The Effects of Stress and Anxiety in Technology-Based Learning Environments

Maliha Mian (m.mian@unsw.edu.au)

Gelareh Mohammadi (g.mohammadi@unsw.edu.au)

Nadine Marcus (nadinem@unsw.edu.au)

School of Computer Science & Engineering, University of New South Wales
Sydney NSW 2052

Abstract

Emotions, including stress and anxiety, strongly influence cognition and learning experiences. This study investigates the impacts of stress on cognitive load during learning, considering baseline anxiety levels and fluctuating stress. With a focus on technology-based learning, a web-based HTML introduction module was used. Using a social stress test, 15 participants underwent a stressful situation during learning, while the control group of 15 were in a neutral condition. Results indicate significantly elevated stress levels in the experimental group throughout the experiment, with a corresponding decrease in learning performance. For high perceived difficulty, the stressed condition demonstrated a significant increase in response time compared to the control condition. In contrast, when experiencing low perceived difficulty, a significant difference in response time across conditions was not found. Findings emphasise the importance of managing stress in educational contexts to optimise learning outcomes in the evolving landscape of technology-based learning.

Keywords: stress, anxiety, and learning; cognitive load; education; emotion and learning

Introduction

Emotions have a multifaceted relationship with cognition (Plass & Kalyuga, 2019), and are an important component of the dynamics of cognition.

Cognitive load refers to the mental effort required to complete a cognitive-based task (Sweller, 2010). The three types of cognitive load include:

1. Intrinsic - difficulty of the learning material, also referred to as element interactivity (Marcus et al., 1996)
2. Extraneous - excess load used to present information.
3. Germane - integrating information with previous knowledge.

Using traditional educational models, it has been suggested that emotions, including stress and uncertainty, can contribute to extraneous cognitive load (Sweller et al., 2019). For instance, Calvo and Eysenck (1992) found that anxiety inhibited academic performance since working memory was found to be overwhelmed with worries rather than the task at hand. Stressful situations can lead to working memory resources being consumed with excessive thoughts and worries about failure, which is more likely to occur in highly anxious students (Paas & van Merriënboer, 2020). Ramirez and Beilock (2011) demonstrated that a pre-test short writing task that allowed students to express themselves, led to better test performance since students were able to free their working memory resources from worries about failing. These examples signify the importance of designing education materials to manage working memory resources and consider cognitive load within the context of emotions and stress.

Mostly adverse emotions tend to hinder the learning process, while positive emotions have been shown to enhance it. Negative emotions including anxiety during learning have been found to lead to longer times needed to achieve proficiency (Brand et al., 2007; Brosnan, 1998; Poropat, 2009, 2014; Seipp, 1991). From a clinical psychology-based perspective Lukasik et al. (2019) found a significant association between clinical anxiety and reduced working memory performance, highlighting that these effects on learning can be more long-term too. Boredom and frustration have also been found to result in lower learning outcomes (Graesser, 2012) whereas, experiencing enjoyment has been found to improve learning due to a greater sense of autonomy experienced by the learner (Pekrun, 2000) and is associated with a more intrinsically rewarding experience of learning (Pekrun, 2006; Pekrun & Stephens, 2010).

In certain instances, a counterintuitive trend has also been observed where negative emotions can enhance learning, while positive emotions appear to have the opposite effect. Confusion has been found to lead to improved learning (D'Mello et al., 2014). Intrinsic cognitive load and acute stress are highly correlated for physicians working in a fast-paced care centre (Vella et al., 2021). Physicians described their ability to handle uncertainty as an integral aspect of dealing with their cases (White et al., 2018). Knörzer et al. (2016) used a combination of past event recall and music to create positive and negative moods. The negative mood group was found to have improved learning outcomes. It was suggested that the positive emotions may have led to extraneous cognitive load impairing learning processes. The

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impact of emotions could be dependent on several factors including how the emotion is induced, the type of learning context, the complexity of the information presented, and individual differences in knowledge.

The emotions experienced during learning can be impacted by the skillset of the learner. Heer et al. (2021) investigated the association between pre-learning emotional state, cognitive load, and the performance of junior medical residents in a simulated medical scenario. Pre-scenario agitation led to higher cognitive load also leading to lower performance scores. Fraser et al. (2014) conducted a study where 116 final-year medical students received training using a simulated scenario of a medical condition being experienced by a 70-year-old woman. There were two conditions participants were placed in where the patient was either transferred to another service or unexpectedly died. Students exposed to the patient death condition reported an increase in cognitive load and had reduced learning outcomes both after the study and when measured 3 months later. These studies (Fraser et al., 2014; Heer et al., 2021) focused on a single proficiency level and were unable to generalise these results to varying proficiency levels. In the present study, we take into consideration learners of varied expertise levels within a single learning domain.

