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Social stress in human-machine teams: Effects on performance and subjective state

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Abstract

Social stress at work, which refers to stressful social interactions with colleagues or clients, can substantially affect health and well-being. Due to technological advancements, an increasing number of employees collaborate with machines that might also induce social stress. The present work used an experimental approach by conducting three lab studies to investigate the possible consequences of both human and machine-induced social stress on performance and subjective state. The first study operationalized the stressor illegitimate task assignment for the first time in the lab. The second study compared the effects of human versus machine versions of the stressor negative performance feedback. The third study used a combination of two stressors (negative feedback and ostracism) in a simulation of a complex work environment, once again comparing human versus machine-induced social stress. Overall, the results suggest that social stress does not impair performance regardless of its source. However, some subjective variables, such as affect, anger, or perceived justice, may be affected by both human and machine-induced social stress. In some aspects, machines appear to be as stressful as humans. I discuss the practical implications of these results for work settings using hybrid teams and the theoretical implications for different work or social stress models. Finally, I also consider the limitations of the studies before outlining directions for future research on social stress.

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Contents

1 Introduction

Employees at the workplace can be subject to several different stressors. Stress may not only arise from environmental stressors, such as noise or heat, but also from social interactions: this is called social stress. Social stress has been defined as "poor social interactions with direct supervisors, coworkers, and others" (Sonnentag & Frese, 2013; p.562). These interactions can cause a feeling of being devalued and may threaten the basic human need of belonging (Leary & Allen, 2011). The prevalence of social stress in the workplace may be relatively high. For example, 22% of respondents in a Swiss sample reported having been exposed in the last 12 months to at least one social stressor (Grebner et al., 2011). Exposure to social stress may cause severe psychological, physical, or behavioral consequences and impair general well-being or work performance (Gerhardt et al., 2021; Semmer et al., 2019). With a high prevalence and potentially heavy negative consequences, social stress represents a serious public health issue, the gravity of which might be further increased following recent technological developments.

In the last decades, machines[1] such as artificial intelligence or algorithms have conquered different domains of society and work in particular (Rahwan et al., 2019). This process has caused an increasing number of employees to work with machines in so-called hybrid teams (i.e., teams of humans and highly automated systems working together). As machines grew in numbers in the workplace (Meijerink et al., 2021; Ravid et al., 2020), so did the tasks they took over. Machines and algorithms can now have management functions such as task assignment or strategic decision-making (Griesbach et al., 2019; Kellogg et al., 2018; Langer & Landers, 2021; Lee et al., 2015; von Krogh, 2018; see section 2.4). These new roles and the increasingly complex interactions between humans and machines have led to machines becoming potential

[1] In the present work, the term "machine" is used as an umbrella term that includes technological devices and agents such as computers, artificial intelligence, algorithms, etc.

sources of social stress (Sauer et al., 2022). However, the consequences of machine-induced social stress on the employee are still poorly understood due to a lack of dedicated studies.

The literature on social stress is dominated by research on human-induced social stress. It is also characterized by a propensity towards field or vignette studies and a lack of objective performance measures. Therefore, the field of social stress needs lab-based studies of both human and machine-induced social stress and to use objective measures of performance (Sauer et al., 2019, 2022). The present work aimed to complement the literature by investigating, in three experimental lab studies, the effect of several human and machine-induced social stressors on performance and subjective state (see Table 1 for a summary of studies). Each study improved on the previous one and added something new to better capture the effects of (machine-induced) social stress, for example, by inducing social stress differently or by varying the performance tasks and subjective measures. The first study compared two different scenarios of human-induced social stress, using the stressor illegitimate tasks assignment and several performance tasks. The second study added machine-induced social stress to compare to human-induced social stress, changed some performance tasks, and used a different stressor: negative performance feedback. Finally, the third and last study used a simulation of a complex system that allowed to compensate for most insufficiencies of the previous studies by granting different, more finely-tuned measures of performance and increasing ecological validity. Human and machine social stress was induced using a combination of two stressors: negative performance feedback and ostracism.

Table 1. Summary of studies

Study	**Social stressor used**	**Source of social stressor**
Study one	ITA	Human
Study two, first experiment	NFB	Human
Study two, second experiment	NFB	Human vs Machine
Study three	NFB & OST combined	Human vs Machine

Note: ITA = illegitimate task assignment; NFB = negative performance feedback; OST = ostracism.

2 Theoretical background

2.1 Social stress

Social stress involves many different social stressors, which may be more or less common depending on work domains and environments (see Table 2 for examples of social stressors). A list and definition of the most frequently encountered stressors can be found in the supplementary material of Gerhardt et al. (2021). Several authors have pointed out that the concepts of the different social stressors may overlap considerably in their definition, the way they are measured, or the actual behavior they describe. Therefore, using a term that refers to a common point of all social stressors would be helpful. Gerhardt et al. (2021) conducted a recent and comprehensive meta-analysis of social stress. They identified a core construct of all stressors for which they proposed to use the term "relational devaluation" (originally from Leary & Allen, 2011). A social stressor will therefore send a devaluing message to the recipient. With stressors such as bullying or harassment, the devaluation is conveyed very directly. However, the devaluing message may also be transmitted in a rather indirect manner, for example when providing subtly offending feedback (Krings et al., 2015), assigning illegitimate tasks (Semmer et al., 2015), or in some forms of social exclusion (Robinson et al., 2013).

Table 2. Examples of social stressors (non-exhaustive list)

Gerhardt et al. (2021)	**Sauer et al. (2019)**
Interpersonal conflicts	Bullying/mobbing
Incivility	Harassment
Physical violence	Illegitimate task assignment
Sexual mistreatment	Injustice
Supervisor mistreatment	Negative performance feedback
Verbal/emotional violence	Ostracism

Relational devaluation, whether direct or indirect, violates the basic need to belong and may initiate cognitive evaluative processes that threaten the self and self-esteem (Gerhardt et al., 2021; Semmer et al., 2007). This threat to the self is at the heart of the 'Stress as Offense to Self' approach (SOS; Semmer et al., 2019), which sees stress as thwarting one's goals, of which a crucial one is to maintain positive self-esteem. People tend to see their professional role as part of their identity and self, which is why events perceived as threatening this role, such as relational devaluation, will induce stress. The SOS makes a distinction between personal and social self-esteem. Personal self-esteem refers to a self-evaluation of intrinsic and aspired qualities, while social self-esteem refers to the degree to which one feels valued by others. In the SOS model, social stress will threaten both types of self-esteem in two ways. In the first mechanism, personal self-esteem may be impaired, for example, when performance is below one's standards, causing stress through insufficiency. In the second mechanism, social self-esteem may be threatened when one is excluded or treated unfairly by others, causing stress through disrespect. Threats to the self may impact several outcome variables: self-esteem, affective reactions, and negative emotions such as shame or anger, or even specific behaviors aiming to protect the self and restore self-esteem (Semmer et al., 2019).

Some categories of outcome variables are particularly relevant when investigating social stress (Sauer et al., 2022; see Table 3). An important distinction is made between instant effects and after-effects. Instant effects include outcome measures that are instantly affected by social stress. In contrast, after-effects include outcome measures on which the effect of social stress is delayed, sometimes long after the occurrence of the stressor. Then, four main categories of outcomes can be measured for instant effects: performance, task management behavior, subjective state, and psychophysiological state. The same categories can be measured as after-effects, except for task management behavior that is replaced by extra-role behavior. While the ideal study would measure all categories of this list, I had to focus on some outcome categories for practical and feasibility reasons. The three studies in the present work focused on instant effects, particularly on the outcomes of performance in the main task and of subjective state.

Table 3. Categories of outcome variables relevant for social stress research (Sauer et al., 2022)

Instant effects*			
Performance in main task*	**Task management behavior**	**Subjective state***	**Psychophysiological state**
Primary performance*	Information sampling behavior	Social-self-related variables*	Endocrine system
Secondary performance*	System control actions	General impact variables*	Peripheral nervous system
			Central nervous system
After-effects			
Performance after-effects	**Extra-role behavior**	**Subjective after-effects**	**Physiological after-effects**

Note. ***Bold*** *represents general categories of outcome variables, with examples below each category. * = Outcome variables looked at in the present work.*

Sauer et al. (2022) also called for researchers on social stress to use a broadband approach. Based on Hockey (1983), this methodological approach emphasizes "the description of performance changes across a wide range of tasks for a single stressor" (Hockey, 1983, p.359). By contrast, the narrowband approach will compare different social stressors on a restricted number of outcome variables. The present work aimed to follow the principles of the broadband approach. For example, since I focused on the instant effects of social stress on performance and subjective state, I used in each experiment a specific stressor (or a combination of two stressors in Study 3) and measured their effect on many different performance tasks as well as several different types of subjective state variables.

2.2 Theoretical consequences of social stress

A key question in work and organization psychology is whether and how much stress impacts work performance. One influential model in the field on this topic, provided by Hockey (1997), is called the compensatory control model (CCM, see Figure 1). The CCM proposes a cognitive-energetical approach to explain how stress may affect human performance. The model assumes that individuals can regulate and control the maintenance of their performance under stress by managing cognitive-energetic resources and effort, thanks to the compensatory control mechanism. This mechanism operates at two levels to monitor effort during performance output and reallocate resources when needed. The lower level (loop A) provides routine regulation related to well-learned skills without effort. In contrast, the upper level (loop B) is associated with effort-based regulation and is activated when the lower level is not enough to maintain performance under stress. An effort monitor can detect when demands are too high in the lower level of regulation. In this case, the CCM predicts two possibilities: 1) effort is increased to answer to the new level of demands, and performance is protected from stress. This solution requires, however, higher energetical costs. 2) The performance targets are lowered. This strategy does not protect performance, but does not cause additional energetical costs.

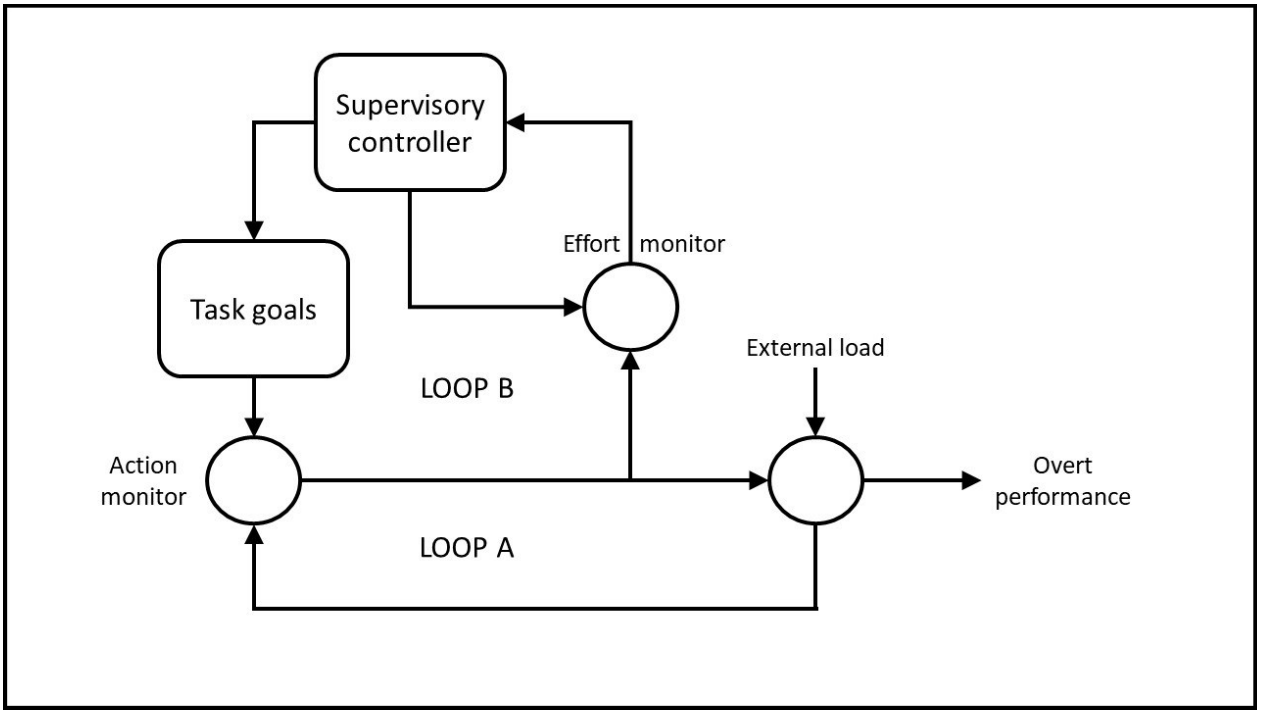

Figure 1. Adapted from the Compensatory Control Model (Hockey, 1997)

One main input of the CCM is that while performance can be protected from stress, the costs of increased regulation will result in lower system efficiency, which may be observed indirectly in different aspects. For example, in tasks with several components of different priority, primary performance may be protected, but at the cost of lower performance in secondary tasks. The costs of performance protection may also be observed in higher physiological activation or affective responses. Finally, the CCM also expects fatigue after-effects of performance protection, which can appear as decreased performance in probe tasks after the main task and the exposure to stress. Overall, the CCM shows that the relationship between stress and performance can be quite complex. Therefore, it is not enough to measure primary performance when investigating the effect of (social) stress on performance. In line with the broadband approach, other outcome variables, such as subjective and physiological states or after-effects, should be added to detect some of the costs of performance protection described above.

More recently, three theoretical mechanisms have been proposed by Sauer et al. (2019) to explain how social stress may affect subsequent performance. The first mechanism, called 'blank-out,' happens when an employee manages to maintain her or his performance despite being the victim of social stress. This mechanism is very similar to the performance protection mode in the CCM and is expected to cause nil results in an experiment. The second mechanism, 'rumination,' is expected to impair performance. As a result of being exposed to social stress, the employee would ruminate about the stressor, shifting attention and focus away from the task. Finally, the third mechanism is called 'increased motivation' and is expected to improve subsequent performance. Despite being exposed to social stress, the employee would react by wanting to show what she or he is capable of and increase the resources allocated to the task. These mechanisms provide additional theoretical outcomes of social stress on performance to those of the CCM.

2.3 General effects of social stress

The field of social stress reached a critical point recently with the publication of the most comprehensive review and meta-analysis on the consequences of social stress at work (Gerhardt et al., 2021). Based on a sample of 88 studies, performance was found to be negatively correlated with social stress (r = -.22). This result indicates that performance is not always protected from social stress and might support the rumination mechanism presented above. However, research on social stress and performance is far from settled, and several additional elements are to be considered. First, the meta-analysis showed that the relationship between performance and social stress varied depending on the stressor. For example, performance was significantly related to the following stressors: social exclusion (r = -.33), role stress (r = -.25), role stress (r = -.25), supervisor mistreatment (r = -.16), and interpersonal conflict (r = -.13). Many stressors have still not been investigated in relationship with performance as an outcome measure. Second, as explained in section 1.0, most research conducted on social stress used methodologies such as field studies, vignettes, or interviews. These methods did not allow for objective measurement of performance. Finally, the effects of social stress on performance may also depend on the type of task used, as shown with the stressor negative performance feedback (Van Dijk & Kluger, 2011). These elements may explain why the literature can show inconsistent results on the effect of social stress on performance, as is the case for the stressor negative performance feedback (see Study 2 in the present work). Overall, these elements also highlight the need to conduct lab-based research with objective performance measures on different tasks and with different stressors to obtain causal conclusions.

Social stress is also expected to have an impact on subjective state. In the CCM, protecting performance might have costs on subjective state such as affective responses or fatigue (Hockey, 1997). In the SOS theory, social stress will impair both personal self-esteem and social self-esteem (Semmer et al., 2019). In the meta-analysis by Gerhardt et al. (2021), social stress was found to be negatively related to, for example, mental well-being (r = -.27), job satisfaction (r = -.36) or life satisfaction (r = -.14), and positively related to negative emotions (r = .30) or burnout (r = .34). Similarly to performance, specific social stressors may have a different impact depending on the subjective variable used. These results also support the broadband approach in including several subjective state variables in studies on social stress. However, the question remains of whether the results presented in this section would still be observed when machines are the source of social stress.

2.4 Social stress and machines

In human-machine interactions, machines do not always have the role of simple objects to be used. The 'Computers Are Social Actors' paradigm suggests that humans tend to mindlessly apply social rules to computers and therefore perceive them as social actors (Nass et al., 1994; Nass & Moon, 2000). For a machine to be perceived as a social actor, it must first exhibit a sufficient amount of social cues to deserve a social response (Nass & Moon, 2000). Second, it must be considered an autonomous source of communication (Sundar & Nass, 2000). Only then will humans apply human-human social scripts in their interactions with computers. Humans, therefore, tend to trust more automated systems with good etiquette concerning rules of communication (Parasuraman & Miller, 2004), to apply gender stereotypes to machines with male or female voices (Nass et al., 1997), to identify as group members with computers and feel peer pressure from computers (Xu & Lombard, 2017), to be sensitive to computer flattery (Fogg & Nass, 1997), and to apply social rules such as politeness or reciprocity to computers (Nass & Moon, 2000). CASA principles have now been extended to other types of agents than computers, such as chatbots, mobile phones, robots, or autonomous vehicles (see for a review Gambino et al., 2020). The fact that humans and machines can have "social" interactions is of great relevance for studying machine-induced social stress, particularly in an increasingly automated society (Rahwan et al., 2019).

In the general automation of society, the workplace is no exception. One of the best illustrations of this process and the new roles of machines at work is the concept of algorithmic management, or "delegation of managerial functions to algorithms" (Jarrahi et al., 2021, p.1). Algorithmic management is highly used in the gig economy of digital platform-based work, such as personal transportation, (food) delivery, or warehouse work (Galière, 2020; Huang, 2022; Lee et al., 2015; Rosenblat & Stark, 2016). Platform-based gig work is well illustrated by the Uber model, in which workers only interact for their daily work with an app on their smartphone. Typically, the app in platform work automatically assigns shifts and tasks, monitors performance and gives feedback on it, rewards or punishes based on performance, and even suspends or fires workers (Kellogg et al., 2018; Lee et al., 2015; Rosenblat & Stark, 2016; Shapiro, 2018; Uhde et al., 2020). Through the app, algorithmic management effectively replaces human managers. It exerts control over workers in several ways (see Table 4), with some companies regulating the time and activities of workers so strictly that the phenomenon has been described as "algorithmic despotism" (Griesbach et al., 2019).

Table 4. The "6 Rs" - mechanisms used by algorithmic management to control workers (Kellogg et al., 2020)

Mechanism	Definition
Restricting	Algorithms restricts the information accessible to the worker to direct behavior.
Recommending	Algorithms make recommendations to make workers take specific decisions.
Recording	Recording and tracking (often real-time) of a wide range of workers' behavior through various means.
Rating	Aggregating various types of data to measure and evaluate workers' performance and productivity.
Replacing	Algorithms automatically fire underperforming workers and replace them with new workers.
Rewarding	Algorithms reward high-performing workers, often with use of gamification processes.

Algorithmic management has spread beyond gig work, increasingly used by human resources in more standard work settings (Jarrahi et al., 2021; von Krogh, 2018). One of the main reasons for this is the rise of electronic performance monitoring (i.e., using technology to track and record different aspects of employees' performance), which allows organizations to collect and use unprecedented amounts of data on employee behavior (Ravid et al., 2020). Organizations may now use algorithms to know whom to fire, hire, promote, and assemble in teams (Gal et al., 2020), or for strategic decision-making (e.g., organizational development, business model elaboration, utilization of resources; Keding, 2021). The quick spread of automation and algorithmic management in several work settings led to more and more employees interacting with machines. Therefore, research must investigate whether these new human-machine interactions can be a source of social stress for employees and, if yes, whether machine-induced social stress affects performance and subjective state.

2.5 Social stress in the present work

To investigate social stress, the present work focused on three different stressors: illegitimate tasks assignment (ITA), negative performance feedback, and ostracism. These stressors were selected due to two main reasons. First, they are all relatively prevalent, though this may vary depending on the work domain or environment. For example, only 12% of Norwegian physicians reported no ITA in their daily work (Thun et al., 2018). In another study (Semmer et al., 2006), employees considered a third of their tasks illegitimate. Negative performance feedback is naturally part of appraisal interviews (Cleveland et al., 1989). However, it also happens in spontaneous comments about the employee's performance that may contain subtly offending cues (Krings et al., 2015). A survey found 71% of respondents in a sample of 1300 employees had experienced at least some form of ostracism in the last six months (O'Reilly et al., 2015). This high prevalence may be explained as ostracism might be non-purposeful, such as forgetting to include a new coworker in a memo or mail (Robinson et al., 2013). The second reason for selecting these stressors is that they may all be induced by a machine and a human, typically in the context of algorithmic management. Lee et al. (2015) interviewed Uber drivers who reported that the app sometimes assigned tasks that made no sense to them, for example, when receiving a request from a distant passenger when other drivers were closer. It is common for platform-based algorithmic management to use automated negative feedback, particularly to inform employees of their unsatisfactory performance (Griesbach et al., 2019; Kellogg et al., 2018; Rosenblat & Stark, 2016). Finally, as reported by an employee in platform-based work, "there are a lot of times when you kind of feel left out" (Shapiro, 2018, p. 2967) because the app sometimes stops sending orders for a while. It is to be noted that other stressors may also fit these two criteria, such as injustice or incivility. However, they appear relatively unlikely to be induced by a machine and, therefore, less relevant for the present work.

3 The Present Work

The present work comprises three empirical studies focusing on the effects of human-induced and machine-induced social stress on performance and subjective state. Each study induces social stress differently. Two main aspects evolved from study one to study three. First, in the approach to capturing effects on performance. From static tasks to a complex system simulation with more detailed measures, the present work covers all aspects of instant effects on performance, as presented in Table 3. Second, the implementation of machine-induced social stress. While study one focused on human-induced social stress, study two added machine stress as a comparison. Study three then added more ecological value by inducing social stress through the complex system simulation. An overview of the three studies is presented below. The full text of the papers is included in sections 4 to 6.

