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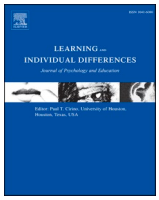

Stress development during emergency remote teaching in higher education

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ABSTRACT

Higher education includes e-learning in addition to on-site learning. Still, the shift to Emergency Remote Teaching (ERT) as reaction to the Covid-19 pandemic in the summer semester 2020, presented a challenging situation for students. Cross-sectional studies pointed towards higher stress levels of students. However, only a few studies addressed the development of students' stress across several dimensions (joy, worry, tension, demands) within one semester. The current study analyzed trajectories of stress in ERT in relation to age, gender, digital readiness, and experience of loneliness, based on a sample of $N = 2795$ German students. Latent Growth Curve Models (LGCM) revealed a significant increase in demands, tension and worries and a decrease in joy during the summer term 2020. The development of tension and demands was influenced by age, gender, digital readiness, and loneliness. The decrease in joy and increase in worries could be primarily attributed to digital readiness and loneliness.

1. Introduction

Digitization in higher education offers several advantages in terms of increasing the accessibility of course offerings to a high number of students (Emili et al., 2019; Kasim & Khalid, 2016). Online courses allow for greater spatial and temporal flexibility in learning (Getto & Kerres, 2018; Naujoks et al., 2021). Accordingly, digital offerings are used to support face-to-face university teaching (Getto & Kerres, 2018), and students are accustomed to e-learning to some degree. Nevertheless, the ad-hoc shift to online learning (so-called Emergency Remote Teaching; ERT) in the wake of the Covid-19 pandemic in the summer semester of 2020 presented a completely new situation for students (Goppert & Pfost, 2021; Hadwin et al., 2022; Voltmer et al., 2021). As a result, first cross-sectional studies reported a higher experience of stress and an increase in mental discomfort of students (Hadwin et al., 2022; Hopp et al., 2021; Tzafilkou et al., 2021). Although stress is a common problem among students and fluctuations in stress levels over the course of a semester are well known (Herbst et al., 2016), ERT is characterized by some specifics that are suspected to increase the stress experience (e.g., Goppert & Pfost, 2021; von Keyserlingk et al., 2021). With regard to the case of Germany, two aspects should be mentioned in relation to ERT: First, Germany responded very quickly and comprehensively to the pandemic by closing educational institutions and converting to digital learning from mid-March 2020 on (Goppert & Pfost, 2021; Matos Fialho et al., 2021). Second, however, Germany seemed not prepared to such a situation as it is lagging behind in terms of digitalization in education (Herzig & Martin, 2018). While half of the students in German universities reported higher levels of stress, perceived loneliness and fear for the future, there were also few students that reported lower mental stress during the pandemic and ERT; maybe due to remedial measures provided by universities (e.g., extension of deadlines; Goppert & Pfost, 2021; Voltmer et al., 2021). However, the few comparative studies (e.g., Goppert & Pfost, 2021) that address student stress before and during the Covid-19-pandemic provide comparable values of stress in the course of regular semesters and the summer term 2020 (e.g., Goppert & Pfost, 2021). Thus, it remains unclear whether and how German students coped with the particular challenges of this exceptional situation, i.e., how their stress level developed over the course of the semester.

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2. E-learning and ERT in German higher education

E-learning in higher education was boosted by the Covid-19 pandemic, which led to severe changes in study conditions and student learning. Although e-learning offers students more flexibility and saves them travel times, it is associated with higher demands in terms of self-regulation skills and characterized by less social integration (Broadbent & Poon, 2015; Goppert & Pfost, 2021; Hadwin et al., 2022). Social embeddedness and interactions are crucial for motivation and retention in studies (e.g., Broadbent & Poon, 2015). Despite numerous online applications that encourage communication and exchange, social interaction in e-learning is different and probably more difficult compared with face-to-face courses (Getto & Kerres, 2018). More cautious use of communication tools (e.g., webcams – Bedenlier et al., 2021), which might be associated with the feeling of higher loneliness, is a frequent point of criticism in connection with e-learning, already before ERT (Jiménez et al., 2018; Rajabalee et al., 2020). Since these criticisms of e-learning have become even more pronounced in the context of ERT, it must be assumed that students will experience the semester in which face-to-face teaching has been completely substituted by e-learning in a significantly different way than in previous semesters (Bedenlier et al., 2021; Hopp et al., 2021). Existing research in Germany, however, has so far produced inconsistent findings with respect to students stress experience (Goppert & Pfost, 2021; Hopp et al., 2021; Voltmer et al., 2021). This could be due to the fact that the individual perception of stress in ERT is linked to university (i.e. competencies of teachers in providing cognitively activating tasks, feedback, enhancing social interactions of students) and student aspects (i.e. digital readiness). Thus, not all students perceived the summer term 2020 as primarily negative and exhaustive (e.g., Goppert & Pfost, 2021).

3. Stress in higher education

3.1. Stress in higher education

Stress represents the individual reaction to external stressors that result from a lack of balance in perceived demands and coping strategies (Kocalevent et al., 2007). According to a common differentiation, stress is distinguished in terms of its perception as “overwhelming and negative” (distress) or as “challenging and positive” (eustress; Rodrigues et al., 2012). Based on assumptions of the transactional stress theory (Lazarus, 1966), stress is a highly subjective construct that arises primarily from individually-experienced psychological arousal based on cognitive evaluations of environmental stimuli (Kocalevent et al., 2007). Stress is typically reported by higher education students (53.1 % of students perceive high stress levels during their studies; Herbst et al., 2016), especially during challenging parts of the semester (e.g., exam period;Goppert & Pfost, 2021; Matos Fialho et al., 2021). Accordingly, the experience of stress is subject to fluctuations, which can be attributed to different levels of motivation and also to changing requirements over the course of the semester.