Psychologists have formulated theories including the Yerkes-Dodson Law and John William Atkinson's Theory of Achievement Motivation which influence learning. Yerkes–Dodson law (Yerkes & Dodson, 1908) refers to the relationship between an individual's arousal level, task difficulty and learning performance. Based on this law maximum learning performance occurs at an increasing level of arousal for easy questions whereas it decreases in the case of difficult test items as the level of arousal reaches a certain level. Anderson (1994) recruited 100 college students and asked them to complete easy (letter cancellation) and difficult (verbal abilities) tasks. Each participant was tested with five different doses of caffeine. As the caffeine dosage increased, performance improved in the easy task. However, for the more difficult task, a lower dosage initially led to improved performance, but as dosage increased, performance eventually declined.

Atkinson's (1966) Theory of Achievement Motivation refers to the need for achievement, influencing behaviour and performance test-based tasks. An individual's motivation to achieve a goal is influenced by their expectation of success and the value placed on the goal. It has been repeatedly shown that motivation leads to increased learning engagement (Dunn & Kennedy, 2019; Glynn et al., 2011; Tseng & Tsai, 2010).

Both the Yerkes-Dodson Law and Atkinson Theory can be applied simultaneously. Keller (2007) recruited 108 secondary school students to explore the effect of being threatened through negative stereotypes on gender differences. Participants were divided into the threat and no threat condition. For difficult items, those who had a low preference for maths performed better under threat whereas those who enjoyed maths performed more poorly. This supported the Theory of Achievement Motivation as the goal to perform better increased for those who didn't enjoy the learning domain. The conditions of threat and no threat can be viewed as manipulations of arousal (with the threat condition elevating arousal levels). Based on the Yerkes-Dodson law individuals with a low preference for maths (hence potentially a lower baseline arousal) would benefit from increased arousal in the threat condition hence aligning with the fact that those with a lower preference for maths performed better under arousal. On the contrary, those with a higher preference for maths (who perhaps started with a higher baseline arousal) may have experienced a decline in performance as arousal increased.

Gender differences in overall stress and anxiety levels have been found. Gao et al. (2020) analysed 1892 undergraduate students and found that female students experienced significantly higher anxiety than males in the first two years of their college years. This is further supported by Hou et al. (2020) who out of a total of 3063 participants found that females were experiencing more severe stress and anxiety symptoms, while males were found to have higher resilience to stress. Bermejo-Franco et al. (2022) investigated how the COVID-19 pandemic had impacted the mental health of physical therapy students at a European University. In a sample of 151 students, females were found to demonstrate lower quality of life and higher depressive, anxiety, and stress symptoms. These studies have been found to reveal poorer mental health in females compared to males. Moreover, gender-based learning differences from various instructional formats (including instructional videos) have also been found (Gupta et al., 2022). With reference to these findings, only females have been selected for our study to control for potential gender differences and to focus on the gender that has been found to be more susceptible to anxiety and stress effects.

Further understanding the relationship between stress and learning has implications for improving learning experiences for all. This involves closely assessing the impact of inducing stress on learning. When it comes to conducting human-based research it is essential to meet all ethical standards and avoid causing long-term negative effects on subjects. Common ethical procedures for inducing stress must be reviewed and evaluated.

The Trier Social Stress Test (TSST; Kirschbaum et al., 1993) was developed to induce moderate levels of psychosocial stress and has become a commonly used standard test for psychological stress induction. The original TSST consisted of a 5-minute public speaking task and 5 minutes of mental arithmetic tasks performed in front of a panel of two unfamiliar evaluators while being recorded by a video camera. Since the original TSST test, researchers have explored various modifications to it.

The Sing a Song Stress Test (SSST) is an easier alternative to the original TSST that involves singing a song instead of preparing a speech. The test involves a very short procedure, is low cost, requires no special equipment and is minimally invasive. It is an effective way to cause short-term mental stress easily and quickly (Brouwer & Hogervorst, 2014). A shorter version of the test (van der Mee et al., 2020) was also found to induce subjective and physiological stress reactivity to a sufficient degree needed for the experiment. In this test, the number of tasks was reduced making it a 6-minute procedure compared to the original 15 minutes. The SSST test is an effective and convenient option to induce stress, hence has been selected for the present study.

