Martin, D, Putwain, D and Ulrike, N

Complex Dynamics: Investigation of Within and Between Person Relationships Between Achievement Emotions and Emotion Regulation During Exam Preparation Through Dynamic Network Modelling

Abstract

In achievement contexts like end-of-semester exam preparation, students experience a variety of positive and negative achievement emotions, and their regulation is crucial. Despite its relevance, the interplay between, and dynamics of, emotions and their regulation is still little understood, particularly as prior research primarily relied on between-person research. In the present study, we use a situated assessment approach and a novel statistical approach, dynamic network modelling, to simultaneously analyze between-person associations, contemporaneous within-person associations as well as temporal lagged within-person associations and stability of achievement emotions and emotion regulation strategies in multivariate models. We used a total of 6,915 assessments of 201 German undergraduate students on six emotions (joy, pride, hope, satisfaction, anxiety, anger, and boredom) and eight emotion regulation strategies (activation, social support, positive refocusing, rumination, reappraisal, suppression, expression, taking action) during exam preparation in two assessment waves (fives week prior, and one week prior to important exams). The results uncovered distinct communities of emotions and emotion regulation strategies, wherein taking action and reappraisal held a particularly central position for explaining their linkages. We found evidence for effects from emotions on use of emotion regulation strategies, and vice-versa, and identified self-enforcing loops and carryover effects. We also observed differences in the stability of the assessed constructs over time, and between the week before the exam and five weeks before, that emphasize the consideration of not only person and situation-specific components, but also the respective context at hand, to which end dynamic network analyses emerge as a promising research avenue.

Keywords: wellbeing, regulation, reappraisal, suppression, ambulatory

Educational Impact and Implications Statement

This study sheds light on how students navigate their emotions during exam preparation and underscores the critical role of effective emotion regulation. By examining real-time emotional experiences and regulation strategies, we uncovered distinct communities of emotions and emotion regulation strategies, with “taking action” (i.e., actively acting to improve the situation) and “reappraisal” (i.e., changing the way one thinks about a situation) emerging as particularly central strategies. Following up on these networks of emotions and regulation strategies can pave the way for the development of personalized emotion regulation skills, enhancing students’ overall exam preparation and academic success.

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A sense of dread and fear, mixed with hints of panic, indicates that it is exam time again. Studying involves many emotionally challenging periods, especially centered around exams. Some students deal with these emotions effectively and turn them into productive agents of effort, others get lost in rumination and increasing despair. This interplay between, and dynamics of, emotions and their regulation is highly relevant, yet still little understood.

Indeed, in achievement contexts like end-of-semester exam preparation, students experience a variety of positive and negative achievement emotions that hold a key role for achievement-related outcomes, including motivation and performance (Forsblom et al., 2022; MacIntyre & Vincze, 2017; Pekrun et al., 2017; Pekrun, Marsh, Suessenbach, et al., 2023). Emotions are also linked to how individuals manage, experience, and express their emotional experiences, i.e., their emotional regulation (Gross, 2015). Students who effectively employ emotion regulation strategies regarding their studies tend to feel more confident in pursuing their academic goals and view their academic environment as supportive and conducive to learning (Boekaerts & Pekrun, 2015). In particular, emotion regulation strategies have been associated with learning outcomes (e.g., Strain & D'Mello, 2015), psychosocial functioning (e.g., De France & Hollenstein, 2017), and socioemotional adjustment across the life span (Riediger & Bellingtier, 2022).

Studies have explored emotion regulation strategies in relation to mood, affect, and specific emotions (Brans et al., 2013; Gross & John, 2003; Heiy & Cheavens, 2014). Mostly, however, these investigations focus on cross-sectional, between-person differences, investigating, for example, if one student is sadder than others, does this go along with increased use of certain emotional regulation strategies. However, it is crucial to understand the dynamic patterns of these constructs over time, including their adaptations across different

situations and their influence on each other (Aldao et al., 2015). Achievement emotions and emotion regulation influence each other dynamically over time with emotional experiences triggering different emotional regulation strategies, and the use of different strategies impacting one's subsequent emotions.

There is only limited research on this dynamic interaction and the temporal dynamics of emotions and emotion regulation (Jacobs & Gross, 2014). Additionally, there is a lack of in-situ assessments of emotion and regulation behaviors, especially regarding state assessments, and particularly for demanding situations like exam preparation (Rottweiler & Nett, 2021; Rottweiler et al., 2023). This is especially relevant as effects of emotion regulation strategies cannot be generalized between such contexts and non-exam-related contexts (Rottweiler et al., 2018). Accordingly, in the present study, we follow a situated assessment approach to disentangle the complex interplay between, and dynamics of, achievement emotions and emotion regulation strategies. To this end, we use a novel statistical approach, dynamic network modelling, to not only analyze between-person associations but also contemporaneous within-person associations (e.g., how do changes in emotional experiences covary with changes in emotion regulation strategy use) as well as temporal lagged within-person associations (e.g., if a student experiences increased anger, what emotion regulation strategies do they use subsequently, and vice versa, how do emotions change following different strategy use?).

Theoretical Background

Achievement Emotions

Achievement emotions are emotions associated with an achievement activity or an achievement outcome, such as studying and thinking about an exam (Pekrun, 2006). They encompass a range of feelings that can be classified according to their valence (positive vs. negative), activation (activating vs. deactivating), and object focus (activity vs. outcome) (Pekrun, Marsh, Elliot, et al., 2023). In the present study, we considered six achievement

emotions, namely *joy*, *pride*, *hope*, *satisfaction*, *anxiety*, *anger*, and *boredom*, as they are particularly commonly experienced when studying and include a mixture of positive and negative, activity and outcome, and activating and deactivating emotions (Pekrun et al., 2011). Joy would be classified as positive, activating, activity-focused, pride as positive, activating, retrospective-outcome-focused, hope as positive, activating, prospective-outcome-focused, satisfaction as a positive, deactivating, retrospective-outcome-focused, anxiety as negative, activating, prospective-outcome-focused, anger as negative, activating, activity-focused, and boredom as negative, deactivating, activity-focused.

Emotions can be conceptualized as traits and states. Trait emotions are enduring emotional tendencies that persist over a long period, while state emotions are fleeting emotional experiences in a particular context (e.g., feeling anxious or hopeful in the last hour when thinking about an exam). Such state emotions have been found to dynamically change during learning, eliciting other emotional experiences and use of learning strategies (e.g., Chevrier et al., 2019; D'Mello & Graesser, 2012; Di Leo et al., 2019). In this study, we specifically assess situational emotions to disentangle trait and state emotions with their dynamic patterns. Given their documented relevance for motivation, learning strategies, and academic performance (MacIntyre & Vincze, 2017; Pekrun et al., 2017; Ranellucci et al., 2015), it is clearly important to regulate such emotions during achievement situations, especially in highly evaluative achievement settings such as exam preparation (see Rottweiler et al., 2018).

Emotion Regulation Strategies

Emotion regulation refers to the active processes through which individuals influence the type of emotions they experience, the timing of these emotions, and how they are expressed (Gross, 1998). Research on emotion regulation has yielded a substantial body of evidence highlighting its crucial role in academic success, psychological functioning, and

overall well-being (De France & Hollenstein, 2017; Eckert et al., 2016; Eftekhari et al., 2009; Riediger & Bellingtier, 2022; Strain & D'Mello, 2015).

Among the various theoretical frameworks, the most widely acknowledged and frequently referenced model is the process model of emotion regulation (PMER; Gross, 1998; Gross, 2014; Gross, 2015). Gross's process model provides a comprehensive framework for understanding how individuals manage and regulate their emotions in diverse situations. It describes emotion regulation as a dynamic process including the use of antecedent-focused strategies, applied before or just after the emotional response is triggered, and response-focused strategies, implemented after the emotional response has occurred (Gross, 1998; Gross, 2014; Gross, 2015). Students have been found to use multiple strategies, and in particular to use multiple different strategies, rather than the same strategy, over time (Webster & Hadwin, 2015). Among these, five different types of strategies can be distinguished (see Gross, 1998; Gross, 2014; Gross, 2015), namely:

(1) *Situation selection strategies*. These involve choosing actions that lead to a different and more favorable situation, such as seeking more pleasant circumstances.

(2) *Situation modification strategies.* These entail altering the current situation to improve one's emotional state, like seeking support from others.

(3) *Attentional deployment strategies.* This group of strategies focuses on directing one's attention either towards or away from the task or situation to induce an emotional change, e.g., by refocusing attention on something positive or engaging in rumination.

(4) *Cognitive change strategies.* These strategies revolve around altering one's thoughts about the situation to influence the emotional significance attached to it, as in the case of reappraisal.