Stress in higher education can be characterized as the result of the evaluation of study-related demands, internal capabilities, and social resources (Demand-Control-Model; Lutz-Kopp et al., 2019; Schmidt et al., 2019). Hence, high capabilities and positively assessed social relations should facilitate lower initial stress and stress development as it enables effective coping with the demands that an individual faces (Chatterjee & Chauhan, 2020; Räisänen et al., 2020).

3.2. Stress in digital learning and teaching

Studying is associated with increased stress (Matos Fialho et al., 2021; von Keyserlingk et al., 2021) even without additional stressors due to the changes brought by the Covid-19 pandemic. With reference to prior findings on the development of stress or students' perception of e-learning (Garrison et al., 2010; Schmidt et al., 2019), social presence and cognitive abilities are crucial for the evaluation of the learning process and the motivation in digital learning environments (Kahn et al., 2017) and ERT (Hadwin et al., 2022; Hopp et al., 2021). Previous studies revealed core conditions for the development of distress in e-learning: limited opportunities for action (e.g., due to technical difficulties and low support; Hara, 2000), reduced social interactions with peers, lecturers, and tutors (Garrison et al., 2010; Henritius et al., 2019; Hopp et al., 2021), and an increased need to control the learning process by oneself (Hadwin et al., 2022). Fewer opportunities for communication, irregular feedback and unclear tasks are correlated with anxiety, frustration, and confusion (Ajmal & Ahmad, 2019; Nummenmaa & Nummenmaa, 2008), and consequently, with stress (Hopp et al., 2021; Kocalevent et al., 2007).

The generally reduced opportunities for interaction in e-learning, which have been frequently described as stressors, can usually be mitigated by face-to-face teaching in regular courses (Rajabalee et al., 2020). The Covid-19 pandemic led to ERT, and as a result, to a severe reduction of social interaction. In the course of contact restrictions, face-to-face teaching was no longer possible, and private contacts were also kept to a minimum (Hopp et al., 2021). The negative effects of the contact restrictions seem to primarily affect people between the ages of 18 and 30, as they report high levels of social and emotional loneliness (Buecker et al., 2020). It is therefore concluded that higher education students represent a particularly vulnerable group (Matos Fialho et al., 2021; Oliveira de Araùjo et al., 2020). Studies in the context of ERT show that students with lower contact to fellow peers or family and friends reported higher stress levels (Hopp et al., 2021; Voltmer et al., 2021). Higher loneliness was associated with greater losses in well-being and motivation in ERT (Dittrich & Müller, 2020; Schober et al., 2020; von Keyserlingk et al., 2021). Current studies in the context of ERT show higher cognitive load and mental exhaustion in video conferencing (Bailenson, 2021; Fauville et al., 2021). They further provide evidence for students' perception of a very high workload, increased worries, and less contact to fellow students (Kindler et al., 2020; Matos Fialho et al., 2021; Räisänen et al., 2020; Traus et al., 2020; von Keyserlingk et al., 2021).

Digital readiness of students (e.g., Hong & Kim, 2018) plays a central role in the perception of stress in ERT (e.g., Händel et al., 2020). Students who are not ready for e-learning experience negative emotions and lower performance outcomes (Hadwin et al., 2022; Händel et al., 2020). Male students seem to be better equipped when it comes to digital readiness (Senkbeil et al., 2019) and less vulnerable in terms of mental health (Voltmer et al., 2021). Female students reported that they were more influenced in their studies due to Covid-19-Pandemic and more prone to suffer from poor mental health in ERT (Voltmer et al., 2021). Hence, gender is presumed to have an effect on the perception of e-learning and ERT (Biasutti, 2011; Zembylas, 2008).

Numerous measures have been taken by the universities to facilitate the transition to ERT for teachers and students and foster social embeddedness and digital readiness (e.g., software training, provision of licenses for digital exchange tools, extension of deadlines). Some studies in the context of ERT in the course of the Covid-19-Pandemic revealed only slight increase of the worry-dimension of stress in summer term 2020 compared to previous semesters (Goppert & Pfost, 2021; Voltmer et al., 2021), which, however, did not cause a higher expression of stress when considering the overall score (Goppert & Pfost, 2021). However, since the summer term 2020 differs from regular face-to-face semesters in all dimensions of the Demand-Control-Model (Kain & Jex, 2010; Schmidt et al., 2019), it is important to analyse and understand how ERT affects students' perceived stress and its development.

4. Research questions and hypotheses

Due to the unique situation of ERT, different explanations about the trajectory of stress development (increase, decrease, curvilinear, or linear development) and related circumstances might be applied. On the

one hand, a high perception of stress at the beginning of the semester (because of the novelty of the situation), reduction or stability in the middle of the semester (due to adaption), and further increase of stress towards the end of the semester (induced by exam period) can be assumed. On the other hand, it is also possible that stress increases across the duration of the whole semester because the perceived demands regarding self-regulation and digital readiness steadily rise (Naujoks et al., 2021). Furthermore, it is unclear how personal characteristics of students, digital readiness, and perceived loneliness influence development of stress during ERT. As different trajectories are possible and there is a research gap regarding longitudinal development and potential predictors of stress, the following research questions are studied:

Q1: How do students' stress experiences develop during ERT?
Q2: How is the development of stress during ERT influenced by students' gender, ages, digital readiness, and social embeddedness?

