X_{13}).

It is important to mention that in the scope of this work, we just considered the reappraisal regarding these two variables. Nonetheless, different kinds of beliefs can be taken into account in the future. We argue so because emotion regulation processes are highly subjective and a certain individual could, for instance, regulate his/her/their belief about the duration of the exam, seeing it no longer as a negative factor that introduces pressure, but as a positive factor that allows him/her/them to have extra time to rest. For our simulation, however, we applied emotion regulation process to two beliefs we considered the most likely to become regulated by an average individual.

In the future, we would like to simulate how the process would look like for a person already suffering from anxiety. We expect the anxiety levels to increase more. Based on preliminary results, it was already possible to see that the reappraisal processes may not manage to significantly reduce the perceived anxiety. Furthermore, the coexistence of other mental health disorders, such as depression or attention deficit hyperactivity disorder could also be included in the model, altering for instance the parameters of the states related to feeling demoralized and to have difficulties in getting focused, respectively.

References

1. May, R.: The Meaning of Anxiety. Pocket Books, New York (1979)
2. Barlow, D.H.: Unraveling the mysteries of anxiety and its disorders from the perspective of emotion theory. Am. Psychol. **55**(11), 1247 (2000)
3. Gross, J.J.: Handbook of Emotion Regulation. Guilford publications, New York (2013)
4. Aldao, A., Nolen-Hoeksema, S., Schweizer, S.: Emotion-regulation strategies across psychopathology: a meta-analytic review. Clin. Psychol. Rev. **30**(2), 217–237 (2010)
5. Mashayekh, M., Hashemi, M.: Recognizing, reducing and copying with test anxiety: causes, solutions and recommendations. Procedia Soc. Behav. Sci. **30**, 2149–2155 (2011)
6. Pekrun, R.: A social-cognitive, control-value theory of achievement emotions. In: Heckhausen, J. (ed.) Motivational Psychology of Human Development: Developing Motivation and Motivating Development, pp. 143–163. Elsevier Science, Amsterdam (2000)
7. Zeidner, M.: Test Anxiety: The State of the Art. Springer Science and Business Media, Berlin (1998)
8. Russo, T.J.: Multimodal approaches to student test anxiety. Clearing House J. Educ. Strat. Issues Ideas **58**(4), 162–166 (1984)
9. Alexander, M.W., Bartlett, J.E., Truell, A.D., Ouwenga, K.: Testing in a computer technology course: an investigation of equivalency in performance between online and paper and pencil methods. J. Career Tech. Educ. **18**(1), 69–80 (2001)

10. Stowell, J.R., Bennett, D.: Effects of online testing on student exam performance and test anxiety. J. Educ. Comput. Res. **42**(2), 161–171 (2010)
11. Akinsola, E.F., Nwajei, A.D., et al.: Test anxiety, depression and academic performance: assessment and management using relaxation and cognitive restructuring techniques. Psychology **4**(06), 18 (2013)
12. Putwain, D.: Do examinations stakes moderate the test anxiety–examination performance relationship? Educ. Psychol. **28**(2), 109–118 (2008)
13. Segool, N.K., Carlson, J.S., Goforth, A.N., Von Der Embse, N., Barterian, J.A.: Heightened test anxiety among young children: elementary school students'anxious responses to high-stakes testing. Psychol. Sch. **50**(5), 489–499 (2013)
14. Gross, J.J.: The emerging field of emotion regulation: an integrative review. Rev. Gen. Psychol. **2**(3), 271–299 (1998)
15. Aldao, A., Nolen-Hoeksema, S.: Specificity of cognitive emotion regulation strategies: a transdiagnostic examination. Behav. Res. Ther. **48**(10), 974–983 (2010)
16. Gross, J.J., Levenson, R.W.: Emotional suppression: physiology, self-report, and expressive behavior. J. Pers. Soc. Psychol. **64**(6), 970 (1993)
17. Gross, J.J., John, O.P.: Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. J. Pers. Soc. Psychol. **85**(2), 348 (2003)
18. Cutuli, D.: Cognitive reappraisal and expressive suppression strategies role in the emotion regulation: an overview on their modulatory effects and neural correlates. Front. Syst. Neurosci. **8**, 175 (2014)
19. Garnefski, N., Kraaij, V., Spinhoven, P.: Manual for the Use of the Cognitive Emotion Regulation Questionnaire. DATEC, Leiderdorp, The Netherlands (2002)
20. Zuzama, N., Fiol-Veny, A., Roman-Juan, J., Balle, M.: Emotion regulation style and daily rumination: potential mediators between affect and both depression and anxiety during adolescence. Int. J. Environ. Res. Public Health **17**(18), 6614 (2020)
21. Brady, S.T., Martin Hard, B., Gross, J.J.: Reappraising test anxiety increases academic performance of first-year college students. J. Educ. Psychol. **110**(3), 395 (2018)
22. Nadinloyi, K.B., Sadeghi, H., Garamaleki, N.S., Rostami, H., Hatami, G.: Efficacy of cognitive therapy in the treatment of test anxiety. Procedia Soc. Behav. Sci. **84**, 303–307 (2013)
23. Ejei, J., Gholamali Lavasani, M., et al.: The effectiveness of coping strategies training with irrational beliefs (cognitive approach) on test anxiety of students. Procedia Soc. Behav. Sci. **30**, 2165–2168 (2011)
24. Strain, A.C., D'Mello, K.: Emotion regulation during learning. In: International Conference on Artificial Intelligence in Education, pp. 566–568. Springer, Heidelberg (2011).https://doi.org/10.1007/978-3-642-21869-9_103
25. Sheppes, G., Scheibe, S., Suri, G., Gross, J.J.: Emotion-regulation choice. Psychol. Sci. **22**(11), 1391–1396 (2011)
26. Treur, J.: Network-Oriented Modeling for Adaptive Networks: Designing Higher-Order Adaptive Biological, Mental and Social Network Models. Springer Nature, Chem (2020). https://doi.org/10.1007/978-3-030-31445-3
27. Ocak, G., Karakus, G.: Undergraduate students' views of and difficulties in online exams during the covid-19 pandemic. Themes eLearn. **14**, 13–30 (2021)