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# Perceived Stress, Individual Psychological Resources, and Social Resources Among Computer Science Students During the COVID-19 Pandemic

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Due to the COVID-19 pandemic, university students worldwide have experienced drastic changes in their academic and social lives, with the rapid shift to online courses and contact restrictions being reported among the major stressors. In the present study, we aimed at examining students' perceived stress over the course of the pandemic as well as individual psychological and social coping resources within the theoretical framework of the Transactional Model of Stress and Coping in the specific group of STEM students. In four cross-sectional studies with a total of 496 computer science students in Germany, we found that students reported significantly higher levels of perceived stress at both measurement time points in the second pandemic semester (October/November 2020; January/February 2021) as compared to the beginning of the first (April/May 2020), indicating that students rather became sensitized to the constant pandemic-related stress exposure than habituating to the "new normal". Regarding students' coping resources in the higher education context, we found that both high (a) academic self-efficacy and (b) academic online self-efficacy as well as low (c) perceived social and academic exclusion among fellow students significantly predicted lower levels of students' (d) belonging uncertainty to their study program, which, in turn, predicted lower perceived stress at the beginning of the first pandemic semester. At the beginning of the second pandemic semester, we found that belonging uncertainty still significantly mediated the relationship between students' academic self-efficacy and perceived stress. Students' academic online self-efficacy, however, no longer predicted their uncertainty about belonging, but instead had a direct buffering effect on their perceived stress. Students' perceived social and academic exclusion among fellow students only marginally predicted their belonging uncertainty and no longer predicted their perceived stress 6 months into the pandemic. We discuss the need and importance of assessing and monitoring students' stress levels as well as faculty interventions to strengthen students' individual psychological and social coping resources in light of the still ongoing pandemic.

**Keywords: stress, individual psychological and social coping resources, self-efficacy, peer exclusion, COVID-19 pandemic, higher education, STEM – Science Technology Engineering Mathematics, computer science**

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## INTRODUCTION

The coronavirus disease (COVID-19) has evolved into a global crisis affecting the physical and mental health of people worldwide. Following its declaration as a pandemic by the World Health Organization on March 11, 2020 (World Health Organization [WHO], 2020), governments across the globe have imposed strict public health measures in order to contain the uncontrolled spread of the SARS-CoV-2 virus. In Germany, these included physical distancing rules, the obligation to wear face masks in indoor public spaces as well as the shutdown of non-essential shops and educational institutions (cf. Steinmetz et al., 2020). Despite young adults' generally lower risk of developing severe COVID-19 symptoms (Wu and McGoogan, 2020; Rommel et al., 2021), university students have experienced drastic changes and challenges in their academic and social lives due to the shift to online teaching and contact restrictions. Moreover, considering the generally high prevalence of stress and mental health problems in university students (Bewick et al., 2010; Stallman, 2010; Auerbach et al., 2018; Eissler et al., 2020; Karyotaki et al., 2020), it was reasonable to expect that the pandemic and its accompanying restrictions as well as current and anticipated future uncertainties (e.g., regarding students' academic progress and career entry) would strongly affect stress experiences in this population.

Therefore, the aim of the present study was to focus on students' perceived stress during the COVID-19 pandemic, and to examine different individual psychological and social resources in the context of higher education in a sample of computer science students in Germany. While many studies have examined students' stress experiences across disciplines (e.g., Husky et al., 2020; Odriozola-González et al., 2020; Rogowska et al., 2020; Son et al., 2020; Wang X. et al., 2020; Hoyt et al., 2021; Zhan et al., 2021), fewer studies have explicitly addressed the situation of students in a particular academic field, especially that of STEM students, who constitute one of the largest student groups in Germany (Federal Statistical Office of Germany, 2022). In fact, the German higher education system has the largest share of STEM students and graduates compared to all other OECD countries (OECD, 2019), which is why we considered it particularly relevant and interesting to examine this student group. More specifically, we examined computer science students, who – given the focus of their studies as well as their potentially higher information and communications technology (ICT) skills – may have been particularly well prepared for the shift to online teaching. At the same time, however, computer science has been found to be a domain with a culture of rather low academic exchange as well as defensive communication and interaction practices among students (Garvin-Doxas and Barker, 2004; Zander and Höhne, 2021a), which is why this particular group of students may have had potentially fewer social resources to draw on in the context of university. Further, most studies conducted since the onset of the pandemic have focused on a single measurement time point, particularly the phase of the first lockdown in spring 2020 (e.g., Odriozola-González et al., 2020; Rogowska et al., 2020; Son et al., 2020; Wang X. et al., 2020; Charles et al., 2021). Thus, the present study furthermore contributes to the current literature on university students' perceived stress during the pandemic by considering a total of four measurement time points in the period from April 2020 to February 2021. By doing so, our study provides insights into computer science students' perceptions over a longer period of time during the pandemic, and sheds light on whether students were more likely to habituate or become sensitized to the prolonged pandemic-related stress exposure. Lastly, our study adds to the existing literature by examining different individual psychological and social coping resources within the theoretical framework of the Transactional Model of Stress and Coping by Lazarus and Folkman (1984, 1987) at two different time points during the pandemic, and thus has the potential to inform future interventions that aim at strengthening students' resources to cope with stress in times of uncertainty.

### Stress Among University Students

The college years are an important developmental period for young people transitioning from adolescence to emerging and young adulthood (Arnett, 2000; Montgomery and Côté, 2003). During this period, students face a number of developmental tasks, e.g., achieving autonomy from parents, establishing a career, developing emotional stability (Havighurst, 1972), and forming new, supportive relationships with peers (Zander et al., 2017), which can be perceived as challenging and stressful. Moreover, students are confronted with numerous study-related stressors, e.g., high academic workload, meeting deadlines for course assignments, studying for and taking exams, and concerns about receiving poor grades (Abouserie, 1994; Robotham and Julian, 2006; Beiter et al., 2015; Pluut et al., 2015). In a study with 20,842 students from 24 universities in 9 countries – including Germany – that participated in the World Health Organization World Mental Health International College Student Initiative, Karyotaki et al. (2020) found that the majority of students (93.7%) reported at least some level of perceived stress in at least one of six different life areas (e.g., relationships at university, financial situation), with about one third reporting moderate to very severe stress levels. Bewick et al. (2010), combining cross-sectional and longitudinal data of a total of 24,234 students in the United Kingdom, further showed that a greater strain was placed on students' well-being once they started university, and that, even though there was a decrease in students' levels of distress over the course of the first two semesters, they did not fall to pre-university levels. When comparing students' perceived stress to that of other social groups in a representative sample of the German population, Klein et al. (2016) also found that university students reported slightly higher levels of stress.

Although a certain level of stress can be perceived as positive and motivating (Selye, 1974; O'Sullivan, 2011), high and constant stress levels can negatively impact students' overall health, well-being, and academic attainment (Stallman, 2010; Pluut et al., 2015; Ribeiro et al., 2017; Karyotaki et al., 2020; for a recent review on the impact of stress on students in higher education see Pascoe et al., 2020). We therefore considered it particularly

important to examine university students' perceived stress as well as appropriate resources to cope with it.

## The Impact of the COVID-19 Pandemic on University Students' Stress

Since pre-pandemic studies have shown that university students are a particularly vulnerable population group with regard to the prevalence of stress and developing mental health problems (Bewick et al., 2010; Stallman, 2010; Auerbach et al., 2018; Eissler et al., 2020; Karyotaki et al., 2020), the ongoing COVID-19 pandemic was expected to even exacerbate students' risk for mental health issues (cf. Bourion-Bédès et al., 2021).