Potential predictors of perceived stress (digital readiness and loneliness) are derived from of the extended Demand-Control-Model (e.g., Schmidt et al., 2019), as well as from prior findings (e.g., Herbst et al., 2016; von Keyserlingk et al., 2021). We conduct a detailed test of the following hypotheses in this study:

H1: High digital readiness has a beneficial effect on initial stress and stress development.
H2: Perception of loneliness negatively influences stress experience and stress development.

5. Materials and methods

5.1. Design and sample

The study was designed as longitudinal study with three measurements in the summer semester of 2020 (April, June, and August). Students of a university in southern Germany participated via online questionnaires. The university switched to digital teaching in mid-March 2020 and also closed learning rooms and the library's book collection at the same time. Employees were urged to switch to home office, and direct contact with students was stopped immediately. Risk groups (e.g., pregnant women) were completely banned from entering the university campus. Shortly thereafter, tools such as Zoom were introduced to substitute teaching. Prompt counseling and training was offered for study problems or difficulties with the digital formats. The survey was conducted using Unipark Questback ESF and disseminated via the university internal student distribution list at each measurement point. Students' participation was voluntary. Data protection guidelines were strictly observed. Anonymity was ensured by assignment of students' data at all three measurements via an individual code word. A total of $N = 2795$ students (61.8 % female, mean age: $M = 23.46$, $SD = 4.70$; 36.6 % Bachelor, 24.8 % Master, 35.2 % state exam, 1.9 % PhD, 1.5 % other) participated at the beginning (t1, $N = 1838$), in the middle (t2, $N = 1111$), and at the end of the semester (t3, $N = 1226$). Thus, as is common in longitudinal studies (Twisk, 2013), there was some drop-out.

Based on students' ratings, on the one hand, their previous experience with e-learning offers and their possession of good technical equipment was assumed. On the other hand, their responses indicated that they felt moderately informed about upcoming e-teaching (51.4 % very bad to rather bad) and between 20 and 30 % were considering or already attending fewer classes than they did during regular semesters.

5.2. Instruments

Students' perception of stress was addressed at all three measurement points using the four dimensions "joy", "worry", "demand", and "tension" of the Perceived Stress Questionnaire (PSQ-20; Fliege et al., 2005). Each subscale was measured via five items and displayed good internal consistency (measured via Cronbach's α). A sample item of the subscale joy was "I am full of energy"; ($0.82 \leq \alpha \leq 0.83$). Separately, a sample item of the subscale worry was "I feel frustrated"; ($0.87 \leq \alpha \leq 0.88$). Another distinct sample item of the subscale demand was "I have too much to do"; ($0.86 \leq \alpha \leq 0.88$). And finally, a sample item of the subscale tension was "I feel rested"; ($0.88 \leq \alpha \leq 0.89$).

With respect to the potential predictors, digital readiness and loneliness were assessed at t1. Two subscales of the Digital Readiness for Academic Engagement questionnaire (DRAE; Hong & Kim, 2018) were applied. Digital Tool Administration (DTA; ex.: "I can set and change the security settings of a web browser", $\alpha = 0.76$) and Information Sharing Behavior (ISB; ex.: "I can collaborate with my fellow students via internet applications"; $\alpha = 0.81$) were both assessed via 4 items. Students' loneliness was operationalized via scales of Gierveld and van Tilburg (2006) that address Social (SOC; 5 items, ex.: "I can always turn to my friends"; $\alpha = 0.90$) and Emotional aspects (EM; 6 items; ex.: "I miss the company of others", $\alpha = 0.76$). High values on both dimensions indicate high loneliness.

All items on perceived stress and digital readiness had to be answered on a 6-point Likert scale (1 = not at all true – 6 = absolutely true). Socio-demographic aspects, i.e., age and gender were also assessed. Gender was dummy coded (0 = female, 1 = male).

5.3. Data analyses

Data analyses were performed in R (version 4.0.4). Firstly, descriptive analyses took place and Pearson correlations were calculated. Secondly, Latent Growth Curve Models (LGCMs) were computed in order to investigate the development of the stress dimensions.

Prior to calculating the LGCMs, the measurement invariance across the three measurement points was assessed according to Liu et al. (2017) using the R package lavaan (version 0.6–8 – Rosseel, 2012). The measurement invariance test proves whether the longitudinally generated data represent the same construct with the same metric at the different measurement points. Using the Diagonally Weighted Least Squares (DWLS) estimator, which generates robust estimates standardized at mean and variance; configural, metric, scalar and strict measurement invariance were tested (Liu et al., 2017). The resulting models were compared by means of χ^2-difference tests. In order to assess the model's suitability, the two-strategy-approach was taken and CFI and RMSEA were compared (Chen, 2007). Values CFI $\geq$ 0.95/0.90 and RMSEA $\leq$ 0.05/0.08 represent an acceptable fit (Hu & Bentler, 1999). According to Chen (2007), strict factorial invariance can be assumed for all dimensions (see Table 1). Missing values were estimated using the common and reliable full information maximum likelihood (FIML) method (Graham, 2009; Little et al., 2014).

The subsequently calculated LGCMs allow estimation of the initial mean value (intercept) and the shape and strength of the mean changes (slope). Furthermore, the procedure allows the consideration of inter-individual variations of the intercept and slope caused by time-invariant covariates (Geiser, 2010). In the present study, second-order LGCMs with five indicators per factor at three measurement points (e.g., Joy1 to Joy3) were calculated. Second-order LGCMs were estimated on the level of latent state-variables and allowed controlling of influences based on measurement errors (Geiser, 2010 – cf. Fig. 1).

The mean structure was specified according to the effects coding method (Little et al., 2007). Full information maximum likelihood was chosen for the estimation of variables with missing values (FIML; Enders & Bandalos, 2001; Isiordia & Ferrer, 2018). Firstly, baseline models representing only the intercept were computed. Secondly, the slopes of the models were specified linearly and quadratically. The models were compared using χ^2-difference testing.