Many learning domains lack research on the relationship between cognitive load and emotions, including web development, which can induce anxiety in new and unfamiliar learners. Hence, an introductory learning module on a web-based language known as HTML (Hypertext Markup Language) has been used as the basis of learning. Those with some prior web development experiences were noted to determine differences in more experienced vs less experienced learners in the domain.

We examined the impact of inducing stress on learning outcomes. Supporting past findings (Brouwer & Hogervorst, 2014; van der Mee et al., 2020) we hypothesised that the SSST would induce higher levels of stress and extraneous cognitive load compared to the control group (Hypothesis 1). Anxiety and stress have been found to negatively impact learning performance and hence those impacted by stress were predicted to exhibit lower learning performance demonstrated by reduced test scores (Hypothesis 2a) and increased time taken to complete tasks (Hypothesis 2b). The level of perceived difficulty will impact the effect of stress with high perceived difficulty significantly increasing response time due to higher than manageable arousal, cognitive load, and stress (Hypothesis 3a). However, low perceived difficulty won't significantly impact response time when stressed due to manageable arousal, cognitive load, and stress. (Hypothesis 3b).

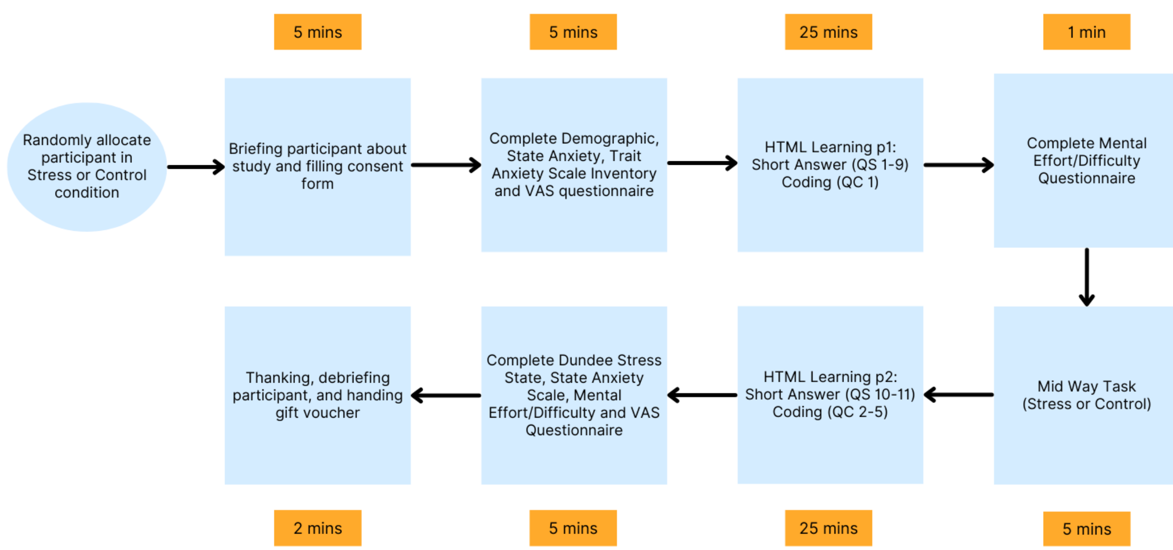

Figure 1: Procedure Flowchart

Experiment

After obtaining ethics approval from the University of New South Wales Human Research Ethics (HC230314), 30 female participants were recruited through university-based newsletters and social media platforms.

Students who were invited to participate were accepted if they were over 18, identified as female, had minimal or ideally no past HTML experience, and had no diagnosed stress or anxiety disorder.

Materials

Learning Module: A previously developed HTML learning module was used, with some changes made to adjust difficulty levels, questions, the learning format, and the addition of features including a time limit on questions and answer-based feedback. The module contains a total of 9 videos for content to learn, 11 short answer questions (QS 1-11) and 5 practical coding-based questions (QC 1-5) for testing. The short answer question time limit ranged from 10 seconds to 1 minute (based on the complexity of the question). For the coding questions, the time range was 2 minutes to 10 minutes (the latter being for the final exam-style question for testing knowledge across the module).