In a Chinese study, 67.5% of the students that were surveyed university-wide in May 2020 reported a medium or high level of stress (Zhan et al., 2021). Studies conducted at European universities found similar results: a study of French students from various faculties in spring 2020 showed that 61.6% of them experienced moderate to severe life stress (Husky et al., 2020); another one among Polish students of different study programs even exceeded these numbers, with 73% of the students reporting moderate to high levels of stress (Rogowska et al., 2020). Regarding specific pandemic-related stressors reported by students, Cao et al. (2020) identified changes in daily life (e.g., contact restrictions) and worries about academic delays in a study with 7,143 undergraduate college students in China, and found that these were positively associated with anxiety symptoms. In the United States of America, Wang X. et al. (2020) found that 71.05% of the 2,031 undergraduate and graduate students from 15 different colleges in their sample indicated that their stress levels had increased during the COVID-19 pandemic, with stressors related to academics (e.g., precipitous transition to and maintenance of online classes), and social isolation being among the most frequently mentioned contributors to this increase. Similarly, 82% of the students in a study by Son et al. (2020) reported concerns about their academic performance (e.g., shift to online classes, difficulty of learning online), and 86% social isolation (e.g., reduced face-to-face meetings, lack of physical interactions with other students) to be among the major stressors during the pandemic. Complementing these results, about one third of U.S. students in a study by Clabaugh et al. (2021) indicated that they were likely to reduce or withdraw from classes in the fall semester 2020 in case that they would be conducted online, and that they had difficulty coping with the pandemic-related elevated levels of stress. Empirical evidence from the higher education landscape in Germany point to similar student experiences: in a study with 5,021 students, Matos Fialho et al. (2021) found that 48% worried that they would not be able to successfully complete the academic year, and that 47% agreed that the change to online teaching caused significant stress. One of the few longitudinal studies with data before and during the pandemic found that both the prevalence and levels of stress increased in a sample of Indian undergraduate medical students compared to pre-pandemic data (Saraswathi et al., 2020). Similarly, Savage et al. (2021) found a longitudinal increase in United Kingdom students' perceived stress 9 months into the pandemic as compared to October 2019, and von Keyserlingk et al. (2021) in U.S. students' study-related stress levels after the onset of the pandemic. Lastly, a study by Elmer et al. (2020) did not only find increased levels of stress among Swiss STEM students during the pandemic compared to two measurement time points the year before, but also that students nominated fewer peers in both social interaction and co-studying networks at university, and that there was a higher proportion of socially isolated students in the latter.

Taken together, the findings of the above studies highlight that the COVID-19 pandemic has resulted in stark uncertainty and distress among university students worldwide, with academic-related changes and contact restrictions being reported among the major contributors to students' heightened levels of stress. The majority of studies, however, have conducted university-wide surveys across different colleges or faculties but have not focused on the situation of a particular group of students in terms of their study program. Also inconclusive is the empirical evidence on the repercussions of the pandemic on university students in the medium- and long-term, which have been examined in only a few studies to date. Whereas the stress levels of U.S. students in a study by Charles et al. (2021) had largely returned to pre-pandemic levels by fall 2020, two other studies conducted in the United States of America and China did not find temporal changes in university students' levels of stress (Wang C. et al., 2020; Hoyt et al., 2021). A study of a Spanish adult population by Planchuelo-Gómez et al. (2020), however, found a significant increase in respondents' perceived stress over the course of the pandemic. In the present study we therefore sought to clarify in the specific group of computer science students whether they habituated to the constant pandemic-related stress exposure (i.e., became less respondent) or whether they perceived the pandemic-related stress as accumulating, ultimately leading to a sensitization (i.e., became more respondent).

## A Theoretical Framework to Understand University Students' Stress: The Transactional Model of Stress and Coping

According to Lazarus and Folkman (1984), stress is a "particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being" (p. 19). Within the Transactional Model of Stress and Coping (Lazarus and Folkman, 1984, 1987), this person-environment relationship is mediated by two key processes: cognitive appraisal, and coping.

The first process, cognitive appraisal, has been described as the process of categorizing an encounter with respect to one's well-being and distinguishes between a primary appraisal, and secondary appraisal.

Primary appraisal is an individual's evaluation of what is happening, or, put in simple terms, the answer to the question: "Am I in trouble or being benefited, now or in the future, and in what way?" (Lazarus and Folkman, 1984, p. 31). Primary appraisals of stress can be distinguished in three types: harm already experienced; threat, which is anticipated harm to one's well-being; and challenge, which is anticipated mastery or

gain, e.g., in the form of personal growth or social reward (Lazarus and Folkman, 1987). Although threat and challenge appraisals of stress are different with regard to their cognitive component (harm or loss vs. mastery or gain), and their affective component (negative vs. positive), they are not mutually exclusive but can instead occur simultaneously (Lazarus and Folkman, 1984). However, based on the findings that students perceived academic-related changes and contact restrictions as stressors during the COVID-19 pandemic (Cao et al., 2020; Son et al., 2020; Wang X. et al., 2020; Clabaugh et al., 2021; Matos Fialho et al., 2021), we regarded them as perceived threats in students' primary appraisal stage in the present study.

Secondary appraisal is concerned with the assessment of coping resources, including whether they are available, the likelihood that they are going to accomplish a certain goal, and whether one can apply the respective coping option, or a set of them, effectively (Lazarus and Folkman, 1984). These coping resources may be psychological (e.g., beliefs, self-esteem), social (e.g., social integration, social support), physical (e.g., health, energy), or material (e.g., monetary, goods). Because of the academic-related changes that students perceived as stressful during the pandemic, we considered individual psychological beliefs as potential coping resources in students' stress appraisal process in our study. More specifically, we focused on university students' academic self-efficacy, which refers to beliefs about their ability to perform academic tasks at designated levels (cf. Bandura, 1997), and which can be regarded as an optimistic view of one's capacity to deal with stressful academic situations (Schwarzer and Fuchs, 1996). Empirical evidence illustrates the theoretically proposed relationship between academic self-efficacy and perceived stress: in a number of studies among university students, both constructs have been found to be moderately to strongly negatively correlated (e.g., Torres and Solberg, 2001; Zajacova et al., 2005). Moreover, a recent study on the effect of general self-efficacy beliefs on stress perceptions in the context of the COVID-19 pandemic has found that reinforcing self-efficacy was the most important resilience factor against perceiving high levels of stress (Meyer et al., 2022). Given the rapid shift to online teaching and distance learning during the pandemic, we also examined students' academic online self-efficacy, i.e., beliefs in their ability to successfully handle academic challenges in digital learning environments (cf. Shen et al., 2013; Zimmerman and Kulikowich, 2016). With regard to the pandemic-related extensive contact restrictions which students reported among the major stressors, we furthermore considered low levels of perceived exclusion from social interactions and academic help exchange among fellow students as a third potential coping resource (cf. Thoits, 1995; Seeman, 1996; Schwarzer and Knoll, 2007). In accordance with the Buffering Hypothesis (Cohen and Wills, 1985), which posits that interpersonal resources protect individuals from the negative effects of stressful situations, research findings within the specific population of university students have shown that interpersonal resources and perceived social support have a buffering effect on students' stress as well as a positive effect on their general well-being (e.g., Misra et al., 2003; Lee et al., 2004; Chao, 2012). In recent studies during the COVID-19 pandemic, perceived social support, e.g., from friends and faculty, has also been found to be positively linked to lower levels of students' perceived stress and higher levels of their well-being, respectively (Ye et al., 2020; Bourion-Bédès et al., 2021; Li et al., 2021; Plakhotnik et al., 2021). Lastly, reappraisal refers to a cognitive appraisal that follows and potentially modifies an earlier appraisal, representing a continuous reevaluation on the basis of new information (Lazarus and Folkman, 1984). Over the past decades, stress researchers have paid increased attention to the concept of uncertainty (e.g., Mishel, 1988; Greco and Roger, 2003; Peters et al., 2017; Wu et al., 2020), which has been described as a state of "incomplete information or knowledge about a situation, i.e., the possible alternatives, or the probability of their occurrence, or their outcomes, are not known by the subjects" within Stress Cognition Theory (Scholz, 1983, p. 4). Empirical studies among university students have shown that the cognitive state of uncertainty is a major predictor of stress and other mental health problems (Greco and Roger, 2003; Wu et al., 2020). Within the context of the COVID-19 pandemic, a study by Lin et al. (2020) with 7,800 Chinese university students could further show that information uncertainty during the pandemic was a significant predictor of students' acute stress disorder. We thus considered low levels of students' uncertainty as another potential coping resource and, given the higher education context of our study, focused specifically on their uncertainty about belonging to their study program. Moreover, because students' academic-related beliefs and perceived exclusion have been shown to be relevant predictors of their sense of belongingness to an academic setting (Höhne and Zander, 2019a; Zander and Höhne, 2021b), we considered low levels of students' uncertainty about belonging as a temporally subsequent coping resource in students' reappraisal stage.