3.1 Overview of studies

As explained in the previous section, the literature on human-induced social stress suffers from a lack of lab studies with objective performance measures. It is particularly the case for the stressor illegitimate task assignment (ITA) since it is a relatively recent concept in the literature. Study one addresses this issue by providing the first operationalization of ITA in a lab experiment with objective performance measures. Two different scenarios of ITA are compared to a control group. Following the broadband approach, we used five different static performance tasks and several subjective state variables such as affect, state self-esteem, or fairness. As it was necessary to develop new protocols to induce social stress in the lab, it was decided for this study to focus first on human-induced social stress.

Study one reference: Thuillard, S., Fejzuli, A., Rrustemi, E., Sonderegger, A., & Sauer, J. Implementing Illegitimate Task Assignment in the lab: a first experimental study. Effects of Illegitimate Task Assignment on performance and subjective state. Manuscript ready to be submitted.

The second study is composed of two experiments. The first experiment focuses again on human-induced social stress, this time with the stressor negative performance feedback. One of the main aims of the first experiment is to test the manipulation and procedure. Negative feedback is compared to positive feedback, and a control group with no feedback. The second experiment uses a stronger version of negative feedback and compares machine negative feedback to human negative feedback and a control group. Since previous research showed that negative feedback may affect performance differently depending on the type of task, and still following the broadband approach, some new static performance tasks are used. In the machine feedback condition, a fake deep-learning-based software on a computer automatically analyzes performance in a pretext task and generates negative feedback.

Study two reference: Thuillard, S., Adams, M., Jelmini, G., Schmutz, S., Sonderegger, S., & Sauer, J. (2022). When humans and computers induce social stress through negative feedback: Effects on performance and subjective state. *Computers in Human Behavior, 133*. https://doi.org/10.1016/j.chb.2022.107270

The third and last study is designed to improve on most insufficiencies of the first and second studies. It is made possible by using a new version of the Cabin Air Management System (CAMS) program, a high-fidelity simulation of a complex work environment. CAMS simulates the life-support system of a space station, in which participants act as operators and have to monitor and repair the system in case of malfunction. This system improves ecological validity as it involves dynamic performance tasks and is more similar to real work than the static performance tasks used before. CAMS also includes both primary and secondary performance measures (i.e., high-priority vs. low-priority tasks). This is crucial since the CCM predicts that primary performance may be protected from stress at the cost of secondary performance, which this experiment can verify. A combination of negative performance feedback and ostracism was used to induce social stress, offering two advantages. First, it appears likely that in natural work settings, several stressors may be induced simultaneously, for example, when an employee is socially excluded following poor performance. Using a combination of stressors increases ecological validity in this regard. Second, since ostracism lasts during the whole experiment, social stress is induced continuously, unlike previous studies in which social stress was only induced once at the beginning of the experiment.

Study three reference: Thuillard, S., Audergon, L., Kotalova, T., Sonderegger, A., & Sauer, J. (2024). Human and machine-induced social stress in complex work environments: Effects on performance and subjective state. *Applied Ergonomics*, *115,* 104179. https://doi.org/10.1016/j.apergo.2023.104179

4 Study One: Implementing Illegitimate Task Assignment in the lab: a first experimental study. Effects of Illegitimate Task Assignment on performance and subjective state

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4.1 Abstract

Illegitimate task assignment (ITA) is a prevalent social stressor at work, defined as giving an employee a task that is either unreasonable or unnecessary. So far, research on ITA has only been carried out in field studies and rarely investigated performance. To complement this existing research and find effect-cause relationships on performance and subjective state, it is necessary to operationalize ITA in the lab. The current experiment attempted to fill this gap by comparing different ITA scenarios, and investigating their effects on participants' (N = 72) performance and subjective state. Results show that one scenario (cleaning the desk for the experimenter) worked better than the other (fetching a coffee for the experimenter). ITA did not impair subsequent performance, nor subjective measures such as affect or state self-esteem. However, ITA impaired procedural fairness, which might have negative consequences in the long term. Overall, the present study shows that it is possible to manipulate ITA in a lab setting and paves the way for further experimental studies.

4.2 Introduction

At work, social stress may be present in the form of illegitimate task assignment, ostracism or negative performance feedback (see for an overview: Sauer et al., 2019). Social stress is considered as interactions that threaten the self (Semmer et al., 2019) and the basic need to belong through relational devaluation (Gerhardt et al., 2021). Social stress exposure may result in various problems at the psychological, physiological or behavioral levels (Semmer et al., 2019), such as lower general well-being, burnout or counterproductive work behavior (Gerhardt et al., 2021). The literature on social stress mostly consists of survey-based field studies, as opposed to lab-based experimental studies. In order to establish cause-effect relationships, more experimental research is needed in the domain of social stress research (Sauer et al., 2022). This is particularly the case for the stressor illegitimate task assignment (ITA), which to our knowledge has not yet been investigated in the lab.

ITA might be relatively prevalent in the workplace. An interview study found that employees considered about a third of their tasks to be illegitimate, with secondary tasks much more likely to be considered illegitimate than core tasks (Semmer et al., 2006). Among Norwegian physicians, only 12% reported no ITA in their daily work (Thun et al., 2018). Tasks that should not be expected from an employee due to their professional role are considered illegitimate and can be a source of stress (Semmer et al., 2015). For example in a restaurant, a cook is not expected to serve. Although serving is a perfectly respectable task, it is not part of a cook's professional role. Therefore, asking a cook to serve might be perceived as a case of ITA. As a social stressor, ITA can induce affective and physiological strain (see for an overview Semmer et al., 2019). ITA therefore deserves more attention, not only from field studies but from experimental research as well. The goal of the present study was twofold. First, we aimed to explore whether ITA could be operationalized and manipulated in a lab setting. Second, we aimed to investigate whether ITA influences subsequent performance and subjective state.

4.2.1 Theoretical background

ITA is a recent concept, being the subject of a journal article for the first time only a decade ago (Semmer et al., 2010), and being established as a social stressor even more recently (Semmer et al., 2015). The core aspect of ITA is when an employee has to carry out a task and thinks "I shouldn't have to do this" (Björk et al., 2013). ITA can be separated in two main categories: unnecessary tasks and unreasonable tasks. Unnecessary tasks lack justification and are therefore considered a waste of time (Semmer et al., 2019). This might be due to impractical or outdated ways of working (e.g. printing lot of documents that are digitally available), dysfunctional systems or technology (e.g. entering the same data in multiple systems that do not synchronize), or unnecessary procedures and rigid bureaucratic demands (e.g. pointless classification work; Kilponen et al., 2021). Unreasonable tasks may be considered illegitimate not necessarily due to the nature of the task itself, but rather as they are outside of an employee's professional role. From the employee's point of view, the task is not unnecessary, it should however be carried out by someone else. This is the case for nurses having to do the tasks of a cleaner, a physiotherapist or a doctor (Kilponen et al., 2021). Additionally, "the person assigning the tasks could, and should, have refrained from doing so" (Semmer et al., 2019, p. 215). Tasks might also be considered unreasonable due to unclear or contradicting demands, or to insufficient resources (Kilponen et al., 2021). Unreasonable tasks have generally been found to have stronger effects than unnecessary tasks (Pindek et al., 2019; Schulte-Braucks et al., 2019; Semmer et al., 2019), which is why the present study focused more on the former than the latter.

ITA is derived from the "Stress as Offense to Self" theory (SOS; Semmer et al., 2019). The main assumption of the SOS model is that maintaining a positive self-esteem and social esteem constitute two important goals for individuals, which may be threatened by social stress. This may take place through two main mechanisms threatening either the personal self or the social self. The first one is related to the personal self, and is called stress through insufficiency. One may feel insufficient in case of performance or moral behavior below one's personal standard. The second mechanism is related to the social self and is called stress through disrespect. Social interactions, work conditions or specific events may send a message to the employee that he or she is not valued by others. ITA appears to be more strongly related to stress through disrespect. However, it could also induce insufficiency in case of an illegitimate task not fitting with one's moral standards.

4.2.2 General consequences of ITA

ITA has been linked in the literature, directly or indirectly, to a number of different forms of strain at several levels. At the behavioral level, ITA has been associated with higher levels of counterproductive work behavior (Schulte-Braucks et al., 2019; Semmer et al., 2010; Zhou et al., 2018), higher sickness presenteeism (Thun et al., 2018), lower proactive behavior (Ma & Peng, 2019), more slips, trips and falls (Elfering et al., 2018) and higher turnover intentions (Bramlage et al., 2021; Ilyas et al., 2020). At the level of subjective well-being, ITA has been associated with negative affect (Eatough et al., 2016; Pindek et al., 2019; Sonnentag & Lischetzke, 2018), burnout (Kilponen et al., 2021; Semmer et al., 2015), injustice (Semmer et al., 2015), exhaustion (Bramlage et al., 2021), lower self-esteem (Eatough et al., 2016; Schulte-Braucks et al., 2019; Semmer et al., 2015; Sonnentag & Lischetzke, 2018), higher anger and resentment toward organization (Eatough et al., 2016; Semmer et al., 2015; Zhou et al., 2018), lower mental health (Madsen et al., 2014), lower psychological detachment from work (Sonnentag & Lischetzke, 2018), and lower job satisfaction and work engagement (Eatough et al., 2016; Kilponen et al., 2021). Finally, at the physiological level, ITA is associated with higher cortisol levels (Kottwitz et al., 2013) and impaired sleep quality (Pereira et al., 2014). Overall, ITA appears to be linked to a considerable number of negative consequences for employees that are exposed to it.

4.2.3 Effects of ITA on performance

Out of the behavioral strain that ITA may cause, performance is of particular importance. Indeed, it is crucial to investigate whether and how ITA influences individual performance at work. However, this topic has so far been neglected by research. Gerhardt et al. (2021) showed in a meta-analysis that social stress and performance were negatively correlated (r = -.22). While ITA as a social stressor was included in the study, the meta-analysis identified only two studies on ITA, highlighting the need for more research. According to Gerhardt and colleagues, there is some similarity across social stressors with regards to effect sizes, which indicate that ITA could be expected to be negatively correlated with performance as well. In the only study we found that assessed performance, Ma and Peng (2019) found that ITA indirectly impaired task performance. However, performance was measured subjectively as an evaluation of employee performance by their direct supervisors. The literature therefore lacks studies with objective measures of performance. As argued by Sauer and colleagues (2019), this is the case not only for ITA but for the whole field of social stress. More experimental research using objective measures of performance is therefore needed. This has been done in the present study.

4.2.4 Present study

The main goals of the present study were twofold. First, we aimed to develop an experimental scenario that allowed us to simulate ITA in the lab. Second, we wished to investigate whether ITA would affect subsequent performance and subjective state. Since unreasonable tasks appear to have a stronger effect than unnecessary tasks (Pindek et al., 2019; Schulte-Braucks et al., 2019; Semmer et al., 2015), we decided to focus more on the former than the latter. We therefore created two different scenarios of unreasonable tasks. However, due to the lack of previous experimental research, it was difficult to estimate how strong the effect of these scenarios on subsequent measures might be. Therefore, in order to increase the strength of the manipulation, we added an unnecessary task after the unreasonable task, the same one in both experimental groups. A control group was added to serve as a baseline for comparison with the two experimental groups.

The current study should contribute to the literature due to its experimental nature, which allowed us to operationalize ITA in the lab for the first time and to use objective measures of performance. The present work also addressed the paucity of research measuring objective performance in the field of social stress in general, and in the field of ITA in particular. We investigated performance-related effects of ITA using several types of tasks measuring a wide range of different types of cognitive performance such as attention, creativity and working memory. Several subjective measures were added based on previous research, such as mood, state self-esteem or injustice. The following hypotheses were put forward:

H1: Based on previous results (Gerhardt et al., 2021; Ma & Peng, 2019), we expected ITA to reduce performance.

H2: Based on previous results (Eatough et al., 2016; Pindek et al., 2019; Sonnentag & Lischetzke, 2018), we expected ITA to increase negative affect and anger.

H3: Based on the SOS approach (Semmer et al., 2019) and previous findings (Eatough et al., 2016; Schulte-Braucks et al., 2019; Semmer et al., 2015; Sonnentag & Lischetzke, 2018), we expected ITA to reduce state self-esteem.

H4: Based on Semmer and colleagues (2015), we expected ITA to increase perceived injustice.

4.3 Methods

4.3.1 Participants

Seventy-two participants (47 women) aged 18 to 43 years old (*M* = 23.69, *SD* = 4.65), completed the study. Participants received CHF 25.- for their participation. Students from various faculties of the University of Fribourg were recruited by flyers, e-mail and social media. Participants had to be fluent in French in order to be eligible in the study. Psychology students were excluded due to their higher familiarity with experimental manipulations using deception. The study was approved by the internal review board of the Psychology department of the University of Fribourg, and informed consent was obtained from participants.

4.3.2 Experimental design

A one-way between-subjects design was used in the present study, with ITA being manipulated at three levels: ITA-coffee condition (n=22), ITA-cleaning condition (n=24) or control condition (n=27). The two experimental conditions each included a specific scenario of an unreasonable task, followed by an unnecessary task (which was equal in both experimental conditions). The two unreasonable tasks and the unnecessary task are described below. Participants were randomly assigned to the three experimental groups. An equal number of participants in each condition could not be achieved due to random attribution and the fact that the experiment was interrupted due to covid restrictions.

4.3.3 Manipulation of experimental conditions

Unreasonable task 1. One unreasonable task involved the experimenter instructing the participant to fetch her a coffee, while pretending to wait for another participant. The experimenter told them: "The other participant still hasn't arrived. I have to stay here, but I really need a coffee. Go to the machine over there, get me a latte macchiato, it's very simple. Thank you". In the meantime, a confederate arrived and pretended to be the other participant keeping the experimenter busy until the real participant arrived with the coffee.

Unreasonable task 2. In the second condition, participants had to clean up the lab. After welcoming the participant, the experimenter opened the room to the lab, which was in a state of disorder (with piles of paper on the desk). At this moment, a confederate arrived, pretending to be another participant. The experimenter then told the real participant: "I leave the cleaning to you, I'll be right back". The experimenter left with the confederate for another room, and waited a few minutes before going back to the room to continue with the experiment. In the control condition, participants simply signed the consent form and began with the tasks.

Unnecessary task. For the unnecessary task manipulation, the participants completed a first performance task (Digit Symbol Coding task; Wechsler 1997). Then, the experimenter pretended that there was a mistake and that this was not the correct task, and threw it in the trash can. Participants in the control group simply completed the task and proceeded to the next part.

4.3.4 Challenges of modelling ITA in the lab

Several challenges are associated with the operationalization of ITA in the lab. First, context plays a crucial role (Semmer et al., 2007; Semmer et al., 2019). Continuing with the example of the cook, it might not be an ITA to ask them to serve in special circumstances, for example if a waiter gets injured and there is no replacement available. Choosing to help, or doing someone a favor does not constitute an ITA. Some degree of justification for the task has to be given, but with the right balance. Too much and the task might not be perceived as illegitimate, while not enough might be considered as rude, which would be a different social stressor. Second, due to the subjectivity in assessing ITA, “differences between individuals are to be expected” (Semmer et al., 2019, p.217). Additionally, since perception of ITA is based on social norms, differences are also to be expected depending on culture. Therefore, it appears likely that any task used in the lab would not be considered illegitimate by every participant. Third, in an experiment with a sample of university students, participating in psychology studies is not their job. To manipulate ITA, it is necessary to find tasks that will not be considered as part of the role of a participant. This can be difficult since participants may most of the time follow any instruction of the experimenter without questioning them (e.g. the Milgram experiment).

4.3.5 Dependent variables

4.3.5.1 Manipulation check and control variables

Illegitimacy. An adapted version of the Bern Illegitimate Tasks Scale (BITS; Semmer et al., 2010) was used to measure whether the tasks assigned were perceived as illegitimate. This seven-point Likert scale (ranging from *not at all* to *completely*) is divided into two parts of four items each, referring to either unreasonable or unnecessary tasks. All items were adapted to fit the experimental context. Instead of referring to the participant’s “daily professional life”, the questions mentioned the experiment the participant has just completed. The overall score averaging both dimensions together was then used (McDonald’s omega in current study, ω = .86, 95% CI [.79, .90]).

Two additional items were used for the manipulation check. A seven-point scale item (ranging from *strongly disagree* to *strongly agree*) was created to assess the stress caused by the experimenter: “*I was unsettled by the attitude of the experimenter*”. Finally, an open question was created to investigate whether the participant faced any illegitimate situation during the experiment: “*During the experiment, were there any inappropriate or disturbing situations? If so, which ones?*”. The goal was to see whether the unreasonable or unnecessary tasks would be reported as inappropriate or disturbing.

4.3.5.2 Performance variables

Processing speed. Processing speed was measured through the Coding subtest from the Wechsler Adult Intelligence Scale III (WAIS-III; Wechsler, 1997). The task was adapted and extended to fit the needs of the experiment. The tasks consists of a series of symbols paired with a number. Participants had thirty seconds to learn the symbols. Then, they participants had to write the corresponding number below as many presented symbols as possible, within a 120 seconds time limit. The task was repeated three times, each time with a different number-symbol association. The overall processing speed score was calculated by aggregating the number of correct answers from the three series.

Mental arithmetic. The Norinder task (Norinder, unpublished; see Frankenhaeuser & Lundberg, 1977), was used to measure mental arithmetic performance. The task required to mentally solve arithmetic operations. Each trial consisted of two operations placed one above the other. Each operation could be an addition or a subtraction of two digits. Participants had to solve and to memorize the result for each of them. Two possibilities were presented: (a) if the result of the operation above was bigger than the one underneath, a subtraction had to be done, (b) if the result of the operation above was smaller than the one underneath, an addition had to be done. The answer of this last operation has then to be given. 84 trials were presented for a total duration of about 15 minutes. Mean reaction time as well as percentage of correct answers were measured.

Attention. Attentional performance was assessed through the d2 test (Brickenkamp, 1998). This sustained visual scanning task required to go through 14 lines of letters surrounded by dashes, and cross the correct ones out. A maximum of 20 seconds is allowed by line. A speed score was obtained by aggregating the total number of processed items, while an accuracy score corresponded to the total number of correctly processed items.

Working memory. The French standardized version (Desmette et al., 1995) of the Reading Span Test by Daneman and Carpenter (1995) was used to assess working memory performance. In this task, participants read out sentences appearing one by one on the screen. The instruction was to remember the last word of each sentence and to repeat them in the correct order when prompted. The testing phase consisted of three sections composed of blocks of two to six sentences. Participants had to recall the words at the end of each block, and the answers had to be correct to move onto the next block of sentences. If not, a new series was started again with a block of two sentences. The overall score corresponded to the total number of correctly recalled words.

Creativity. Creativity was assessed using the subtest "*Jeu 2*" from the Torrance Test of Creative Thinking (Torrance, 1976). The goal is to complete 10 unfinished drawings within a period of ten minutes. Following the scoring procedure from the manual of Torrance (1976), four criteria were employed: (a) fluency (number of drawings produced), (b) flexibility (number of different categories of the drawings), (c) originality (rarity of the answer) and (d) elaboration (amount of details of the answer). An overall creativity score was then calculated by aggregating the scores from each dimension.

4.3.5.3 Subjective measures variables

Perceived stress. A purpose-built item was used to assess perceived state stress: "*I feel stressed*" (with a seven-point scale ranging from *not at all* to *a great deal*).

Affect and arousal. Affective state was assessed using the Self-Assessment Manikin scale (SAM) by Bradley and Lang (1994). This nine-point Likert scale measures two dimensions: valence (negative vs positive affect) and arousal (low vs high).

Anger. An item to measure perceived state anger was added: "*I feel angry*" (using a seven-point Likert scale ranging from 1, *"not at all",* to 7, *"extremely"*).

State self-esteem. State self-esteem was investigated using the State Self-Esteem Scale (SSES; Heatherton & Polivy, 1991). This seven-point Likert scale (ranging from 1, *"not at all",* to 7, *"extremely"*) contains 20 items divided into three sub-scales: performance-related self-esteem (McDonald's omega in current study: ω = .87, 95% CI [.82, .91]), appearance-related self-esteem (ω = .85, 95% CI [.78, .90]) and social self-esteem (ω = .38, 95% CI [.26, .90]). The scores of all 20 items were then aggregated to obtain an overall score (ω = .71, 95% CI [.10, .94]).

Interpersonal unfairness. The interpersonal unfairness subscale of the Organizational Justice Scale (Colquitt et al., 2015) was used to evaluate the unfairness of the behavior of the experimenter by means of a seven-point Likert scale (ranging from *not at all* to *completely*). All four items were modified to refer to the experimenter rather than to the organization, as in the original scale. The scores from all four items were then averaged to obtain an overall interpersonal fairness score (ω = .82, 95% CI [.41, .97]).

Procedural unfairness. Three items were selected from the procedural subscale of the Organizational Justice Scale (Colquitt et al., 2015) and modified to assess the unfairness of the processes and procedures used during the context of the experiment. The items were rated using a 7-point Likert scale (ranging from *not at all* to *completely*). An overall score was then obtained based on the mean of all eight items (ω = .61, 95% CI [.10, .82]).

4.3.6 Procedure

Prior to manipulations. Participants were recruited to take part in a study on executive functions. Every participant first met with the experimenter in front of the testing room and had to give their consent before starting. Then, depending on the condition, participants had to complete an unreasonable task and an unnecessary task, as described in section 2.3. The SAM scale was used right before and after the unnecessary task.

After manipulations. Four performance tasks were completed in a row in a randomized order. When the tasks were completed, participants had to fill in the SAM for the third and last time. They then completed the remaining questionnaires as well as the manipulation check items (see Figure 2). Another cover story was created so participants could answer our manipulation check questions without guessing the purpose of the study. These questions must be addressed carefully since they can reveal the goal of the study (Hauser, Ellsworth & Gonzalez, 2018). Participants were told they were completing questionnaires for the ethics committee. They were told the committee wanted to control if the experiment respected the rules. The questionnaires part of this cover story measured procedural and interpersonal unfairness, illegitimacy, open question, and some subjective state items.