Mid-Way Task: A modified version of the SSST was designed for the stress condition, which included reading passages on a neutral topic related to vacuums (the reading task only was also repeated for the control condition) and a singing task with instructions being presented on a desktop monitor. Video recording was using an iPhone 14 Pro placed on a tripod. A panel session of university researchers was played on a laptop as the social evaluative component. This session was pre-recorded via Microsoft Teams due to the logistical challenge of organising a live panel for each experiment.

Measurement Scales: Previously validated measurement scales were administered including the:

- Trait and State Anxiety scales which measure aspects of anxiety (Marteau & Bekker, 1992)
- Visual Analogue Scale (VAS) which measures subjective perceptions of stress using a rating scale (Lesage et al., 2012)
- Dundee Stress State Questionnaire (DSSQ) which measures stress based on emotional states, cognitive appraisal, and physiological arousal (Kosch et al., 2021; Matthews et al., 1999, 2002)
- Fred Paas's (1992) post-test questionnaire scale which measures mental effort and difficulty

Procedure

Participants were randomly allocated to either the stress or control group and consent was obtained about being video recorded and assessed by a live panel. The demographic-based questionnaire, Trait Anxiety, State Anxiety and VAS scale were completed. They began the learning module and halfway through (by this point had watched 4 learning videos and completed 9 short answer questions and 1 coding question) were asked to pause to complete the post-test questionnaire followed by the 5-minute mid-way task. For the mid-way task, those in the stress condition were recorded as the evaluative panel session played. The brief and introduction on the panel took about 1 minute, they then read three passages out aloud for around 3 minutes and then sang an impromptu song of their choice for a minute upon a 10-second countdown. In contrast, those in the control condition silently read some passages at their own pace for 5 minutes without any social evaluative component, video recording, or timed conditions and they were not required to sing either. Everyone then continued with the learning module (by watching the remaining 5 videos and completing 2 short answer questions and 4 coding-based questions) and ended with filling out the Dundee stress state, state anxiety, post-test questionnaire, and VAS scales. In the end, they all received a $30 gift card and those in the stress group were debriefed about the panel being a recording and the reasoning behind it (see Figure 1).

Scoring Participants

A standardised marking criteria was used to mark with a maximum score of 30 (marks equally split for practical-based coding and short answer questions). For the coding questions partial marks were given if the code didn't run to account for participants who were close to running their code. The responses and time taken to answer each question were automatically recorded in the backend of the learning website.

Analysis and Results

ANOVAs (including one-way and two-way ANOVA and repeated measures) and ANCOVAs were run on the data collected with different combinations of variables including past experiences in the learning domain, stress and anxiety levels, difficulty, mental effort, and learning-based measures of scores and time taken. Results yielded several useful insights, and the significant findings are summarised here.

A one-way ANOVA was used to examine stress levels experienced in the two groups (Control and Stress). A significant effect was found for the Dundee Stress State Questionnaire Score [F (1,28) = 11.059, p = .002], indicating significant stress levels elevation in the stress condition compared to the control condition (see Figure 2).

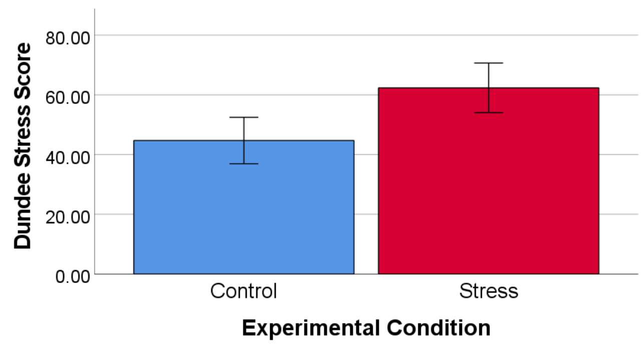

Figure 2: Dundee stress test scores for the control and stress condition (error bars calculated with 95% CI)

A 2-way ANOVA using group (Control and Stress) and perceived difficulty (Low and High) was used to explore whether main and interaction effects existed for both performance and time taken scores. Perceived difficulty scores were split into two categories with scores higher than the median placed in the high category and the remaining placed in the low category.

Score: Performance in the post-midway task questions was found to be lower under stress, particularly in the practical coding questions including QC 5 - the final exam style question [F (1,28) = 8.607, p = .007] which assessed more comprehensive skills acquired throughout the learning module. The final question exhibited a strong correlation with overall performance due to its wider scoring range (with a total possible score of 9) compared to other questions (see Figure 3).