The second process, coping, consists of conscious and unconscious efforts undertaken to master, reduce, or tolerate the internal and/or external demands that are caused by the stressful event (Folkman and Lazarus, 1980). In this regard, Folkman and Lazarus proposed two major functions that coping serves: the management or alteration of the source of stress (problem-focused coping), and the regulation of the emotions that come with the stressful event (emotion-focused coping). In the present study, however, we only focused on university students' stress appraisal process, and not their actual coping.

## THE PRESENT STUDY

While several studies have examined university students' stress during the first pandemic semester, less empirical attention has been paid to their stress experiences over the course of COVID-19 as well as their coping resources in the context of higher education. Further, no previous studies have focused on computer science students – a population that is of particular interest because they presumably had more resources to cope with the rapid transition to online teaching, but presumably fewer resources in terms of social support within their academic peer group to cope with the extensive contact restrictions during the pandemic (cf. Garvin-Doxas and Barker, 2004;

Zander and Höhne, 2021a). The present study aimed to help fill this gap in the literature by examining computer science students' perceived stress as well as individual psychological and social resources in the higher education context over the course of the COVID-19 pandemic. Given the mixed findings regarding the medium- and long-term effects of the pandemic on stress, we explored perceived stress at four measurement time points (T1–T4) during the pandemic in order to contribute to the empirical evidence on whether students were more likely to habituate or become sensitized to the prolonged pandemic-related stress exposure. Moreover, we explored the levels of students' self-reported academic self-efficacy, academic online self-efficacy, perceived social and academic exclusion as well as uncertainty about belonging to their study program over the course of the pandemic. Based on the Transactional Model of Stress and Coping (Lazarus and Folkman, 1984, 1987) and the research discussed, we considered academic-related changes and contact restrictions as pandemic-related stressors for university students, and expected that high (a) academic self-efficacy and (b) academic online self-efficacy, as well as low (c) perceived exclusion and (d) belonging uncertainty as coping resources would predict lower levels of perceived stress. Further, we predicted that the relationships between (a) academic self-efficacy, (b) academic online self-efficacy, and (c) perceived social and academic exclusion and our outcome variable perceived stress would be mediated by (d) students' uncertainty about belonging to their study program (see **Figure 1**). Because pre-pandemic studies (Brougham et al., 2009; Zhang et al., 2018; Graves et al., 2021) as well as studies conducted during the pandemic (Aristovnik et al., 2020; Elmer et al., 2020; Clabaugh et al., 2021; El-Monshed et al., 2021; Zhan et al., 2021) have found that female students reported higher levels of stress, and because they appeared to be at higher risk of facing negative mental health consequences during the pandemic, we included gender as a covariate in our regression analyses.

# MATERIALS AND METHODS

## Participants

A total of 496 computer science students (T1: 137 students, 97 males; T2: 81 students, 54 males; T3: 161 students, 111 males; T4: 117 students, 74 males) from three medium to large German universities (10,000 to 30,000 students) participated and completed our study. All three universities are located in the same federal state in Germany and have a technical focus. Of our overall sample, 67.7% indicated their gender to be male, 27.8% to be female, 1.4% to be diverse, and 3.0% did not indicate any gender. In addition, 9.5% stated that they were born in a country other than Germany. Students were, on average, 22.94 years old ($SD$ = 4.77), and primarily studied for their Bachelor's degree (83.5%). All participants were recruited using convenience sampling methods (e.g., distribution of the link to the survey via lecturers and email lists). Of the students who clicked on the survey link, between 46.00% (T3) and 58.62% (T4) completed the online survey.

## Measures

### Perceived Stress

We used a shortened German version of the Perceived Stress Scale (PSS) developed by Cohen et al. (1983) to assess students' perceived stress. The PSS questions have been designed to assess how uncontrollable and overloaded respondents perceived their lives during the past month (e.g., "In the last month, how often have you felt nervous and 'stressed'?", "In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?"). Students responded to the five items in our study on a 5-point Likert response scale (1 = never, 5 = very often). In contrast to the original scoring procedure of the measure, in which respondents receive a score between 0 and 40, indicating a low, medium, or high level of stress, all items were averaged to create a mean score, and formed a reliable scale ($\alpha_{Total}$ = 0.880, α between 0.867 and 0.907).

### Academic Self-Efficacy

Students' beliefs about their ability to accomplish academic tasks in their study program were measured using an adapted and shortened measure by Jerusalem and Schwarzer (1986) that has been applied previously in the context of higher education (cf. Höhne and Zander, 2019a,b): "I am confident that I have the competencies to perform well in this subject" and "I can cope with difficult situations and challenges in my studies if I try hard". Both items used a 5-point Likert response scale (1 = strongly disagree, 5 = strongly agree), and formed a sufficiently reliable scale ($\alpha_{Total}$ = 0.736, α between 0.595 and 0.837).

### Academic Online Self-Efficacy

We adapted a measure by Shen et al. (2013) to assess students' confidence in their ability to succeed in online courses. Whereas the original measure consists of five dimensions altogether, we applied an adapted and shortened seven-item version of the first dimension "Self-efficacy to complete an online course" (e.g., "I am confident that I can successfully complete all of the required online activities", "I am confident that I can adapt my learning styles to meet the course expectations"). Again, students indicated their agreement on a 5-point Likert response scale (1 = strongly disagree, 5 = strongly agree). Because all seven items were found to be internally consistent ($\alpha_{Total}$ = 0.877, α between 0.856 and 0.891), they were summed and averaged to form a composite variable.

### Social and Academic Exclusion

To measure students' perceived exclusion from both non-academic social activities and academic exchange by fellow students, we adapted a measure by Höhne and Zander (2019a) consisting of four items (e.g., "Sometimes I have the feeling that other students interact privately, and I am not included, although I would like to be", "I have already noticed that other students engage in subject-related exchange, and I am not included, although I would like to be"). All items were completed on a 5-point Likert response scale (1 = strongly disagree, 5 = strongly agree), and formed a reliable scale ($\alpha_{Total}$ = 0.887, α between 0.850 and 0.903).