Debriefing. The experimenter finished the experiment by debriefing the participant on the study. She explained that fetching a coffee, cleaning the room and the WAIS task were illegitimate tasks. She explained the purpose of the study and asked the participant how they felt during the study. If they still felt uncomfortable after the debriefing, they were informed of the possibility to use the in-house counselling service of the university. No participant has made use of this service after the experiment and no participants left the experiment feeling uncomfortable. The participants completed the payment form. The experiment lasted approximatively 1 hour and 15 minutes.

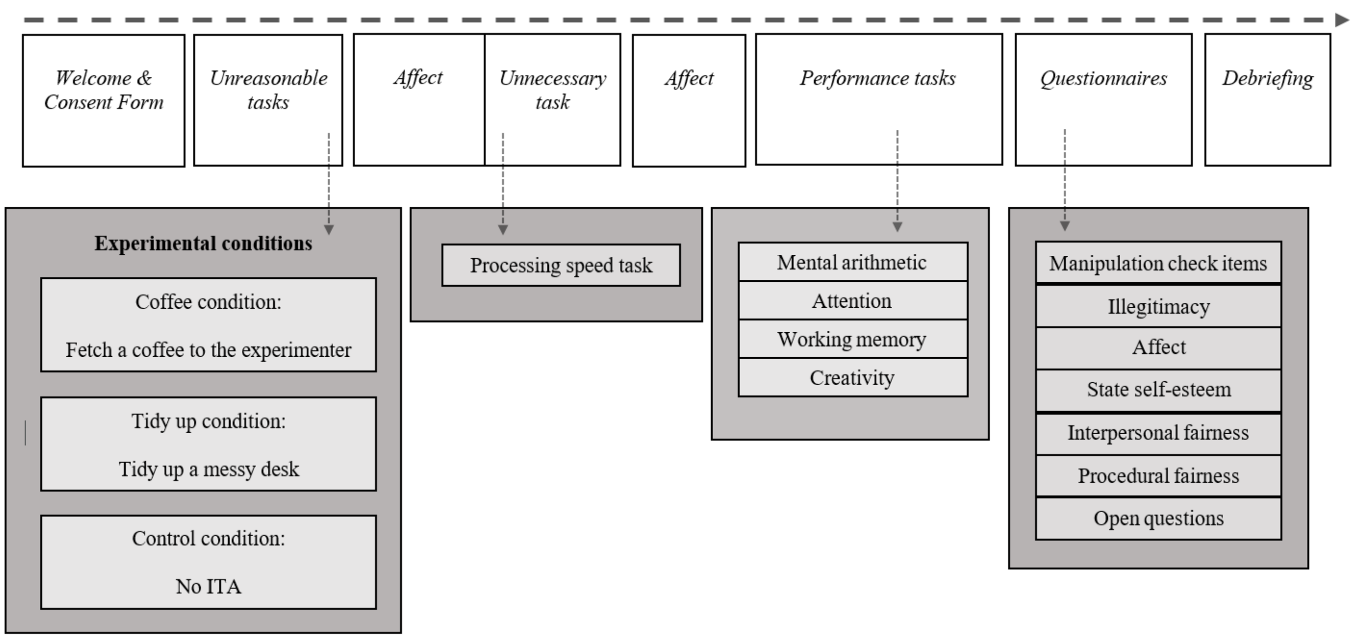

Figure 2. Procedure of the experiment.

4.3.7 Data analysis

We conducted the following analyses: between-subjects ANOVAs (with Bonferroni corrected pairwise comparisons) and mixed ANOVAs (with Greenhouse-Geisser correction when assumption of sphericity was violated). We controlled for the assumption of normality of distribution and homogeneity of variance. In case both assumptions were violated, non-parametric tests such as a Kruskal-Wallis analysis of variance were conducted. The reliability of the scales used in the present study was assessed with McDonald's omega, based on recommendation by Dunn et al. (2014).

4.4 Results

4.4.1 Manipulation check

Bern Illegitimate Tasks Scale. ITA increased illegitimacy in one condition (see Table 5); $H(2) = 9.59$, $p = .008$. Bonferroni-corrected pairwise comparisons using Wilcoxon rank sum tests showed that the ITA-cleaning group scored significantly higher on the BITS than the control group (see Table 5 for descriptive statistics), $p = .01$, but not than the ITA-coffee group, $p = 1.0$. The control and ITA-coffee groups did not differ significantly, $p = .97$. These results represent a first indicator of a successful manipulation for the ITA-cleaning condition.

Perceived experimenter attitude. ITA increased how much unsettling participants found the attitude of the experimenter (see Table 5); $H(2) = 14.06$, $p<.001$. Bonferroni-corrected pairwise comparisons using Wilcoxon rank sum tests showed that participants in the ITA-cleaning group were significantly more unsettled by the experimenter's attitude than participants in the control group, $p<.001$, but not than in the ITA-coffee group, $p = .34$. The control and ITA-coffee groups did not differ significantly, $p = .12$.

Open question. To the question asking whether any inappropriate or disturbing situation had been encountered, several participants of the two experimental groups mentioned the unreasonable task: one in the ITA-coffee group (5%), and six in the ITA-cleaning group (25%). A Chi-square test showed that the difference between these two groups was marginally non-significant; $H(1) = 3.57$, $p = .059$. Three participants reported the unnecessary task as inappropriate or disturbing, all in the ITA-cleaning group (12.5%). This was not significantly higher than in the ITA-coffee group, $H(1) = 3.00$, $p = .083$.

Table 5: Means and standard deviations of manipulation checks and control variables.

Variable	ITA-coffee group Mean *(SD)*	ITA-cleaning group Mean *(SD)*		Control group Mean *(SD)*
Bern Illegitimate Task Scale score (1-7)	1.44 (*1.28)*	2.19 *(2.53)*	***	1.25 *(.75)*
Perceived experimenter attitude (1-7)	1.73 *(1.58)*	2.21 *(1.61)*	**	1.04 *(.19)*
Unreasonable task mentioned in open question (% of participants)	5.0	25.0		N/A
Unnecessary task mentioned in open question (% of participants)	0.0	12.5		N/A

Notes: * = *p* < .05; ** = *p* < .01; *** = *p* < .001

4.4.2 Performance

Processing speed. ITA did not significantly affect performance in the processing speed task. The number of symbols processed did not differ between conditions (see Table 6 for descriptive statistics); $F(2,70) = 1.18$, $p = .31$, partial $\eta^2 = .033$.

Mental arithmetic. ITA did not affect the mean reaction time in the mental arithmetic task (see Table 6); $F(2,70) = 1.29$, $p = .28$, partial $\eta^2 = .036$. ITA had an effect on the percentage of correct answers; $F(2,70) = 4.45$, $p = .015$, partial $\eta^2 = .11$. Bonferroni-corrected pairwise comparisons using t-tests showed that the ITA-coffee group was significantly higher than the control group, $p = .016$, but did not differ from the ITA-cleaning group, $p = 1$. The ITA-cleaning and control groups did not differ significantly, $p = .13$.

Attention. ITA did not significantly affect attention performance (see Table 6). This was the case for both processing speed; $F(2,70) = .02$, $p = .98$, partial $\eta^2 = .001$, or processing accuracy; $F(2,70) = .1$, $p = .91$, partial $\eta^2 = .003$.

Working memory. Working memory performance was significantly improved by ITA in one condition (see Table 6); $F(2,70) = 4.6$, $p = .013$, partial $\eta^2 = .002$. Bonferroni-corrected pairwise comparisons using t-tests showed that performance in the ITA-coffee group was significantly higher than in the control group, p = .013, but did not differ from the ITA-cleaning group, p = 1. The ITA-cleaning and control groups did not differ significantly, p = 1.

Creativity. ITA did not significantly affect creativity performance (see Table 6). The total score in the Torrance test did not differ between conditions; $F(2,70) = 2.53$, $p = .09$, partial $\eta^2 = .067$.

Table 6: Means and standard deviations of performance measures.

Variable	ITA-coffee group Mean *(SD)*	ITA-cleaning group Mean *(SD)*	Control group Mean *(SD)*
Processing speed total score (0-540)	234.68 *(26.38)*	245.96 *(32.06)*	247. 37 *(33.01)*
Mental arithmetic reaction time (ms)	3837 *(1067)*	3653 *(1417)*	4182 *(1066)*
		*	
Mental arithmetic correct answers (%)	92.86 *(4.28)*	90.88 *(7.47)*	86.33 *(10.22)*
		*	
Working memory score (0-60)	23.27 *(9.23)*	18.00 *(8.98)*	16.30 *(6.47)*
Creativity total score	88.41 *(26.67)*	100.21 *(24.05)*	103.59 *(22.32)*
Attention: speed (no. of processed items)	227.32 *(40.57)*	226.83 *(38.85)*	225.18 *(37.12)*
Attention: accuracy (no. of items correctly processed)	216.54 *(39.68)*	216.50 *(40.31)*	212.37 *(36.62)*

Notes: * = $p < .05$; ** = $p < .01$; *** = $p < .001$

4.4.3 Subjective state

Perceived stress. The mixed ANOVA showed no effect of ITA on perceived stress at any of the three time of measurement (see Table 5 for descriptive statistics); $F(2,70) = .79$, $p = .46$, partial $\eta^2 = .022$.

Affect. The mixed ANOVA showed that ITA significantly interacted with time of measurement for affect (see Table 7 for descriptive statistics); $F(2.86,100.1) = 3.49$, $p = .02$, partial $\eta^2 = .09$. The ANOVA at T2 showed that ITA lowered affect; $F(2,70) = 3.45$, $p = .037$, partial $\eta^2 = .09$. Bonferroni-corrected pairwise comparisons using t-tests showed that affect in the ITA-cleaning group was significantly lower than in the ITA-coffee group, p = .033, but did not differ from the control group, p = .83. The ITA-coffee condition and the control group did not differ significantly, p = .33. The ANOVAs for T1 ($F(2,70) = 1.99$, $p = .14$, partial $\eta^2 = .054$) and T3 ($F(2,70) = .49$, $p = .061$, partial $\eta^2 = .14$) were not significant. The main effects of ITA ($F(2,70) = 1.51$, $p = .23$, partial

η^2 = .04) and time of measurement ($F(1.15,100.1) = .53$, $p = .53$, partial η^2 = .008) were not significant.

Arousal. The mixed ANOVA showed significant main effects of condition (see Table 7); ($F(2,70)$ = 7.58, $p = .001$, partial η^2 = .18) and of time ($F(1.55,108.27) = 7.12$, $p = .003$, partial η^2 = .09). Bonferroni-corrected post-hoc tests showed that arousal was higher in the control group than the ITA-cleaning group $p<.001$, and in T3 than T1; $p<.001$. Other comparisons were not significant. The interaction was not significant; $F(3.09,108.27) = 1.00$, $p = .38$, partial η^2 = .03.

Anger. The mixed ANOVA showed no effect of ITA on anger (see Table 7), be it the main effects of condition; $F(2,70) = 1.07$, $p = .35$, partial η^2 = .03, the main effect of time; $F(1.9,133.29) = .48$, $p = .61$, partial η^2 = .007, or the interaction effect; $F(3.81,133.29) = .13$, $p = .97$, partial η^2 = .004.

State self-esteem. ITA had no effect on state self-esteem (see Table 7), be it on the performance subscale; $F(2,70) = .15$, $p = .86$, partial η^2 = .004, the social subscale; $F(2,70) = .32$, $p = .72$, partial η^2 = .01, the appearance subscale; $F(2,70) = .25$, $p = .78$, partial η^2 = .002, or the total self-esteem score; $F(2,70) = .1$, $p = .91$, partial η^2 = .003.

Interpersonal and procedural injustice. The ANOVA on interpersonal injustice just failed to be significant (see Table 7); $F(2,70) = 2.69$, $p = .07$, partial η^2 = .07. The Kruskall-Wallis test showed significant differences in procedural injustice; $H(2) = 7.84$, $p = .02$. Bonferroni-corrected pairwise comparisons using Wilcoxon rank sum tests showed that participants in the ITA-cleaning group evaluated the procedures in the experiment as more unfair than participants in the ITA-coffee group, $p = .016$, but not compared to the control group, $p = .5$. The ITA-coffee and control groups did not differ significantly, $p = .39$.

Table 7: Means and standard deviations of subjective measures.

Variable	ITA-coffee group Mean *(SD)*	ITA-cleaning group Mean *(SD)*	Control group Mean *(SD)*
Perceived stress averaged score (1-7)	3.02 *(1.63)*	2.81 *(1.56)*	3.53 *(1.83)*
Affect T1 (1-9)	6.86 *(1.32)*	6.08 *(1.89)*	5.96 *(1.72)*
	*	*	
Affect T2 (1-9)	6.82 *(1.37)*	5.58 *(1.74)*	6.07 *(1.64)*
Affect T3 (1-9)	6.27 *(1.07)*	6.54 *(1.59)*	6.15 *(1.54)*
Arousal averaged score (1-9)	4.68 *(1.66)*	4.19 *(1.72)*	5.56 *(1.74)*
Anger averaged score (1-7)	1.33 *(.68)*	1.75 *(1.26)*	1.72 *(1.57)*
State self-esteem total score (0-140)	93.73 *(22.43)*	89.50 *(22.88)*	92.22 *(21.13)*
Interpersonal injustice (1-7)	1.27 *(.67)*	1.47 *(1.09)*	1.00 *(.00)*
	*	*	
Procedural injustice (1-7)	1.35 *(.70)*	2.15 *(1.19)*	1.70 *(.88)*

Notes: * = $p < .05$; ** = $p < .01$; *** = $p < .001$

4.5 Discussion

The main goals of this study were to conceive an effective implementation of ITA for the lab, and to investigate experimentally its effect on subsequent performance and subjective state. The manipulation check items and open question showed a successful implementation of ITA for the ITA-cleaning group, while the experimental manipulation for the ITA-coffee group was less successful. ITA did not impair subsequent performance on any of the tasks used. Compared to the ITA-coffee group, participants in the ITA-cleaning group perceived the procedure as more unfair and at T2 (right after the unnecessary task) displayed more negative affect. Other subjective state variables were not affected by ITA.

The manipulation check overall indicates that the manipulation of ITA was successful for the cleaning group. Indeed, the BITS score was higher in this condition than in the control group, showing higher perceived illegitimacy. Additionally, participants in the ITA-cleaning group perceived the attitude of the experimenter as more unsettling than in the control group. Answers to the open question also indicate a successful ITA manipulation. For example, some participants clearly reported cleaning the desk as inappropriate or disturbing: “Cleaning the desk because it was not my mess”, or “I was asked to do it so I did it but it should not have been up to me to do that”. This data clearly shows that for some participants at least, the task was perceived as illegitimate. Finally, the item about the experimenter's attitude provides additional evidence that the manipulation was successful for the ITA-cleaning group.

4.5.1 Effects on performance

In the present study, no measure of performance was impaired following ITA. The only effects on performance detected were contrary to our hypothesis. The ITA-coffee group obtained higher scores than the control group in the working memory task and on a subscale of the mental arithmetic task. The performance results may be discussed based on Sauer et al. (2019), who proposed three mechanisms on how social stress, including ITA, may affect subsequent performance. The 'blank-out' mechanism protects performance from social stress and would cause nil results, the 'rumination' mechanism causes employees to ruminate about the social stress they were victim of and would result in impaired performance, while the 'increased motivation' mechanism would improve performance as a result of the employee wanting to show what she or he is capable of. Based on Sauer et al. (2019), this could be a case of increased motivation mechanism: participants responded to social stress by aiming to show what they were capable of. However, considering the lack of support for the coffee manipulation, it appears unlikely that these effects are due to ITA. With regard to participants of the ITA-cleaning group, for whom the manipulation appeared to have been the most effective, the non-effect on performance measures could be a case of blank-out mechanism. Despite having been subject to social stress and ITA, they managed to protect their performance on all tasks. This might have been the case in the ITA-coffee group as well for most performance measures. Ma and Peng (2019) found that ITA impaired performance. The difference with our present results might be due to how performance was measured. Whereas they relied on a subjective supervisor's evaluation of employee performance, performance in the present study was measured objectively. So while supervisors may perceive their employees' performance to go down with more ITA, it is possible that actual performance was unimpaired.

4.5.2 Effects on subjective state

ITA did influence subjective state, starting with affect. At T2, right after the unnecessary task, participants in the ITA-cleaning condition were in more negative affect than participants in the ITA-coffee group. This effect is interesting since both conditions had the same unnecessary task, only the unreasonable task differed. Considering the cleaning task might have been more illegitimate, this could have made participants in this condition more sensitive to subsequent illegitimacy, resulting in a stronger affective reaction to the unnecessary task. This might explain why only participants in the ITA-cleaning group complained about the unnecessary task in the open question. Surprisingly, perceived stress did not differ significantly between conditions or between timing of measure. This is particularly surprising since ITA as a social stressor was expected to be stressful. We could explain this result by the manipulation possibly not having been strong enough, or by ITA building stress only with repeated exposition or on the longer term. Contrary to what was hypothesized, state self-esteem was not affected by ITA. This is unexpected since self-esteem is considered by the SOS approach to be a core construct threatened by social stress. This result could be explained by the timing of the measurement. State self-esteem was measured at the end of the experiment, after the completion of several demanding tasks, while the experimental manipulations were conducted at the beginning. It is possible that ITA impaired state self-esteem shortly after the manipulations, but the effect did not last until the measurement. The SOS approach however explains that a threat to self-esteem does not necessarily result in lower self-esteem. It is possible to protect self-esteem from some social stressors by attributing them to a lack of fairness (Semmer et al., 2019). In the case of negative feedback, it is possible to attribute it to a lack of fairness from the supervisor, which helps protect self-esteem. If this mechanism had been in operation with ITA, this could explain some of our results with self-esteem and fairness.

Procedural unfairness refers to how much participants perceived the procedures and processes of the experiment (i.e. including the unreasonable and unnecessary tasks) as unfair. The only difference between the two experimental groups was the nature of the unreasonable task they had to perform. It appears that cleaning the desk was perceived as more unfair than having to fetch a coffee for the experimenter. This result is congruent with other results above indicating that the cleaning manipulation was more effective than the coffee one. However, no effects were found for interpersonal unfairness, i.e. how unfairly the experimenter had treated the participants. Participants may have attributed unfairness to the unreasonable tasks rather than to the experimenter. Following the SOS theory, it might be that ITA in the cleaning group did threaten participants' self-esteem, but attributing ITA to a lack of fairness may have protected said self-esteem. This protection mechanism may however have a downside. In the long term, lack of fairness at the workplace can increase negative work behavior and decrease positive work behavior (Colquitt et al., 2013). Additionally, lack of justice is a social stressor in itself, with strong effects for example on job satisfaction or commitment (Gerhardt et al., 2021). ITA may therefore have more serious consequences in the longer term.

4.5.3 Implications

A central contribution of the present article is the methodological knowledge gained on implementation of ITA in the lab. The present study has shown that ITA can be manipulated in the lab, with the unreasonable task of cleaning the desk appearing to have functioned well. This should open the way for more experimental studies on this topic. At the theoretical level, our results might suggest that ITA could be performed in a non-professional context. ITA is conceptualized as a work-related social stressor. However, participants in our experiment were in a non-professional context and some of them experienced illegitimacy nonetheless after ITA. So even though completing an experiment is not a professional role, some students still perceived the cleaning task as outside the boundaries of their role as participant. It appears that ITA can happen outside the workplace. We could therefore imagine ITA to happen in relationship with a great diversity of roles, professional or personal, that people have in their lives, though this would need to be investigated.

4.5.4 Limitations and future research

The effect of the coffee task being too small to reach significance is one of the main limitation of the present study. There are several possible reasons to explain this result and at the same time highlight where improvements could be made. First, the way the assignment of this task was phrased may have played a role. Since the experimenter had to stay in order to wait for another participant, this may have been perceived as justified by the participant and therefore not illegitimate. Participants may have felt they were doing the experimenter a favor, and favors do not constitute a case of ITA (Semmer et al., 2019). Second, cleaning the desk took more time and required more effort than fetching a coffee at the vending machine. This may have left participants more time to ruminate about the situation and realize it was not part of their role to do this. Third, it is possible that the place where ITA was done played a role. In the ITA-coffee condition, ITA happened in front of the lab, while in the ITA-cleaning condition, it happened in the lab. To be exposed to ITA in the room in which the experiment took place might have increased the effect of the manipulation. Finally, it is possible that some participants did perceive some situations as inappropriate without mentioning it in order not to bring trouble to the experimenter.

Several additional limitations of the study need to be stated. Following several interruptions of the study due to COVID, we could not achieve the sample size originally aimed for nor equal sample size across conditions since the original experimenter was not available anymore. It was unfortunately not possible to extend the study with another experimenter. Considering the highly experimenter-dependent manipulations, using another experiment for the remaining participants would probably have caused serious experimenter effects. This lower sample size may have caused power to be insufficient to detect some effects. For example, several analyses were close to significance. In the present study, two subtypes of ITA were used in a row, at short intervals of time. Therefore, our results do not apply to repeated exposition to ITA on a longer period of time, which may have stronger consequences. While our design allowed us to isolate the effect of unreasonable task on performance and on some subjective state measures, this was not the case for unnecessary tasks. Future studies could focus on unnecessary task alone. With the benefit of hindsight, the control condition could have been improved with regards to the unreasonable task. While the participants in the experimental groups had to either fetch coffee or clean the desk, participants in the control group had no task to complete. It would have been better to have them do a similar task that is not illegitimate, as it was done for the unnecessary task.

There are several interesting directions for future experimental research on ITA. Future studies could be aimed at further testing and improving the cleaning and coffee fetching scenarios, and test new unreasonable and unnecessary tasks that could be used in the lab. It would be important to test repeated or long-term exposure to ITA, or its effect on primary and secondary performance in a complex multiple task environment. Additionally, future studies could investigate the influence of ITA on after-effects such as unscheduled probe tasks or extra-role behavior. If performance can be protected in a case of blank-out mechanism, it would be necessary in future research to test this blank-out mechanism to better understand how it happens. Once more protocols for ITA operationalization are developed, future research should investigate whether ITA may be induced by machines. With the rise of algorithmic management, it has become more common for machines to assign tasks to employees and even induce social stress (see e.g. Jarrahi et al., 2021; Kellogg et al., 2018; Lee et al., 2015). It would be worth investigating machine-induced ITA and whether it differs from human-induced ITA.