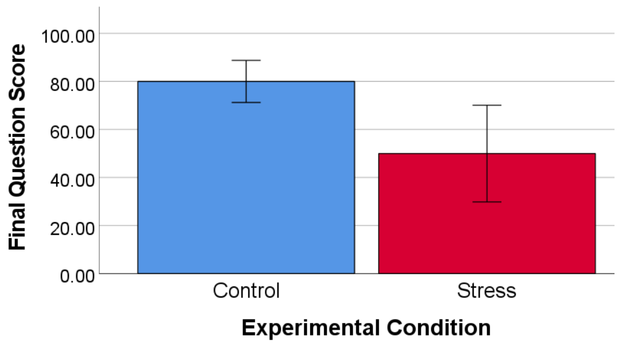

Figure 3: Final question performance score for the control and stress condition (error bars calculated with 95% CI)

Time: Compared to the control condition, participants in the stress condition took significantly longer time to answer the questions that immediately followed the mid-way task QC 2: [F (1,28) = 5.299, p = .029], QC 3: [F (1,28) = 5.615, p = .025] and QC 4: [F (1,28) =7.109, p = .013]). These three questions had a significantly high completion rate allowing for a more detailed analysis of time variations across participants unlike QC 5 where most participants were unable to complete the whole question resulting in timeout.

Significant differences were found across conditions for the percentage of time taken (out of time allotted) based on the perceived difficulty for two questions following the mid-way task, which had a higher completion rate compared to the other two questions [QC 2 = F (1, 26) = 4.730, p = .039; QC 4 = F (1, 26) = 4.293, p = .048] (see Figure 4).

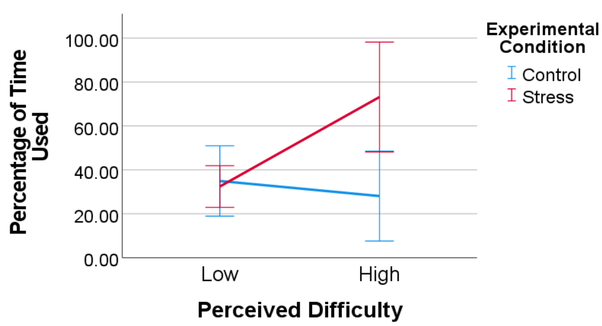

Figure 4: Time Taken for QC 4 based on perceived difficulty levels (error bars calculated with 95% CI)

For participants experiencing higher perceived difficulty, a higher level of significant differences in time were found across conditions for the three questions (QC 2: [F (1,13) = 7.057, p = .020], QC 3: [F (1,13) = 5.179, p = .040] and QC 4: [F (1,13) =5.401, p = .037]) with the stress group taking more time than the control group. Significant differences in time were not found with low perceived difficulty.

Discussion

We investigated the impact of inducing stress on learning outcomes. Based on the Dundee Stress Test responses the SSST led to significantly higher stress and arousal levels for those in the stress condition compared to the control condition. (Hypothesis 1). Moreover, overall learning performance was found to be lower in the stress group with lower test scores (Hypothesis 2a) and more time taken (Hypothesis 2b). Due to experiencing higher than manageable stress and cognitive load levels the stress group took longer to complete tasks when experiencing higher difficulty (Hypothesis 3a). When experiencing lower difficulty, the stress group managed to maintain a manageable level of overall load, taking a similar amount of time as the control group (Hypothesis 3b).

The present study offers valuable insights that extend beyond the immediate aims. Research in this area has become increasingly important as we switch to more online-based mediums (including hybrid options) which poses a challenge with the additional cognitive load of software applications as well as the notifications that are often transient (Darejeh et al., 2022; Wong et al., 2012). By understanding what causes stress and anxiety during learning we can gain insights into managing cognitive load in education-based settings. It is important to understand all that can be done to optimise conditions of learning particularly considering individual differences. This work opens avenues to adapt online learning to individuals' anxiety and stress levels. Tailoring educational experiences based on the emotional and cognitive needs of learners can pave the way for a more inclusive and effective educational environment.