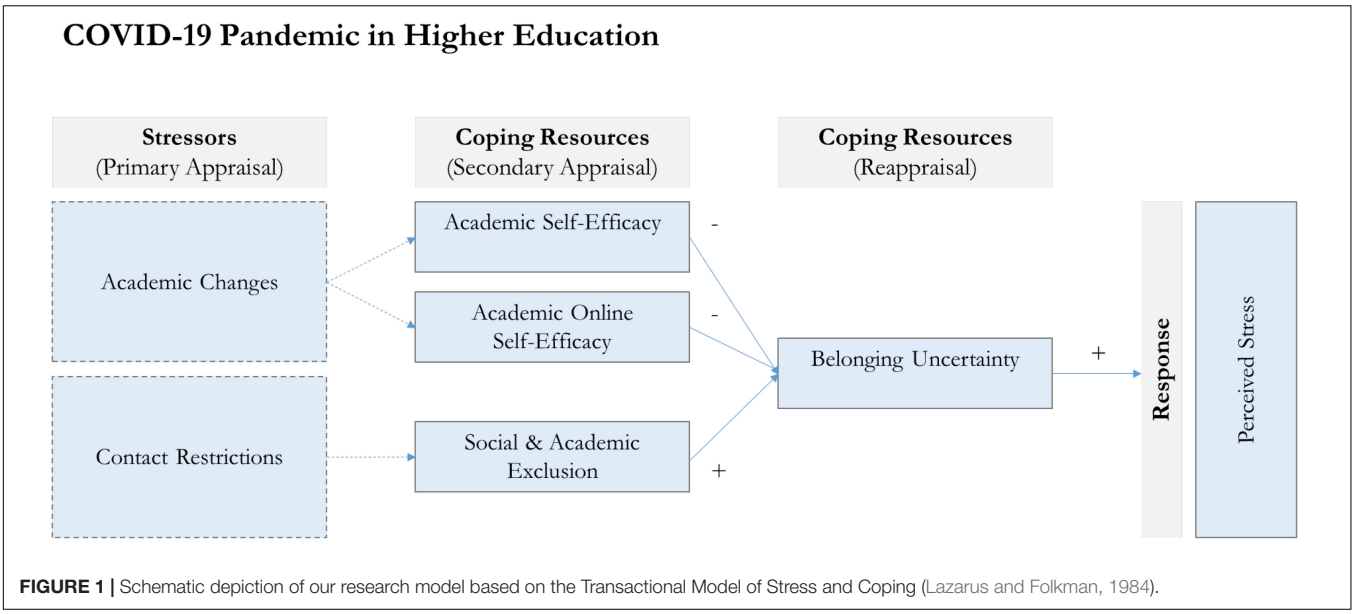


**FIGURE 1 |** Schematic depiction of our research model based on the Transactional Model of Stress and Coping (Lazarus and Folkman, 1984).

### Belonging Uncertainty

Students reported their uncertainty about belonging to the domain of computer science by responding to two items adapted from Walton and Cohen (2011): "Sometimes I feel that I belong to this study program, and sometimes I feel that I don't belong to this study program" and "When things don't go well, I often think that maybe I don't belong to this study program" (1 = strongly disagree, 5 = strongly agree). Reliability analysis yielded a sufficient internal consistency ($\alpha_{Total} = 0.697$, $\alpha$ between 0.607 and 0.719).

### Demographics

Students were asked to indicate their gender, age, country of birth, and intended degree at the end of the online survey.

## Procedure

We conducted our survey study at the beginning and end of the summer term 2020 and the winter term 2020/21, respectively. At all four measurement time points (T1: April/May 2020; T2: July 2020; T3: October/November 2020; T4: January/February 2021), data was collected online using the web-based survey software Unipark.de. Before giving their written consent, students read about the content and aim of the study, and were assured of voluntary participation, the anonymity of their responses, and their right to withdraw from the study at any time without giving any reason.

## Statistical Analyses

Statistical analyses, unless stated differently, were performed using Mplus version 8.1 (Muthén and Muthén, 1998-2017). At first, we calculated descriptive statistics for all variables of interest at the four measurement time points (T1–T4). Subsequently, mean differences between the four measurement time points were tested using simple linear regression analyses. For the two measurement time points with the largest sample sizes (T1, T3), we calculated bivariate correlations, and performed mediated multiple linear regression analyses in order to examine students' individual psychological as well as social coping resources in the higher education context as predictors of their perceived stress. More specifically, we tested whether students' academic self-efficacy, academic online self-efficacy, and perceived social and academic exclusion would predict belonging uncertainty, which, in turn, would predict their perceived stress. Gender was included as a covariate in our analyses. Because the share of students that indicated their gender to be diverse was too small to compare it to the male and female students in our sample, we excluded these cases in the mediated multiple linear regression analyses. All mediations were tested with 5,000 bootstrapped iterations. For all analyses, a robust maximum likelihood (MLR) estimator was used. Missing values were estimated using full information maximum likelihood estimation (FIML), which is preferable to traditional missing data approaches, such as listwise deletion and single imputation methods (Peugh and Enders, 2004).

# RESULTS

## Descriptive Statistics

**Table 1** shows the means and standard deviations of all variables of interest (i.e., perceived stress, academic self-efficacy, academic online self-efficacy, social and academic exclusion, and belonging uncertainty) at the four measurement time points. In addition, mean differences were calculated and are presented in **Figure 2**. Overall, students reported more stress at T3 ($\beta = 0.153$, $p \leq 0.01$) and T4 ($\beta = 0.180$, $p \leq 0.01$) as compared to T1, and thus, perceived their lives to be more overloaded and uncontrollable during the second pandemic semester than at the beginning of the first. Regarding students' beliefs about their abilities to master general academic tasks as well as online-related tasks in their

**TABLE 1 |** Means and standard deviations.

| | | Perceived stress | Acad. self-efficacy | Acad. online self-efficacy | Social and acad. exclusion | Belonging uncertainty |
|---|---|---|---|---|---|---|
| | *N* | *M* (*SD*) | *M* (*SD*) | *M* (*SD*) | *M* (*SD*) | *M* (*SD*) |
| T1 | 137 | 2.84 (0.90) | 4.12 (0.82) | 3.96 (0.72) | 2.70 (1.16) | 2.90 (1.22) |
| T2 | 81 | 3.03 (0.91) | 4.22 (0.74) | 3.79 (0.79) | 2.82 (1.13) | 2.79 (1.11) |
| T3 | 161 | 3.13 (0.95) | 4.01 (0.68) | 3.67 (0.75) | 2.99 (1.03) | 3.21 (1.16) |
| T4 | 117 | 3.17 (0.91) | 3.99 (0.75) | 3.75 (0.70) | 3.00 (1.13) | 3.37 (1.11) |

*All values were estimated using Mplus, FIML and a MLR estimator. T1, April/May 2020; T2, July 2020; T3, October/November 2020; T4, January/February 2021.*