Due to the greater suitability of the linear models compared to the quadratic models for all stress dimensions, the linear model was chosen as the basis for further model specifications with covariates. For each of

Table 1
Measurement invariance test of the dimensions of perceived stress.

Invariance level	Model–fit					χ^2–difference test		
	χ^2	df	*p*	CFI	RMSEA	Δ χ^2	Δ df	*p*
Joy								
Configural	417.81	72	0.000	0.983	0.041			
Metric	428.84	78	0.000	0.983	0.040	16.42	6	0.012
Scalar	590.02	116	0.000	0.976	0.038	178.12	38	0.000
Strict	574.73	126	0.000	0.978	0.036	9.90	10	0.449
Worry								
Configural	448.60	72	0.000	0.989	0.043			
Metric	473.79	78	0.000	0.988	0.043	24.07	6	0.001
Scalar	566.66	116	0.000	0.986	0.037	106.75	38	0.000
Strict	548.28	126	0.000	0.987	0.035	14.93	10	0.135
Tension								
Configural	354.11	72	0.000	0.991	0.037			
Metric	425.09	78	0.000	0.990	0.040	78.86	6	0.000
Scalar	590.80	116	0.000	0.986	0.038	179.25	38	0.000
Strict	596.71	126	0.000	0.986	0.037	41.32	10	0.000
Demands								
Configural	314.48	72	0.000	0.990	0.035			
Metric	357.42	78	0.000	0.989	0.026	48.23	6	0.000
Scalar	510.45	116	0.000	0.984	0.035	164.38	38	0.000
Strict	569.79	126	0.000	0.982	0.036	75.20	10	0.000

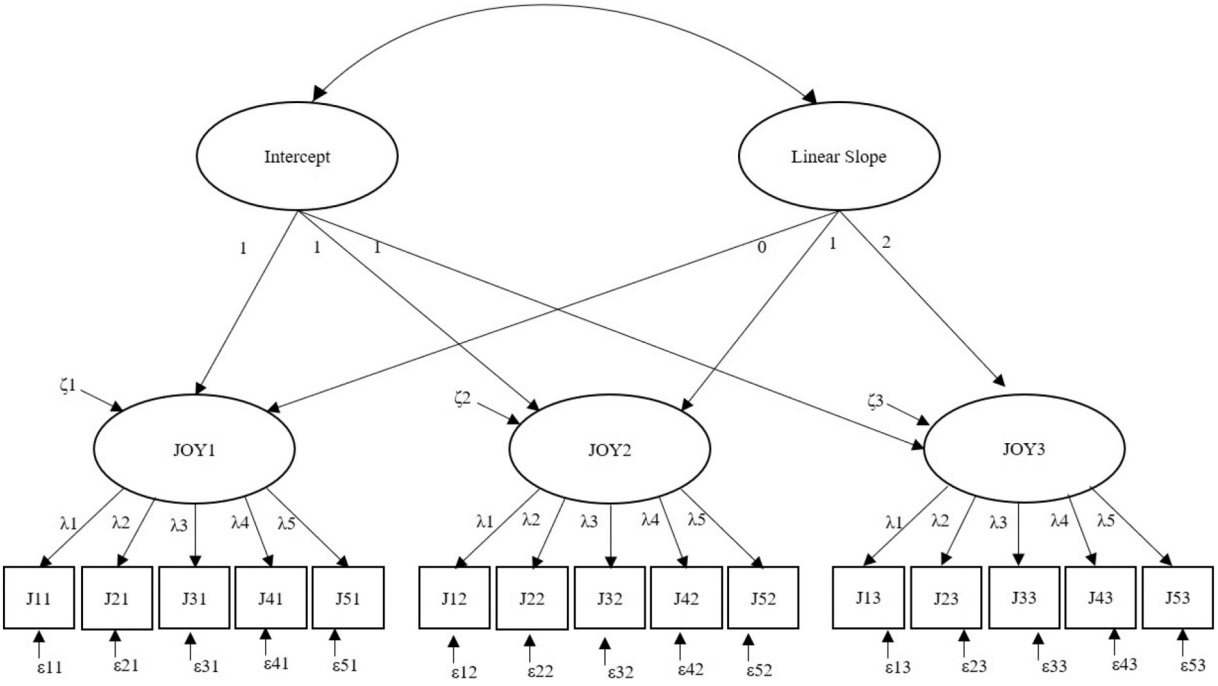

Fig. 1. Schematic diagram of the tested second–order LCGMs (exemplary for joy).
Note. JOY1 = latent variable joy, measured at t1; JOY2 measured at t2; JOY3 measured at t3; J11–J51 (indicators of joy – t1), J12–J52 (indicators of joy – t2), J13–J53 (indicators of joy – t3), ε = measurement error, λ = time invariant state–factor–loading, ζ = latent residual variables.

the four stress dimensions, a baseline model without a slope and constraints was calculated. In addition, three models with increasing number of covariates were calculated. Firstly, in the linear model, a linear slope factor was included. This model was extended by student characteristics, i.e., age and gender (SC Model). The model was then again extended by the initial values of the covariates concerning digital readiness and loneliness (DTA, ISB, SOC, and EM) on the intercept and slope (DRL Model).

6. Results

6.1. Descriptive results

Joy decreased during the semester, whereas worry, tension, and demands increased, particularly from measurement point one to two (Table 2). The students judged their digital readiness at t1 on the scales DTA ($M = 4.60$; $SD = 0.93$) and ISB ($M = 5.10$; $SD = 0.93$) on a quite high level. Social ($M = 4.57$; $SD = 1.01$) and emotional loneliness ($M =$

Table 2
Means and standard deviations of PSQ–dimension assessed at multiple measurement points.