(5) *Response modulation strategies*. Utilized later in the emotion-generation process, these strategies involve directly modifying the emotional experience by addressing behavioral

or physiological components of the emotion. Examples include suppression and emotional expression.

Within and Between Person Dynamics of Achievement Emotion and Emotion Regulation Strategies

Following the PMER model, emotions arise in achievement settings when students assess and direct their attention to a highly evaluative situation, such as an upcoming exam, resulting in specific emotional responses, like feelings of anxiety. The ERAS model (Emotion Regulation in Achievement Situations; Harley et al., 2019), an integration of the PMER model with Pekrun's Control Value Theory (Pekrun, 2006), illustrates that emotion experiences and emotion regulation are linked. Along the four phases of setting the achievement situation, directing attention to it, making appraisals, and eliciting an emotional response, the model suggests that emotional responses in achievement situations can alter the situation, attention, and appraisals of this situation and affect the effectiveness and implementation of emotion regulation strategies. For instance, when preparing for an important exam, a student's attention to the prospective outcome may lead to appraisals of medium control and negative value, resulting in anxiety. In such cases, a cognitive change strategy like reappraisal might, at least in the short term, not be as effective as a situation selection strategy, such as distracting themselves. Likewise, facing a boring lesson, a student can remind themselves of the importance of paying attention to memorize information for the upcoming exam, leading to a positive value appraisal. Such reappraisal, wherein control and value appraisals are altered, can help to increase experience of positive emotions, such as enjoying a class discussion more, while simultaneously decreasing negative emotions like boredom. The employed strategy also affects the valuation system, either leading to adjustments or maintenance of the current regulation approach. Accordingly, the success of the regulation strategy determines its future usage, where a successful strategy might be employed more frequently in subsequent cycles, while an unsuccessful one may be revisited.

Moreover, these current control and value (re)appraisals are likely to influence subsequent appraisals. For instance, experiencing more positive emotions may lead to a more positive interpretation of the academic situation, thereby triggering a further upswing in subsequent positive emotions. This can create a reciprocal loop between reappraisal and emotional experiences, allowing students to better manage their emotional responses and enhancing their overall academic experience. As such, the ERAS model illustrates that emotional responses are related to emotion regulation over time through complex interactions of situational aspects (e.g., task difficulty), individual characteristics (e.g., personal competencies), and appraisal-related factors concerning an individual's perceived control and value (i.e., importance) of achievement activities and their outcomes. Note that this not only pertains to the relationships between emotions and emotion regulation strategies—but also to the dynamics within emotions and within emotion regulation strategies (which also influence each other contemporaneously and over time, e.g., Brockman et al., 2017; Di Leo et al., 2019).

More specifically, the ERAS model implies that there are between-person relationships between achievement emotions and regulation strategies, as well as within-person dynamics, where emotions and use of emotion regulation strategies can change together over time and influence each other bidirectionally. Besides temporal covariation, emotions can trigger specific regulation strategies, and in turn, regulation strategies can influence subsequent emotions. So far, research has predominantly focused on between-person differences (e.g., Dixon-Gordon et al., 2015; Gross & John, 2003; Lougheed & Hollenstein, 2012), typically through a onetime assessment of individuals' habitual use of emotion regulation strategies. As noted however, it is essential to recognize the dynamic relationship between emotions and emotion regulation strategies that is not solely determined by interindividual tendencies, but can significantly vary within individuals over time. Likewise, mapping which emotional experiences go along with each other, and which

emotional regulation strategies do, on a between-person and within-person level, can be deemed a relevant endeavor to better understand the complex dynamics at hand. The limited research on the within-person relationships may be a function of such investigations requiring a complex assessment of emotions and regulation repeatedly over time within a specific achievement setting, along with specific analytical methods to disentangle these between and within-person dynamics.

Investigating the Interplay and Dynamics of Emotions and Emotion Regulation: Experience Sampling Methods and Dynamic Network Analyses

Investigating how one construct influences another in subsequent hours or days, necessitates intensive longitudinal data collection techniques, like ambulatory assessment, along with an investigation of autoregressive and cross-lagged effects. Recently, a number of studies have begun to use intraindividual approaches to study emotion regulation (e.g., Benson et al., 2019; Brans et al., 2013; Catterson et al., 2017; Heiy & Cheavens, 2014; Rottweiler & Nett, 2021), typically through experience sampling approaches (for a recent overview see Colombo et al., 2020). *Experience sampling* involves multiple assessments, often multiple times per day, allowing to capture real-time fluctuations and momentary changes in order to unpack the relative impact of the intraindividual contextual variation and the interindividual variation across situations while reducing retrospective biases (McMahon & Naragon-Gainey, 2018). This approach allows to directly tap into the genesis of emotions and regulation strategies that, as outlined before, arise from situational demands (context specificity of emotion regulation, e.g., Benson et al., 2019; Catterson et al., 2017; Webb et al., 2012) and current experiences (emotion specificity, e.g., Schmidt et al., 2010; Southward et al., 2019). The relevance of explicitly considering this intraindividual variation has also been highlighted by recent research showing that up to 83% of the variation in assessments of emotion regulation lies within individuals (ICCs =.17-.63; Brockman et al., 2017; Grommisch et al., 2020; Rottweiler et al., 2018).

Previous research has also explored autocorrelations and cross-lagged correlation of positive and negative affect, revealing individual differences from negative affect to positive affect, and vice versa (Hamaker et al., 2018). A current overview of the prior research on emotions and emotion regulation (Rottweiler & Nett, 2021) found that most studies focused solely on anxiety, while leaving positive emotions largely unexplored. Further, the authors emphasized the lack of research on the dynamic patterns of emotions and emotion regulation strategies, especially during highly evaluative settings like exam preparation, where short-term dynamic effects remain largely unexplored.

The first comprehensive investigation of dynamic within-person relations was conducted by Rottweiler and Nett (2021) who studied the temporal interplay of exam-related anxiety and hope and four regulation strategies (cognitive approach, cognitive avoidance, behavioral approach, and behavioral avoidance). In their study, students completed questionnaires via an electronic device during two measurement periods before an exam, answering short questionnaires six times a day during daily routines. The authors estimated bivariate dynamic multilevel models, one for each combination of emotion and regulation strategy, and found cross-lagged relationships between exam-related emotions and regulation strategies, especially between hope and cognitive approach regulation strategies. Additionally, the temporal distance to the exam was associated with the strength and direction of these relationships. With the present work, we follow up on these findings and extend them by not only considering anxiety and hope, but seven achievement emotions in total, along with eight emotion regulation strategies. This puts high affordances on the statistical analyses. Using the same approach as Rottweiler and Nett (2021), this would entail running a total of 56 models (to analyze each goal – regulation strategy combination) while not being able to analyze and control for the relationships within the emotions and within the regulation strategies. To accommodate for that and to allow detailed, multivariate insights into the complex interplay of emotions and emotion regulation, we propose dynamic network analyses.

Network Analysis (NA) is a novel and increasingly popular analytic approach to study, visualize, and analyze multivariate associations among variables in a network (Bringmann et al., 2016). Recently, dynamic network models have been introduced and gained attention in research due to their capacity to model both lagged effects over time and contemporaneous effects (Park et al., 2020; Wright et al., 2019). Essentially, network models represent a collection of variables, referred to as *nodes*, connected to each other through partial correlations, referred to as *edges* (Bringmann et al., 2016). Nodes can form distinct communities, similar to factor analysis, where groups of closely related nodes, such as positive emotions, exhibit strong edges (Epskamp et al., 2017). NA is advantageous for analyzing large numbers of related variables, avoiding multicollinearity issues common in factor analysis. Moreover, NA is well-suited for studying complex phenomena, such as the interplay between emotions and regulation strategies—that, as elaborated before, can be considered to consist of a number of dynamically interacting components—by considering all nodes simultaneously in a holistic network (Bar-Kalifa & Sened, 2020; Bringmann et al., 2016). Unlike other analytical methods such as Linear Mixed Models (LMM), Structural Equation Modeling (SEM), or cluster analyses that often examine fixed structures, relationships, or groupings at a point in time or under static conditions, dynamic network analyses capture the temporal dynamics and shifting patterns within complex systems. Specifically, they allow disentangling emotional dynamics on different levels by parametrizing three different networks simultaneously that describe between-person associations, contemporaneous within-person associations, and temporal lagged within-person associations, respectively. The latter associations are particularly informative as they potentially represent causal mechanisms (Hamaker et al., 2018), allowing to directly follow up on the theoretical assumptions of causal links from experienced emotions on the use of emotion regulation strategies, and vice versa, from the use of emotion regulation strategies on subsequently experienced emotions (Gross, 2015; Harley et al., 2019).