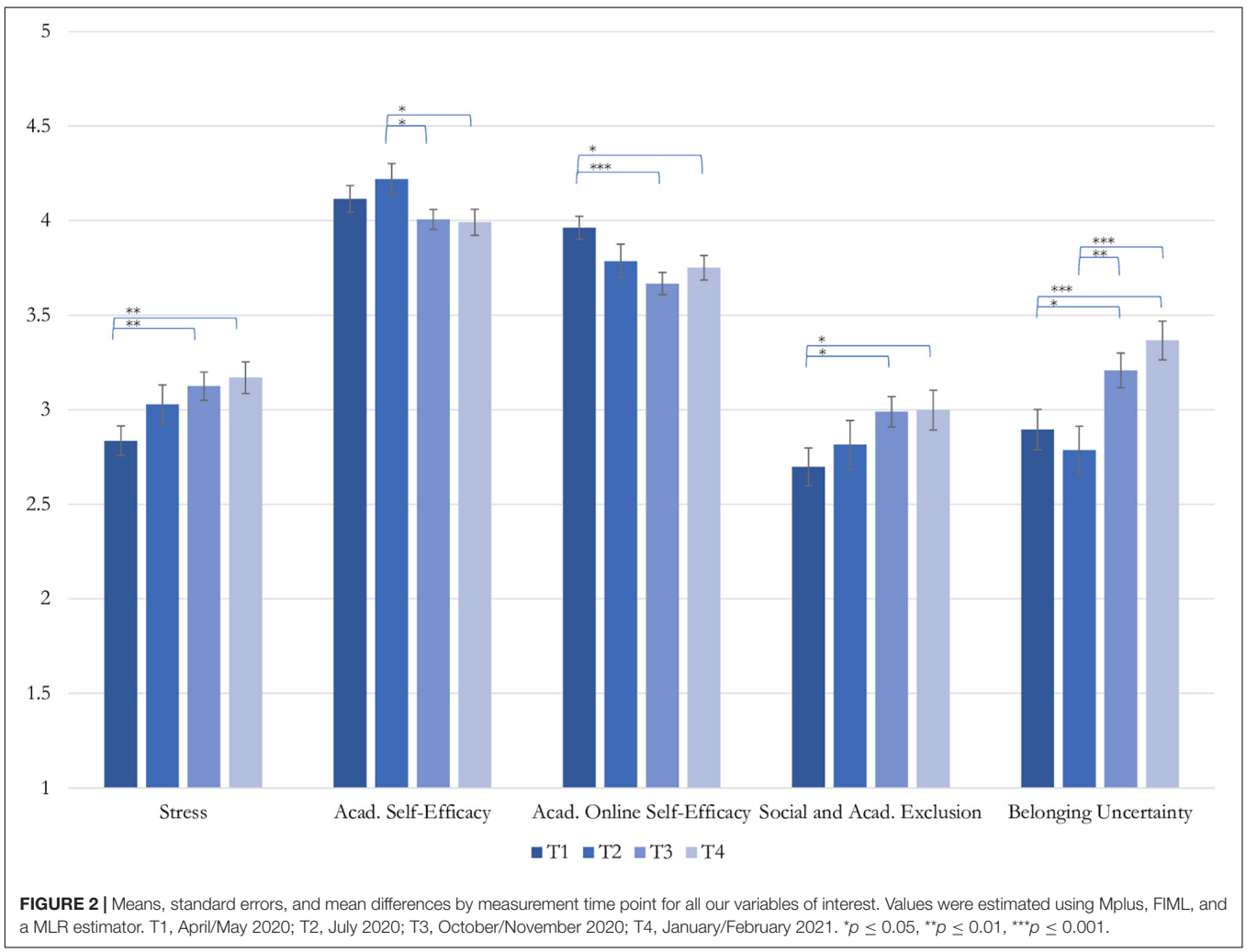


**FIGURE 2 |** Means, standard errors, and mean differences by measurement time point for all our variables of interest. Values were estimated using Mplus, FIML, and a MLR estimator. T1, April/May 2020; T2, July 2020; T3, October/November 2020; T4, January/February 2021. *$p \leq 0.05$, **$p \leq 0.01$, ***$p \leq 0.001$.

studies, our results, overall, show a decline over the course of the pandemic. Compared to T2, students reported less academic self-efficacy at T3 ($\beta = -0.142$, $p \leq 0.05$) as well as at T4 ($\beta = -0.148$, $p \leq 0.05$). Moreover, they reported less confidence in their ability to succeed in online courses both at T3 ($\beta = -0.196$, $p \leq 0.001$) and T4 ($B = -0.147$, $p \leq 0.05$) as compared to T1. With regard to our social factors, students perceived to be more excluded from the social and academic exchanges of their fellow students, and to be more uncertain about their belonging to their study program the longer the pandemic lasted. Both at T3 ($\beta = 0.132$, $p \leq 0.05$) and T4 ($\beta = 0.130$, $p \leq 0.05$) as compared to T1, students reported more perceived exclusion. Moreover, students reported more belonging uncertainty at T3 ($\beta = 0.130$, $p \leq 0.05$) and T4 ($\beta = 0.197$, $p \leq 0.001$) as compared to T1 as well as at T3 ($\beta = 0.170$, $p \leq 0.01$) and T4 ($\beta = 0.248$, $p \leq 0.001$) as compared to T2.

Bivariate correlations between all variables at T1 and T3 are presented in **Table 2**. At both time points, all predictor variables correlated significantly with computer science students' perceived stress: academic self-efficacy and academic online self-efficacy negatively, and social and academic exclusion as well as belonging uncertainty positively. Given the moderate

**TABLE 2 |** Correlations of the dependent and independent variables.

| | 1 | 2 | 3 | 4 | 5 | 6 | VIF |
|---|---|---|---|---|---|---|---|
| (1) Perceived Stress T1 | 1 | −0.444*** | −0.461*** | 0.395*** | 0.572*** | −0.227** | |
| (2) Acad. Self-Efficacy T1 | | 1 | 0.415*** | −0.097 | −0.487*** | 0.242** | 1.478 |
| (3) Acad. Online Self-Efficacy T1 | | | 1 | −0.201* | −0.373*** | 0.011 | 1.309 |
| (4) Social and Acad. Exclusion T1 | | | | 1 | 0.271*** | 0.068 | 1.118 |
| (5) Belonging Uncertainty T1 | | | | | 1 | −0.195* | 1.470 |
| (6) Gender T1 | | | | | | 1 | 1.098 |
| (1) Perceived Stress T3 | 1 | −0.384*** | −0.544*** | 0.298*** | 0.418*** | −0.172* | |
| (2) Acad. Self-Efficacy T3 | | 1 | 0.392*** | −0.123 | −0.352*** | 0.217** | 1.316 |
| (3) Acad. Online Self-Efficacy T3 | | | 1 | −0.305*** | −0.260*** | 0.090 | 1.299 |
| (4) Social and Acad. Exclusion T3 | | | | 1 | 0.231** | −0.086 | 1.139 |
| (5) Belonging Uncertainty T3 | | | | | 1 | −0.213** | 1.227 |
| (6) Gender T3 | | | | | | 1 | 1.076 |

*T1, April/May 2020; T3, October/November 2020. Values were estimated using Mplus, FIML, and a MLR estimator. VIF, Variance inflation factor of the independent variables (variables 2–7; results were estimated using SPSS version 28). Gender: 0 = male, 1 = female. *p ≤ 0.05; **p ≤ 0.01; ***p ≤ 0.001.*

correlations between some of the predictor variables, we calculated variance inflation factors (VIFs) in SPSS (version 28.0; IBM Corp, 2021) in order to determine whether collinearity posed a problem for the analyses used. With the lowest VIF-score being 1.076 and the highest being 1.478, no significant inflation of standard errors due to non-orthogonality among the predictors was indicated.

## Mediated Multiple Linear Regression Analyses

The results of the mediated multiple linear regression analysis at T1 are presented in **Figure 3**. In line with our expectations, academic self-efficacy (β = –0.363, $p \leq 0.001$), academic online self-efficacy (β = –0.179, $p \leq 0.01$), and perceived social and academic exclusion by fellow students (β = 0.209, $p \leq 0.01$) were significant predictors of students' belonging uncertainty. In addition, academic online self-efficacy (β = –0.233, $p \leq 0.01$), perceived social and academic exclusion (β = 0.258, $p \leq 0.001$), and belonging uncertainty (β = 0.323, $p \leq 0.001$) significantly predicted students' perceived stress. As hypothesized, when testing the indirect effect of belonging uncertainty as mediator in the relationship between students' academic self-efficacy and perceived stress, we found a full mediation effect (β = –0.117, $p \leq 0.01$, 95% *CI* = –0.200 to –0.048). Moreover, with regard to the relationships between students' academic online self-efficacy (β = –0.058, $p \leq 0.05$, 95% *CI* = –0.115 to –0.008) as well as perceived exclusion (β = 0.067, $p \leq 0.05$, 95% *CI* = 0.013 to 0.137) and perceived stress, we found significant partial mediations with belonging uncertainty as mediator. Our model explained a total of 32.3% of the variance in belonging uncertainty, and a total of 48.5% of the variance in perceived stress.