4.5.5 Conclusion

ITA is a relatively prevalent social stressor in the workplace with potentially serious consequences, and has unfortunately lacked attention from experimental research. The current study showed that, despite some difficulties, it is possible to implement ITA in a lab context. While protocols need to be improved and may need to test additional ITA scenarios, the current study provided examples of an unreasonable task and of an unnecessary task that may be used in future experimental research.

5 Study Two: When humans and computer induce social stress through negative feedback: Effects on performance and subjective state

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When humans and computers induce social stress through negative feedback: Effects on performance and subjective state

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ABSTRACT

People increasingly work with autonomous systems, which progressively take over functions previously performed exclusively by humans. This may lead to situations in which automated agents give negative performance feedback, which represents an important work-related social stressor. Little is known about how negative feedback provided by computers (as opposed to humans) affects human performance and subjective state. A first experiment (N = 60) focused on the influence of human feedback on performance. After participants had performed a cognitive task, they received a manipulated performance feedback (either positive or negative) from a human (comparing to a control with no feedback) and subsequent performance on several cognitive tasks and the participants' subjective state was measured. The results showed that while negative feedback had a negative influence on several subjective state measures, performance remained unimpaired. In a second experiment (N = 89), participants received manipulated negative feedback by a human or by a computer (or no feedback at all) after having completed an ability test. Subsequent performance was measured on attention tasks and creativity tasks and participants' subjective state was assessed. Although participants felt stressed by both negative computer and human feedback, subsequent performance was again not impaired. However, computer feedback was rated as being less fair than human feedback. Overall, our findings show that there are costs of protecting one's performance against negative feedback and they call for caution regarding the use of negative feedback by both human and automated agents in work settings.

1. Introduction

Humans at work may be exposed to different social stressors, such as bullying, ostracism, harassment, or negative performance feedback. These social stressors refer to different types of interactions between employees (at different hierarchical levels or not), which can affect a person's social esteem and self-esteem by initiating cognitive evaluative processes (Semmer et al., 2007). This may have serious implications for employees at the psychological, physical and behavioral levels (Semmer et al., 2019).

Of these social stressors, negative performance feedback (i.e. informing someone of her or his inadequate performance), is particularly prevalent in work settings (Cleveland et al., 1989; Sauer et al., 2019). In addition to the formal and planned procedure of providing performance feedback as part of an organizational appraisal process, the prevalence of the stressor can be increased when supervisors give spontaneous comments on the performance of an employee that (without the supervisor being aware) may contain subtly offending cues (Krings et al., 2015). While the effects of human feedback have been studied in some depth (see for example Cawley et al., 1998; Kuvaas, 2006; Stanton, 2000), the literature remains rather inconclusive regarding its influence on human performance. In this regard, previous research has shown that negative feedback may improve, impair, or not affect subsequent performance. It has been argued that expecting simple causal relationships between negative feedback and performance would be too simplistic (Ilgen et al., 1979). Instead, additional factors such as characteristics of the feedback, of its source and of its recipient may play a role. Furthermore, experimental research on negative feedback may potentially overlook or confound the distinction between feedback source and feedback medium (see section 1.2).

While performance feedback and social stress were until now exclusively addressed in contexts of human-human collaboration (or

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leadership), these topics received recently increased attention in the context of human-automation interaction (Sauer et al., 2019). Automation and technological advancements allowed computers and machines to take over managerial tasks (Wesche & Sonderegger, 2019), including providing negative performance feedback (Sauer et al., 2019). With these developments arises the question of whether computer feedback[1] affects its recipients differently from human feedback. Automated negative feedback to human employees has been used in organizations for some years now. One well-known application is in the transport company Uber, in which drivers are managed by an automated system that allocates tasks, plans shifts, and gives performance feedback (Wesche & Sonderegger, 2019). The literature review on the effects of computer feedback on performance (again focusing on experimental studies using objective measures of performance), highlighted a similar variety of results as with human feedback. Again, these differences might be related to different feedback characteristics, though we think another explanation is possible.

In this matter, we raise the question regarding the transferability of older research findings of computer feedback to more modern forms of computer feedback. The literature we reviewed on negative computer feedback spans several decades, from 1985 to 2016. Perceptions of and attitudes towards technology are very likely to have changed over time, as technology itself evolved considerably (Alder & Ambrose, 2005). Such a change in the perception of computers over time has been observed (Gardner et al., 1989; Immonen & Sintonen, 2015). In the field of algorithmic reliance, recent research showed that participants followed advice more frequently when they thought it came from an algorithm rather than a human (Logg et al., 2019). This result was different from research conducted in previous years, which often found aversion towards algorithmic advice (e.g., Dietvorst et al., 2015; Dzindolet et al., 2002; Promberger & Baron, 2006). Overall, these examples show that perceptions of and attitudes towards technology can shift with time and technological progress. This shift may take place as well in relation to computer feedback, suggesting that previous and current forms of computer feedback are different to such an extent that they have different effects. Therefore, we argue that research needs to be conducted on modern forms of automated feedback (for example based on algorithms or deep learning) to obtain more ecologically valid results with regard to the impact of current technologies. This was done in the second study of this article.

The main goal of this article is to understand how negative performance feedback as a form of social stress affects recipients' behavior (subsequent performance) and subjective reactions, when induced by either a human or a computer. This was done in two parts. Study 1 evaluated the effect of negative human performance feedback on subsequent performance on a wide range of cognitive tasks and on subjective state, compared to no feedback or positive feedback, while also putting the effectiveness of our experimental manipulation to the test. In Study 2, we investigated the effect of modern forms of automated feedback provided by a computer agent, compared to negative human feedback and no feedback, still using a wide range of cognitive tasks and assessing additional subjective constructs. Study 2 should contribute to the literature as it is the first one to investigate a *modern* form of automated feedback, and it does so by focusing on computers as the source of feedback and not the medium (see section 1.2 for an explanation of this distinction).

The studies depicted in the current paper were exploratory in design and intent. The literature is inconclusive regarding the link between negative feedback provided either by humans or technology/computers on performance. Thus, we considered our work to be exploratory in nature, allowing us to investigate a broad range of variables, possibly finding some leads for future research. Additionally, there is to our knowledge no previous experiment investigating a modern form of computer feedback which we could use to guide our study. Implications of this exploratory nature are threefold. First, no a priori power analyses were conducted, though Study 2 aimed at groups large enough (N = 30) to have a normal distribution. Second, variables in Study 1 and Study 2 differed to some degree. On the one hand, this allows covering a large horizon of variables, congruently with our exploratory design. On the other hand, some choices had to be made due to time constraints for the length of experiments as well as the development process of the project. On that last point, in the time gap between Studies 1 and 2, more literature and concepts came to our attention which we decided to include in Study 2. Details on which variables exactly were added for Study 2 are presented in section 1.4. Third, some variables were added to the experiments because they were of potential interest, even though there was sometimes a lack of literature about these variables with regards to social stress. The theoretical background below details the literature review that was conducted on the effects of human and computer negative feedback on performance. We then present the main dependent variables used in the two studies, as well as relevant theoretical models.

1.1. *Performance feedback as a stressor*

Although commonly used as a technique in human resource management, performance feedback is quite often a source of dissatisfaction and stress for both employees and supervisors (Fletcher, 1997; Murphy & Cleveland, 1995). During an appraisal interview, negative performance feedback may result in undesirable consequences at several levels (Holbrook, 2002). This is particularly true when the feedback is too general, inconsiderate, contains threats and attributes poor performance to internal factors. Such features are typical for destructive negative feedback, which can have strong effects on the recipient (Baron, 1988). In the current article, both "standard" negative feedback and destructive negative feedback were examined, in Study 1 and Study 2 respectively.

Sauer et al. (2019) recently proposed three mechanisms to explain how social stress (including negative performance feedback) can affect performance. (1) 'Blank out'-mechanism: despite being the target of social stress, the employee is able to protect his or her performance from being impaired. If this mechanism takes effect, nil effects on performance will be found. This mechanism may take place when safety-critical tasks are carried out, representing a context in which decreased performance needs to be avoided because it might have serious safety-related consequences. (2) 'Rumination'-mechanism: due to negative feedback threatening his or her self-esteem, the employee ruminates about it. It is expected that such thoughts distract cognitive resources from the main task, leading to impaired performance. This mechanism is similar to what was proposed in the Feedback Intervention Theory (Kluger & DeNisi, 1996). (3) 'Increased motivation'-mechanism: the employee responds to negative feedback by trying to demonstrate that he or she can do better than that, leading to an improvement of subsequent performance. This mechanism may take effect when the employee performed the task at reduced levels of motivation and effort expenditure. In this case, self-esteem of the employee is not threatened by the social stressor. Following negative feedback, the employee may then decide to increase effort expenditure resulting in improved performance. The three mechanisms are part of the theoretical framework of this article, helping to improve our understanding of the effects of negative feedback on performance.

1.1.1. *Human feedback*

Research on how feedback affects subsequent performance has a long tradition, going back to the beginning of the last century (Kluger & DeNisi, 1996). Being influenced, for example, by Ammons' review (1956), there was for a long time a consensus in the research literature that any type of feedback (even if negative) would improve

[1] Please note that in this article, the terms computer feedback or automated feedback are used as general terms referring to any type of technology that can communicate with humans and that is used in a work environment.

performance, typically by increasing learning and motivation. When Kluger and DeNisi (1996) reviewed the literature, they identified biases and methodological problems with previous research, largely demonstrating that the idea of general feedback always improving subsequent performance was false. Instead, they found a large variety of effects of feedback in their meta-analysis. While feedback interventions often improved performance, it sometimes had no effect or even impaired performance in about one third of cases. A considerable number of moderating variables of the effect of feedback on performance were identified in the meta-analysis. For example, according to the moderator analyses by Kluger and DeNisi (1996), feedback tended to impair performance if it praises, discourages, threatens self-esteem or is given verbally. Conversely, performance tended to improve if feedback contained the correct solution, informed about the change of performance since last feedback, or was delivered by a computer.

We continued the review of the literature on human negative feedback posterior to Kluger and DeNisi's meta-analysis, focusing on experimental studies with objectively measured performance. We chose these selection criteria to focus on the most relevant literature for this present article, since it is concerned with experimental studies measuring performance objectively. The goal was to examine whether such a variability of results would be found again in this specific part of the literature. The review revealed that further experiments have confirmed Kluger and DeNisi's claim that negative feedback can indeed impair subsequent performance (Alder, 2007; Alder & Ambrose, 2005; Nease et al., 1999; Raver et al., 2012). This raises some concerns that appraisal interviews would fail their purpose if negative performance feedback would actually lead to performance decreases rather than increases (considering that performance improvement represents one of the main goals of the appraisal process; Holbrook, 2002). However, this was not the case in all studies. For example, Alder (2007) found performance in a clerical task to be improved following constructive negative feedback from a supervisor. Finally, recent work also suggested the occurrence of nil effects on objective performance measures in a highly complex task environment (Peifer et al., 2020). This may be due to the complexity of the task used in this experiment, as more complex tasks have been found to reduce the effect of feedback interventions (Kluger & DeNisi, 1996). Overall, although most studies found subsequent performance to be impaired, performance improvements and nil effects were also found. These results support the findings of Kluger and DeNisi (1996), showing that negative human feedback can affect performance in different directions.

1.1.2. Computer feedback

An even larger variety of effects is found in the literature on computer negative feedback on performance. Kluger and DeNisi's meta-analysis (1996) showed that computer feedback in general improved performance. However, focusing again on experimental studies measuring performance objectively, negative computer feedback was found to lead to either improved performance (Alder, 2007; Earley, 1988; Fyfe & Rittle-Johnson, 2016; Nebeker & Tatum, 1993; Van Dijk & Kluger, 2011), decreased performance (Alder, 2007; Resnik & Lammers, 1985; Van Dijk & Kluger, 2011), or had no effect at all (Kluger & Adler, 1993; Sauer et al., 2020). Overall, our literature review shows that negative feedback provided by human and computer alike can affect performance in several ways.

This variety of results has already been discussed in the literature long ago by Ilgen, Fisher and Taylor (1979). They pointed out that assuming simple causal relationships between feedback and performance would be oversimplifying. Instead, characteristics of feedback, of its source and of its recipient should influence feedback effects on behavior and subsequent performance. A recent review by Lechermeier and Fassnacht (2018), focusing on feedback source, timing and valence, reiterated this point. They also stated that the main effects on performance are inconsistent, and that they can vary considerably depending on the source, message, task or individual characteristics. This might explain why so many different results patterns can be found when comparing the effects of human and computer feedback on performance. Relevant characteristics for the present studies are discussed below.

1.2. Feedback source and task type

To understand the respective effects of negative human and computer feedback, it is crucial to make a distinction between feedback source and medium (Alder & Ambrose, 2005). Source refers to the agent generating the feedback (i.e. human or computer) while medium refers to by whom the feedback is given (i.e. human or computer). This distinction may affect the extent to which subsequent performance is impaired. For example, face-to-face human feedback provides participants with an opportunity to justify themselves. This possibility of justifying oneself after receiving negative feedback can have positive effects on the recipient's reactions such as perceived interpersonal fairness, and possibly performance (Alder, 2007; Alder & Ambrose, 2005). The main implication of these results is that when examining the effect of feedback source alone, feedback medium needs to be the kept the same across experimental conditions. We noticed this was not the case in the literature we reviewed. Most studies focused on either human or computer feedback only (Nease et al., 1999; Nebeker & Tatum, 1993; Raver et al., 2012; Resnik & Lammers, 1985; Van Dijk & Kluger, 2011). Some of this work examined negative feedback but operationalized it as computer feedback without conceptualizing it as a specific source potentially having specific effects. One study looked at computer feedback and varied only the medium (Alder & Ambrose, 2005). Two studies compared human and computer negative feedback (Alder, 2007; Kluger & Adler, 1993). However, in both cases feedback source was manipulated as well as feedback medium. Human source was paired with human medium, and computer source was paired with computer medium. While these methods are clearly valid, the literature shows that no study so far has truly isolated the effect of feedback source. Study 2 is thus the first study to investigate feedback source alone, by keeping feedback medium constant across conditions.

Since this article focuses on objective performance as an important outcome measure, the role of task type needs to be addressed. Van Dijk and Kluger (2011) showed, for example, that the effect of negative computer feedback on performance was influenced by the type of task to be performed. The authors distinguished between two types of tasks based on the regulatory focus theory by Higgins (1997). This theory postulates that humans have two regulatory foci: the prevention focus that regulates goals of avoiding punishment, and the promotion focus that regulates goals of achieving rewards. Van Dijk and Kluger (2011) extended the notion of regulatory focus to task type, showing that some tasks would induce a promotion focus while others would induce a prevention focus. They thus made a distinction between prevention tasks (i.e. requiring error avoidance and caution such as in proofreading) and promotion tasks (i.e. requiring imagination and an open mind such as in product development). In prevention tasks, negative feedback improved subsequent performance, whereas positive feedback decreased it. In promotion tasks, subsequent performance decreased following negative feedback, and improved when positive feedback had been given. Additionally, in Kluger and DeNisi (1996) and Lechermeier and Fassnacht (2018), task type was found to moderate the effect of feedback on performance for human feedback as well. A major implication of this work is that research on the effects of feedback should use different types of tasks to measure performance-related effects.

1.3. Subjective effects

In order to obtain a more complete picture of the effects of negative performance feedback on recipients, it appears insufficient to measure performance alone. Subjective reactions to feedback must be investigated as well. Subjective indicators of strain were classified by Sauer et al. (2019) as a group of outcome variables, along with performance, with which effects of social stress can be measured. Additionally, the model of compensatory control mechanism (Hockey, 1997) predicts active human performance management with a view to protecting overall task performance. This is typically in the form of taking some compensatory action that sometimes involves adaptations at the cognitive-energetical level (e.g., increased effort expenditure, increased focus on primary task). This illustrates how performance may be protected from negative feedback, but at the cost of a subjective strain that may be detected by subjective indicators and not by objective tests.

The 'Stress as Offense to Self' theory (SOS; Semmer et al., 2019) focuses on the effects of social stress on a person's subjective state and well-being. It postulates that social stress acts mainly through threats to the self. The SOS approach identifies three mechanisms in which social stress, and negative feedback in particular, might impinge on the self. (1) Stress as thwarting important goals: one almost universal goal is to maintain self-esteem, which can be threatened by receiving negative performance feedback. (2) Stress through insufficiency: one may feel inadequate following negative feedback. (3) Stress as disrespect: independently of the content, the way negative feedback is given can be offensive or disrespectful, and thus stressful. Based on this model, we added a measure of state self-esteem in Study 2 in order to verify whether social stress in the form of negative feedback does indeed act on the recipient's self-esteem. The SOS approach, through its mechanisms on social stress affecting well-being, constitutes an additional reason to use subjective variables in the present studies.

In line with assumptions of the SOS paradigm, previous research has indicated subjective consequences of negative feedback. For example, at the personal level negative feedback can lower one's feelings of self-worth (Brown, 2010) and impair self-esteem (Krings et al., 2015; Moore & Klein, 2008). At the emotional level, negative feedback can induce negative affective states such as anger or tension (Baron, 1988; Cianci et al., 2010), and even stress reactions such as anxiety (Nummenmaa & Niemi, 2004). At the relationship level, the negative feedback giver is more likely to be blamed and be less trusted by the recipient (Raver et al., 2012), and perceived interpersonal fairness can be impaired (Alder, 2007). This last construct refers to the degree of perceived fairness in the personal relationship between the feedback giver and the recipient (Colquitt et al., 2015). It was deemed a key construct by Alder (2007) in understanding the effect of negative feedback source on performance, and as such was added in Study 2.

1.4. Present studies and hypotheses

The main goal of the two studies was to examine how negative feedback as a prominent social stressor affects subsequent task performance and subjective state of the feedback recipient. This question is addressed for human and computer feedback, with a modern form of computer feedback being used in the latter case. The present work used different types of tasks to investigate performance-related effects of negative feedback. In the first study, we investigated whether positive and negative feedback provided by a human would have different effects on performance, using a wide range of established tasks measuring different types of cognitive performance, with a control group (i.e. no feedback) serving as a baseline. The second study focused on negative feedback, making a comparison between the two sources (i.e. human versus computer) while controlling for medium, and again a control group that received no feedback. This study used a somewhat different set of tasks than the first to increase the total number of tasks being examined and to use both promotion and prevention tasks as defined by Van Dijk and Kluger (2011). Based on our experience of the first study, the number of subjective state measures was increased to include further relevant concepts. More precisely, we added interpersonal fairness, level of distraction and motivation to improve based on Alder (2007), and state self-esteem based on the SOS (Semmer et al., 2019). Additionally, to measure affect we used a shorter questionnaire in Study 2 than in Study 1 due to time constraints in the second experiment.

The methodological approach used in both studies was similar in that it used previous lab-based manipulations of social stress under highly controlled conditions. In both studies, we employed cognitive tests that are well established in personnel selection and other diagnostic settings. In each study a slightly different set of tasks was performed. In the first study, we measured processing speed, perceptual reasoning, backward counting and attention while in the second one, we investigated two types of creativity and attention again. This allowed us to examine the effects of negative performance feedback on a large set of outcome measures. Overall the two studies are complementary since Study 1 was the basis on which we tested our experimental manipulation and procedure while also investigating several performance tasks. Study 2 extended this work by adding computer feedback as well as more tasks and measures while controlling for the effect of medium. Additionally, Study 2 used the same attentional performance task as Study 1, aiming at replicating the result. Three main research questions were addressed in these two studies. (a) Does negative performance feedback lead to poorer performance on tasks that are completed following the feedback? (b) Are different types of tasks affected to a different extent? (c) Does feedback generated by humans and computers impair subsequent performance differently?

In Study 1 no hypothesis on the performance variables was put forward due to the inconclusive research findings with regard to performance. Based on the assumption that performance appraisal involving feedback was generally stressful, we hypothesized regarding subjective variables that:

1a) Receiving negative and positive performance feedback will result in higher state anxiety than when receiving no feedback, with negative feedback showing the highest strain levels.
1b) Receiving negative feedback will induce higher negative affect than no feedback, and receiving positive feedback will induce the lowest negative affect. We expected reverse effects for positive affect.

In Study 2, performance-related hypotheses were based on the regulatory focus theory by Higgins (1997), which was extended to task type by Van Dijk and Kluger (2011). The latter article showed that negative feedback impaired performance in promotion tasks, such as creativity tasks (H2a). In prevention tasks such as attention tasks, performance should be improved following negative feedback. However, performance on the same attention task in Study 1 was not impaired by negative feedback. We thus formulated H2b based on this result of Study 1 instead of Van Dijk and Kluger (2011). As a social stressor, and following the SOS theory (Semmer et al., 2019), negative feedback should have a negative impact on subjective variables such as affect (H2c) or state self-esteem (H2d). The variables in H2e were based on Alder (2007). As explained in section 1.2, Alder (2007) compared human and computer negative feedback without controlling for medium. The results from this reference were not sufficiently strong to formulate directed hypotheses. However, it still helped provide a general expectation about these variables in H2e.

The specific hypotheses for Study 2 were as follows:

2a) Based on results by Van Dijk and Kluger (2011), performance in creativity tasks will be lower in the human and computer feedback conditions than in the control group.
2b) Attentional performance will not be affected by negative feedback.
2c) Overall affect will be more negative in the human and computer feedback conditions than in the control group.
2d) State self-esteem will be lower in the human and computer feedback conditions than in the control group.
2e) We generally expected feedback source to affect interpersonal fairness, level of distraction and desire to improve. However, since this is the first study to truly investigate feedback source alone, we could not formulate directed hypotheses for these variables.

2. Study 1

2.1. Goal of the study

The goal of the first study was to examine whether negative performance feedback induced by a human as a prominent social stressor at work can be modelled in a lab-based context, and whether it would impair cognitive performance on several subsequent tasks as well as subjective state measures.

2.2. Participants and experimental design

Sixty students from the University of Fribourg took part in the study (23 females, age between 19 and 53 years, M = 24.12, SD = 5.31). They were recruited from all university departments, except for the departments of psychology, education and special education. This was because students from these departments generally have some good knowledge of psychological testing and might have been less responsive to the experimental manipulation. For the same reason, we excluded participants who had previously completed an intelligence test because they may have known their personal test score. Half of the students were German native speakers, the other half were French native speakers. The experimental materials were available in both languages. Participants received CHF 20.- as a financial compensation for their participation.