The Present Research: Research Questions

In this research, our central research question focused on the dynamic interplay between emotions and emotion regulation strategies (Jacobs & Gross, 2014), particularly regarding highly evaluative situations like exam preparation (Rottweiler & Nett, 2021; Rottweiler et al., 2023). Based on the methodological considerations provided in the section before, and the still largely unexplored within-person dynamics involved, we sought to investigate between-person associations, contemporaneous within-person associations, as well as temporal lagged within-person associations, through a situated experience sampling assessment approach and dynamic network modelling. Accordingly, our research aims were to examine (1) between-person associations, (2) contemporaneous within-person associations as well as (3) temporal lagged within-person associations and stability of achievement emotions and emotion regulation strategies. Specifically, we were interested in the different communities of emotions and emotion regulation strategies, and the linkages between them, as well as the stability of these constructs over time. As another research question, we were interested in differences in the emerging structure between the three different types of networks (particularly comparing between-person and within-person associations). This follows the before-described rationale that effects on the general person level can diverge from effects in a specific learning situation. Following Rottweiler and Nett (2021) our final research question was about differences in these networks depending on distance to exam (five weeks vs. one week before exam), expecting denser networks the closer the exam was.

Method

To answer our research questions, we relied on experience sampling data from 201 students who, regarding an upcoming exam, made assessments on emotions and emotion regulation strategies during their everyday lives in two assessment periods (five weeks before the exam; one week before the exam) that each contained up to six individual assessments per day for a week. These data have partially already been used to investigate cross-lagged

relationship between two emotions and four regulatory types as well as person-centered analyses of emotion regulation patterns [details-anonymized for peer review]. In the present study, we analyzed the data through networks that reflect between-person relationships alongside within-person contemporaneous and temporal lagged associations.

Procedure

Participants were recruited during first semester tutorials, which were part of lectures with an exam at the end of the semester. Specifically, exams were selected that had shown high importance for students as informed by the organizers of the respective study programs. All of these students were given the opportunity to participate. They were informed that the study would assess their emotions and emotion regulation strategies before the exam, and they could receive personalized feedback afterwards. The study adhered to ethical standards and was deemed unproblematic in this regard by the local IRB board [details anonymized for peer review]. Participation was voluntary, and students were informed that they could withdraw at any time without any consequences. Monetary compensation or course credit was provided to incentivize participation.

One day prior to each measurement period, participants attended a lab session where they received smartphones programmed with *movisensXS* (MovisensXS, Version 0.7.4162), a research tool for experience sampling. At that point, they also provided demographic information and informed consent. Each measurement period spanned seven days. Measurement Period A was days 35 to 29 before the exam, Measurement Period B was on the days 7 to 1 before the exam.

In each measurement period, a random interval sampling scheme was implemented, where participants received six alarms per day with a minimum interval of two hours and a maximum interval of three hours. The average time lag between alarms was 2 hours and 30 minutes, with the alarms scheduled between 9 a.m. and 10 p.m. Each participant could respond to a maximum of 42 short questionnaires per week (Measurement Period B included

an additional 43rd assessment point just before the exam). Participants were given 4 minutes to begin completing the questionnaire after the beep; otherwise, it was recorded as missing. The compliance rate was very high with an overall compliance of 92% (90% in Measurement Period A and 93% in Measurement Period B). At each of the possible 42 assessment points of the week, we first asked students to answer the following dichotomous item: "In the past hour, I thought about [name of the exam]." We only measured exam-related emotions if they answered this item with "yes". This was the case in 29% of the assessment points in Measurement Period A, and 48% in Measurement Period B.

Sample

Overall, the dataset consisted of 6,915 individual assessments by 201 students. Measurement period A (five weeks before the exam) consisted of 2577 assessments, measurement period B (one week before the exam) of 4338 assessments. The students were enrolled in a psychology (53%), economic science (42%), or a medical course (4%), at a German university. All were first year undergraduates, and, typically for the respective study programs, 76% were women, with an average age of 21.9 years (SD = 3.1). To confirm that the exam was, as expected, important for the students, we asked them to rate the following item using a Likert type scale from 1 (*disagree*) to 5 (*agree*): "The exam #nameofexam# is very important to me". The vast majority (85%) chose answer options 4 and 5, with an overall mean of 4.47 (SD = 0.81). For further details on the sample and the study procedure see Authors (Anonymized).

Measures

We measured achievement emotions using single items that were slightly adapted from previous studies (Bieg et al., 2014; Goetz et al., 2013). Specifically, we measured *joy*, *pride*, *hope*, *anxiety*, *anger*, and *boredom* using a single item each that read "In the past hour, while thinking about the exam, I experienced [name of emotion]" on a five-point Likert scale ranging from 0 (*disagree*) to 4 (*agree*). Such a scale is frequently used in experience sampling

research in German language as it allows for a clear presentation of the names of the emotions after a common item stem and reflects the intensity of experienced emotions (Goetz et al., 2013; Goetz et al., 2007; Krannich et al., 2022). Further, for experience sampling measures, it is recommended to adopt a single-item approach (Goetz et al., 2016) and research has demonstrated that employing a single item to evaluate academic emotions is a viable substitute when it is not feasible to assess comprehensive scales (Gogol et al., 2014).

After assessing the intensity of the achievement emotions during the past hour, the extent of a given emotion regulation strategy used in the past hour was assessed. Each emotion regulation strategy was measured with two items on a five-point Likert Scale ranging from 0 (*disagree*) to 4 (*agree*). For each strategy, we used two items that stood out in terms of their factor loadings and content from established scales, including the Emotion Regulation Questionnaire (ERQ; Abler & Kessler, 2009; Gross & John, 2003), the Coping Orientation to Problems Experienced Inventory (COPE; Carver, 1997; Carver et al., 1989), and the Cognitive Emotion Regulation Questionnaire (CERQ; Garnefski & Kraaij, 2007). Following the item stem "In the last hour, …" we measured *activation* (e.g., "I have done something to distract myself"; Spearman-Brown: $r = .77$; COPE) as a key situation selection strategy, *social support* (e.g., "I have asked fellow students for advice"; COPE; $r = .52$) as a situation modification strategy, *positive refocusing* (e.g., "I have thought about something else"; $r = .65$; CERQ) and *rumination* (e.g., "I was preoccupied with what I think and feel about what I have experienced"; $r = .66$; CERQ) as attentional deployment strategies, *reappraisal* (e.g., "I have looked for the positive sides to the matter"; $r = .72$; CERQ) and *suppression* (e.g., "I kept my emotions to myself"; internal consistency: $r = .32$; ERQ) as key cognitive change strategies, and *expression* (e.g., "I have openly shown how I felt"; $r = .68$; COPE) and *taking action* (e.g., "I have actively acted to improve the situation"; $r = .75$; COPE) as response modulation strategies. Note that we assessed each strategy use with two distinct behaviors that were not necessarily intended to yield reliable measures at a given measurement occasion, but

to reflect the breadth of the relevant construct. For example, the two items to measure social support asked whether fellow students or one's best friend were consulted. Naturally, we do not expect a participant to do both, but likely only one of these two behaviors. While this approach helps to maintain conceptual validity and capture the breadth of the construct, a noteworthy trade-off is increased difficulty in detecting statistically significant effects due to the increased noise in the scale means.

Analysis

To answer our research questions, we used, with separated analyses for both measurement periods, graphical vector autoregressive modeling (gVAR; Epskamp, van Borkulo, et al., 2018; Wild et al., 2010). This method examines the structural characteristics of nodes within a network by considering both between-persons and within-individual perspectives. Specifically, gVAR models non-directional associations by analyzing the residual process noise of a VAR, i.e., a Gaussian Graphical Model (Epskamp, Waldorp, et al., 2018). This, in turn, utilizes the inverse of the sample covariance matrix to estimate conditional associations between variables (Wild et al., 2010). An assumption underlying this analysis is that the data are stationarity, meaning that the mean and moment-to-moment interactions of the emotion processes are stable over time (Hamaker & Dolan, 2009). To ensure this, we detrended the data prior to the analyses by subtracting any linear time trends that were present at $p < .05$ significance level (see Freichel et al., 2023; Speyer et al., 2021).