The results of the mediated multiple linear regression analysis at T3 are presented in **Figure 4**. Again, academic self-efficacy (β = –0.272, $p \leq 0.001$) was a significant predictor of students' uncertainty about belonging to their study program; however, perceived social and academic exclusion (β = 0.146, $p = 0.064$) was only marginally predictive of belonging uncertainty. In contrast to our expectations, academic online self-efficacy (β = –0.106, $p = 0.202$) was no longer a predictor of belonging uncertainty, but instead still directly predicted students' perceived stress (β = –0.392, $p \leq 0.001$). In addition, students' belonging uncertainty significantly predicted their perceived stress (β = 0.247, $p \leq 0.001$). When testing the indirect effect of belonging uncertainty as mediator in the relationship between students' academic self-efficacy and perceived stress, we found a full mediation effect (β = -0.067, $p \leq 0.01$, 95% *CI* = –0.126 to –0.022), as hypothesized. Our model explained a total of 16.7% of the variance in belonging uncertainty, and a total of 40.0% of the variance in perceived stress.

# DISCUSSION

The COVID-19 pandemic and related public health measures (e.g., contact restrictions, shutdown of educational institutions) have severely impacted the academic and social lives of university students worldwide. Considering the generally high prevalence of stress and mental health problems in university students, the aim of the present study was to take a closer look at students' perceived stress over the course of the first two semesters during the pandemic, and to examine different individual psychological and social resources in the context of higher education in a sample of computer science students in Germany.

## Computer Science Students' Perceived Stress During the COVID-19 Pandemic

Numerous studies worldwide have shown the detrimental impact of the pandemic on students' perceived stress since its onset (Cao et al., 2020; Elmer et al., 2020; Husky et al., 2020; Rogowska et al., 2020; Saraswathi et al., 2020; Son et al., 2020; Wang C. et al., 2020; Wang X. et al., 2020; Charles et al., 2021; Clabaugh et al., 2021; Hoyt et al., 2021; Savage et al., 2021; von Keyserlingk et al., 2021; Zhan et al., 2021). Although

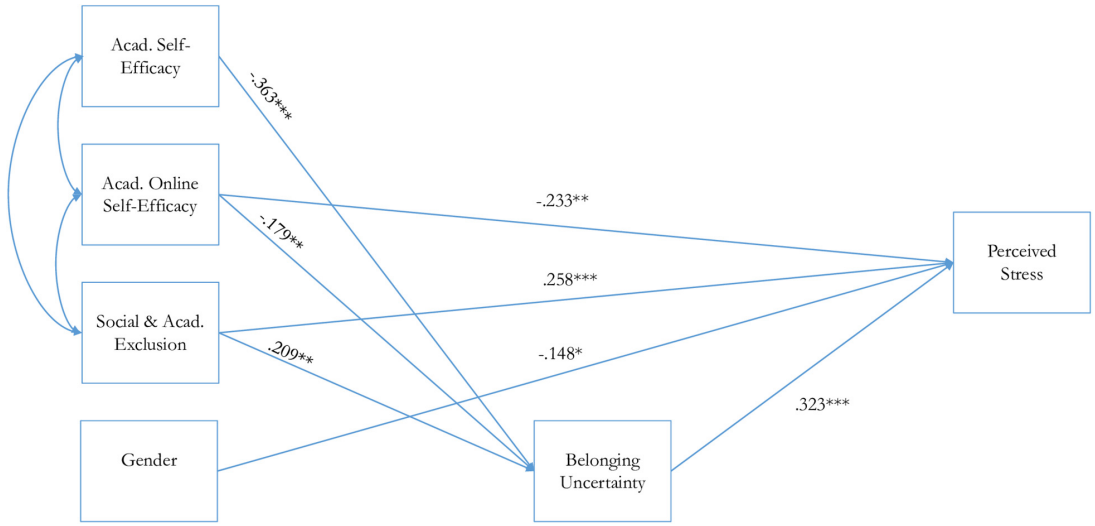


**FIGURE 3 |** Mediated multiple regression analysis with standardized direct regression coefficients at T1. Values were estimated using Mplus, FIML and a MLR estimator. Gender: 0 = male, 1 = female. $^{*}p \leq 0.05$, $^{**}p \leq 0.01$, $^{***}p \leq 0.001$.

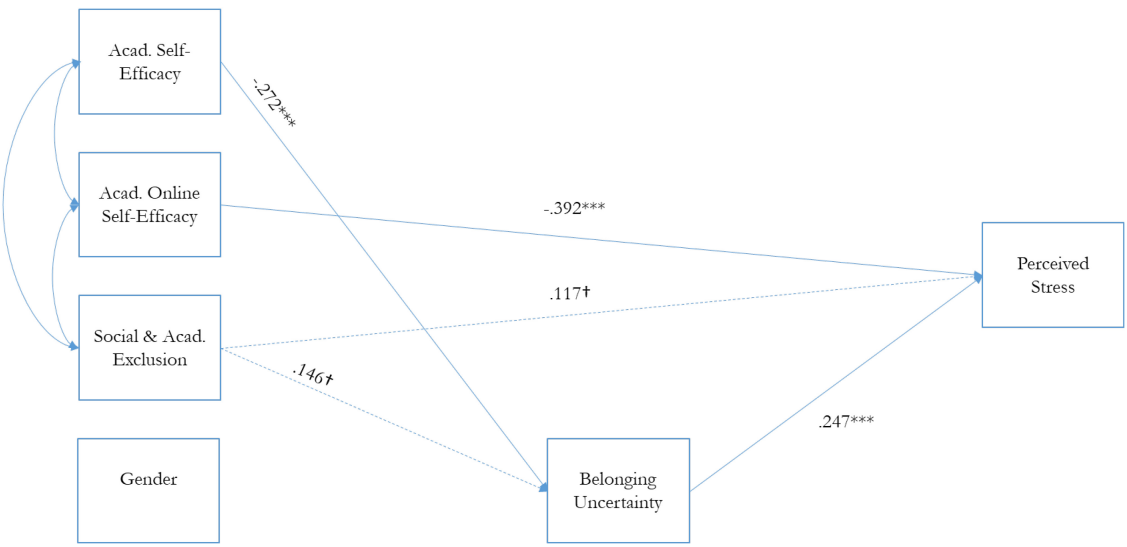


**FIGURE 4 |** Mediated multiple regression analysis with standardized direct regression coefficients at T3. Values were estimated using Mplus, FIML and a MLR estimator. Gender: 0 = male, 1 = female. $^{\dagger}p \leq 0.1$, $^{***}p \leq 0.001$.

our results are limited in that we do not have pre-pandemic comparison data, they indicate some degree of elevated stress in our sample: at three of four measurement time points, computer science students reported higher-than-average stress levels. A closer look at the distribution of students' responses across the four measurement time points showed that 68% of the students in our sample suffered moderate to high levels of stress during the pandemic, which closely corresponds to the percentage share reported in other studies and student samples from Europe, China, and the United States of America (Husky et al., 2020; Rogowska et al., 2020; Wang X. et al., 2020; Zhan et al., 2021).