Stress dimension	t1	t2	t3
Joy	3.91 (0.85)	3.78 (0.88)	3.71 (0.87)
Worry	3.24 (1.14)	3.38 (1.15)	3.41 (1.17)
Tension	3.07 (1.10)	3.46 (1.10)	3.69 (1.13)
Demands	3.02 (1.04)	3.66 (1.10)	3.71 (1.08)

3.92; $SD = 0.84$) can also be regarded as moderate to high at t1.

Fig. 2 illustrates the progression of the longitudinally-analyzed dimensions of PSQ in the course of the semester.

Pearson correlations revealed low to moderate relations between stress dimensions, digital readiness, and social or emotional loneliness at t1. Especially the correlations between the stress dimensions and the two facets of loneliness (e.g., joy and EM: $r = -0.42$, $p < .01$ or worry and EM: $r = 0.44$, $p < .01$) were substantial (see Table 3).

6.2. Latent growth curve models

6.2.1. Development of joy

For the experience of joy, the baseline model showed a reasonable degree of suitability ($\chi^2(62) = 320.98$; CFI = 0.97; RMSEA = 0.04). The linear model revealed a decrease in joy. Inclusion of the student characteristics (SC Model) led to insignificance of the slope and slight deterioration of the model's fit due to an increase of the standard errors. However, there was a significant effect of gender on the intercept of joy. Moreover, both dimensions of digital readiness and loneliness proved to predict the intercept of joy (DRL Model). Further coefficients and quality criteria of all models are described in Table 4.

6.2.2. Development of worry

Tested models for development of worry showed a good fit (baseline model: $\chi^2(62) = 280.54$, CFI = 0.98, RMSEA = 0.04). The linear model, as well as the SC Model revealed a significant increase in worries. Gender induced positive changes in the intercept of worries, although the slope was not influenced significantly. In the DRL Model, which included student characteristics and digital readiness and loneliness at the same time, the slope was no longer significant. The intercept was still influenced by gender, and additionally by digital readiness and loneliness with one exception at DTA (see Table 5).

6.2.3. Development of tension

The baseline model regarding tension fitted well to the data ($\chi^2(62) = 613.06$, CFI = 0.96, RMSEA = 0.06). Students' experience of tension increased significantly over the course of the semester. In contrast to the models of joy and worry, the decrease of the slope of tension remained significant even when controlling for digital readiness and loneliness. Age proved to have a significant effect on the intercept and the slope, while there was only a significant effect of gender on the intercept in both the SC and the DRL Model. The DRL Model further showed significant effects of ISB, SOC, and EM on the intercept of tension. In addition, SOC increased the slope of perceived tension (see Table 6).

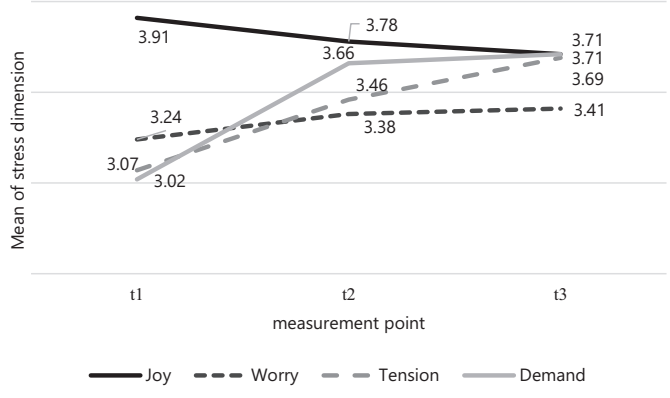

Fig. 2. Graphical representation of the latent means of the PSQ–dimensions in the course of ERT.

6.2.4. Development of demands

The degree of suitability of the baseline model was acceptable ($\chi^2(62) = 818.95$, CFI = 0.93, RMSEA = 0.07). The analysis of the change in perceived demands provided evidence of a significant increase in the course of the semester. The intercept and slope remained significant in all tested models. In the SC and DRL Model, age influenced the intercept positively and the slope negatively, while gender influenced the intercept of perceived demands positively only in the SC Model. In the DRL Model, SOC and EM influenced the intercept of tension positively, which indicated a higher perception of demands when social loneliness is higher, whereas higher ISB reduced perceived demands. Furthermore, higher SOC increased the slope of tension (see Table 7).

7. Discussion

7.1. Summary of the findings

In conclusion, LGCMs showed significant changes in students' perceived stress during ERT in the summer term 2020. All models fitted well to the data. The analyses revealed effects of social embeddedness and digital readiness, as well as age and gender differences.

Overall, the models suggest that all four stress dimensions developed negatively between April and August 2020 (Q1). The finding was evident for two of the dimensions (tension and demands) even when all predictors were included (DRL-Models, Q2). The positive slopes implied a higher perception of demands and tension in the middle and at the end of the summer term 2020 (e.g., Traus et al., 2020). In an existing study conducted in a regular term in higher education (Büttner & Dlugosch, 2013), it is pointed out that the stress dimension demands and the tension are considered to be rated high by students, whereas worries are less pronounced among higher education students. The authors attribute this to the pressure to perform. Pressure to perform was also present during ERT and may have been increased by the purely digital delivery of learning content and the higher demands upon self regulated learning, even if countermeasures (extension of deadlines, training in the use of digital tools) were taken. An American study in the context of ERT showed higher stress levels of students compared to before the pandemic (von Keyserlingk et al., 2021). The results, however, should be qualified against also demonstrated non-significant differences in stress experience evident in comparative studies before and during the pandemic in Germany (Goppert & Pfost, 2021; Voltmer et al., 2021). Thus, it cannot be conclusively answered whether the increase in students' stress between April and August 2020 can be attributed to ERT or to fluctuations in stress perception in the course of the semester (e.g., Goppert & Pfost, 2021).