A one-way between-subjects design was implemented in the experiment. The independent variable 'social stress' was manipulated through inducing feedback at three levels: positive performance feedback, negative performance feedback and no performance feedback.

2.3. Dependent variables

Manipulation check. The following three items were used as a manipulation check to verify whether the experimental manipulation was successful: (1) "*How do you evaluate your own performance on the test?*" (*very poor – very good*); (2) "*How much stress are you feeling right now?*" (*very little – a great deal*); (3) "*How stressful did you find the performance feedback to be?*" (*not at all – very*). Each item used a 10-point Likert scale. Participants completed the items after having received performance feedback. These questions where formulated in order to see whether the participants actually believed in the feedback they received and to assess whether negative feedback was actually stressful.

Cognitive performance. Four standardized tests were used to measure different facets of cognitive performance. (a) *Backward counting:* The participants were asked to count down from number 1022 in steps of 13 over a period of 150s, following a procedure adapted from the Trier Social Stress Test (Kirschbaum et al., 1993). Each time participants made a mistake, they were asked to start again from the beginning. The number of mistakes was used as an indicator of performance. (b) *Attentional performance:* attention and concentration performance was measured in a sustained visual scanning task, the d2-test (Brickenkamp, 1962), in the form of accuracy (errors in %) and speed (number of characters processed). Participants completed the first 10 lines of the test. (c) *Digit symbol:* This test of the WAIS-R (Wechsler, 1981) measures perceptual speed and visual-motor coordination. In this test, the association of nine symbols with their corresponding number (1–9) was shown to the participant. Participants were then presented a list of 93 symbols, with each of them having to be marked with the corresponding number (within a total time limit of 90s). Performance was scored by calculating the number of correct responses. (d) *Picture completion (WAIS-R):* In this test (Tews, 1994), participants were asked to rearrange three series of pictures (comprising five or six each) such that the set of pictures will tell a coherent story. For this task, two scores were obtained (number of correct responses and task completion time).

State anxiety. To assess state anxiety, we employed the State-Trait Anxiety Inventory (STAI), comprising 40 items (Spielberger et al., 1983). This instrument aims to measure several dimensions of subjective strain in a more elaborate way, complementing the short measures of strain used as a manipulation check. In this study, we only employed the 20 items measuring state anxiety, with each of them using a 4-point Likert scale (i.e. total score can range from 20 to 80). We administered either the German version of the instrument (Laux et al., 1981) or the French one (Spielberger et al., 1983). This questionnaire was filled 3 times by the participants. One time at the very beginning of the experiment (t_0), one time after receiving feedback (t_1), and one time at the end of the experiment (t_2). Reliability of this scale in this study was satisfactory (McDonald's omega, $\omega = 0.91$, 95% CI [0.88, 0.94]).[2]

Emotion. The Positive and Negative Affect Schedule (PANAS) was used to assess affect (Watson et al., 1988). Comprising 20 items, it makes use of a 5-point Likert scale, ranging from 'very slightly' or 'not at all' to 'extremely'. To assess the emotional state of the participants, we administered a German version of the instrument (Breyer & Bluemke, 2016) or a French one, for which the items were translated from English (following the back-translation method) since the research literature did not offer a ready-to-use version. This questionnaire was filled in at the same time as the STAI. The reliability of the scale for positive affect was $\omega = 0.84$ (95% CI [0.78, 0.90]), and $\omega = 0.84$ (95% CI [0.78, 0.90]) for negative affect.

2.4. Procedure

Participants were randomly attributed to the three experimental conditions. The participants entered the laboratory in which they were welcomed by the experimenter. The experimenter gave the participants some instructions about the purpose of the study. Since the goal was to create social stress, it was required that a 'cover story' was provided (see below), which dissimulated the true nature of the experiment. Participants were informed that they might experience some stress during the experiment. After the oral instructions and the experimenter having responded to all the questions they might have had, participants were requested to read the form of informed consent carefully and to sign it

[2] Please note that due to issues related to the use of Cronbach's alpha as a measure of internal consistency (see e.g. Dunn et al., 2014, for a summary), McDonald's omega with 95% CI is reported in the present article.

afterwards.

As part of the cover story, participants were told that a new intelligence test for students was being developed by a university. The present study would help determine the qualities of the intelligence test. Participants were informed that they would have to complete a series of tests and several questionnaires. Having completed the first set of cognitive tests (cultural knowledge test, repeating numbers, numerical thinking; WAIS-R; Wechsler, 1981), the experimenter pretended to score the test. Participants were then given some bogus feedback about the test results (unless they were in the control condition with no feedback). If the feedback was negative, they were told that their IQ score was amongst the lowest ones of all student participants. This was demonstrated by using a large sheet of paper with a graph showing the test results. The experimenter added that the participants had not only had a very poor test score but had also been extremely slow in completing the test. Conversely, if the feedback was positive, they were told that their IQ score were amongst the best ones of all student participants. Again, a sheet of paper displaying the graph was used to underline the statement. The experimenter added that the participants had not only had a very high score but had completed the test extremely fast, too. In both feedback conditions, the provision of feedback was embedded in some discussion about the general purpose of intelligence testing. The choice of using an intelligence test to give feedback on was made to increase the strength of the manipulation in order to induce social stress. It was expected that results on such a personally and socially valued factor would be relevant to everyone and thus increase the impact of negative feedback.

Prior to the experimental manipulation in form of the cover story, participants completed a demographic questionnaire, followed by the completion of baseline assessments of PANAS and STAI (t_0). After the experimental manipulation, participants filled the PANAS and STAI again (t_1). Then, the following tests and questionnaires were completed: manipulation check, backward counting, d2, digit symbol coding, picture completion, and finally PANAS and STAI a third time (t_2).

Following the completion of the tasks and questionnaires, each participant was fully debriefed about the true nature of the study. First, the experimenter presented their apologies for providing incorrect information to the participant about the true nature of the experiment. The experimenter pointed out the need to misinform the participant to create the experimental conditions necessary for running the study. Furthermore, the experimenter pointed out the important applications of research of this kind, providing some examples of how this could help humans in the future (e.g., 'would there be a risk of negative feedback affecting subsequent performance of airline pilots?'). It was expected that this would increase the participant's understanding for the necessity to provide incorrect information as part of the experimental instruction. The participant was given the opportunity to ask questions about the experiment. Before the participant being paid and leaving the lab, the experimenter enquired whether the participant felt now at ease with the situation, following the debriefing. If the participant had still felt uneasy about the experiment, they would have been offered the possibility to make an immediate appointment at the in-house therapy center of the psychology department.

2.5. Data treatment

Following the experimental design, most measures were analyzed using a one-way analysis of variance, followed by Bonferroni's corrected pairwise comparisons for significant ANOVAs. If the homogeneity of variance and normality of distribution assumptions were both violated, a Kruskal-Wallis analysis of variance or a Wilcoxon rank-sum test was conducted. Additionally, one factorial analyses of covariance were conducted on variables measured before and after the experimental manipulation.

2.6. Results

2.6.1. Manipulation check

For item 1, *"How do you evaluate your own performance on the test?"*, participants rated their own performance differently depending on their condition; $F(2, 56) = 21.48$, $p = .001$, partial $\eta^2 = 0.434$. Participants in the positive feedback condition evaluated their own performance higher than the control group ($p < .001$) and the negative feedback group ($p < .001$). However, these two last groups did not differ significantly ($p = .29$). Item 2, *"How much stress are you feeling right now?"*, showed no significant differences between conditions; $F(2, 56) = 0.748$, $p = .49$, partial $\eta^2 = 0.026$. For item 3, *"How stressful did you find the performance feedback?"*, a *t*-test revealed significantly higher stress levels for participants having received negative feedback than those in the positive feedback condition; $t(36) = 2.68$, $p = .01$. Please note that this item was not administered in the control condition since it was not applicable. Overall, the statistical tests confirm the successful experimental manipulation of social stress through performance feedback, although one of the items was not significant.

2.6.2. Performance

Backward counting. The number of errors in backward counting are presented in Table 1. The analysis of variance revealed no significant effect of feedback; $F(2, 59) = 2.673$, $p = .08$, partial $\eta^2 = 0.086$.

Visual scanning. (d2-test). Attentional performance showed no difference in both speed and accuracy subscales as a function of feedback (see Table 1). The analysis of variance confirmed this by revealing a non-significant effect for the speed score between conditions $F(2, 57) = 0.48$, $p = .62$, partial $\eta^2 = 0.017$. Similar results were found for accuracy score; $F(2, 57) = 1.80$, $p = .17$, partial $\eta^2 = 0.059$.

Digit symbol coding. In Table 1, the number of correct responses for the test involving digit symbol coding is presented. No significant effect of performance feedback was found; $F(2, 59) = 0.006$, $p = .99$, partial $\eta^2 = 0.000$.

Picture completion. The two performance scores for the picture completion test are shown in Table 1. The analysis showed a significant effect of feedback type for accuracy; $F(2, 57) = 3.459$, $p = .04$, partial $\eta^2 = 0.108$. A Bonferroni corrected post-hoc test showed that the scores for positive feedback were significantly higher than the scores for negative feedback ($p = .036$) but there were no significant differences between the two experimental groups and the control group. With regard to speed, the analysis revealed no significant effect of feedback type; $F(2, 57) = 0.983$, $p = .38$, partial $\eta^2 = 0.033$.

2.6.3. Subjective measures

State anxiety. For this variable, the one factorial analysis of covariance at t_1, with t_0 as covariate, showed significant differences between conditions; $F(2, 56) = 5.34$, $p = .008$, partial $\eta^2 = 0.16$. Indeed, participants who received positive feedback had a lower state anxiety than the negative feedback group ($t(37) = 2.886$, $p = .006$) and the control group ($t(39) = -2.795$, $p = .007$). However, these two last groups did not differ significantly ($t(38) = 0.167$, $p = .868$), only partly supporting hypothesis 1a.

Table 1
Effects of type of performance feedback on the main dependent variables.

Variable	Positive feedback Mean (*SD*)	Negative feedback Mean (*SD*)	No feedback Mean (*SD*)
Manipulation checks			
Item 1	7.37 *(1.92)*	3.58 *(2.24)*	4.57 *(1.32)*
Item 2	4.16 *(2.93)*	5.05 *(2.37)*	5.00 *(2.32)*
Item 3	3.37 *(2.41)*	5.37 *(2.19)*	n.m.
Performance			
Attention: accuracy (no. of items correctly marked)	388.20 (34.14)	367.37 (35.16)	375.31 (34.95)
Attention: speed (no. of items worked through)	428.00 (34.72)	414.16 (54.27)	417.43 (47.98)
Backward counting (no. of errors)	1.35 (*.99*)	2.16 (*2.01*)	1.19 (*1.03*)
Digit symbol coding (no. of points)	66.35 *(13.55)*	66.26 (12.922)	65.95 *(11.24)*
Picture completion: accuracy (no. of points)	1.37 *(0.34)*	0.965 *(0.47)*	1.11 *(0.60)*
Picture completion: speed (s)	42.55 *(14.11)*	40.70 *(13.45)*	47.33 *(18.32)*
Subjective measures			
Positive affect (10-50)			
t_1	31.80 *(6.33)*	29.89 *(7.27)*	32.10 (5.91)
t_2	31.00 *(6.48)*	30.05 *(6.91)*	32.19 (6.05)
Negative affect (10-50)			
t_1	16.85 *(5.33)*	16.74 *(4.05)*	18.33 *(5.95)*
t_2	17.0 *(5.12)*	15.68 *(3.95)*	17.38 *(5.10)*
State anxiety (20-80)			
t_1	36.85 *(9. 66)*	40.00 *(11.24)*	39.81 (9.84)
t_2	39.60 *(8.44)*	37.32 *(7.91)*	39.52 (8.00)

Notes: * = *p* < .05; ** = *p* < .01; *** = *p* < .001; n.m. = not measured

Positive affect. A one-factorial analysis of covariance at t_1 with t_0 as covariate was calculated. The analysis revealed a significant main effect of type of feedback: $F(2, 56) = 6.264$, $p = .004$, partial $\eta^2 = 0.88$. Planned contrasts confirmed that there were significant differences between the condition positive and negative $t(37) = 3.458$, $p = .001$ whereby the subjects with the positive feedback showed a higher value in positive affect (see Table 1). The positive feedback group had lower positive affect than the control group, $t(39) = 2.428$, $p = .018$, while the control group and the negative feedback group did not differ significantly, $t(38) = 1.076$, $p = .287$. Hypothesis 1b for positive affect was only partly supported.

Negative affect. The one factorial analysis of covariance at t_1, with t_0 as covariate, did not show an effect of type of feedback on negative affect; $F(2, 56) = 1.886$, $p = .16$, partial $\eta^2 = 0.063$. Hypothesis 1b for negative affect was thus not supported.

2.7. Discussion

This is the first study that examined negative performance feedback using a wide range of established cognitive tests, allowing us to determine whether different types of cognitive performance would be vulnerable to this social stressor. Although participants felt stressed after having received negative feedback, their subsequent performance on the cognitive tests remained unimpaired on all tasks.

The primary outcome variables in this study were the different performance measures. Three out of the four measures were not affected by performance feedback, being in line with the 'blank out'-mechanism postulated by Sauer et al. (2019). Participants could protect their performance even though they were the target of social stress. Picture completion as the most creative task in the set of tasks showed higher accuracy levels in the positive feedback condition than for negative feedback whereas no such effect was observed for the speed component. This differential effect for speed and accuracy bears some similarity to the results of Alder's (2007) work, in which he found quality of performance to be affected by negative feedback but not quantity. This might also be explained in the framework of the speed-accuracy trade-off. A change in the speed-accuracy trade-off function under stress (i.e. involving a faster but less accurate response) has also sometimes been found when humans were exposed to stressors such as noise and time pressure (Hockey & Hamilton, 1983). An alternative explanation for this result is that the picture completion task, compared to the other tasks used, was the one most closely related to cognitive ability typically assessed by an intelligence test. It would then make sense that this task would be the most affected by negative feedback on a preceding intelligence test.

Although recent work modelling social stress found similar results, with performance on four different tasks being unimpaired (Peifer et al., 2020), there is overall an inconsistent results pattern in the very small number of studies examining social stressors and objective performance. There is also empirical work that was in line with the predictions of the 'rumination'-mechanism (i.e. performance decrease; Lustenberger & Jagacinski, 2010) or the 'increased-motivation'-mechanism (i.e. performance increase; Byrne et al., 2016). The support for the 'blank out'-mechanism found in the present study and some other work may be considered a positive finding. Indeed, it may carry the practical implication that performance levels may be maintained by operators (especially in safety-critical jobs) despite negative effects at the subjective level.

The results for the subjective measures showed a different pattern. The manipulation checks indicated overall that participants were negatively affected by negative feedback compared to positive feedback. The results for positive affect revealed significantly higher ratings for positive feedback than negative feedback and the control group. Our first hypothesis was only partly confirmed in that positive feedback induced less state anxiety compared to receiving negative feedback or not receiving any feedback at all. This is an interesting finding, which may suggest that even if participants were subject to a stressful negative feedback (as shown by the manipulation check), this did not spread over to the general state of anxiety. This might indicate that specific or stimulus-related stress states do not necessarily affect general states of stress. As a last point, we would like to add that a considerable number of participants, after having received negative feedback, attempted to offer excuses to the experimenters to justify their poor performance. For example, some participants said they would have performed better in different types of tasks, or that they were tired and they did not sleep well the previous night. This may also be taken as an indication of the successful experimental implementation of negative feedback as a stressor since such justifications might also be observed in a work context.

3. Study 2

3.1. Goal of the study

The main goal of the second study was to examine whether negative feedback coming from a computer produces different effects than when coming from a human. This was implemented by using a modern form of computer feedback, and focusing on the source of feedback while keeping the medium constant.

The second goal was to investigate whether performance on a different set of tasks would be affected differently, using a stronger form of negative feedback, which contains elements of destructive feedback.

3.2. Participants and experimental design

A total of 89 students (50.5% female), aged 18–35 years ($M = 22.48$; $SD = 2.84$), participated in the study, all of which were French native speakers. They were recruited from the different faculties of the University of Fribourg and schools of higher education, with the exception of students from psychology and related sciences (e.g., education). They were not allowed to take part in the experiment since they may be familiar with experimental scenarios using deception. Participants received CHF 20.- as a financial compensation for their participation.

A one-way between-subjects design was used in this experiment. The independent variable 'feedback source' was manipulated at three levels: human source, computer source or no feedback (i.e. control group).

3.3. Dependent variables

3.3.1. Manipulation checks

Several measures were used for the manipulation check. First, an item was created to verify whether the induction of stress was successful between the two experimental groups and the control group: "*To what extent are you feeling stressed?*" (with a 7-point scale ranging from *not at all* to *a great deal).* Second, another item measured subjective state anger on a scale ranging from 1 (*not at all*) to 7 (*a great deal*): "*To what extent are you feeling angry?*". This was based on Baron (1988), who showed that destructive feedback induces anger. All manipulation checks were administered twice: at the very beginning of the experiment and right after participants received feedback.

3.3.2. Performance

3.3.2.1. Attention and concentration: d2-R (speed and accuracy). Attentional performance was measured by using the d2-R (Brickenkamp, 1962). Representing a sustained visual scanning task, this test allowed us to assess both quantitative and qualitative aspects of performance. The speed score was calculated by the number of items worked through, whereas for the accuracy score the number of errors made was subtracted from the total number of items worked through. While several test scores can be used in the d2-test, only the scores for speed and accuracy are considered to meet psychometric criteria for reliability (Steinborn et al., 2018).

3.3.2.2. Convergent creativity: Remote Associates Task. Convergent creativity was measured by an adapted version of the Remote Associates Task (Mednick, 1968). This test consists of sets of three words, and the goal is to find a new word that is related to the three words presented in the test item. The new word can be a synonym, semantic association or compound word. For example, the answer for the item "home – sea – stomach" is the word "sick", as people can be homesick, seasick or sick in the stomach.

As there is currently no French version of the Remote Associates Task, items were specifically developed for this study (see section 3.4). 15 items were chosen and balanced out for difficulty: 5 difficult items (17–26% correct answers from pilot study), 5 moderately difficult items (50–54%), and 5 easy items (76–84%). The performance score used in the experiment was the total number of correct responses to the 15 test items.

3.3.2.3. Divergent creativity: Alternate Uses Task. Divergent creativity was assessed by the Alternate Uses Task (Guilford, 1960). In this test, participants were asked to list the potential uses of a brick. The instructions were formulated such to encourage participants to find truly original and creative answers (Runco et al., 2005). Performance was measured by the number of valid answers (fluency score) and the degree of originality. The scoring procedure for determining degree of originality was taken from O'Connor et al. (2013). Answers given by less than 1% of the participants were scored 2 points, and answers given by less than 5% of participants were scored 1 point. To control for higher originality being due to higher fluency, an index was calculated (originality/fluency).

3.3.3. Subjective measures

Affect. The Self-Assessment Manikin scale (Bradley and Lang, 1994) was used to assess the affective state of participants on two dimensions: valence (negative vs positive affect) and arousal (low vs high). This 9-point scale was administered twice: once at the very beginning of the experiment and once right after participants received feedback.

Interpersonal fairness. Four items were selected from the interpersonal fairness subscale of the Organizational Justice Scale (Colquitt et al., 2015) to assess the fairness of the feedback source for the participants. The items were translated into French (using the back-translation method) and slightly adapted to the experiment. The four items (and the instructions preceding them) were worded as follows: "*The questions below refer to the person/program who formulated the feedback you received at the beginning of the experiment. (a) To what extent did she/he/it treat you with dignity? (b) To what extent did she/he/it treat you in a polite manner? (c) To what extent did she/he/it treat you with respect? (d) To what extent did she/he/it refrain from improper remarks or comments?*" All items were rated on a 5-point Likert scale (ranging from *not at all* to *a great deal*). The scores from all four items were averaged to obtain an overall fairness score. Reliability of this scale in this study was satisfactory (McDonald's omega, ω = 0.94, 95% CI [0.92, 0.97]).

Level of distraction. Six 5-point scale items (ranging from *strongly disagree* to *strongly agree*) were used to measure the level of feedback-related distraction from the task after receiving feedback. Two items were taken from Alder's scale (2007) and translated into French, using the back-translation method (i.e. "*The feedback I received helped me focus my attention on the task*" (reverse scoring), and "*The feedback I received was often a distraction*"). The following four items were specifically developed for this study, based on the Feedback Intervention Theory (Kluger & DeNisi, 1996): "*For the rest of the experiment, I often thought about the feedback I received*", "*I often felt threatened by the feedback I received*", "*The feedback I received made me question my abilities*" and "*I was annoyed by the feedback I received*". The scores of all items were averaged to obtain a global score of task-unrelated attention, with a high score indicating that attention was focused on feedback and the self rather than the task. The reliability of the scale was ω = 0.81, 95% CI [0.74, 0.89].

Desire to improve. To measure the participants' desire to improve their performance after feedback, two items from Alder (2007) were translated into French, employing the back-translation method ("*I felt I wanted to improve my performance in response to the feedback I received*", "*I tried to work harder after I had received feedback on my performance*"). A 5-point scale ranging from '*strongly disagree*' to '*strongly agree*' was used. The scores from both items were averaged. Reliability was satisfactory, Spearman-Brown = 0.84.

State self-esteem. The State Self-Esteem Scale (SSES; Heatherton & Polivy, 1991) was administered after the last task of the experiment. It consists of 20 items using a 5-point scale (ranging from *not at all* to *extremely*), and three sub-scales: self-esteem related to performance (7 items; ω = 0.83, 95% CI [0.78, 0.88]), appearance (6 items; ω = 0.83, 95% CI [0.77, 0.88]) and social (7 items; ω = 0.86, 95% CI [0.82, 0.90]). For the purpose of this experiment, the overall score was calculated by aggregating the scores of all 20 items.