We utilized the *graphicalVAR* R-package (Ver. 0.3.1) to estimate between-persons, temporal, and contemporaneous network models (Epskamp & Asena, 2023). The package employs the multivariate regression with covariance estimation (MRCE) algorithm to estimate the gVAR model (Epskamp, Waldorp, et al., 2018). To handle the large number of associations in the network analysis, graphicalVAR utilizes the LASSO regularization technique, which helps prevent Type I error, without compromising statistical power like Bonferroni corrections (Epskamp & Fried, 2018). Specifically, it estimates temporal

coefficients (regression weights between *t-1* and *t*) using regularized regression and contemporaneous coefficients (partial correlations after accounting for temporal effects) using the graphical LASSO algorithm (Friedman et al., 2008). The LASSO uses a tuning parameter to limit the sum of partial correlation coefficients, effectively reducing weak effect sizes to zero (removing edges between nodes) and thus producing a sparser network (Epskamp & Fried, 2018). We focused on two consecutive beeps within the same day, treating non-consecutive beeps as missing and not regressing the first measurement of a day on the last measurement of the previous day. Following Beck et al. (2023), the EBIC tuning parameter gamma was set to $\gamma = .25$ to calculate a network that is relatively sparse but that minimizes EBIC to ensure good model fit. Doing so, 2500 models were estimated. Edges were retained if they were significant at the $p < .05$ level or if the 95% credibility interval did not include 0. For the interpretation of effect sizes, we followed Jongeneel et al. (2020), using Cohen's definition for standardized partial correlations with $|r| \approx .10$ being considered small, $|r| \approx .30$ moderate, and $|r| \approx .50$ large.

As our study involves multiple individuals, we used a multilevel modeling framework. This enables the inclusion of random, person-specific auto- and cross-regressive effects, allowing to simultaneously examine dynamics between emotions and regulation strategies on the level of between-person associations, contemporaneous within-person associations, and temporal within-person associations. We briefly describe these three types of jointly estimated networks next.

The *between-persons network* examines the relationship between regulation strategies and emotions across participants, similar to traditional between-person analyses. Instead of using a single measure, however, it builds on the average association between emotions and regulation across multiple waves of data. This network is a type of Gaussian Graphical Model specifically designed to capture dependencies between nodes even after considering all other nodes in the network. The presence of undirected edges indicates that two nodes are not

independent, after considering all other nodes in the network, and is quantified using partial correlation coefficients.

The within-individual relationships are separated into temporal and contemporaneous network structures. As we estimate multivariate networks with both autoregressive and cross-lagged effect, all predictors were person-mean centered to remove between-person variance in measured scores (Hamaker & Grasman, 2014).

The *contemporaneous network* captures undirected relationships between two nodes within the same measurement period, accounting for their relationships with all other nodes in that period and the previous period (controlling for lagged effects). This network examines how changes in an individual's typical level of a specific emotion or regulation strategy at time *t* relate to changes in their typical level of emotion or regulation strategy at the same time, while considering the within-individual changes in all other nodes at time *t-1* and *t*.

The *temporal network* examines directed relationships between lagged and current nodes, including autoregressive effects. Edges between nodes are represented by regression coefficients, indicating how a node at time *t-1* predicts a node at time *t* (the next measurement) while accounting for all other nodes at time *t-1*. This allows for an exploration of how deviations from an individual's average levels of emotions and regulation at time *t-1* influence deviations from their average levels at time *t*. The autoregressive effects are also informative in terms of ipsative stability. As individuals' scores were person-mean centered, the autoregressive effects reflect the scatter component of ipsative stability (Bringmann & Eronen, 2018).

We plotted the network graphs with the *qgraph R*-package (Vers. 1.5; Epskamp et al., 2023) and visualized the network structures via the "spring" layout corresponding to the Fruchterman-Reingold algorithm. In the graphical visualization, stronger partial correlations are represented as thicker edges. Layouts for the between-person and the contemporaneous networks, as well as the two temporal networks, were averaged for better comparability of

findings. As supplementary information, we also used this package to compute measures of centrality describing the networks' structural properties (Opsahl et al., 2010): *Betweenness* represents how often a node lies on the shortest path between two other nodes. *Closeness* represents the inverse of the summed distance from all other nodes. As such, nodes with high closeness can help explain how conceptually distinct variables come together in the same network. Finally, *strength* refers to the sum of the absolute weights of all edges connected to a node.

Transparency and Openness

We provide the complete analysis code in an open repository at https://osf.io/b9x4s/?view_only=da40670d2139453598643a2ea1d31a9f. The underlying data can be accessed after an embargo period at [stable link to GESIS repository, blinded for peer-review]. This study's design and its analysis were not pre-registered. We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study, and we follow JARS (Kazak, 2018).

Results

Descriptive statistics and within and between-person bivariate correlations are presented in Table 1. Descriptively, these statistics did not differ substantially between the two measurement periods. We observed substantial intra- as well as inter-individual variability in all variables (as reflected in substantial standard deviations and intraclass correlations).

Between-Persons Networks

The between-persons networks, focused on relationships between the habitual levels of the observed constructs between the participants, are shown in Figure 1. They were similar in terms of their structure, albeit slightly less dense, five weeks before the exam (A) compared to the week before the exams (B). This was also reflected in slightly higher closeness observed for most nodes (see Figure 1 in the supplementary materials). Overall, we found that the positive emotions joy, pride, satisfaction, and hope were clustered together. This means for

example that students who experienced, on average when thinking about the exam, more joy than their peers, also experienced more satisfaction, pride, and hope. Conversely, anger was linked to anxiety and boredom. For the regulation strategies, we found activation and positive refocusing clustered together. Taking action and reappraisal held a central position in the network and were closely linked, as were social support, rumination, and suppression that were linked pairwise in a row. In network B, these were more strongly linked and expression was also linked to reappraisal. Edges between emotions and regulation strategies primarily emerged between reappraisal and hope. In network B, boredom and social support also shared an edge. While in network A, joy was associated with reappraisal, in network B, we also observed a positive edge between joy and expression.

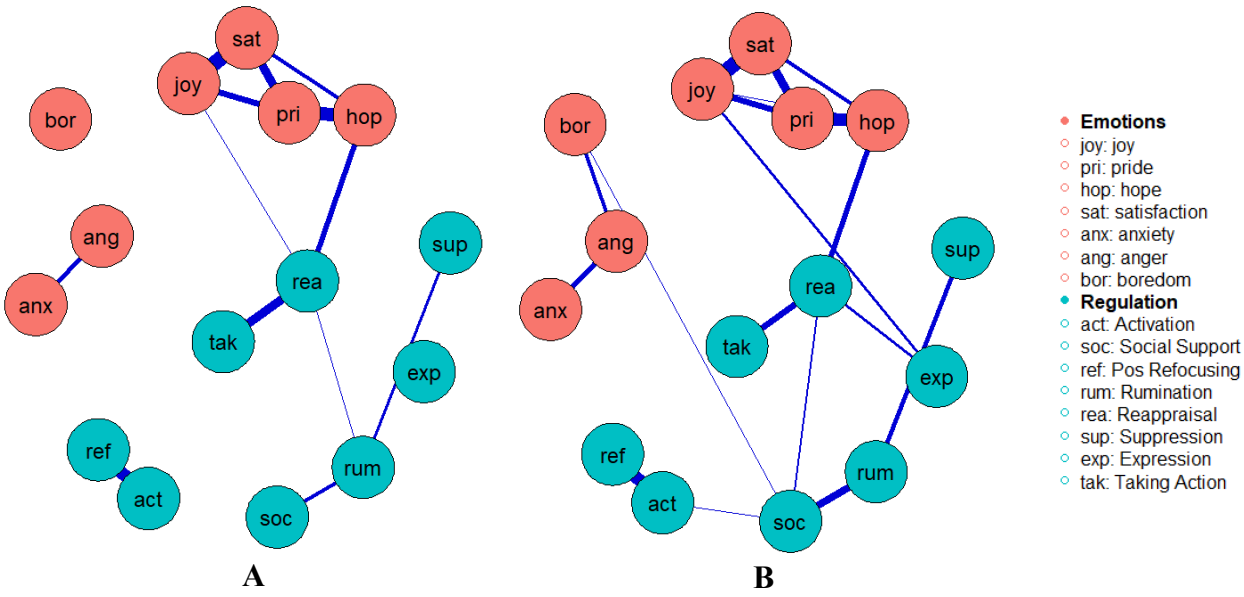

Figure 1. Between-persons network for the two measurement periods A (five weeks before exam) and B (one week before exam). Edge weights are determined by the magnitude of the effect sizes (i.e., thicker edges indicate stronger associations). Straight and blue lines indicate positive relationships, red and dashed lines indicate negative relationships. Weights ranged from .01 to .33 in model A and .01 to .36 in model B (see Table S1 in the supplementary materials for all values).