Nevertheless, our study revealed significant influencing factors on stress of students that can be seen as specific to the situation in ERT: The increase of worries and the reduction of joy could be primarily attributed to loneliness and digital readiness (H1, H2). As perception of worries of students who felt less lonely and reported a high digital readiness did not significantly change in the course of the semester (Matos Fialho et al., 2021) the hypotheses concerning digital readiness (H1) and loneliness (H2) can partly be confirmed. DTA increased the initial values of joy and ISB decreased the initial values of worry, tension and demands during ERT. Thus, it could be affirmed that students with higher degrees of digital readiness were more likely to experience lower stress levels (Tzafilkou et al., 2021). However, digital readiness had no effect on stress development (slope), which means there are no differing trajectories for students with differences in digital readiness. As ISB

Table 3
Pearson correlations of the potential predictors and stress dimensions at t1.

Variable	1	2	3	4	5	6
1. Joy	–					
2. Worry	−0.72**					
	[−0.75, −0.71]					
3. Tension	−0.74**	0.77**				
	[−0.78, −0.74]	[0.75, 0.78]				
4. Demands	−0.58**	0.66**	0.73**			
	[−0.63, −0.58]	[0.65, 0.69]	[0.75, 0.78]			
5. Age	−0.02	−0.01	0.07**	0.14**		
	[−0.06, 0.01]	[−0.07, 0.01]	[0.01, 0.08]	[0.05, 0.12]		
6. Gender	0.03	−0.03	−0.05*	−0.04	−0.02	
	[−0.02, 0.07]	[−0.08, 0.01]	[−0.09, −0.00]	[−0.09, 0.00]	[−0.05, 0.02]	
7. DTA	0.21**	−0.19**	−0.16**	−0.14**	0.13**	−0.43**
	[0.17, 0.24]	[−0.22, −0.15]	[−0.19, −0.11]	[−0.17, −0.10]	[0.08, 0.16]	[−0.46, −0.38]
8. ISB	0.26**	−0.22**	−0.19**	−0.21**	−0.03	−0.20**
	[0.20, 0.27]	[−0.24, −0.17]	[−0.20, −0.13]	[−0.20, −0.13]	[−0.07, 0.00]	[−0.23, −0.13]
9. SOC	−0.40**	0.35**	0.32**	0.25**	0.03	−0.11**
	[−0.43, −0.37]	[0.32, 0.39]	[0.26, 0.33]	[0.20, 0.27]	[−0.00, 0.07]	[−0.15, −0.05]
10. EM	−0.42**	0.44**	0.37**	0.26**	0.07**	0.05
	[0.39, 0.45]	[−0.48, −0.43]	[−0.40, −0.33]	[−0.30, −0.23]	[0.04, 0.12]	[−0.09, 0.01]

Note. Values in square brackets indicate the 95 % confidence interval for each correlation.
DTA = digital tool administration, ISB = information sharing behavior, SOC = social loneliness, EM = emotional loneliness; Gender: 1 = male/0 = female.
* Indicates $p < .05$.
** Indicates $p < .01$.

Table 4
LGCMs with linear slope (linear model), linear slope and students characteristics (SC Model) and linear slope and individual covariates (DRL Model) – Joy.

	Linear Model				SC Model				DRL Model			
	Intercept		Slope		Intercept		Slope		Intercept		Slope	
	β	*SE*	β	*SE*	β	*SE*	β	SE	β	*SE*	β	*SE*
Mean value	**3.89**	**0.02**	**−0.11**	**0.01**	**4.13**	**0.10**	−0.09	0.07	**4.63**	**0.17**	0.01	0.14
Variance	**0.51**	**0.04**	**0.07**	**0.02**	**0.50**	**0.04**	**0.07**	**0.02**	**0.29**	**0.03**	**0.06**	**0.02**
Age					−0.01	0.00	−0.00	0.00	**−0.01**	**0.00**	−0.00	0.00
Female					**−0.17**	**0.04**	−0.00	0.03	**−0.10**	**0.04**	−0.03	0.04
DTA									**−0.07**	**0.03**	−0.02	0.02
ISB									**−0.12**	**0.02**	−0.03	0.02
SOC									**−0.20**	**0.02**	−0.02	0.02
EM									**−0.28**	**0.02**	−0.04	0.02
χ^2 (df)	228.79 (59)				275.27 (85)				356.90 (137)			
p	0.00				0.00				0.00			
CFI	0.98				0.98				0.98			
RMSEA [90 % KI]	0.032 [0.028–0.037]				0.028 [0.025–0.032]				0.024 [0.021–0.027]			
SRMR	0.03				0.03				0.03			

Note. Significant coefficients are marked in bold ($p < .05$); reference category: 1 = male.
DTA = digital tool administration, ISB = information sharing behavior, SOC = social loneliness, EM = emotional loneliness.

Table 5
LGCMs with linear slope (linear model), linear slope and student characteristics (SC Model) and linear slope and individual covariates (DRL Model) – Worry.