## The Increasing Weight of the Pandemic: Higher Perceived Stress, Lower Resources to Cope

Given the inconclusiveness of previous findings regarding the medium- and long-term effects of the pandemic-related stress exposure on university students' perceived levels of stress, one central aim of our study was to determine whether the students in our sample habituated to the "new normal" or whether they rather became sensitized to the constant stress exposure. The results of our study point to the latter: computer science students reported significantly higher levels of perceived stress,

and thus, perceived their lives to be more overloaded and uncontrollable at both measurement time points in the second pandemic semester as compared to the beginning of the first. Although we had a high percentage of first-semester computer science students ($n$ = 86) that had just entered university at our third measurement time point in October/November 2020, there was no significant mean difference with regard to perceived stress between the first- and higher-semester students, further supporting the interpretation of our findings. In comparison to other studies with more than one measurement time point during the pandemic, our results are consistent with those by Planchuelo-Gómez et al. (2020), who also found a temporal increase in respondents' perceived stress over the course of the pandemic, but in contrast to those that did not show significant temporal changes (Wang C. et al., 2020; Hoyt et al., 2021) or indicated a habituation (Charles et al., 2021). Although our study does not allow to answer the question of what exactly explains these divergent results, we would like to suggest several explanations, including varying national contexts with different time points at which public health measures and restrictions had been in place as well as specific sample characteristics. Clearly, further research is needed to systematize and comprehensively describe similarities and differences in stress experiences across different student populations and countries.

With regard to computer science students' coping resources in the higher education context, we found that they reported less academic self-efficacy and academic online self-efficacy, as well as more perceived exclusion from the exchanges of their fellow students and uncertainty about belonging to their study program in the second pandemic semester as compared to the first, providing further evidence for the increasing weight of the pandemic. While the latter finding was less surprising given the lack of social interactions with fellow students due to the prolonged contact restrictions, which had been reported as a major pandemic-related stressor in previous studies (Cao et al., 2020; Son et al., 2020; Wang X. et al., 2020), the generally "chilly" academic exchange and interaction climate among students in the domain of computer science (Garvin-Doxas and Barker, 2004; Zander and Höhne, 2021a), and the results by Elmer et al. (2020), who found a decrease in STEM students' nominations in both social interaction and co-studying networks after the onset of the pandemic, the decrease in students' self-efficacy beliefs was somewhat unexpected. Although university students worldwide had reported academic-related changes (e.g., precipitous shift to and maintenance of online classes, difficulty learning online) as a significant stressor during the pandemic (Cao et al., 2020; Son et al., 2020; Wang X. et al., 2020; Clabaugh et al., 2021; Matos Fialho et al., 2021), especially our finding that the students in our sample reported less confidence in their ability to successfully handle academic challenges in digital learning environments over the course of the pandemic was not expected given the supposedly good preparedness of computer science students for the transition to online learning in terms of their digital literacy and frequent interactions in digital environments. One explanation could be that students perceived their digital skills to be too specific and not suited to meet the specific academic challenges they faced in digital learning environments. Future studies could address this by including context-specific measures of digital literacy and self-efficacy as students commence and continue their studies. Another possible explanation for the decrease in both students' academic and academic online self-efficacy beliefs could be that relevant sources of self-efficacy information (cf. Bandura, 1997) were not or only to a limited extent available during the pandemic, e.g., verbal persuasion from university lecturers and vicarious learning through peer observation. Lastly, emotional and physical states, such as arousal, mood states, and stress also provide students with self-efficacy information, i.e., they gauge their degree of confidence by the emotional or physical state they experience when considering or engaging in an action (cf. Bandura, 1997; Britner and Pajares, 2006). Since negative states can inhibit an academic performance and decrease the likelihood of a good outcome, thereby contributing to lower self-efficacy beliefs (cf. Britner and Pajares, 2006), our finding that computer science students reported increasing levels of stress over the course of the pandemic may also explain the decrease in their academic and academic online self-efficacy beliefs.

## Individual Psychological and Social Coping Resources in the Higher Education Context

Because of the academic-related changes and contact restrictions that students worldwide reported as major stressors during the COVID-19 pandemic (Cao et al., 2020; Son et al., 2020; Wang X. et al., 2020; Clabaugh et al., 2021; Matos Fialho et al., 2021), we considered individual psychological and social coping resources within the secondary appraisal and reappraisal stage of the Transactional Model of Stress and Coping (Lazarus and Folkman, 1984, 1987) in our study.

In line with our expectations, we found that high general academic self-efficacy and academic online self-efficacy predicted lower levels of computer science students' perceived stress at our first measurement time point in April/May 2020. These results support the theoretical assumption that self-efficacy can be regarded as an optimistic view of one's capacity to deal with stressful academic situations (cf. Schwarzer and Fuchs, 1996), and correspond with pre-pandemic studies among university students that found a negative relationship between academic self-efficacy and perceived stress (Torres and Solberg, 2001; Zajacova et al., 2005). As expected, we also found that students who felt excluded to a lower extent from the social activities and academic exchanges with fellow students reported lower levels of stress, pointing to the importance of supportive peer relations as social coping resources (cf. Thoits, 1995; Seeman, 1996; Schwarzer and Knoll, 2007). Our finding is consistent with Cohen and Wills (1985) and empirical evidence illustrating the protective effect of interpersonal resources on students' perceived stress (Misra et al., 2003; Lee et al., 2004; Ye et al., 2020; Bourion-Bédès et al., 2021; Li et al., 2021). Moreover, we considered students' uncertainty in our study – a cognitive state which has been theorized and empirically found to be a major predictor of stress (cf. Scholz, 1983; Mishel, 1988;

Greco and Roger, 2003; Peters et al., 2017; Lin et al., 2020; Wu et al., 2020). Because students' academic-related beliefs and perceived exclusion have been shown to be relevant predictors of their sense of belongingness to an academic setting (Höhne and Zander, 2019a; Zander and Höhne, 2021b), we considered students' uncertainty about belonging as a temporally subsequent coping resource in students' reappraisal stage, and predicted that belonging uncertainty would be a significant mediator between the other three coping resources and students' perceived stress. As hypothesized, we found that students' academic self-efficacy, academic online self-efficacy, and perceived exclusion were significant predictors of belonging uncertainty, which, in turn, predicted students' perceived stress.

At our third measurement time point in October/November 2021, however, we found a different pattern of results. Similar to the beginning of the first pandemic university semester, computer science students' uncertainty about belonging to their study program mediated the relationship between academic self-efficacy and perceived stress. However, students' academic online self-efficacy no longer predicted belonging uncertainty, but instead had a direct buffering effect on their perceived stress. Thus, students' academic online self-efficacy appears to have been a relevant source of their belonging uncertainty only at the beginning of the pandemic when students had to master the transition to online learning. By the second pandemic semester, students may have already had enough experience with online courses, which is why their academic online self-efficacy may have lost its relevance in predicting uncertainty and doubts about their academic belonging. Also contrary to our expectations, computer science students' perceived social and academic exclusion among fellow students only marginally predicted their uncertainty about belonging and their perceived stress 6 months into the pandemic. Although students, overall, perceived more exclusion over the course of the pandemic in the context of university, one possible explanation for this finding could be that their experiences with peers at university were overshadowed by the generally prevalent contact restrictions in all areas of life, so that academic and private interactions with fellow students no longer served as a reliable resource to cope with the pandemic-related stress. Moreover, both the general contact restrictions and conditions in online learning environments may have hindered students' opportunities to maintain supportive peer relationships and to form new ones. As a consequence, over time, students may have focused more on their individual psychological resources than on social resources in the context of university. Future comparative research could examine in more detail whether this tendency has been particularly typical for students in the traditionally male-connoted STEM domains for which a generally less supportive climate has been reported among peers (Garvin-Doxas and Barker, 2004; Zander and Höhne, 2021a).