3.4. Pilot studies

Two pilot studies were conducted before starting Study 2. The first one was to determine the appropriateness of the wording of the negative feedback used to verify its destructive nature. The second pilot study was necessary to create French items for the Remote Associates Task, since no established French version is available.

3.4.1. Pilot study on feedback destructiveness

In Study 2, negative feedback was given in a destructive manner, following Baron's (1988) principles. According to Baron, destructive feedback is too general, inconsiderate, contains threats and attributes poor performance to internal factors. This meant that feedback contained expressions such as "*Extremely low score*" or "*Seems to have had great difficulties with a rather simple task*". The pilot study (N = 15) was conducted to ensure that the destructive feedback used in the main study increased the strength of the experimental manipulation. The wording of the feedback was presented to participants in text form, with the following questions asked (using a 7-point Likert scale): (item a) "In your opinion, was the feedback presented in a rather sensitive or insensitive way?" (scale ranging from '*very sensitive*', 1, to '*very insensitive*', 7); (item b) "In your opinion, did the presented feedback contain threats?" (scale ranging from '*no threats*', 1, to '*containing threats*', 7); (item c) "In your opinion, was the feedback presented rather specific or general in content?" (scale ranging from '*very specific*', 1, to '*very general*', 7); and (item d) "In your opinion, did the feedback attribute the performance to causes that are external or internal to the participant?" (scale ranging from '*internal causes*', 1, to '*external causes*', 7). Overall, the destructive nature of the feedback was confirmed: feedback was perceived to be very insensitive (item a; $M = 6.2$, $SD = 0.91$), general rather than specific (item b; $M = 6.27$, $SD = 1.06$), and performance was attributed to internal causes (item c; $M = 1.53$, $SD = 0.81$). However, the feedback was not judged as containing threats (item d; $M = 2.8$, $SD = 1.64$).

3.4.2. Remote Associates Task items

For the Remote Associates Task, sixty-nine items were created in French, based on the original items of the English version (Thuillard & Richter, unpublished). Item difficulty was assessed using an online questionnaire (N = 187). The complete set of 69 items was divided into three lists of 23 items. Before completing the online questionnaire, participants were randomly assigned to one of the three lists. The items on the assigned list were presented one by one, with a time limit of 1 min per item. On average, each item was tested by 62 participants. This allowed us to determine item difficulty based on the percentage of participants who found the correct answer (0–100%), and select the items to use in the study based on this percentage (see section 3.3.2).

3.5. Procedure

Participants were recruited by email, which was sent out to students from selected university faculties (see section 3.2). When students accepted to take part in the study, they were invited to the laboratory. Having arrived at the laboratory, they received an information sheet providing a cover story dissimulating the real purpose of the study, and a consent form that they were asked to sign before starting the experiment. The cover story was that they would have to perform several attention and creativity tasks with a view to investigating the link between attention and creativity. Participants were randomly assigned to conditions in the following way: each participant code was assigned to a particular condition beforehand, then each person taking part in the experiment received their code and condition simultaneously. In the human source condition, participants were informed that they would receive performance feedback on the first task from the supervisor of the experimenter (the supervisor was not visible to the participant). Giving performance feedback was justified by explaining that it represents a common procedure in experimental psychology because it improves data quality and ensures that participants feel more involved during the course of the experiment. Participants in the computer source condition received the same cover story, except that a newly developed deep-learning-based software rather than a human would provide their feedback. Participants in the control group did not receive any feedback. Feedback was given on the participants' performance on the first task, which was a difficult version of the Remote Associates Task based on recommendations from McFarlin and Blascovich (1984). We chose 10 extremely difficult items (less than 10% of correct answers in pilot study), three relatively difficult items (about 30%), one item of medium difficulty (50%), and an easy item (88%). This manipulation allowed us to decrease the performance of participants, which made the faked negative feedback subsequently given to participants more credible.

Human feedback. The manipulation in the human source condition was performed as follows: after having completed the first task, participants had to wait for 5 min while their performance data was corrected and analyzed by the supervisor of the experimenter (according to the cover story). After 5 min, the experimenter went to fetch the handwritten feedback from the supervisor. The feedback sheet was placed inside an opaque folder and afterwards handed out to the participant. Participants were informed that the experimenter was not allowed to read it and did not know its content in order not to influence the results of the experiment. This prevented participants from justifying their poor performance to the experimenter. After receiving feedback, the participants were left alone to read it, and then continued the experiment as soon as they were finished reading.

Computer feedback. In the computer source condition, a purpose-built, fake automatic correction software was presented on the participant's computer screen to increase the credibility of the manipulation.

The software pretended to load and analyze the data from the first task, finally printing out the feedback on paper in another room. Following the same procedure as in the human feedback condition, the experimenter went to fetch the printed feedback and handed it over to the participant in the same opaque folder. It was programmed to take 5 min in order to match the waiting time in the other conditions. In this way, feedback was provided to the participant in a similar form as in the human source condition, that is, matching feedback medium used in both conditions. The information sheet printed out in the computer feedback condition was the same as in the human feedback condition, except for a computer printout being used instead of handwriting. Thus, only the feedback source differed from the human feedback condition.

No feedback condition. In the control condition, participants were simply told that they would have a 5-min break after the first task. They received the same cover story as in the other conditions.

Remainder of experiment and debriefing. After the experimental manipulation, all participants completed the remaining part of the experiment, which did not differ between conditions. Performance tests were completed in the following order: d2-test (lasting 5 min), Remote Associates Task (maximum time of 15 min) and Alternate Uses Task (maximum time of 5.5 min). Before the end of the experiment, participants completed the state questionnaires in the following order: state self-esteem scale, interpersonal fairness, level of distraction, and desire to improve. After the experiment, participants were debriefed in the same way as in study 1.

3.6. Data analysis

The data for each dependent variable were analyzed in the same way as in study 1 (see section 2.5). Additionally, hypothesis 2b required a different procedure since it predicted a nil effect of negative feedback on attentional performance. Based on Cortina and Folger (1998) and Onnasch (2015), we adapted alpha to a 20% level for the relevant analyses.

3.7. Results

3.7.1. Manipulation checks

The item (*'To what extent are you feeling stressed?'*) being used as a manipulation check showed that participants perceived general stress to be higher in the two experimental conditions (see Table 3) than in the control group. The one-factorial analysis of covariance, with pre-feedback stress as covariate, proved this difference to be statistically significant; $F(2, 85) = 9.91$, $p < .001$, partial $\eta^2 = 0.117$. Bonferroni-corrected post-hoc comparisons showed a significant difference between human condition and control ($p < .001$), and marginally non-significant between computer condition and control ($p = .052$). The two feedback conditions did not differ significantly ($p = .24$). Post-feedback anger differed between conditions; $F(2, 85) = 11.14$, $p < .001$, partial $\eta^2 = 0.208$, with pre-feedback state anger being used as a covariate. It was rated significantly higher in both the human ($p < .001$) and the computer source ($p = .002$) conditions than in the control group. However, the human and computer conditions did not differ significantly ($p = 1.0$). Overall, these results indicate that the experimental manipulation of feedback as a source of stress was effective.

3.7.2. Performance

Convergent creativity performance (Remote Associates Task). The scores for convergent creativity performance are presented in Table 2. No significant differences between conditions were found in the Remote Associates Task; $F(2, 86) = 1.67$, $p = .19$, partial $\eta^2 = 0.037$.

Divergent creativity performance (Alternate Uses Task). The data for both aspects of divergent creativity (i.e. fluency and originality) are shown in Table 2. The fluency scores differed as a function of experimental conditions; $F(2, 86) = 3.51$, $p = .03$, partial $\eta^2 = 0.075$. Post-hoc analyses with Bonferroni correction showed that the fluency score in the computer condition was significantly higher than in the control group; $p = .047$. No other post-hoc comparison was found to be significant. For response originality, no significant effect was observed; $F(2, 86) = 0.74$, $p = .48$, partial $\eta^2 = 0.017$. To test for a possible shift in speed-accuracy trade-off, we also tested the index as a ratio of fluency and originality but found no difference between experimental conditions; $F(2, 86) = 0.65$, $p = .52$, partial $\eta^2 = 0.015$. Overall, hypothesis 2a was not supported.

Table 2
Means and standard deviations of performance as a function of feedback source.

Variable	Human feedback Mean *(SD)*	Computer feedback Mean *(SD)*	No feedback Mean *(SD)*
Attention: accuracy (no. of items correctly marked)	513.6 *(65.3)*	526.7 *(85.5)*	521.4 *(55.1)*
Attention: speed (no. of items worked through)	532.5 *(69.5)*	546.7 *(85.9)*	541.13 *(57.0)*
Convergent creativity (0–15)	9.1 *(2.9)*	8.52 *(3.0)*	7.77 *(2.6)*
		*	
Divergent creativity: fluency (no. of points)	4.41 *(2.3)*	6.0 *(3.6)*	4.16 *(2.6)*
Divergent creativity: originality (no. of points)	1.55 *(1.6)*	2.14 *(2.3)*	1.84 *(1.5)*

Notes: * $p < .05$.

Attentional performance (d2-test). The data for attentional performance in the form of accuracy and speed are presented in Table 2. For accuracy, the analysis of variance revealed no significant difference between conditions; $F(2, 85) = 0.26$, $p = .77$, partial $\eta^2 = 0.006$. Similar results were found for the speed performance score, with the analysis of variance showing no significant difference between human feedback, computer feedback and the control group; $F(2, 85) = 0.29$, $p = .75$, partial $\eta^2 = 0.007$. These results provide additional evidence for acceptance of hypothesis 2b suggesting a nil effect.

3.7.3. Subjective measures

Affect. Table 3 shows the valence scores of assessing affect by means of the Self-Assessment Manikin. The one-factorial analysis of covariance, with pre-feedback valence as a covariate, showed that after receiving feedback affect scores differed between conditions; $F(2, 85) = 17.53$, $p < .001$, partial $\eta^2 = 0.292$. Bonferroni-corrected post-hoc comparisons showed that valence was rated significantly higher in both the human and the computer source conditions than in the control group (both comparisons: $p < .001$). However, the human and computer source conditions did not differ significantly from one another ($p = .23$). No significant differences were found for arousal; $F(2, 85) = 2.33$, $p = .10$, partial $\eta^2 = 0.052$. Hypothesis 2c was supported by these results.

State Self-Esteem Scale. The data in Table 3 show that there was no difference in self-esteem between the three conditions when examining the total score by using analysis of variance; $F(2, 86) = 0.82$, $p = .44$, partial $\eta^2 = 0.02$. The most relevant subscale 'performance' showed a marginally significant difference, with the score in the two experimental groups being lower than in the control group; $F(2, 86) = 2.85$, $p = .06$, partial $\eta^2 = 0.06$. These results do not support hypothesis 2d.

Perceived fairness. Perceived fairness was rated significantly higher in the human feedback condition than in the computer feedback condition (see Table 3). The Wilcoxon rank sum test confirmed this difference to be significant; $W = 583$, $p = .007$.

Level of distraction. As the data in Table 3 show, the level of distraction was significantly higher in the human source condition than in the computer source condition; $W = 534$, $p = .04$. This indicates that the attention of participants was more strongly focused on the task in the computer source condition than in the human source condition.

Desire to improve. The data for the variable 'desire to improve' are

Table 3
Means and standard deviations of manipulation checks and subjective variables as a function of feedback source.

Variable	Human feedback Mean *(SD)*	Computer feedback Mean *(SD)*	No feedback Mean *(SD)*
Manipulation checks			
Perceived stress (1-7)	2.97 *(1. 68)*	2.93 *(1.25)*	2.13 *(1.34)*
State anger (1-7)	2.93 *(1.87)*	2.45 *(1. 5)*	1.39 *(0.72)*
Subjective measures			
Affects: valence	4.95 *(2.29)*	5.28 *(1.46)*	6.84 *(1.34)*
Affects: arousal	4.86 *(1.64)*	5.00 *(1.49)*	4.19 *(1.25)*
Interpersonal fairness (1-5)	2.0 *(1.18)*	1.4 *(.82)*	n.m.
Level of distraction (1-5)	3.18 *(1.0)*	2.67 *(0.76)*	n.m.
Desire to improve (1-5)	3.71 *(1.24)*	3.33 *(1.31)*	n.m.
State self-esteem (20-100)	71.0 *(12.99)*	72.96 *(13.22)*	75.19 *(11.92)*
Performance self-esteem	25.38 *(5.71)*	26.93 *(4.61)*	28.26 *(3.46)*

Notes: * = $p < .05$; ** = $p < .01$; *** = $p < .001$; n.m. = not measured

presented in Table 2. The analysis showed that the desire to improve performance after feedback did not differ significantly between the human source condition and the computer source condition; $W = 476.5$, $p = .26$.

3.8. Discussion

The main goal of the second study was to examine whether performance would be impaired after using a destructive form of negative human feedback, using a different set of tasks, and employing a computer as an additional source of feedback. The replication was successful for the performance measures (i.e. attention and creativity), with negative feedback from a human having no negative influence on subsequent performance. The same results emerged when negative feedback was provided by a computer, with one exception in an unexpected direction (i.e. a small effect of negative computer feedback increasing fluency in divergent creativity). Overall, the findings for performance are again in support of the 'blank out'-mechanism.

The analysis of the subjective variables (which were larger in number than in the first study) indicated that performance protection was paralleled by considerable changes in the participants' subjective state. Negative feedback increased stress, anger and negative mood in both experimental groups, which is consistent with previous research on negative human feedback (e.g., Baron, 1988; Nummenmaa & Niemi, 2004; Raver et al., 2012). The observation that negative computer feedback induced the same affective reactions as human feedback represents an important result considering the lack of recent empirical data on computer feedback and affect. Both experimental groups reported being motivated to improve their performance after having received negative feedback, though human feedback was felt to be more distracting from the task than computer feedback. Surprisingly, the participants who received negative feedback were not affected in their state self-esteem, which seems to be opposed to what could be expected based on the 'Stress-as Offense-to-Self'-approach (Semmer et al., 2019). Interestingly, the evaluation of interpersonal fairness differed between the two experimental groups. Negative computer feedback was perceived as being more unfair than the same feedback coming from a human, indicating an effect of feedback source.

Overall, the subjective measures seem to indicate that some costs are associated with the successful protection of task performance under social stress no matter whether a human or a computer is responsible for these stressful conditions. Additionally, automated negative feedback does not appear to be a like-for-like replacement of human feedback due to its perceived unfairness, which calls for some caution when considering its implementation in the workplace.

4. General discussion

The main goal of this article can be summarized in three points: (a) to examine whether negative performance feedback as a social stressor affects subsequent performance, (b) whether different types of tasks were affected to a different extent, and (c) to determine whether the effects were different when feedback was provided by a computer rather than a human. Overall, the two studies indicated that negative feedback did not impair performance, and this regardless of feedback source or task type, though some subtle effects emerged. It appeared that performance maintenance under stress came at a cost in form of stress-related effects being detected at the subjective level. Finally, negative human and computer feedback were found to be perceived differently by recipients on several dependent variables.

4.1. Performance

In both studies, the manipulation check indicated a successful induction of social stress, and in both studies, no effects of negative human feedback on performance were found even though a wide range of tasks was used. This pattern of results supports the 'blank out'-mechanism, according to which participants are capable of focusing on the task such that they are impervious to the effects of social stress at the performance level. The research literature did not provide consistent support for the 'blank out'-mechanism, with negative feedback sometimes impairing subsequent task performance (e.g., Alder, 2007; Alder & Ambrose, 2005; Nease et al., 1999; Raver et al., 2012), as predicted by the 'rumination'-mechanism. However, the present findings are in line with the results of some recent studies, which found that participants were able to protect their performance from the stress caused by inadequate human feedback (Peifer et al., 2020), or a combination of negative feedback and social exclusion (Sauer et al., 2020). Together, studies 1 and 2 measured the following types of performance: backward counting, attention, picture completion, symbol coding and convergent and divergent creativity. Although this wide range of tasks covering a large spectrum of cognitive abilities was used in all this work, performance was never impaired following negative feedback. The only significant effect on performance detected, an improved performance on picture completion, appeared subsequently to positive human feedback. These results also do not appear to support Van Dijk and Kluger's findings (2011) that negative feedback affects performance differently depending on task type. Alternatively, it may be that well-established cognitive tests, such as used in study 1, represent a type of task that is unaffected by negative human feedback. Overall, the main implication of these results is that it appears possible for humans to protect their performance from the impact of social stressors, though this might be associated with some cost.

While performance was largely protected from social stress in the form of negative performance feedback, there were several indications of this stressor having an impact at the subjective level. The manipulation checks provided a first sign of the presence of social stress in participants. Then, we observed a negative impact in both studies on affective measures (with slight variations in the type of variable affected) but also on self-reported task management behavior (i.e. task-related distraction). This pattern may suggest that there are some costs associated with protecting task performance under social stress, which are in line with the model of compensatory control mechanism (Hockey, 1997). This model predicts active human performance management to protect overall task performance, though this protection may have costs at the cognitive-energetical level. In the present study, the costs observed were of a slightly different nature. In the two experimental conditions, less positive affect was observed compared to the no-feedback condition. This may also indicate some evaluative process to digest the negative feedback even if the hypothesized effect for self-esteem was rather small (and just not reached the level of significance). However, it must be noted that this protection of performance was detected as negative feedback was given only once. The subjective costs associated with performance protection might make it more difficult to keep maintaining performance in case of repeated social stress induction or in the long term.

4.2. Computer feedback

With regard to one of our main research questions addressing the effects of feedback source on performance, we found that computer and human feedback both showed almost no effects. Only one minor difference emerged in that participants who received negative feedback from a computer found more uses in the Alternate Uses Task than the control group. No such difference was found for participants who received human feedback. While it may represent a case of 'increased motivation'-mechanism (as described in Sauer et al., 2019), it would be surprising to observe this mechanism on only one subscale and not on the other performance measures. Despite this minor difference being observed, there seemed to be overall little impact of feedback source on performance. However, the overall pattern shows some differences compared to the reference study by Van Dijk and Kluger (2011), which may be related to the different set-up of the two studies. First, in Van Dijk and Kluger's study a computer did not only generate the feedback (i.e. source) but also delivered it (i.e. medium) whereas in the present study, a computer generated the feedback but a human delivered it. Second, in contrast to the other study, we used in our experimental cover story the concept of deep learning, with a view to investigating a modern form of automation as well as increasing the credibility of the computer feedback. Both aspects may have worked in the same direction, contributing to a higher similarity of the two feedback types. This is because computer generated feedback based on deep learning may make computer feedback appear more similar to human feedback than when employees assume that a simpler form of computing had been used. Indeed, since feedback content was exactly the same in both experimental conditions, the text was analogous to what a human could write. At the same time, the two feedback conditions become more equivalent if they both use a human to deliver the feedback (as in the present study). While keeping the feedback medium stable and varying only the feedback source (as in the current work) enjoys the advantage of being able to isolate the effect of source, it has the disadvantage of reducing the distinctiveness of the two types of feedback (i.e. computer and human feedback become more similar). This may have led to a lower probability of demonstrating a distinct difference in performance between human and computer feedback.

4.3. Subjective variables

Participants who received negative feedback (either from a human or from a computer) were stressed, angry and in a negative mood. This might suggest that maintaining performance following computer feedback would be associated with some cost comparable to human feedback. Thus, similar concerns could be raised about the effects of repeated negative computer feedback over a longer period of time. However, the pattern of results for human and computer feedback is not completely the same. Although both experimental groups reported being equally motivated to improve their performance after feedback, this motivation resulted in improved performance only in one task for the computer group. This difference might be explained by the fact that participants reported being more focused on the task when receiving computer feedback than human feedback. This would represent a positive aspect of computer feedback being less distracting than human feedback. As shown by Raver et al. (2012), in case of destructive human feedback participants are more likely to blame and distrust the feedback-giver while also thinking he or she intended to harm them. This negative reaction might be attenuated if the feedback-giver is a computer.

In contrast to what was expected, state self-esteem was not affected in either of the two experimental groups, which is quite surprising considering the effects detected for stress and affect. According to the SOS approach (Semmer et al., 2019), negative feedback can induce stress by thwarting important goals (such as maintaining a positive self-view), or through insufficiency or disrespect. These three mechanisms should all be able to unfold in case of destructive negative feedback. At first view, this does not appear to be in support of this aspect of the SOS approach. Indeed, threats to the self are a core postulate of this model, and effects of social stress on self-esteem have been found in the literature (e.g., Eatough et al., 2016; Schulte-Braucks et al., 2019). Yet, there are several possible reasons that could explain why self-esteem was not affected. As explained previously, there was only one induction of social stress through negative feedback. Even though a state self-esteem scale was used, which is sensitive to quick changes, it is possible that effects on self-esteem may be more easily detected following repeated, longer or more intense stress inductions. However, the SOS approach also hypothesizes protection mechanisms, which could explain that no effects on self-esteem were found. For example, it is possible to protect oneself from negative feedback by attributing it to a lack of fairness of the feedback source (Semmer et al., 2019). Crucially, this effect on fairness has been found in our study. Believing that the feedback was unfair may have helped the participants to protect their self-esteem, which would have otherwise been threatened by negative feedback.

Perhaps the most remarkable effect of feedback source in the present work is that negative computer feedback was considered as less fair than negative human feedback. This means that although feedback was provided in exactly the same way and had the exact same content in both conditions, participants felt they were treated more unfairly by the computer than by the human. This difference is in line with previous work, which found face-to-face feedback to influence interpersonal fairness (Alder, 2007; Alder & Ambrose, 2005) because it gives recipients a possibility to offer excuses for their poor performance. For example, such behavior was observed by the experimenters in Study 1 when providing negative performance feedback to participants on a face-to-face basis. Providing justifications for poor performance may help participants to cope better with negative feedback, which hence would increase perceived fairness. However, it is much more difficult for employees to offer excuses to an automated system by providing explanations for their unsatisfactory performance. Crucially, our work goes even beyond these findings in that it shows that differences in interpersonal fairness arise even when human feedback is not given face-to-face, indicating that regardless of how feedback is delivered, there might be something in automated feedback that is perceived as fundamentally more unfair. This result could be interpreted within the SOS mechanism of unfairness being attributed to feedback source as a means to protect self-esteem. Since computer feedback was felt as more unfair than human feedback, it could mean that it posed a greater threat to the participants' self-esteem, and thus required a stronger attribution of unfairness in order for self-esteem to still be protected. Alternatively, this result could be seen as a possible violation of etiquette in human-machine communication. Since in Study 2 human and computer feedback had exactly the same content, computer feedback included characteristics of human communication. While this was congruent with the cover story of a "deep-learning based automated system", it might at the same time have violated participants' expectations of how a machine should communicate with them.