Contemporaneous Within-Person Networks

The contemporaneous within-person networks (Figure 2) focused on associations among deviations of constructs from their average values. Compared to the between-person network, there was substantially more density along with stronger edges, especially for the emotion regulation strategies. This was also reflected in increased closeness and strength of all nodes (see supplementary materials). Similar to the between-person network, we observed more density, along with on average stronger edges, in the period right before the exam (B) than five weeks before (A; as also indicated in more closeness and strength of the nodes). The structure itself was rather similar between both measurement periods, with the positive emotions, the negative emotions, activation and positive refocusing, taking action and reappraisal, as well as social support, rumination, expression, and suppression clustered together. Opposed to the between-person networks, we also observed negative edges, primarily between negative and positive emotions as well as between suppression and expression. This means for example that in a moment when students experienced more positive emotions than usual, they also tended to experience fewer negative emotions, and vice-versa. In model A, edges between emotions and regulation strategies emerged between hope and reappraisal (like in the between-person network) as well as less intense between joy, satisfaction, and reappraisal. Further, there were edges between pride as well as anger and taking action, anger and expression and between anxiety and activation as well as rumination. Interestingly there were slight negative edges between pride as well as satisfaction and activation and between satisfaction and refocusing. Differences between both measurement periods emerged regarding social support that shared a positive edge with anger in model B but not in model A, positive refocusing that was positively linked to boredom in model B and negatively to satisfaction in model A, as well as activation that was linked to anxiety, satisfaction, and pride in model A but only to anger in model B.

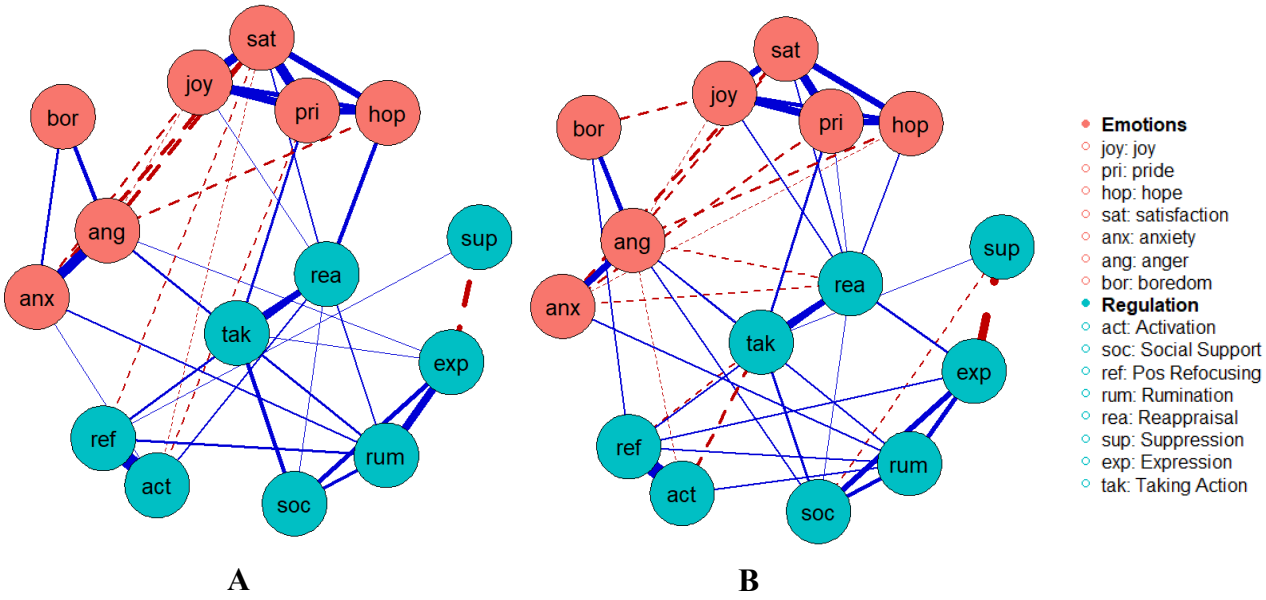

Figure 2. Contemporaneous within-person network for the two measurement periods A (five weeks before exam) and B (one week before exam). Edge weights are determined by the magnitude of the effect sizes (i.e., thicker edges indicate stronger associations). Straight and blue lines indicate positive relationships, red and dashed lines indicate negative relationships. Weights ranged from –.17 to .49 in model A and –.31 to .58 in model B (see Table S2 in the supplementary materials for all values).

Temporal Within-Person Networks

The temporal within-person networks (Figure 3) focused on directed associations in terms of how deviations from the person-specific means of constructs at one measurement point were associated with such deviations at the next measurement point. Here, we found striking differences between the networks across the two measurement periods and the between-person as well as the contemporaneous networks. Five weeks before the exam, the network was characterized by only two temporal edges: participants with increased activation at one measurement point compared to their average levels reported more positive refocusing than usual on the next measurement point, and suppression was positively related to subsequent changes in satisfaction. Conversely, the network on the week before the exam contained numerous, small temporal edges, including negative ones. None of the three edges

described before were statistically significant in that period. Closely clustered together were joy, pride, and satisfaction. Hope, however, clustered together with the negative emotions, and was negatively predicted by prior experiences of anxiety. Between them, activation, taking action, positive refocusing, suppression, and rumination were clustered. Within these clusters there were numerous links, including self-enforcing loops, between experiences of pride and satisfaction as well as boredom and anxiety. There were also multiple direct and indirect paths between regulation strategies indicative of temporal sequences, such as taking action, followed by activation, followed by suppression and rumination. Edges between emotions and regulation strategies showed how changes in the use of regulation strategies were attributable to prior experiences of anger (positive effects on expression) and pride (negative effects on social support and positive effect on activation), as well as, conversely and more frequently, how both positive and negative emotional experiences emerged following regulation strategies, including activation (positive effects on joy), social support (positive effects on anxiety), rumination (positive effects on both anxiety and hope), and positive refocusing (positive effects on boredom). In terms of stability, we found, in both periods, substantial autoregressive effects for joy, anxiety, rumination, and reappraisal. Expression and suppression were slightly more stable in network A than network B, for the other nodes increased stability was found in network B than in network A, particularly for anger, boredom, and social support.

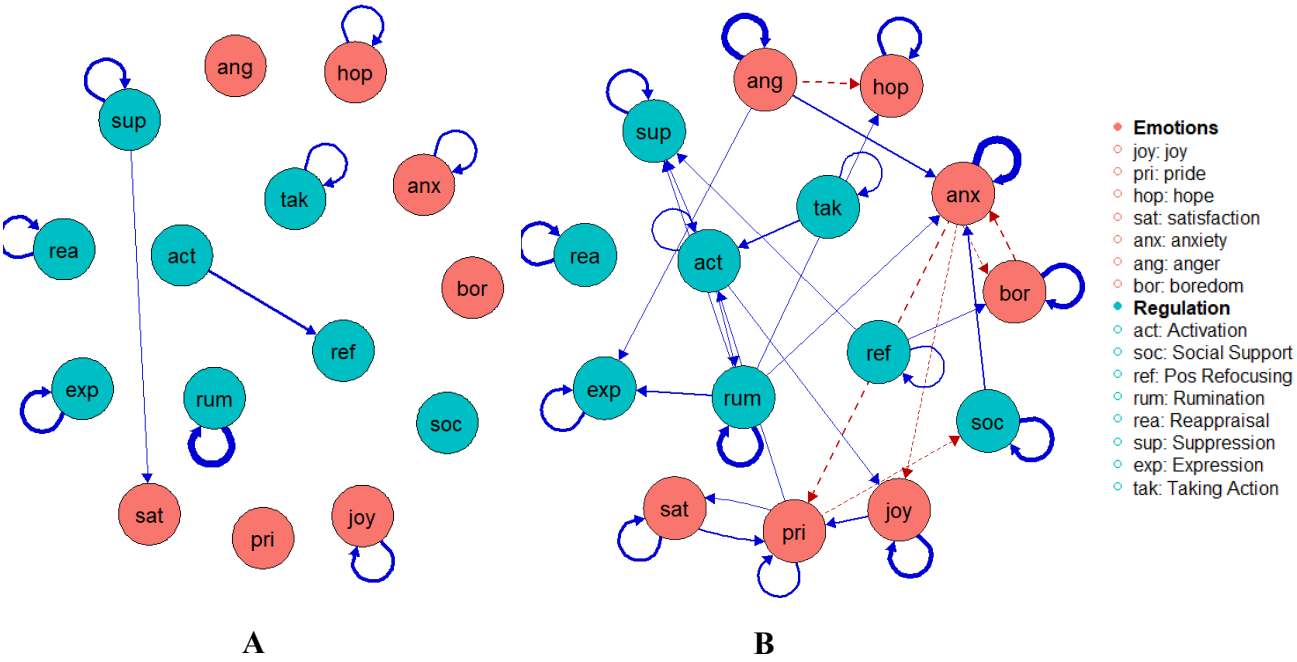

Figure 3. Temporal within-person network for the two measurement periods A (five weeks before exam) and B (one week before exam). Edge weights are determined by the magnitude of the effect sizes (i.e., thicker edges indicate stronger associations). Straight and blue arrows indicate positive relationships, red and dashed arrows indicate negative relationships. Lagged effects (lag-1) are represented by directed arrows, while autoregressive effects are depicted by self-looping arrows (curved arrows that exit and enter the same node). Weights ranged from .01 to .10 in model A and –.04 to .15 in model B (see Table S3 in the supplementary materials for all values).