## Limitations and Future Directions

Despite the contribution of the present study to our understanding of university students' perceived stress as well as different individual psychological and social coping resources over the course of the COVID-19 pandemic, it is not without limitations pointing to avenues for future research.

To begin with, although our study provides an insight into computer science students' perceptions over a longer period of time during the pandemic, it is not truly longitudinal in nature but rather a repeated survey including varying participants, and thus, does not allow to make inferences about actual change in students' perceived stress, competence-related beliefs, perceived social and academic exclusion, and sense of belongingness. Moreover, due to the cross-sectional study design, conclusions about the causal relationships between our variables should be drawn with caution. Therefore, future studies should ideally use longitudinal research approaches to investigate the courses of stress and its associated coping resources among university students. In the context of the current loosening of restrictions in the still ongoing pandemic, it is furthermore of particular interest to investigate students' perceived stress and coping resources following the (partial) re-opening of the universities. Moreover, as online courses have undoubtedly made their way into higher education and will become more prominent as part of university teaching portfolios in the future, it would be interesting to systematically examine students' stress in different learning contexts, such as face-to-face, online, and blended courses, along with whether they differentially influence students' uncertainty about the relevance of individual psychological and social coping resources – without the additional weight of pandemic constraints.

Second, because our sample consisted of only a relatively small number of computer science students from three universities in one federal state in Germany – with the majority of them being males – our results cannot be generalized to the population group of STEM students or university students as a whole. Given current empirical evidence that students in STEM domains experienced lower levels of perceived stress and better mental health trajectories during the pandemic than students in the arts, humanities, social sciences, and health sciences (Chirikov et al., 2020; Odriozola-González et al., 2020; El-Monshed et al., 2021), it would be an interesting next step to examine whether these differences can be explained by the lower share of female students in STEM because female students have generally been shown to report higher levels of stress (Brougham et al., 2009; Zhang et al., 2018; Aristovnik et al., 2020; Elmer et al., 2020; Clabaugh et al., 2021; El-Monshed et al., 2021; Graves et al., 2021; Zhan et al., 2021). Another explanation could be STEM students' potentially higher ICT skills, which have become more important during the pandemic due to the shift to online courses. The particular difficulties of online teaching associated with courses such as fine arts, dance, art, and music (cf. Sahu, 2020) provide a third possible explanation.

Third, although our statistical model could explain a total of 48.5% of the variance in computer science students' perceived stress at our first measurement time point (T1), and a total of 40.0% at our third measurement time point (T3) 6 months later, there may be other factors that add to the full picture of students' perceived stress during the COVID-19 pandemic – especially because we measured students' general rather than university-related stress. Stressors identified in other studies, such as worry about one's own health and the health of loved ones as well as financial concerns (Son et al., 2020; Wang X. et al., 2020), may

further contribute to students' perceived stress but were not the focus of our study given our theoretical anchoring in the stress appraisal process among higher education students.

Lastly, within Lazarus and Folkman's (1984, 1987) Transactional Model of Stress and Coping, on which we based our study, we only focused on students' secondary appraisal and reappraisal stage as well as their perceived stress as outcome variable. Thus, a promising next step would be to also include other parts of the theoretical model in an empirical study, i.e., students' primary appraisal and coping strategies.

## Practical Implications

The present study gave evidence that computer science students' levels of perceived stress increased over the course of the pandemic, illustrating the importance of assessing and monitoring students' stress levels in order to provide appropriate psychological services tailored to the uncertain circumstances of the pandemic and students' specific needs. Even though many universities in Germany at least partially re-opened in fall 2021, the pandemic is still ongoing and may thus continue to impact students' stress and mental health. Specific online stress management programs for university students that aim at strengthening their coping resources and skills by providing individual motivational feedback and teaching stress management strategies (e.g., MyStudentBody-Stress, Chiauzzi et al., 2008), or by increasing their perceived present control over stressful situations (e.g., Hintz et al., 2015), provide low-threshold yet effective and valuable interventions.

Further, the results of our study have the potential to inform future interventions with faculty in order to strengthen students' coping resources. Based on our finding that both computer science students' academic self-efficacy and academic online self-efficacy were important resources to cope with stress, university lecturers may wish to address different sources of efficacy information in order to strengthen students' confidence in their academic abilities. More specifically, and in line with Social Cognitive Theory (Bandura, 1997), lecturers could work on providing many opportunities to experience mastery, which has been shown to be an important source of university students' self-efficacy (Luzzo et al., 1999; Bautista, 2011). Faculty social persuasion in the form of encouragement or effort attributional feedback has been shown to be a second significant source of self-efficacy information for university students (Hsu et al., 2021; Nob, 2021). In this regard, Wong (2015) proposed that effective encouragement messages should emphasize process-oriented factors including effort (e.g., "If you keep on working hard, you are going to do well in this course"), strategy (e.g., "Your approach to solving today's task was very good. Keep up the good work"), and attitude (e.g., "I am convinced that you can do well in this course because you are very ambitious"). It should be noted, however, that university lecturers reported in a recent study that it was particularly challenging to provide regular feedback to students in remote teaching during the pandemic (Haase and Zander, in press). A third significant source of self-efficacy in the university context is the modeling of success through vicarious experiences that students undergo when they observe similar others performing academic tasks (Zeldin and Pajares, 2000; Bartsch et al., 2012). Therefore, lecturers may wish to provide opportunities for collaborative learning and design specific tasks where students work together and learn from each other – both in face-to-face and online courses. Given our finding that, overall, computer science students' academic self-efficacy and academic online self-efficacy decreased over the course of the pandemic, addressing these different sources of self-efficacy may be of particular importance.

Lastly, our results also point to the importance of students' perceived social and academic inclusion as well as belongingness as coping resources. Similar to our findings regarding the individual psychological coping resources, the aggravated levels of perceived exclusion and uncertainty about belonging to the computer science program over the course of the pandemic seem to indicate the need for faculty interventions – especially because belonging uncertainty has been found to adversely affect STEM students' academic domain identification, achievement, and persistence (Woodcock et al., 2012; Walton et al., 2015; Höhne and Zander, 2019b). University lecturers should therefore enable recurring in-class group work and foster academic peer networks, which may be of particular importance in online and hybrid classrooms where students have potentially more difficulty in building relationships with fellow students (cf. Elmer et al., 2020).

# CONCLUSION

With the rapid shift to online courses and contact restrictions, the COVID-19 pandemic has had a large impact on university students worldwide. In the present study, we found in the specific group of computer science students – a student group who had presumably more resources to cope with the rapid transition to online teaching, but presumably fewer resources in terms of social support within their academic peer group to cope with the extensive contact restrictions during the pandemic – that they reported higher levels of perceived stress at two measurement time points in the second pandemic university semester as compared to the beginning of the first. Thus, our results indicate that they rather became sensitized to the prolonged pandemic-related stress exposure than habituating to it. Moreover, we found that students reported lower levels of individual psychological and social coping resources over time – further illustrating the increasing weight of the pandemic. At the same time, our study provided evidence for the positive impact of both types of coping resources in the context of higher education, yielding important cues for future interventions with faculty in order to strengthen students' ability to cope with stress in times of uncertainty.

# DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

# ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and

institutional requirements. The patients/participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

EH: study conception, statistical analyses, and first draft of the manuscript. EH and LZ: study design, interpretation of results, and revision of the manuscript. EH, SF, JS, and LZ: data collection. All authors approved the final version of the manuscript.

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