	Linear Model				SC Model				DRL Model			
	Intercept		Slope		Intercept		Slope		Intercept		Slope	
	β	*SE*	β	*SE*	β	*SE*	β	*SE*	ß	*SE*	ß	*SE*
Mean value	**3.26**	**0.03**	**0.12**	**0.02**	**3.11**	**0.13**	**0.23**	**0.11**	**2.15**	**0.22**	0.11	0.16
Variance	**0.96**	**0.06**	**0.08**	**0.03**	**0.94**	**0.06**	**0.08**	**0.03**	**0.62**	**0.06**	**0.06**	**0.03**
Age					−0.00	0.01	−0.01	0.00	0.01	0.01	−0.01	0.00
Female					**−0.26**	**0.06**	−0.01	0.04	**0.19**	**0.06**	−0.03	0.04
DTA									−0.06	0.04	−0.05+	0.03
ISB									**−0.13**	**0.03**	0.01	0.02
SOC									**−0.17**	**0.03**	0.03	0.02
EM									**−0.46**	**0.03**	0.04	0.02
χ^2 (*df*)	220.79 (59)				305.80 (85)				387.71 (137)			
p	0.00				0.00				0.00			
CFI	0.99				0.98				0.98			
RMSEA [90 % KI]	0.031 [0.027–0.036]				0.031 [0.027–0.034]				0.026 [0.023–0.029]			
SRMR	0.03				0.03				0.03			

Note. Significant coefficients are marked in bold ($p < .05$); reference category: 1 = male; + represents a significant tendency ($p < .08$); DTA = digital tool administration, ISB = information sharing behavior, SOC = social loneliness, EM = emotional loneliness.

Table 6
LGCMs with linear slope (linear model), linear slope and student characteristics (SC Model) and linear slope and individual covariates (DRL Model) – Tension.

	Linear Model				SC Model				DRL Model			
	Intercept		Slope		Intercept		Slope		Intercept		Slope	
	β	*SE*	β	*SE*	β	*SE*	β	*SE*	*β*	*SE*	*β*	*SE*
Mean value	**3.07**	**0.02**	**0.34**	**0.02**	**2.44**	**0.13**	**0.52**	**0.09**	**1.51**	**0.23**	**0.60**	**0.18**
Variance	**0.84**	**0.06**	**0.12**	**0.03**	**0.81**	**0.06**	**0.12**	**0.03**	**0.60**	**0.06**	**0.10**	**0.03**
Age					**0.02**	**0.01**	**−0.01**	**0.00**	**0.02**	**0.01**	**−0.01**	**0.00**
Female					**0.26**	**0.06**	0.03	0.04	**0.21**	**0.06**	−0.04	0.05
DTA									−0.06	0.04	0.04	0.03
ISB									**−0.08**	**0.03**	0.01	0.03
SOC									**−0.17**	**0.03**	**0.08**	**0.02**
EM									**−0.37**	**0.03**	0.03	0.03
χ^2 (df)	238.34 (59)				314.52 (85)				424.97 (137)			
p	0.00				0.00				0.00			
CFI	0.99				0.98				0.98			
RMSEA [90 % KI]	0.033 [0.029–0.037]				0.031 [0.027–0.035]				0.027 [0.024–0.030]			
SRMR	0.04				0.040				0.03			

Note. Significant coefficients are marked in bold ($p < .05$); reference category: 1 = male.
DTA = digital tool administration, ISB = information sharing behavior, SOC = social loneliness, EM = emotional loneliness.

Table 7
LGCMs with linear slope (linear model), linear slope and student characteristics (SC Model) and linear slope and individual covariates (DRL Model) – Demands.

	Linear Model				SC Model				DRL Model			
	Intercept		Slope		Intercept		Slope		Intercept		Slope	
	β	*SE*	β	*SE*	β	*SE*	β	*SE*	*β*	*SE*	*β*	*SE*
Mean value	**3.09**	**0.02**	**0.36**	**0.02**	**2.28**	**0.13**	**0.61**	**0.10**	**2.30**	**0.22**	**0.51**	**0.18**
Variance	**0.66**	**0.07**	**0.13**	**0.03**	**0.62**	**0.07**	**0.13**	**0.03**	**0.48**	**0.06**	**0.11**	**0.03**
Age					**0.03**	**0.01**	**−0.01**	**0.00**	**0.03**	**0.01**	**−0.01**	**0.00**
Female					**0.15**	**0.06**	0.03	0.04	0.08	0.06	−0.04	0.05
DTA									−0.04	0.03	0.02	0.03
ISB									**−0.16**	**0.03**	0.03	0.03
SOC									**−0.12**	**0.03**	**0.05**	**0.02**
EM									**−0.24**	**0.03**	0.02	0.03
χ^2 (df)	351.44 (59)				430.33 (85)				543.13 (137)			
p	0.00				0.00				0.00			
CFI	0.97				0.97				0.96			
RMSEA [90 % KI]	0.042 [0.038–0.046]				0.038 [0.035–0.042]				0.033 [0.030–0.035]			
SRMR	0.06				0.05				0.05			

Note. Significant coefficients are marked in bold ($p < .05$); reference category: 1 = male.
DTA = digital tool administration, ISB = information sharing behavior, SOC = social loneliness, EM = emotional loneliness.

influenced all stress dimensions, this dimension of digital readiness seems to be most important for perception and development of stress.

Social and emotional loneliness raised the intercepts of worry, tension and demands and reduced the experience of joy during ERT. Furthermore, high levels of social loneliness increased the slopes of tension and perceived demands. The findings could be interpreted in a way that students who felt less lonely perceived lower stress at the beginning and in the course of the semester compared to fellow students who reported higher levels of loneliness. This result is in line with current research (Matos Fialho et al., 2021; Räisänen et al., 2020). The hypotheses concerning digital readiness (H1) and loneliness (H2) can partly be confirmed.