Components of proven stress-based tests were tested to find the most cost-effective, practical, and ethical way to induce stress for the study. Modifications have been made to the TSST over time to reduce reliance on real-life evaluators, simplify the process and shorten its duration. In the present study, inspiration was taken from the SSST, a variation of the TSST. Originally the SSST lasted 15 minutes requiring two confederates (Brouwer & Hogervorst, 2014). With a recent modification (van der Mee et al., 2020) the test was reduced to 6.5 minutes with just a single experimenter while still maintaining its effectiveness in inducing stress. In the present study, despite decreasing the overall task length to approximately 5 minutes the singing duration was increased from 20 seconds to 1 minute. This adjustment aimed to focus more on the anxiety-inducing aspect of the test i.e. singing. Aspects from successful variations of the original TSST were incorporated including timed conditions, video recording and social evaluation through a pre-recorded panel. The SSST used in the current study proved to be a quick, cost-effective, and easy-to-administer task to induce stress. Participants found the task to cause significantly more stress and arousal based on the results of the Dundee Stress Test Survey. Our results provide support for a more accessible variation of a stress test which can be further validated in future studies due to its proven effectiveness in causing the required arousal ethically for the experiment.

The evaluative nature of the stress task would influence the amount of stress caused. While talking to participants in the stress condition (at the end of the experiments) approximately 90% of them believed the recording to be real which played a key role in inducing a significant amount of stress as part of the SSST.

Plass and Kalyuga (2019) alluded to the importance of exploring the relationship between emotions and cognitive load with its impact on learning outcomes. Stress and anxiety have been found to contribute to extraneous cognitive load (Sweller et al., 2019) impeding performance (Calvo & Eysenck, 1992; Fraser et al., 2014; Heer et al., 2021). Some of these studies have considered only a particular expertise domain e.g. final-year medical students (Fraser et al., 2014) or junior medical residents (Heer et al., 2021). The present study focussed on various proficiency levels within the chosen learning domain and demonstrated similar effects where the participants in the control group outperformed those in the stress group based on both the time taken to complete tasks and performance scores.

The Yerkes Dodson law (1908) and Atkinson's Theory of Achievement Motivation (1966) can be used to explain the interactions found between perceived difficulty level - (low vs high) and group (stress vs control) on learning outcomes.

Based on the Yerkes-Dodson Law there is an optimal level of stress needed for peak performance, with learning expected to decrease with very low or high stress levels. With those experiencing higher perceived difficulty in the stress condition, stress levels would have increased beyond the optimal point leading to a slower and more cautious approach to completing the tasks. Arousal levels for those in the stress condition experiencing low perceived difficulty would not have been affected too much. Hence participants were able to maintain a more optimum stress level needed to perform at a similar rate to the control group.

From the Theory of Achievement Motivation perspective participants in the stress condition with higher perceived difficulty may have experienced increased thoughts of failure, leading to investing more time in task completion to ensure accuracy. The significant increase in time taken for questions in the stress condition, particularly for those with higher completion rates, could be attributed to the relationship between achievement motivation and stress. The stress group may have approached their challenging tasks with increased motivation but also greater anxiety leading to a longer time to respond.

The present study looked at female participants to control for potential gender differences. Follow-up studies can look at males to assess what factors may affect their learning performance and the relationships between stress and anxiety on their cognitive load and learning. We could also consider physiological measures such as GSR and HRV to assess fluctuating stress and cognitive load levels.

To conclude, this study delved into the dynamics of cognition by investigating the impact of inducing stress on learning outcomes. It also provided support for a simplified stress test using a modified version of the Trier Social Stress Test (TSST) and Sing a Song Stress Test (SSST). Overall, stress was found to hinder learning outcomes with the control group outperforming the stress group. Those who experienced higher perceived difficulty in the stress group were found to have increased response times as opposed to those who experienced lower perceived difficulty. High stress makes it more difficult to cope with a higher cognitive load. The focus was on females due to prior research findings (Bermejo-Franco et al., 2022; Gao et al., 2020; Hou et al., 2020) which suggest the need for more gender-specific studies. The findings contribute to understanding the role of stress in technology-based learning, serving as a stepping stone for future studies exploring the complex relationship between emotions, cognition, and learning. The findings also pave the way for more adaptive and personalised learning systems.

References

Anderson, K. J. (1994). Impulsivity, caffeine, and task difficulty: A within-subjects test of the Yerkes-Dodson law. *Personality and Individual Differences*, *16*(6), 813–829.