This difference in fairness perception may raise some concerns about the consequences of the increasing tendency to provide automated feedback. In the literature, interpersonal fairness has been linked to task performance, organizational citizenship behavior and counterproductive work behavior (Colquitt et al., 2013), which could all be impaired by automated feedback that is not perceived as fair. While the idea of interpersonal interactions between a human and a system could be counterintuitive, this was already proposed by Alder (2007). Though he found no differences in interpersonal fairness between human and computer feedback, our result could be a sign that, since his study, perceptions and attributions in society regarding automation have changed. Indeed, computers using complex algorithms are playing an increasingly important role in work environments, even entering the leadership domain (Lee et al., 2015; Wesche & Sonderegger, 2019), in which negative performance feedback is part of leader-follower communication. Lower perceived interpersonal fairness could be a sign of lower acceptance of automated agents and of their decisions at work in general. Interestingly, another study recently showed that in decision situations, automated agents have the same impact on procedural fairness as humans (Ötting & Maier, 2018). Although an experimental setting may make it more difficult to distinguish between these different facets of fairness, future research should consider these different aspects when investigating human-machine interaction in work domains.

4.4. *Generalization of results in work settings*

It is possible that negative feedback would have different effects in real work settings when given to employees rather than to students. In the case of employees working in safety-critical settings, it could be imagined that they would be able to protect their performance as well, due to the pressure of preventing highly undesirable consequences. However, in less critical settings, it is also possible that employees would be more affected by negative feedback. Indeed, people usually see their professional role as part of their identity (Ashforth & Schinoff, 2016). Therefore, and according to the SOS approach (Semmer et al., 2019), negative performance feedback should represent a bigger threat to the self to an employee than to a student. It might then be more likely for subsequent performance to decrease as a result of the 'rumination' mechanism, as postulated in Sauer et al. (2019). Even in the case where performance could be maintained regardless, we could imagine that greater subjective costs would be associated to this protection. It must be noted however that since the cognitive tasks used in the present studies are not closely modelled on real work activities (see Limitations section below), our results cannot be directly transferred to actual work settings.

4.5. *Limitations and future studies*

There are several limitations of the studies. (a) Most analyses were conducted in an exploratory way. This means that the hypotheses tests should be interpreted with some caution since power may have been insufficient to detect some other effects. This limitation mostly applies to the performance measures. After Study 1, we used in Study 2 bigger samples and a stronger manipulation, and still found no effect of feedback on performance. Despite these results, it is still possible that there are effects that we could not detect. Therefore, our results will need to be replicated in future research.

(b) The current studies modelled preceding exposure to the social stressor (i.e. performing after having been given negative performance feedback) rather than simultaneous exposure (i.e. performing while being given negative performance feedback). Both represent typical situations at work. However, we assume that intermittent (i.e. repeated) or continuous exposure to the social stressor may represent a higher intensity of the stressor than post-exposure task completion. Therefore, we would recommend that future research examines the impact of intermittent or continuous exposure to the social stressor to determine whether the 'blank out'-mechanism would also be observed under these aggravated conditions, and whether the costs of maintaining performance would be the same. (c) We used (static) cognitive tests rather than cognitive tasks that were closely modelled on real work activities. On the one hand, this may have reduced ecological validity. On the other hand, such tests have good psychometric properties (high objectivity, high reliability, and high predictive validity), being very widely used in personnel assessment to predict future job performance. It is difficult to assess the impact of this limitation on our findings. Considering how task type appears to moderate how performance is affected by social stress, future studies could also test more tasks focusing on specific cognitive functions that have not been used yet. Additionally, given that the present work used a series of non-dynamic single tasks, future work should envisage making more use of tasks modelling real work activities. This may also include the use of multiple-task environments that allow a distinction to be made between primary and secondary tasks. All the cognitive tests used were equivalent to primary tasks (even if they tested low-level cognitive abilities like visual scanning), which required no trade-off in allocating cognitive resources to different tasks. Considering our results, future research should continue to use subjective measures to complement objective performance measures. (d) Although precautions were taken to avoid them, we cannot completely rule out experimenter demand effects. Such effects are less likely to appear for performance measures, since the goal of these tasks is to perform as well as possible. However, it is possible that subjective measures such as fairness, state stress or state self-esteem raised suspicions and cued participants in the experimental conditions that we expected them to be in a more negative state than at the beginning of the experiment. This is why we decided to use a sample of non-psychology students since they usually are less familiar with experimental manipulations.

Fairness appears to be a promising concept to explain the underlying processes, in particular in the context of automation. In addition to interpersonal fairness, other types of fairness could be measured with regard to the effects of social stress in human-machine teams. Future studies on fairness could try to understand what exactly in automated feedback is more unfair than human feedback. In this regard, it would be interesting to investigate human attribution when they receive negative feedback from some form of automation. Indeed, in this situation, the human could always blame other humans for the automated feedback. For example, they could blame the people who programmed the machine, or the experimenter for deciding to use it. We could also imagine that attribution could vary depending on how "modern" the automation is perceived. The more modern and autonomous the automated system is perceived, the less likely it might be to attribute the blame to humans. Future research could thus investigate these attribution processes with different levels of automation, ranging from low (e.g. an old computer) to high technological level (e.g. AIs). Alternatively, future studies could investigate whether fairness is linked to machine etiquette. Etiquette in human-machine interaction can influence perception of automation, such as trust (Parasuraman & Miller, 2004). Poor machine etiquette, such as impoliteness, might possibly impact perceived interpersonal fairness. It could once again be interesting to use more or less "modern" automated systems, since humans might have different etiquette expectations depending on how advanced the system is.

Finally, future research should aim for disentangling the different effects of source and medium when comparing human and computer feedback, ideally comparing all the different combinations possible in one experimental study.

4.6. Implications

At the theoretical level, our findings may bear some relevance to the 'Computers are Social Actors' (CASA) paradigm, which suggests that humans consider computers as social actors, interacting with them in the same way as with other humans (Nass et al., 1994; Nass & Moon, 2000; Sundar & Nass, 2000). According to this work, it is sufficient that a computer communicates to a user via text (such as in Study 2) to be considered as a social actor. It is already known that these human-machine interactions can lead to group identification and even peer pressure with computers (Xu & Lombard, 2017). The present article goes beyond that and adds to the CASA paradigm by showing how computers (possibly perceived as social agents) can be just as effective as humans when inducing social stress and influencing emotions. Furthermore, there is something happening at the interpersonal level in these human-machine interactions, as shown in the fairness ratings, which can further highlight how computers are perceived as social agents.

At the practical level, our results highlight some negative consequences of using destructive elements in feedback, regardless of the source from which the feedback stems. Even though performance was unimpaired, stress and negative affect still increased. Therefore, it could be beneficial to train managers or program automated systems to use constructive elements of feedback rather than destructive ones. Automated feedback might require additional carefulness due to how they are perceived. Perceived interpersonal fairness could be taken into account to increase acceptance of such systems in the workplace. For example, if unfairness implies a lack of acceptance of automation, high transparency in how such systems evaluate performance, generate feedback and function in general could possibly help in this direction.

4.7. Conclusion

The present studies were one of the first that examined the influence of negative performance feedback on a wide range of established cognitive tests, totaling six different tasks. Study 2 was the first to investigate a modern form of computer negative feedback as a source while controlling for feedback medium. No impairments on subsequent performance were found, regardless of task type and feedback source. This was interpreted as supporting the 'blank out'-mechanism postulated in Sauer et al. (2019), suggesting that participants were able to protect their performance from social stress. Although our results show successful performance maintenance, the findings do not speak in favor of using destructive elements in negative feedback at work, due to the apparent costs of performance maintenance. Indeed, negative feedback caused stress, negative mood and anger. These costs raise some concerns about repeated inductions of social stress and negative feedback in the long term, particularly for computer feedback.

One of the most interesting results of this paper is that negative computer feedback was perceived as more unfair than human feedback. In times when algorithms, artificial intelligence and automation are increasingly prominent not only in the workplace but in society in general, human-machine interaction continues to be a highly relevant topic. In such a context, the finding surrounding fairness, if it were to be replicated in further studies, might have important ramifications for automation design and interactions with humans. Perceived lack of fairness may possibly lead to counterproductive behavior in the workplace, ultimately impairing performance. It would therefore appear wise not to forget employees' perception of an automated system before implementing it in the workplace.

Credit author statement

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Declaration of competing interest

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Appendix A. Supplementary material

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6 Study Three: Human and machine-induced social stress in complex work environments: Effects on performance and subjective state

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Human and machine-induced social stress in complex work environments: Effects on performance and subjective state

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ABSTRACT

Social stress at work can lead to severe consequences. As a result of technological developments, social stress will increasingly be induced by machines. It is therefore crucial to understand how machine-induced social stress affects operators. The present study aimed to compare human and machine-induced social stress with regard to its effect on primary and secondary task performance, and on subjective state (e.g., self-esteem, mood and justice). 90 participants worked on a high-fidelity simulation of a complex work environment, on which they had received extensive training (2h15). Social stress was induced by a human or a machine using a combination of negative performance feedback and ostracism. Results indicate that social stress did not affect performance, affect or state self-esteem. Machine-induced and human-induced social stress overall had similar effects, except for the latter impairing perceived justice. We discuss implications of these results for automation at the workplace and outline future research directions.

1. Introduction

The workplace can be a stressful environment in a number of different ways. In addition to environmental aspects, stress may arise from social interactions in the workplace. Social stress has recently been gaining interest the field of ergonomics and human factors (e.g. Gerhardt et al., 2021; Kluge et al., 2019; Sauer et al., 2022). Social stress may appear in different forms such as negative performance feedback, ostracism or illegitimate tasks (see for an overview e.g. Sauer et al., 2019). Exposure to social stress has a serious impact on operators at psychological, physical and behavioural levels (Semmer et al., 2019), which eventually may impair well-being or work performance (Gerhardt et al., 2021).

In the wake of the rapid technological advancement, humans work increasingly in hybrid teams together with technology (i.e. robots, intelligent agents etc.). Machines and algorithms are increasingly prevalent in the workplace (Meijerink et al., 2021; Ravid et al., 2020) and taking over functions of leadership (Quaquebeke and Gerpott, 2023; Wesche and Sonderegger, 2019), decision-making (Langer and Landers, 2021) and other management tasks (Lee et al., 2015). This can lead to situations where the technological agent is the source of social stress (Sauer et al., 2022). However, empirical understanding of the consequences of machine-induced social stress is still scarce. The present study addressed this gap by comparing the effects of human-induced and machine-induced social stress on subsequent performance and subjective state.

1.1. Social stress at work

A number of different social stressors may be present at the workplace (see for a list e.g. Gerhardt et al., 2021; Sauer et al., 2019). This diversity of stressors might explain the relatively high prevalence of social stress at work. Indeed, in a Swiss sample, 22% reported being exposed to at least one social stressor in the last 12 months (Grebner et al., 2011). According to the 'Stress as Offense to Self' approach (SOS; Semmer et al., 2019), social stress threatens the self, and self-esteem in particular. A distinction is made in the SOS approach between personal self-esteem (i.e. self-evaluation of intrinsic and aspired qualities) and social self-esteem (i.e. degree to which one feels valued by others). According to the SOS model, both types of self-esteem will be threatened by social stress, with possible consequences on several levels.

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1.2. Consequences of social stress: performance and subjective state

1.2.1. Effects on performance

A crucial outcome of social stress is subsequent performance. At the theoretical level, three mechanisms have been postulated to explain how performance may be affected by social stress (Sauer et al., 2019). The 'blank-out' mechanism allows protecting performance, the 'rumination' mechanism leads to impaired performance, and the 'increased motivation' mechanism causes improved performance. A meta-analysis found social stress to be negatively correlated with performance ($r = -0.22$ Gerhardt et al., 2021). It has to be noted that research on social stress, such as the one used in the cited meta-analysis, has mainly been performed as field studies or using methodologies such as vignettes or interviews. Such methodological approaches do not allow for an objective assessment of indicators of performance.

When focusing the literature review on lab studies of specific stressors, rather mixed results can emerge. This is the case for example for negative performance feedback, which is used in the present study. Human negative feedback impaired subsequent performance in several studies (Alder, 2007; Alder and Ambrose, 2005; Nease et al., 1999; Raver et al., 2012). However, performance improvement has also been found (Alder, 2007), as well as nil effects (Peifer et al., 2020; Thuillard et al., 2022). We also reviewed studies for the stressor ostracism, which was used in the present study as well. Lab studies on the effect of ostracism on subsequent performance are extremely scarce in the literature. Some studies found human-induced ostracism to decrease performance in a working memory task (Fuhrmann et al., 2019), in a word-search task (Lustenberger and Jagacinski, 2010) and on an eye-movement task (Jamieson et al., 2010). However, performance decrease could be restricted to some age groups (Fuhrmann et al., 2019), and ostracism could also lead to an increase in performance in some conditions (Jamieson et al., 2010). Overall, the current state on experimental research in this domain is inconsistent, with a majority of studies however indicating that human ostracism is linked with decreased subsequent performance.

When measuring performance, a crucial distinction has to be made between primary and secondary tasks (i.e. high-priority vs. low-priority tasks). The Compensatory Control Model by Hockey (1997) postulates that, under environmental stress, humans can maintain performance on primary tasks, however at the cost of lower performance on secondary tasks. It is unknown whether social stress will have the same effect as environmental stress on primary and secondary task performance. A recent theoretical article however assessed secondary tasks as sensitive to the effects of social stress on performance and called for more experimental studies using it (Sauer et al., 2022). Peifer et al. (2020) found that social stress in a complex multiple task environment left subsequent performance unaffected on both primary and secondary tasks. Overall, experimental research on social stress is still scarce. More studies are needed to complement the existing literature and establish cause-effect relationships (Sauer et al., 2019, 2022).

1.2.2. Effects on subjective state

Beyond performance, social stress may affect operators at the personal level (Sauer et al., 2019, 2022). As indicated above, the SOS model expects social stress to influence personal and social self-esteem (Semmer et al., 2019). In the Compensatory Control Model, performance protection is expected to build up fatigue (Hockey, 1997), which might have effects that are not detectable in performance tasks but rather in subjective indicators. In the meta-analysis by Gerhardt et al. (2021), social stress was negatively related to several subjective variables such as mental well-being, and job satisfaction, and positively related to negative emotions. It is therefore important to assess subjective state variables in addition to performance measures.

Focusing on the social stressors used in the present study, effects on subjective state have been found. Negative performance feedback can impair personal self-esteem (Brown, 2010; Krings et al., 2015; Moore and Klein, 2008) and reduce perceived interpersonal justice (Alder, 2007; Thuillard et al., 2022), or induce negative affective states (Nummenmaa and Niemi, 2004), and anger or tension (Baron, 1988; Cianci et al., 2010). Ostracism has negative effects on the four fundamental needs of belonging, control, meaningful existence and personal self-esteem (Buelow and Wirth, 2017; Jamieson et al., 2010; Robinson et al., 2013; Smith and Williams, 2004; Williams, 2007; Zadro et al., 2004). Additionally, ostracized individuals are more likely to feel burdensome (Buelow and Wirth, 2017), to experience lower positive mood and relatedness (Lustenberger and Jagacinski, 2010) and to act more aggressively (Warburton et al., 2006).

1.3. Machine-induced social stress

The "Computers Are Social Actors"-paradigm (CASA) explains how humans easily tend to apply social scripts and rules mindlessly to computers (Nass et al., 1994; Nass and Moon, 2000; Sundar and Nass, 2000). As soon as a computer exhibits a sufficient level of social cues and is considered an autonomous source of communication, humans will interact with it socially (Nass and Moon, 2000; Sundar and Nass, 2000). This means, for example, applying social rules of politeness or reciprocity to a computer. Originally focusing on computers, CASA has been extended to more moderns types of agents such as chatbots, mobile phones or robots (Gambino et al., 2020). The social interaction between humans and machines is crucial when considering machine-induced social stress. Indeed, the increasing use of autonomous technologies at work leads to a growing risk of machines inducing social stress. In the industry, human-machine interaction is at the heart of what is considered the fourth industrial revolution, or "Industry 4.0" (Galin and Meshcheryakov, 2019). This implies collaborating robots, or "cobots", working jointly on the same task with humans as colleagues rather than as simple tools of the human operator, which includes social aspects (Gualtieri et al., 2022; Paliga, 2022).

Algorithmic management even goes beyond human-machine collaboration. Defined as "the delegation of managerial functions to algorithms" (Jarrahi et al., 2021, p.1), it typically involves tasks such as monitoring operator performance and giving feedback on it, planning and assigning tasks and shifts, giving rewards and fines, assigning employees to teams, and even making operators redundant (Gal et al., 2020; Jarrahi et al., 2021; Kellogg et al., 2018; Lee et al., 2015; Meijerink et al., 2021; Uhde et al., 2020). Algorithmic management is mostly prevalent in the gig economy related to online platforms work, such as for example personal transportation, warehouse work or food and groceries delivery (Galière, 2020; Huang, 2022; Rosenblat and Stark, 2016). However, its presence is increasing in more common work settings and organizations (Jarrahi et al., 2021; von Krogh, 2018; Wesche and Sonderegger, 2019). It appears likely that machine-induced social stress will increase as algorithmic management spreads.

Machine-induced negative feedback and ostracism have been addressed in some studies, with a similar inconclusive result pattern regarding consequences on performance as observed for human induced social stress. For example, following computer negative feedback performance improved (Alder, 2007; Earley, 1988; Fyfe and Rittle-Johnson, 2016; Nebeker and Tatum, 1993; Van Dijk and Kluger, 2011), decreased (Alder, 2007; Resnik and Lammers, 1985; Van Dijk and Kluger, 2011) or stayed unchanged (Kluger and Adler, 1993; Sauer et al., 2021; Thuillard et al., 2022). With regard to the effect on subjective state, previous research has shown that machine-induced negative feedback is perceived as less fair than human feedback (Thuillard et al., 2022). No study investigating the effect of machine-induced ostracism on performance was found. However, it has already been shown about 20 years ago that human can feel ostracized by computers, impairing their four fundamental needs in the process (Zadro et al., 2004). In this study, humans also tended to be angrier when they were ostracized by computers than by humans. Computer-induced ostracism has been replicated many times since experimental studies often used the software

"Cyberball" (Williams and Jarvis, 2006) to induce ostracism (see e.g. Buelow and Wirth, 2017; Jamieson et al., 2010; Robinson et al., 2013; Williams, 2007). In this software, participants can be ostracized by computers or humans alike.

1.4. Present study

The main goal of this study was to examine experimentally whether social stress affected performance and subjective state, and whether human-induced and machine-induced social stress had different effects. This study should contribute to the ergonomics and human factors literature as it combines the controllable environment of experimental research with the ecological validity of field studies. Indeed, rather than static cognitive tests such as IQ tests for example, the present work makes use of a simulation of a complex multiple-task work environment, called Cabin Air Management System (CAMS; see below section 2.2). CAMS includes primary and secondary tasks and allows measuring performance during social stress induction. In addition to performance measures, we added several subjective variables such as affect, state self-esteem or justice (see section 2.3.3). This was done following the proposition of a 'broadband approach' (Hockey, 1997), which advocates the use of a number of different variables in stress research.

Based on the Compensatory Control Model (Hockey, 1997), we expected primary performance not to be affected by social stress and to stay the same in all three groups (H1a). Secondary performance, however, will be impaired in both experimental groups compared to the control group (H1b). Based on the SOS theory, we expected state self-esteem to be impaired in both experimental groups compared to the control group (2a). Based on previous research (Thuillard et al., 2022; Sauer et al., 2021), we expected affect (2b) and justice (2c) to be lower in both experimental groups compared to the control group. Interpersonal justice in particular will show the lowest level in the machine-induced stress group (2d). Due to the lack of research on machine-induced social stress, we could not know whether differences should be expected compared to human-induced social stress for most variables. Therefore, the present study is partly of an exploratory nature with regard to the differences between the two social stress conditions.

2. Methods

2.1. Participants and experimental design

90 participants (46 females) took part in this study, aged 20–29 years ($M = 23.54$; $SD = 3.11$). Participants were all students, recruited from various faculties of different Swiss Universities. They were recruited by e-mail, flyers and through social media. They were paid 80 CHF for their participation. An excellent understanding of French and good knowledge of English was required. Psychology students or students having participated in similar studies were excluded from this study, since they may be too familiar with experimental scenarios using deception. Informed consent was obtained from all participants, and the study was approved by the internal review board of the Psychology Department of the University of Fribourg.

This study employed a one-way between-subjects design, with social stress being manipulated at three levels. Participants were randomly allocated to either of the three conditions: a human-induced social stress group, a machine-induced social stress group or a control group with no stress induction. A combination of negative performance feedback (informing the participants of their insufficient performance) with ostracism (participants were not allowed to use the chat with the rest of the group) was used to maximize the effect of social stress. We chose to use these stressors due to their prevalence in work settings (Cleveland et al., 1989; Robinson et al., 2013) and due to the fact they can originate from both human and machine (Endsley and Kiris, 1995; Jarrahi et al., 2021; Kellogg et al., 2018; Lee et al., 2015; Zadro et al., 2004). Additionally, using these two stressors together appeared to be ecologically valid since an operator could be ostracized by others following poor work performance.

2.2. Material: simulation environment

This study used a new version of the simulation environment CAMS (see Fig. 1). CAMS simulates a complex work environment in the form of a space station's life-support system (see for details of a previous version; Manzey et al., 2008). Participants act as operators responsible for monitoring and repairing the system in case of malfunctions. CAMS uses dynamic tasks evolving in real time and closely modelling a real work environment. This includes two primary and two secondary tasks, allowing us to measure the allocation of cognitive resources to the different elements of the task environment. Additionally, since social stress induction lasted during the whole experiment, using this tool allowed us to measure performance during social stress exposure. This is unlike previous experiments that usually measured performance subsequently to the stress induction rather than simultaneously. Some new functions such as a chat facility were added to the new CAMS version, allowing for the experimental induction of social stress. Using CAMS in a study requires considerable resources, since participants need extensive training (2 h 15 min in present study) to become familiar with the complexity of the simulation.