Discussion

We investigated the complex relationships and dynamic patterns between achievement emotions and emotion regulation strategies among students during exam preparation. Using a situated assessment approach and dynamic network modeling, a novel method for analyzing intensive longitudinal data in a multivariate way, we analyzed between-person associations, contemporaneous within-person associations, as well as temporal lagged within-person associations. Taken together, our findings revealed that taking these three levels of associations into perspective is necessary to clarify distinct relations and dynamic

interactions. We identified distinct communities of emotions and emotion regulation strategies, wherein taking action and reappraisal held a particularly central position for explaining the linkages between these constructs. We found evidence for effects from emotions on use of emotion regulation strategies, and vice-versa, and identified self-enforcing loops and carryover effects. We also observed differences in the stability of the assessed constructs over time, and between the week before the exam and five weeks before, that emphasize the consideration of not only person and specific components, but also the respective context at hand, to which end dynamic network analyses provide a promising research perspective.

Communities of Emotions and Emotion Regulation Strategies

The structure of the between-person and the contemporaneous within-person networks served to investigate which emotions went along with each other, and which emotion regulation strategies did. The communities identified in all four networks regarding exam preparation fundamentally confirmed the theoretical nature of emotions with positive and negative emotions being separated in two distinct communities, and clear positive ties within them (with pride holding a central role within the positive emotions). An interesting observation was that only in the contemporaneous within-person networks, but not in the between-person network, negative edges between positive and negative emotions appeared. This matches well with the notion that individual students, over time, can equally experience both positive as well as negative emotions; however, in a specific learning situation, experiences of a positive (respectively, negative) emotion go along with experiences of less negative (respectively, positive) emotions as well as more of the other positive (respectively, negative) emotions. This also emphasizes the importance of distinct studies of between- and within-person interrelations and dynamics (see Nett et al., 2017). The latter finding is further elaborated by the different stabilities shown in the temporal within-person networks that revealed autoregressive loops of varying strength of the emotions as well as positively

reinforcing loops between experiences of pride and satisfaction and negatively reinforcing loops between boredom and anxiety. These might indicate that boredom and anxiety are largely independent from each other at the moment but mutually exclusive over time.

Reflecting the between-person network, for emotional regulation strategies in turn, we found three communities (positive refocusing and activation, taking action and reappraisal, as well as social support, rumination, expression, and suppression). We interpret that in line with students typically not preferring multiple strategies from a particular set of commonly distinguished strategies, such as antecedent-focused and response-focused, or situation selection, situation modification, etc. (Gross, 2015; Naragon-Gainey et al., 2017). Instead, the specific strategies that are preferred together indicate a higher-level functional organization into avoidance (refocusing and activation), emotion-focused (social support, rumination, expression, suppression), and problem-focused (taking action, reappraisal) strategies. That the communities in the within-person network were very similar to the between-person network, likely reflects that strategies that are individually preferred are also applied simultaneously. There was one interesting and specific exception: while suppression and expression were not significantly connected on the between level—showing that students who tend to suppress their emotions do not tend to express their emotions much less or more as well—, they were strongly negatively related on the within-person network, showing that both regulation strategies can hardly be applied simultaneously. Indeed, some emotion regulation strategies, such as social support, may only be possible to use depending on one's circumstances (e.g., availability of friends to help). Adding to this, we also observed limited density between emotion regulation strategies emphasizing that students use different strategies over time instead of the same strategies consistently. Further and with focus on the within-person network, we did observe that some strategies tended to go hand in hand, or were very closely linked temporally: especially taking action and reappraisal as well as positive refocusing and activation. This implies that when thinking about the upcoming exam, looking for positive

sides to the matter may not be feasible without actively acting to improve the situation (well in line with the rather consistent positive link between reappraisal and problem solving; Naragon-Gainey et al., 2017). Likewise, it is apparently challenging for students to think about something else than the exam without doing something to distract themselves from it. It's worth mentioning that in situations that are less cognitively demanding and relevant than exam preparation, this dynamic may change, highlighting the importance considering the specific context at hand.

Adressing the temporal within-person networks, there was, most interestingly, only one temporal edge of activation on refocusing at the first measurement point, while temporal edges occured more often, but only with weak weights, at the second measurement point. This might be an indication for emotion regulation strategies being applied very situation-specifically and getting more timely structured in specific contexts, such as the exam-preparation context.

Considering the networks as a whole, another interesting observation was the central position of taking action and reappraisal. This implies that linkages of other emotion regulation strategies with emotions, besides direct effects, were often indirect through these two emotion regulation strategies. Taking an active role and looking for positive sides might also be particularly well combinable with the other emotion regulation strategies as these are particularly flexibly implementable across situations, object foci, and timeframes (Harley et al., 2019). We discuss their specific effects in more detail in the next section.

Linkages Between Emotions and Emotion Regulation Strategies

Regarding the linkages between emotions and emotion regulation strategies, we observed few links between emotions and emotion regulation in the between-person networks, speaking to the notion that associations between these constructs are not so much a function of stable between-person differences but emerging in the respective situation. To this end, it is important to note that both emotions and emotion regulation strategies exhibited

about the same amount of variance situated on the between-person as well as the within-person level (with an average ICC in measurement period A of .51, and .56 in period B). This finding clearly emphasizes that it is not the case that students with different emotions use different regulation strategies, but rather that experiencing different emotions goes along with use of different emotion regulation strategies. This matches well with emotional responses being related to emotion regulation through not only individual characteristics but their interplay with situational aspects and appraisal-related factors concerning the achievement activities and their outcomes (Harley et al., 2019). This highlights once more the importance of exploring situational within-personal relation in addition to between-person differences as the implications of both perspectives are unique and important. Given the number of individual linkages and the need for further replication, we focus our discussion of the individual effects on the two most central emotion regulation strategies.

The link between reappraisal and emotions was particularly noteworthy, with the relationship with hope being clear in both between-person networks. This is well in line with the frequently documented adaptivity of reappraisal across different contexts (Ford & Troy, 2019) and the prior finding on the positive linkage between reappraisal and hope during exam preparation (Rottweiler & Nett, 2021). With the present research we extend these insights, as we studied partial effects, that is we documented the relationship between reappraisal and hope under simultaneous consideration of the other emotions and regulation strategies. As such, these results highlight the robust linkage of students using reappraisal more frequently also being more hopeful in general. That most other edges were situated in the contemporaneous network speak to reappraisal primarily being an immediate strategy—using it for an extended period of time would likely be more demanding of attention and therefore not always feasible.

Taking action held a similarly central position like reappraisal, yet was only directly associated with two emotions, namely anger and pride (positive effects each). As elaborated

before, the strong edge between taking action and reappraisal points to indirect effects with the other emotions through reappraisal. The direct effects with anger and pride imply that irrespective of reappraisal, and the other regulation strategies for that matter, taking action is accompanied by both increased anger and pride. This may be because anger and pride are both activating emotions that can empower students to autonomously take action and change the situation in order to solve their problem (anger) or maintain success (pride). However, it should be noted that not all activating emotions lead to action; particularly activating negative emotions are assumed to be complex and can also result in inaction (Pekrun, 2006). This further emphasizes the need to consider multiple discrete emotions instead of overarching distinctions (such as positive vs negative, activating vs deactivating) for thoroughly understanding their dynamics with emotion regulation strategies.

Interpreting the aforementioned edges of the contemporaneous networks it needs to be borne in mind that this likely does not solely reflect occurrences at the exact same moment, but also causal and temporal effects across a short timespan (minutes, up to hours). Especially when dealing with a sparse temporal network, it is thereby important to consider the contemporaneous network (Epskamp, Waldorp, et al., 2018). Specifically, the effects of changes within individuals may occur within a timeframe shorter than the one captured between time t−1 and time t. With an average time lag of 2 hours and 30 minutes, many temporal effects are likely also included in this model, and, accordingly, more difficult to detect in the temporal network. Especially effects of emotions on emotion regulation should often be quick (particularly for negative emotions), while effects from emotion regulation on emotion, on average, likely take a longer time span: some effects can be short as well (such as taking action to alleviate boredom for example), but others (such as rumination) might take longer to function. More specifically, following the PMER (Gross, 1998; Gross, 2014; Gross, 2015), strategies like “taking action” can be used to already preemptively manage emotions, such as initiating study habits to mitigate exam anxiety before it fully develops. Conversely,

strategies like suppression are applied reactively, managing emotions as they occur. This might also be one reason for more effects from emotion regulation on emotion being visible in the temporal networks than the other way around. A perspective for future research emerging from this is to consider other forms of assessments, for example non-self-report methods (such as EEG, Facereading) to allow for shorter time lags, and to consider event-based assessments instead of, or paired with, time-based assessment (prompting students to fill out the questionnaire after important, emotional, moments). A combination of both might be particularly intriguing (assessment prompted by spikes on the physiological data). Further and in sum, as these findings are exploratory in nature, they require further confirmation.