Atkinson, J.W. (1966). *A Theory of Achievement Motivation* (Vol. 6). Wiley

Bermejo-Franco, A., Sánchez-Sánchez, J. L., Gaviña-Barroso, M. I., Atienza-Carbonell, B., Balanzá-Martínez, V., & Clemente-Suárez, V. J. (2022). Gender Differences in Psychological Stress Factors of Physical Therapy Degree Students in the COVID-19 Pandemic: A Cross-Sectional Study. *International Journal of Environmental Research and Public Health 2022*, *19*(2), 810.

Brand, S., Reimer, T., & Opwis, K. (2007). How do we learn in a negative mood? Effects of a negative mood on transfer and learning. *Learning and Instruction*, *17*(1), 1–16.

Brosnan, M. J. (1998). The impact of computer anxiety and self-efficacy upon performance. *Journal of Computer Assisted Learning*, *14*(3), 223–234.

Brouwer, A. M., & Hogervorst, M. A. (2014). A new paradigm to induce mental stress: the Sing-a-Song Stress Test (SSST). *Frontiers in Neuroscience, 8*(8 JUL).

Calvo, M. G., & Eysenck, M. W. (1992). Anxiety and Performance: The Processing Efficiency Theory. *Cognition & Emotion*, *6*(6), 409–434.

Darejeh, A., Mashayekh, S., & Marcus, N. (2022). Cognitive-based methods to facilitate learning of software applications via E-learning systems. *Cogent Education, 9*(1).

D'Mello, S., Lehman, B., Pekrun, R., & Graesser, A. (2014). Confusion can be beneficial for learning. *Learning and Instruction*, *29*, 153–170.

Dunn, T. J., & Kennedy, M. (2019). Technology Enhanced Learning in higher education; motivations, engagement and academic achievement. *Computers & Education*, *137*, 104–113.

Fraser, K., Huffman, J., Ma, I., Sobczak, M., McIlwrick, J., Wright, B., & McLaughlin, K. (2014). The emotional and cognitive impact of unexpected simulated patient death: a randomized controlled trial. *Chest*, *145*(5), 958–963.

Gao, W., Ping, S., & Liu, X. (2020). Gender differences in depression, anxiety, and stress among college students: A longitudinal study from China. *Journal of Affective Disorders*, *263*, 292–300.

Glynn, S. M., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science motivation questionnaire II: Validation with science majors and nonscience majors. *Journal of Research in Science Teaching*, *48*(10), 1159–1176.

Graesser, A. C., & D'Mello, S. (2012). Emotions During the Learning of Difficult Material. *Psychology of Learning and Motivation - Advances in Research and Theory*, *57,* 183–225.

Gupta, R., Marcus, N., & Ayres, P. (2022). Investigating the impact of gender-differences and spatial ability on learning from instructional animations. *L'Année Psychologique, Vol.122*(3), 537–561.

Heer, S. Van, Cofie, N., Gutiérrez, G., Upagupta, C., Szulewski, A., & Chaplin, T. (2021). Shaken and stirred: emotional state, cognitive load, and performance of junior residents in simulated resuscitation. *Canadian Medical Education Journal*, *12*(5), 24–33.

Hou, F., Bi, F., Jiao, R., Luo, D., & Song, K. (2020). Gender differences of depression and anxiety among social media users during the COVID-19 outbreak in China:a cross-sectional study. *BMC Public Health*, *20*(1), 1–11.

Keller, J. (2007). Stereotype threat in classroom settings: The interactive effect of domain identification, task difficulty and stereotype threat on female students' maths performance. *British Journal of Educational Psychology*, *77*(2), 323–338.

Kirschbaum, C., Pirke, K. M., & Hellhammer, D. H. (1993). The 'Trier Social Stress Test'--a tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology*, *28*(1–2), 76–81.

Knörzer, L., Brünken, R., & Park, B. (2016). Emotions and multimedia learning: the moderating role of learner characteristics. *J. Comput. Assist. Learn*., *32*(6), 618–631.

Kosch, T., Berlin, H., Jakob Karolus, G., Zagermann, J., Reiterer, H., Schmidt, A., & Woźniak, P. W. (2021). A Survey on Measuring Cognitive Workload in Human-Computer Interaction. *ACM Computing Surveys, 55*(13s)

Lesage, F. X., Berjot, S., & Deschamps, F. (2012). Clinical stress assessment using a visual analogue scale. *Occupational Medicine (Oxford, England)*, *62*(8), 600–605.