Regarding student characteristics (gender and age) (Q2), it can be concluded that both aspects had an impact on the initial values and particularly also on stress development. The initial values of female students related to worry, tension, and demands were higher than the values of male students wich is in line with previous findings (Herbst et al., 2016; Voltmer et al., 2021), whereas male students' self-rated joy exceeded the levels reported by females. The higher initial values and negative slopes of the stress dimensions regarding the age of the students may be interpreted as follows: Older students (who are presumably enrolled in more advanced semesters) seem to have experienced more stress due to the ad-hoc shift to remote teaching. Still, increasing age predicted lower increase in tension and demands during the semester. That is, older students seemed to be able to cope better with the situation compared to younger (including first-year) students, which might be explained by the better-developed study abilities of more experienced students (Räisänen et al., 2020). Younger and especially first-year students have less or no experiences with higher education, and more problems in adjusting to the situation (e.g., von Keyserlingk et al., 2021). This result is also in line with findings on higher stress levels of bachelor students compared to master students in regular semesters (Herbst et al., 2016). It could be attributed to better support systems for older students, that are probably already better connected with their fellow students, lecturers and administrative staff (von Keyserlingk et al., 2021). According to recent studies, students had fewer contact with lecturers during the Covid-19-pandemic compared to the time before the pandemic (e.g., Matos Fialho et al., 2021), which could be particularly problematic for younger students. However, the time spent at university did not correlate with the experience of stress in previous studies (e.g., Goppert & Pfost, 2021). In our, the effect of age is very small and the variance in age is also very low. Therefore, the findings should be interpreted with caution and further analyses should focus on social networks and quality aspects of the interactions for older and younger students (Hopp et al., 2021).

7.2. Limitations

Since Covid-19 led to closure of universities around the world, and as this situation was a novelty, profound theoretical models or empirical

knowledge about trajectories of perceived stress and potential coping mechanisms during ERT are rare. Hence, this study was based on research on e-learning, distance learning, and stress research in regular higher education as like many other studies before. Still, the interpretation of results is limited due to the lack of access to a comparison group that was taught on-site at the same time as the group under study or data from previous semesters that would provide information on how stress develops during a regular semester with on-campus courses. On the one hand, studies comparing stress levels from cohorts that started studying prior the pandemic (Goppert & Pfost, 2021; Voltmer et al., 2021) with current data from the summer term 2020 confirm the trajectories of stress found in our study but do not suggest any more negative trajectories in ERT. This should be taken into account when interpreting the negative trend found. On the other hand, few existing cross-sectional studies in ERT point towards high perception of stress and mental problems (e.g., Bailenson, 2021; Matos Fialho et al., 2021; von Keyserlingk et al., 2021) and thus are in line with our findings.

With respect to the covariates (age and gender) investigated in our study, there are also some limitations. Besides age and gender, the field of study and the prior experience would also be an interesting aspect with regard to student stress development. In addition, lecturers from different fields of studies might show a vast heterogeneity in the implementation of ERT. Additional covariates with respect to the study situation (e.g., achievement level), familial or professional circumstances, and skills of the teaching staff (e.g., providing cognitive activating tasks, creating a sense of community, giving feedback) that could contribute to differential effects of ERT on perceived stress, have not been addressed. Those should be addressed in future research (cf., Hopp et al., 2021; Voltmer et al., 2021).

The Covid-19 pandemic might not have impacted only study conditions but also the social and private life of the students (e.g., Hopp et al., 2021). The separate recording of study-related and other stressors in the students' private social context would be helpful in order to obtain a more differentiated picture of their state of mind and to derive implications.

With respect to the analysis procedure, it should be mentioned that strict measurement invariance was assumed although the χ^2-difference test was significant. According to Chen (2007), this approach can be justified on the basis of the negligible deterioration of the fit. Furthermore, age, gender, loneliness, and digital readiness were considered only at the beginning of the semester. As digital readiness and social embeddedness might have also developed (e.g., through reduction in the contact restrictions and increasing experiences with ERT) after the ad-hoc change to online learning, this might influence results. The same applies for stressors not directly related to study but to the pandemic situation itself (e.g., fear of infection). This was also not recorded in the study, but may have influenced the students' stress experience (Matos Fialho et al., 2021).

8. Conclusion

To sum up, students perceived increasing stress during ERT. The results of this study extend recent findings on mental health and negative emotions of students in ERT (Matos Fialho et al., 2021; Tzafilkou et al., 2021). However, the negative trend found in this study seems to be moderated by several student related aspects, i.e. digital readiness (e.g., Händel et al., 2020) and loneliness (e.g.,Goppert & Pfost, 2021 ; Matos Fialho et al., 2021). Especially when students felt socially isolated and showed lower digital readiness, they were more prone to experience higher worries, tensions, demands, and lower joy. Social isolation is one of the most frequently mentioned stress factors in the context of the Covid-19 pandemic (Dittrich & Müller, 2020) and it proved to be a core predictor of students' stress in ERT (e.g., Hopp et al., 2021). Thus, it is of great importance to support social interaction in online learning (e.g., by providing platforms for student interaction; Hopp et al., 2021). Furthermore, as digital readiness is also vital, firstly for dealing with requirements of e-learning, and secondly for staying in touch with fellow students, digital readiness must be fostered by universities (e.g., by offering trainings on how to use several digital tools). Although the results of this study refer to ERT as a novelty, they might be useful for the further development of e-learning offers in higher education.

Statement regarding accordance with human subjects guidelines

We confirm that data collection behalf of an online tool took place in accordance with human subjects principles. Participation of students in the study was absolutely voluntary. All respondents were informed about the objectives of the research project before the survey. They were also informed about anonymous use of collected data and the voluntariness of their participation. An ethics approval was not required as per applicable institutional and national guidelines and regulations.

Data availability statement

Raw data were generated at university b. Derive data supporting the findings of this study are available from the corresponding author a on request.

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Declaration of competing interest

None.

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