Stability Over Time and Differences Between the two Measurement Occasions

Regarding temporal stability, note that the autoregressive effects from the temporal network are based on the construct at time t being regressed on itself, as well as all other constructs, at time t-1. These effects therefore primarily reflect effects of the previous experience / strategy use, an important aspect that can be disentangled from person specific components (Respondek et al., 2019). We found that expression, rumination, social support, and reappraisal were more stable than the other regulation strategies, implying that if students tended to use one of these strategies, they also tended to use it more often subsequently; whereas the other strategies were chosen more variably. This might partially reflect the availability of resources that were more stable across the observed time span (suitable friends, for social support), personality differences (extraversion, for expression), and the nature of the strategies (rumination and reappraisal being more difficult to facilitate and requiring more frequent use than simply changing a situation, which might also be more successful when employed).

For emotions, we found that negative emotions were more stable than positive emotions, especially in the week before the exam, pointing to vicious circles of negative emotions that students had trouble getting out of. This finding generally speaks to the

relevance of transitions of state emotions and the relevance of the context for such processes (see D'Mello & Graesser, 2012; Di Leo et al., 2019). As the exam approaches, situations might tend to occur more frequently and become increasingly similar, potentially hindering healthy emotion regulation, especially in managing negative emotions, which may impede students' emotional recovery compared to when the exam is more distant. According to the PMER, specific strategies must be applied early before an emotion fully emerges since they require resources that might be unavailable when negative emotions are already high (Harley et al., 2019). Though the effects may be modest, this also underscores that an approaching exam can pose a risk to students' emotional well-being.

It is worth noting that this finding on the stability of emotional experiences stands in contradiction to prior research that found stronger carryover effects for positive emotions than for negative emotions during exam preparation using similar time lags (Respondek et al., 2019). Our results might be a function of the statistical approach. Respondek et al. (2019) used univariate analyses while we also considered students' emotional regulation and emotions at the previous timepoint. For example, we found that students experienced more pride at a given moment if they experienced joy and satisfaction beforehand (which were in turn strongly related to joy at the prior assessment). Without the consideration of these two emotions, the estimated carryover effect for pride would have been larger (omitted variable bias; Wilms et al., 2021). On a methodological level, this extends prior research by suggesting that a multivariate graphical vector autoregressive modeling, such as the one used in the conducted dynamic network analyses, can serve to more comprehensively study the stability of emotional experiences, including transitions among emotions alongside person-stable and carryover effects.

Besides these differences in autoregressive effects, we did not find substantial differences in the strength of experienced emotions and the total use of emotion regulation strategies between the two measurement points. We did, however, observe that the networks

tended to be denser when closer to the exam, most notably there were more lagged effects in the week before the exam than in five weeks before. This might imply that certain emotion regulation strategies that are effective in one situation may not yield the same effectiveness immediately before the exam. For example, with enough distance to the exam, suppression may generally work well for resolving negative emotions, but the closer and more salient the exam gets, many different regulation strategies may need to be used in order to be successful (as indicated by the disappearing link between suppression and satisfaction in the week before the exam).

Taken together, we interpret this as another indication of the importance of specifically considering the students' context to better understand their emotions and emotional regulation. Besides person-stable aspects, and carryover effects, variance in emotional experiences and regulation strategies should also be attributable to the specific context that students are in. In different contexts, different regulation strategies may make sense, for example studying at home, being in a lecture or taking an actual test. In our analyses, we only included the first two aspects, however, through an assessment of the specific learning context and its explicit consideration in cross-classified multilevel methods, it might also become feasible to additionally account for the context specificity of the studied effects (see Daumiller et al., 2023). Doing so might be another step forward to even more directly reflect emotion regulation as a complex interaction of situation, individual, and strategy (Doré et al., 2016) as well as the strategy-situation fit hypothesis (Haines et al., 2016). Related to this, it would also be informative to investigate these dynamics for different groups of students, such as comparing networks of high-performing students with those of low-performing students. Another intriguing aspect of using dynamic network analysis to study emotions and emotion regulation lies in its application to idiographic research. This can help identify, better understand, and provide tailored support to individual students based on their unique networks of emotions and emotion regulation strategies.

Theoretical Conclusions for Achievement Emotions and Their Regulation

The theoretical implications of our study for achievement emotions and their regulation among students preparing for exams can be summarized along four central lines.

First, our analysis confirmed distinct communities of emotions and ER strategies. Positive and negative emotions formed separate clusters, supporting a theoretical taxonomy of emotions based on valence. In terms of emotion regulation strategies, we found groupings that suggest a higher-level functional organization into avoidance (refocusing and activation), emotion-focused (social support, rumination, expression, suppression), and problem-focused (taking action, reappraisal) strategies.

Second, the numerous edges within the contemporaneous within-person network and the absence of negative relations in the between-person network underscore the situational sensitivity of emotions and their regulation. This supports the notion that emotions and emotion regulation strategies can be conceptualized and studied at varying levels of granularity, with momentary emotions and emotion regulation strategies exhibiting clearer negative relationships with their momentary counterparts than when considered as traits.

Third, the positive relationships among the different emotion regulation strategies used by students highlight a versatile approach to emotion regulation, where students employ a variety of strategies depending on their emotional states and situational demands. This versatility underlines the adaptive nature of emotion regulation in achievement settings.

Fourth, we found evidence indicating that emotions and emotion regulation strategies work in differing directions (e.g., social support reducing anxiety, rumination increasing anxiety and hope; anger facilitating expression, pride hindering use of social support) which provides a complex view of the bidirectional interplay between specific emotions and emotion regulation strategies.

Practical Implications

The ability to effectively regulate emotions during the preparation for crucial exams is important for students. Acknowledging that complete avoidance of negative emotions is impractical—they are, after all, inherent to the human condition—it is critical to ensure that these emotions do not escalate to levels that could negatively impact study routines and examination outcomes. Based on our findings, enhancing use of reappraisal and taking action (i.e., problem-focused strategies) and decreasing use of rumination, could especially help to ensure the presence of positive emotions while limiting potentially damaging negative emotions.

Many student support services in higher education institutions already provide a foundation for assisting students in developing study skills and managing examination stress. We suggest that such forms of support would benefit students by incorporating either psychoeducation on emotion regulation or resources pertaining to emotion regulation into existing delivery of student support (i.e., one-to-one or group, online or face-to-face). Specifically, student support could involve the following three elements. First, instructing students on what emotion regulation is, the different forms of emotion regulation, and which strategies are more effective than others. Second, reflective exercises for students to identify which strategies they have used in the past and their effectiveness. Third, practice on how to implement effective strategies (i.e., taking action) while minimizing ineffective strategies (i.e., rumination). Problem-solving, for instance, may be an effective approach to both stopping ruminative worry thoughts while also identifying courses of action one could take.

Limitations

Besides the issues already discussed, for the interpretation of the results some further limitations should be borne in mind. First, in the measurement period five weeks before the exam, there were more missing values as students did not think about the exam as frequently as in the week before. This can be another reason for why we observed fewer lagged effects in

this period. An explicit consideration of time-varying effects might help ameliorate this in future research (Bringmann et al., 2017).

Second, while the cross-lagged effects may suggest causality (Hamaker et al., 2018), two important considerations must be kept in mind. First, omitted variables, particularly time-varying ones, could confound causal interpretations within-person effects. Second, the time lag between these variables is specific to the assessed 2-hour and 30-minute time interval in our study, rendering the generalizability to other distances unclear ("lag problem"; Gollob & Reichardt, 1987).

Third, while the number and breadth of emotion regulation strategies that we considered is a strength of our study, there are many more potential strategies students can use to manage emotions in academic settings. Exploring additional emotion regulation strategies might yield additional insights, and could also be added through an open question in future research allowing to tap into further potentially relevant mechanisms.

Fourth, while our data basis consisted of a large number of individual assessments, the sample on the student level is not particularly large and stems from selected study programs from one university only. This hinders investigations into different subgroups (e.g., based on academic performance) and limits the generalizability of findings. Future research should include a broader and larger sample to gain deeper insights. Doing so would allow analyzing differences in networks based on students' performance or their well-being, and could also include relevant antecedents and mediators such as the academic tasks that students deal with or their self-efficacy.