Lukasik, K. M., Waris, O., Soveri, A., Lehtonen, M., & Laine, M. (2019). The relationship of anxiety and stress with working memory performance in a large non-depressed sample. *Frontiers in Psychology*, *10*:4.

Marcus, N., Cooper, M., & Sweller, J. (1996). Understanding instructions. *Journal of Educational Psychology, 88*(1), 49–63.

Marteau, T. M., & Bekker, H. (1992). The development of a six-item short-form of the state scale of the Spielberger State-Trait Anxiety Inventory (STAI). *British Journal of Clinical Psychology*, *31*(3), 301–306.

Matthews, G., Campbell, S. E., Falconer, S., Joyner, L. A., Huggins, J., Gilliland, K., Grier, R., & Warm, J. S. (2002). Fundamental dimensions of subjective state in performance settings: task engagement, distress, and worry. *Emotion (Washington, D.C.), 2*(4), 315–340.

Matthews, G., Joyner, L., Gilliland, K., Campbell, S., Falconer, S., & Huggins, J. (1999). Validation of a Comprehensive Stress State Questionnaire: Towards a State "Big Three"? *Personality psychology in Europe, 7*, 335–350.

Paas, F. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: *A cognitive load approach. Journal of Educational Psychology, 84,* 429-434.

Paas, F., & van Merriënboer, J. J. G. (2020). Cognitive-Load Theory: Methods to Manage Working Memory Load in the Learning of Complex Tasks. *Current Directions in Psychological Science*, *29*(4), 394–398.

Pekrun, R. (2000). 7 A social-cognitive, control-value theory of achievement emotions. *Advances in Psychology, 131*(C), 143–163.

Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and

implications for educational research and practice. *Educational Psychology Review, 18*(4), 315–341.
Pekrun, R., & Stephens, E. J. (2010). Achievement Emotions: A Control-Value Approach. *Social and Personality Psychology Compass, 4*(4), 238–255.
Plass, J. L., & Kalyuga, S. (2019). Four Ways of Considering Emotion in Cognitive Load Theory. *Educational Psychology Review, 31*(2), 339–359.
Poropat, A. E. (2009). A Meta-Analysis of the Five-Factor Model of Personality and Academic Performance. *Psychological Bulletin, 135*(2), 322–338.
Poropat, A. E. (2014). Other-rated personality and academic performance: Evidence and implications. *Learning and Individual Differences*, *34*, 24–32.
Ramirez, G., & Beilock, S. L. (2011). Writing about testing worries boosts exam performance in the classroom. *Science*, *331*(6014), 211–213.
Seipp, B. (1991). Anxiety and academic performance: A meta-analysis of findings. *Anxiety Research*, *4*(1), 27–41.
Sweller, J. (2010). Element Interactivity and Intrinsic, Extraneous and Germane Cognitive Load. *Educational Psychology Review, 22*(2), 123-138.
Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive Architecture and Instructional Design: 20 Years Later. *Educational Psychology Review, 31*(2), 261–292.
Tseng, S. C., & Tsai, C. C. (2010). Taiwan college students' self-efficacy and motivation of learning in online peer assessment environments. *Internet and Higher Education, 13*(3), 164–169.
van der Mee, D. J., Duivestein, Q., Gevonden, M. J., Westerink, J. H. D. M., & de Geus, E. J. C. (2020). The short Sing-a-Song Stress Test: A practical and valid test of autonomic responses induced by social-evaluative stress. *Autonomic Neuroscience, 224*, 102612.
Vella, K. M., Hall, A. K., van Merrienboer, J. J. G., Hopman, W. M., & Szulewski, A. (2021). An exploratory investigation of the measurement of cognitive load on shift: Application of cognitive load theory in emergency medicine. *AEM Education and Training, 5*(4), e10634.
White, M. R., Braund, H., Howes, D., Egan, R., Gegenfurtner, A., van Merrienboer, J. J. G., & Szulewski, A. (2018). Getting Inside the Expert's Head: An Analysis of Physician Cognitive Processes During Trauma Resuscitations. *Annals of Emergency Medicine, 72*(3), 289–298.
Wong, A., Leahy, W., Marcus, N., & Sweller, J. (2012). Cognitive load theory, the transient information effect and e-learning. *Learning and Instruction, 22*(6), 449–457.
Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology, 18*(5),459–482.