Fifth, the experience sampling design may have placed significant demands on students as they had to respond multiple times daily while preparing for an upcoming exam. Although we screened the data for common indicators of careless responding, such as unusually fast responses or repeated selection of the same response category, we cannot entirely rule out inauthentic answers that could have increased noise in the data. Furthermore,

through the frequent assessments, students' focus on their emotions might have heightened, possibly leading to our study serving as an intervention, with students potentially not regulating their emotions as much as they reported if they hadn't been reminded of their emotions multiple times daily. While emotions could also be sought to be assessed through other means than self-report (such as physiological measures, or through facial coding; Bailenson et al., 2008), this remains a severe challenge for cognitive emotion regulation strategies. Thus, while an inclusion of non-self-reported data presents a relevant avenue for future research (also to mitigate same-source biases), research on these phenomena is likely inevitably bound to heightened attention to the processes under investigation. While unlikely to affect the linkages between the constructs, this needs to be borne in mind for interpreting the frequencies to which students report such strategies.

Conclusion

Taken together, this study offers valuable insights into the dynamics of students' emotions and their emotion regulation processes, which past research has primarily investigated with between-person research approaches. Using an experience sampling approach and a novel analytical approach, dynamic network analyses, we uncovered distinct communities of emotions and emotion regulation strategies, with taking action and reappraisal holding central roles in explaining their interconnections. Bidirectional effects between emotions and regulation strategies, including self-reinforcing loops and carryover effects illustrated the complex emotional dynamics at hand and emphasized the need for additional guidance in effectively regulating emotions during exam-related situations, and considering the specific context at hand. Emotion regulation in students, and individuals in general, involves a diverse range of strategies that interact with individual and context features, making it a challenging but crucial research area to gain a comprehensive understanding of emotion regulation dynamics. To this end, we documented that the use of dynamic network analyses can provide an auspicious direction for future research.

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Table 1
Descriptive Statistics and Bivariate Correlations

	Descriptive statistics					Bivariate correlations													
	M	*SD*	Skew	Kurtosis	ICC	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]
Measurement period A (five weeks to exam)																				
[1] Joy	1.45	1.13	0.31	–0.71	.50		.79	.63	.83	–.36	–.28	–.07	.08	.01	.32	.16	–.05	.16	.10	.08
[2] Pride	1.24	1.12	0.46	–0.73	.48	.55		.73	.71	–.16	–.05	.03	.08	.09	.43	.27	.02	.29	.22	.24
[3] Hope	1.91	1.09	–0.15	–0.59	.61	.45	.48		.61	–.18	–.15	–.07	–.06	.13	.59	.22	.05	.36	.34	.21
[4] Satisfaction	1.62	1.17	0.22	–0.76	.55	.60	.59	.48		–.50	–.36	.01	–.01	–.02	.25	.05	–.08	.19	.06	.01
[5] Anxiety	1.36	1.29	0.44	–1.04	.56	–.26	–.18	–.15	–.29		.69	.10	.20	.25	.08	.34	.26	–.02	.19	.22
[6] Anger	0.85	1.07	1.03	0.04	.40	–.21	–.15	–.17	–.25	.41		.21	.19	.31	.17	.36	.29	.02	.22	.21
[7] Boredom	0.93	1.09	0.97	0.05	.47	–.10	–.04	–.05	–.03	.16	.18		.24	.32	.09	.21	.36	–.12	.05	.20
[8] Suppression	1.78	1.13	0.11	–0.64	.58	–.01	–.03	.03	–.01	.02	–.01	.06		.46	.14	.38	.50	–.46	.21	.05
[9] Positive refocusing	1.76	1.12	0.06	–0.78	.57	–.10	–.16	–.07	–.14	.09	.05	.11	.11		.46	.41	.90	–.08	.46	.18
[10] Reappraisal	1.66	1.10	0.06	–0.85	.62	.18	.19	.28	.18	–.07	–.06	.02	.03	.19		.44	.46	.18	.80	.42
[11] Rumination	1.04	0.98	0.70	–0.25	.49	–.04	–.04	–.03	–.08	.17	.15	.05	–.02	.17	.16		.37	.18	.39	.53
[12] Activation	1.66	1.26	0.19	–1.10	.47	–.09	–.15	–.09	–.14	.09	.05	.08	.09	.64	.17	.13		–.17	.46	.16
[13] Expression	1.45	1.13	0.43	–0.58	.47	.05	.03	.01	.01	.03	.08	–.03	–.37	.06	.11	.29	.08		.12	.29
[14] Taking action	1.63	1.12	0.19	–0.81	.53	.12	.21	.20	.12	–.02	.04	–.01	.03	–.08	.34	.07	–.05	.10		.40
[15] Social support	0.63	0.90	1.36	1.12	.32	.03	.05	.05	.01	.08	.09	.02	–.14	–.02	.13	.23	–.01	.25	.18	
Measurement period B (one week to exam)																				
[1] Joy	1.30	1.12	0.48	–0.59	.60		.82	.62	.81	–.30	–.22	–.10	.13	.01	.18	.12	.04	.09	–.05	.04
[2] Pride	1.35	1.09	0.39	–0.59	.57	.54		.77	.81	–.22	–.13	–.06	.05	.07	.27	.14	.02	.17	.09	.12
[3] Hope	1.96	1.09	–0.16	–0.59	.67	.42	.51		.71	–.26	–.29	–.21	–.03	.17	.38	.08	.07	.20	.14	.02
[4] Satisfaction	1.52	1.09	0.23	–0.57	.62	.52	.60	.54		–.45	–.31	–.02	.01	.02	.17	.02	–.03	.10	–.07	–.03
[5] Anxiety	1.80	1.31	0.06	–1.15	.58	–.25	–.26	–.21	–.30		.59	.20	.16	.20	.09	.33	.26	.06	.23	.25
[6] Anger	1.11	1.24	0.83	–0.45	.44	–.22	–.20	–.27	–.29	.35		.50	.21	.21	.01	.30	.20	–.03	.18	.25
[7] Boredom	0.89	1.17	1.18	0.42	.53	–.16	–.08	–.09	–.08	.05	.23		.17	.23	.04	.24	.26	–.02	.07	.15
[8] Suppression	1.69	1.10	0.11	–0.61	.64	.01	–.02	.01	.01	.02	–.04	–.01		.33	.04	.23	.45	–.47	.02	.02
[9] Positive refocusing	1.72	1.12	0.15	–0.75	.59	–.03	–.07	–.01	–.03	.01	–.03	.11	.08		.51	.36	.87	.17	.36	.16
[10] Reappraisal	1.69	1.09	0.05	–0.70	.66	.16	.17	.23	.18	–.09	–.13	–.04	.05	.12		.45	.47	.27	.62	.40
[11] Rumination	1.11	0.99	0.55	–0.44	.50	–.04	–.07	–.06	–.05	.17	.11	.02	–.01	.16	.07		.37	.15	.29	.52
[12] Activation	1.67	1.24	0.18	–1.02	.50	–.04	–.08	–.05	–.07	.05	–.03	.08	.06	.65	.08	.14		.01	.31	.24
[13] Expression	1.65	1.12	0.30	–0.56	.58	.06	.06	.04	.04	.03	.05	–.01	–.39	.11	.15	.28	.09		.15	.19
[14] Taking action	1.93	1.20	0.00	–0.89	.58	.09	.17	.13	.12	–.03	.03	.02	.07	–.14	.29	–.02	–.15	.02		.30
[15] Social support	0.80	1.01	1.06	0.23	.37	.02	.01	–.02	.01	.07	.09	.05	–.14	.04	.09	.22	.04	.25	.11	

Note. *N*(Period A) = 2577, *N*(Period B) = 4338 assessments of 201 students. Theoretical and empirical range for all variables: 0-4. Lower triangular: within-subjects, upper triangular: between-persons bivariate correlations. ICC = ICC1.

Table 2
Overview of Statistically Significant Edges

	Joy	Pride	Hope	Satisfaction	Anxiety	Anger	Boredom
Measurement period A (five weeks to exam)							
Activation		-		-			
Social support							
Positive refocusing				-			
Rumination				+	+		
Reappraisal	+ +		+ +	+			
Suppression				$+^{2}$			
Expression						+	
Taking action		+					
Measurement period B (one week to exam)							
Activation		$+^{2}$ $+^{1}$				-	
Social support					$+^{2}$	+	+
Positive refocusing		$-^{2}$					+ $+^{2}$
Rumination			$+^{2}$		+	$+^{2}$	
Reappraisal	+	+	+ +	+	-	-	
Suppression							
Expression	+						$+^{1}$
Taking action		+				+	

Notes. Presented is an overview which edges were statistically significant in the between-person network (left, blue color), the contemporaneous within-person networks (middle, black color), and the temporal within-person network (right, orange color). For the latter, the superscript denotes the direction (^{1}: emotion → regulation, ^{2}: regulation → emotion). Positive edges are denoted with +, negative ones with -.