2.3. Dependent variables

2.3.1. Manipulation check and control variables

Three items were used as manipulation check for the induction of stress and implementation of ostracism. We also added two items to control the valence and level of stress induced by negative feedback. All five items were developed specifically for this experiment.

Perceived stress. Overall stress was assessed using a single item "Do you feel stressed? How much?", ranging from 1, "*not at all*", to 7, "*extremely*".

Ostracism. We assessed the manipulations' effect on perceived social exclusion ("To what extent did you feel excluded by not being able to use the chat during the experiment?") and believed exclusion ("How much do you think the other participants used the chat?") on a seven-point Likert scale ranging from 1, "*not at all*", to 7, "*a lot*". These two items were presented after an item ("Could you use the chat during the experiment?") that needed a yes/no answer.

Negative feedback. The perceived feedback valence was assessed with a single item: "To what extent did you find the feedback you received …", ranging from 1, "*negative*" to 7, "*positive*". Level of stress induced by the feedback was assessed with a single item; "How stressful did you experience the feedback you received?" ranging from 1, "*not at all*", to 7, "*extremely*".

2.3.2. Performance measures

The following four measures of performance were recorded throughout the experiment on two primary tasks and two secondary tasks. (a) *Parameters control failure:* percentage of deviation from the safety limits in all five air parameters averaged together. (b) *Malfunctions diagnosis:* number of wrong diagnoses and number of corrected malfunctions. (c) *Reaction time (ms):* mean reaction time on every completed transmission check. (d) *Prospective memory:* percentage of correctly completed logs.

2.3.3. Subjective measures

Affect. The participants' affect was measured by the Self-Assessment Manikin (SAM; Bradley & Lang, 1994) pictographic questionnaire. A nine-point Likert scale was used to measure the dimensions of valence (1, negative vs 9, positive affect) and arousal (low vs high) were measured on a nine-point Likert scale.

State Self- Esteem Scale. The State Self-Esteem Scale by Heatherton and Polivy (1991) measures the temporary variations in self-esteem, on

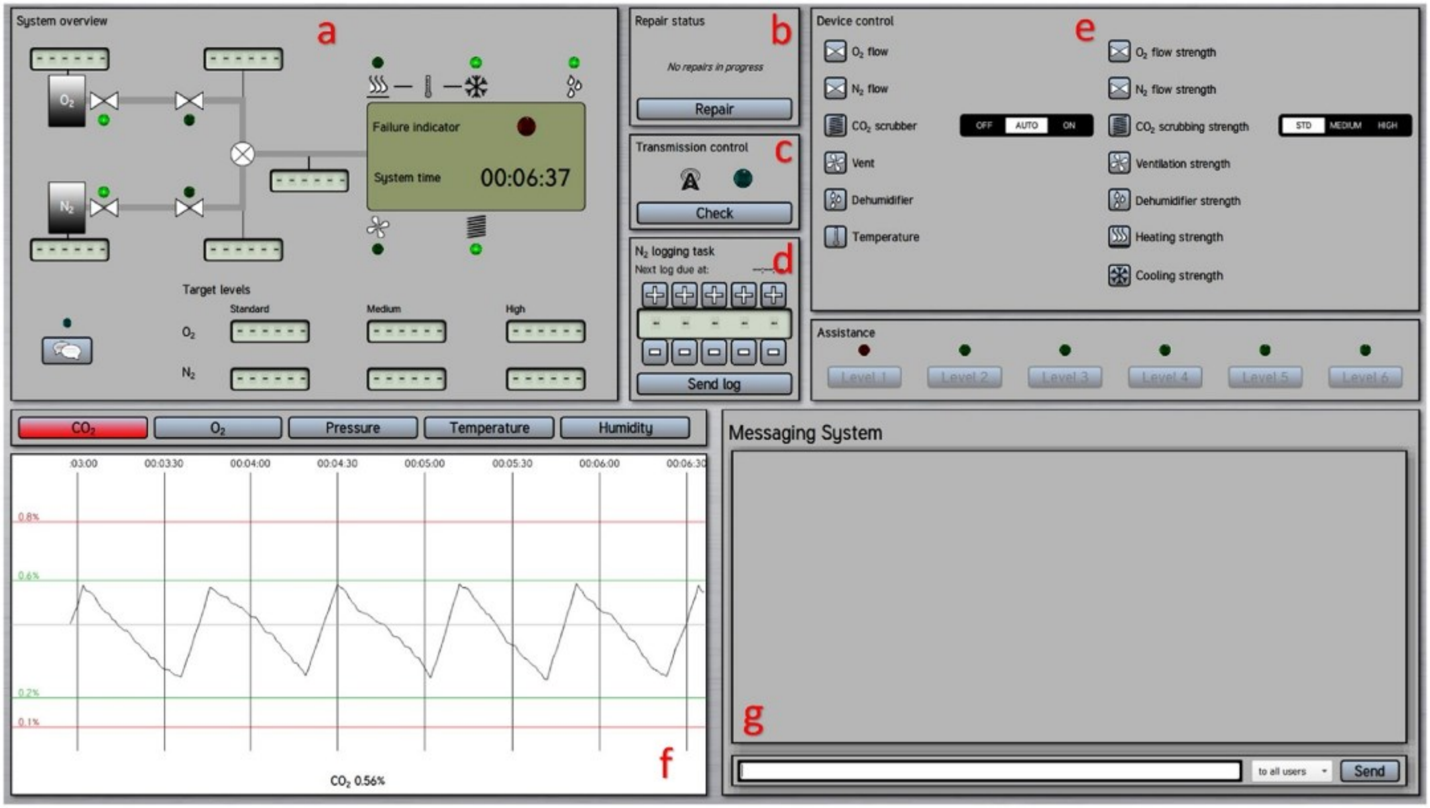

Fig. 1. *Cabin Air Management System (CAMS). The system overview (a), at the upper left side, schematically represents the air management system and the devices involved. At the top center can be found the repair tab (b) and the secondary tasks tabs (c and d). The device and strength controls of all devices and valves are located on the upper right side of the interface (e). The lower left side rectangle displays the five parameters of the cabin's air quality (f) and their change over time. The rectangle at the bottom right shows the chat facility (g).*

three sub-dimensions: performance self-esteem (7 items; McDonald's omega in current study, $\omega = 0.84$, 95% CI [0.79, 0.89]), social self-esteem (6 items; $\omega = 0.82$, 95% CI [0.76, 0.88]) and appearance self-esteem (7 items; $\omega = 0.89$, 95% CI [0.85, 0.92]). The total score uses all 20 items. For each, the higher the score, the higher the self-esteem is. All items were answered on a scale ranging from 1, "*not at all*", to 7 "*extremely*".

Procedural and Interpersonal Justice. Perceived interpersonal justice was measured using the 'interpersonal justice' subscale from the organizational justice scale (Colquitt et al. (2015). The four items were modified to refer either to the experimenter, or to CAMS. They were filled twice by each participant in order to evaluate interpersonal justice in the interactions with either the experimenter or CAMS. Items asked for example to what extent: "Has the experimenter/the program treated you in a polite manner?". Each item was rated on a 7-point Likert scale, from 1, "*not at all*", to 7, "*extremely*". McDonald's omega in current study was $\omega = 0.61$, 95%CI [0.34-0.8] for human interpersonal justice and $\omega = 0.85$, 95%CI [0.74-0.95] for machine interpersonal justice.

Perceived procedural justice was measured by 4 items from the 'procedural justice' subscale from the organizational justice scale (Colquitt et al., 2015). We selected items that could be modified to refer to the experiment. The selected items asked to what extent: "Were you able to express your views during the experiment?", "Was the experiment applied consistently?", "Was the experiment free of bias?", "Did the experiment uphold ethical and moral standards?". Each item was rated on a seven-point Likert scale, ranging from 1, "*not at all*", to 7, "*extremely*". McDonald's omega was $\omega = 0.45$, 95%CI [0.12-0.67].

2.4. Procedure

2.4.1. Training session

All participants received an extensive training on CAMS (2 h 15 min in total; see Fig. 2). The aim was for participants to really understand how the different sub-systems of CAMS interact with one another, and how their actions would influence the different parameters.

2.4.2. Testing session

Prior to experimental manipulation. The testing session (1 h 30 min; see Fig. 3) took place approximately one week after training and was administered by the same experimenter. Participants returned in different groups ranging from three to four and were randomly assigned to one experimental condition. We tested one condition by group. Participants were separated by screens and had to wear headphones.

Manipulation. In the human stress condition, the experimenter talked to each participant one by one during the warm-up and gave them negative feedback on their performance in the training session. She pointed out that their overall performance score was 60 points out of 300. Using a graph, she showed that they were in the lowest 12%, significantly below average of other participants' performance. She explained that based on this result, she had decided to deactivate their chat facility since they would probably disturb other participants rather than help them. The experimenter was trained to give this feedback in a highly standardized way, and participants were not given the opportunity to discuss the feedback. With regard to ostracism, participants believed that they were the only ones not being allowed to use the chat facility. To increase the strength of this manipulation, CAMS displayed scripted fake messages in the chat facility (always at the same time), with the content hidden, to give the impression that other participants were actively using the chat facility. In the computer stress condition, the same feedback, though adapted to make CAMS appears as the source of social stress, was displayed on the screen at the end of the warm-up. In this case, it was as if CAMS itself took the decision to block a participant from using the chat facility. In the control condition, participants were told that the chat facility was unfortunately faulty and that nobody

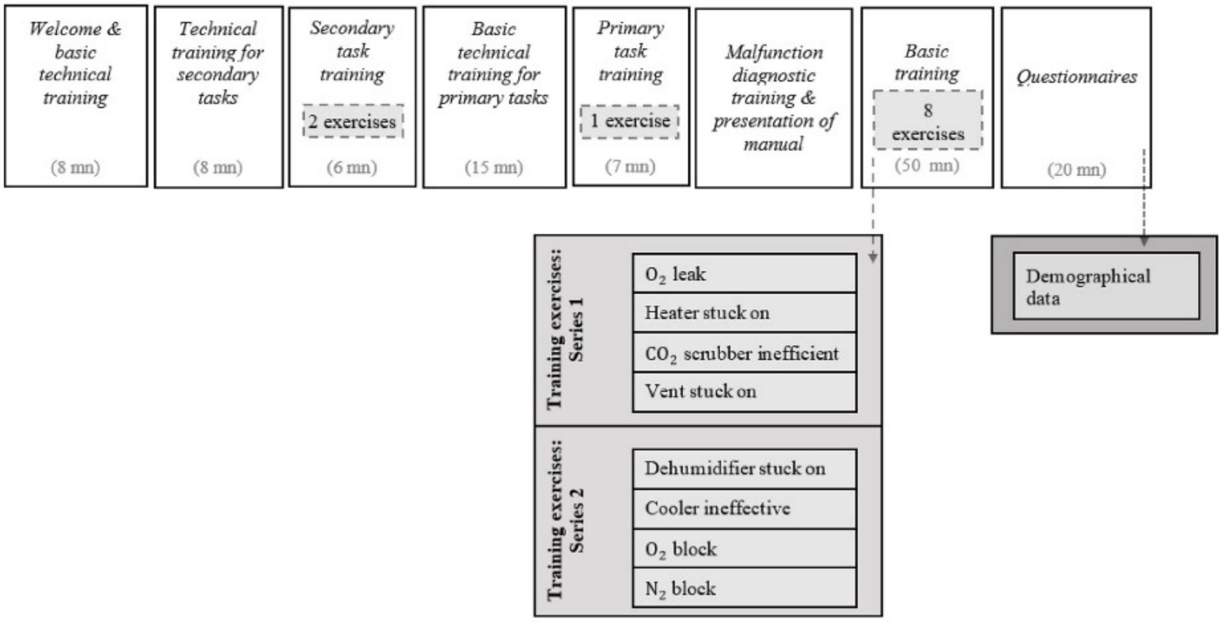

Fig. 2. *Procedure of the training session.*

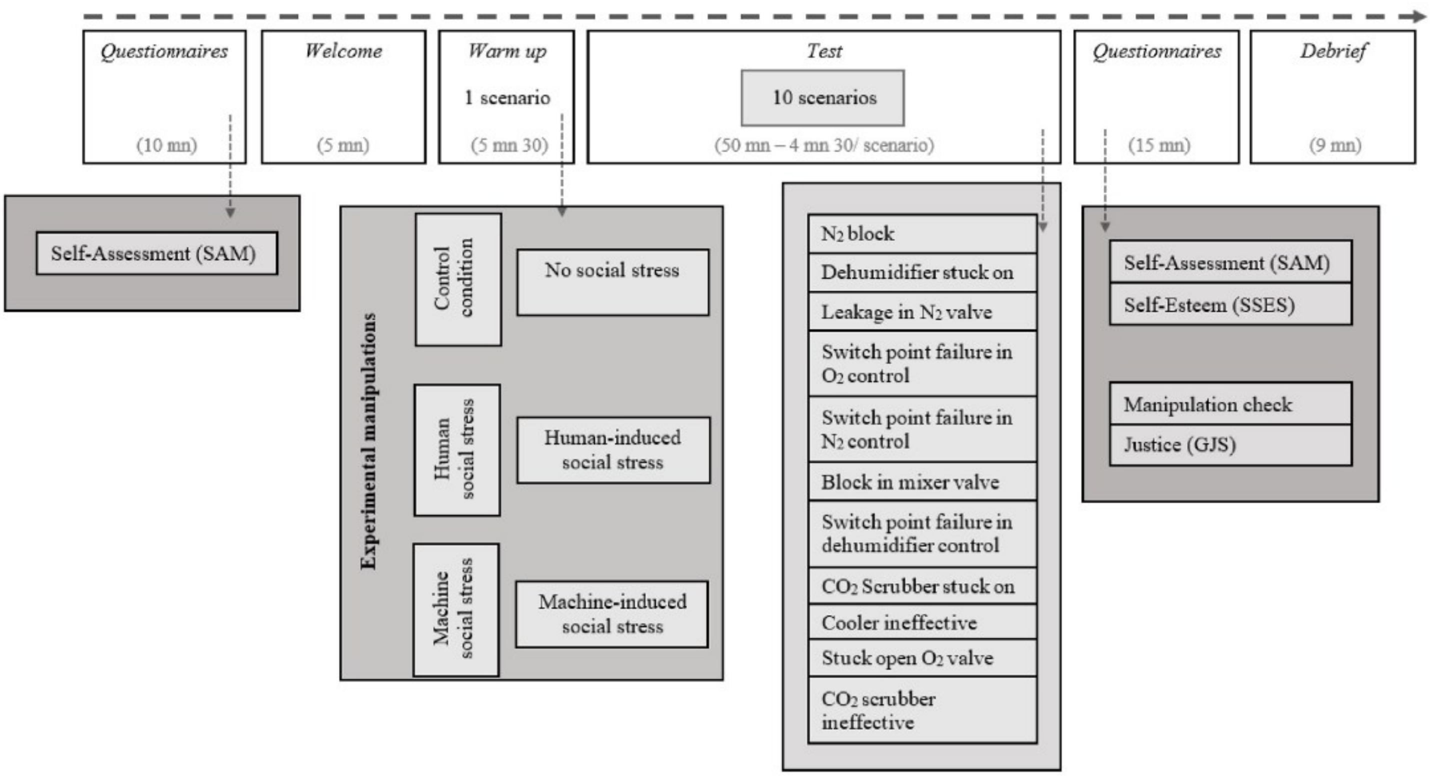

Fig. 3. *Procedure of the testing session.*

could use it, and no fake messages were displayed.

After manipulation. Following the warm-up, participants in both experimental conditions were reminded that the ones that were allowed using the chat could help each other. Participants then completed the testing phase (see Fig. 3), followed by questionnaires.

Debriefing. Participants were fully debriefed. The experimenter apologized for providing inaccurate information, and explained why it was necessary to provide incorrect feedback and to make participants believe that they were ostracized. Participants had the opportunity to ask questions if they had any. The experimenter made sure that participants had understood and accepted the manipulation before leaving.

2.4.3. Cover story

Manipulation check questions had to be carefully presented to conceal the purpose of the study (Hauser et al., 2018). A cover story was used to minimize this risk: the ethics committee of the university would like to control whether our experiment respected ethical rules. To this end, participants would have to answer some questions not as part of the experiment, but for the ethics committee. This allowed presenting manipulation check and some subjective state items at the end of the experiment after all other dependent variables.

2.5. Data analysis

Analyses consisted of ANOVAs (with Bonferroni corrected pairwise comparisons), ANCOVAs (for variables measured before and after the experimental manipulation), and t-tests. We controlled for normality of distribution and homogeneity of variance assumptions.

Non-parametric tests, such as a Kruskal-Wallis analysis of variance or a Wilcoxon rank-sum test, were conducted only in cases in which both assumptions were violated. Reliability of the scales used in the present study was assessed with McDonald's omega, based on recommendation by Dunn et al. (2014). Additionally, hypothesis 1a required a different procedure since it predicted a nil effect of social stress on primary performance. Based on Cortina and Folger (1998) and Onnasch (2015), we adapted alpha to a 20% level for the relevant analyses.

3. Results

3.1. Manipulation check and control variables

3.1.1. Perceived stress

The post-test state stress measure (see Table 1 for descriptive statistics), with the pre-test measure as a covariate, did not significantly differ between groups; F (2,87) = 1.782, p = .174, partial η^2 = 0.04.

3.1.2. Perceived ostracism

Significant differences were found in how much participants felt excluded due to not having been able to use the chat, H (2) = 23.1, p < .001. Bonferroni-corrected pairwise comparisons using Wilcoxon rank sum tests showed that the control group was significantly lower than the human group, p < .001, and than the machine group, p < .001. These two last groups did not differ significantly, p = .97.

Similar results were found with regards to how much participants thought others used the chat, H (2) = 30.13, p < .001. Bonferroni-corrected pairwise comparisons using Wilcoxon rank sum tests showed that the control group was significantly lower than the human group, p < .001, and than the machine group, p < .001. These two last groups did not differ significantly, p = .43.

3.1.3. Negative feedback

No differences were found between the human and the machine groups for feedback valence; t (58) = −1.56, p = .12, and feedback stressfulness; t (58) = 0.22, p = .82.

3.2. Performance measures

3.2.1. Primary performance

Parameters control failures. The overall deviation from the safety limits in the air parameters did not differ significantly between conditions; F (2, 87) = 0.62, p = .54, partial η^2 = 0.014 (see Table 2 for descriptive statistics of all performance measures).

Malfunction diagnosis. The analysis of variance revealed no significant effect of social stress on the number of correct diagnoses; F (2, 87) = 0.24, p = .78, partial η^2 = 0.005 and of wrong diagnoses; F (2, 87) = 1.06, p = .35, partial η^2 = 0.024. Overall, results appear to provide reasonable support for Hypothesis 1a as both alphas are over the adapted level of 20%.

3.2.2. Secondary performance

Reaction time. Performance on the reaction time task was not affected by social stress. Mean reaction time did not differ significantly between conditions; F (2, 87) = 0.76, p = .47, partial η^2 = 0.017.

Prospective memory. No significant effect of social stress was found for the percentage of logs completed; F (2, 87) = 0.67, p = .52, partial η^2 = 0.015.

3.3. Subjective state measures

3.3.1. State self-esteem

No significant effects of social stress on state self-esteem were detected, whether it be in the performance subscale; F (2, 87) = 0.98, p = .38, partial η^2 = 0.022, the social subscale; F (2, 87) = 0.54, p = .58, partial η^2 = 0.012, the appearance subscale; F (2, 87) = 0.09, p = .91, partial η^2 = 0.002, or the total score; F (2, 87) = 0.63, p = .53, partial η^2 = 0.014. These results do not support Hypothesis 2a.

3.3.2. Affect

The one-factorial analysis of covariance, with pre-manipulation

Table 2
Means and standard deviations of performance as a function of social stress.

Variable	Control group Mean *(SD)*	Human social stress Mean *(SD)*	Machine social stress Mean *(SD)*
Primary performance			
Parameters control failure (%)	16.41 *(7.19)*	18.93 *(9.6)*	17.63 *(9.07)*
Total number of wrong diagnoses	6.77 *(4.2)*	7.66 *(4.59)*	9 *(8.27)*
Number of correct diagnoses (0–10)	7.2 *(2.73)*	6.9 *(2.01)*	6.77 *(2.47)*
Secondary performance			
Reaction time (ms)	3061 *(602)*	3244 *(539)*	3112 *(602)*
Logs completed (%)	15.41 *(26.64)*	8.79 *(15.92)*	11.38 *(22.54)*

Table 1
Means and standard deviations/median and interquartile range of manipulation check and control variables.

Variable	Control group Mean/Median *(SD/IQR)*	Human social stress Mean/Median *(SD/IQR)*	Machine social stress Mean/Median *(SD/IQR)*
State stress T2 (T1 as covariate; 1-7)	2.67 *(1.49)*	2.24 *(1.3)*	2.39 *(1.58)*
	* * *		
		* * *	
Experienced ostracism (1-7)	1.00 *(.75)*	3.00 *(3.00)*	4.00 *(4.00)*
	* * *		
		* * *	
Other participants chat use (1-7)	1.00 *(1.00)*	3.00 *(3.00)*	5.00 *(3.00)*
Feedback valence (1-7)	n.m.	1.97 *(.91)*	2.58 *(1.93)*
Feedback stressfulness (1-7)	n.m.	3.79 *(1.74)*	3.68 *(2.18)*

Notes: * = p < .05; ** = p < .01; *** = p < .001; n.m. = not measured.

(baseline) score as a covariate, showed that valence did not differ between the experimental conditions (see Table 3 for descriptive statistics); F (2, 87) = 2.47, p = .09, partial η^2 = 0.054. Similar results were found with the ANCOVA for the arousal scale; F (2, 87) = 0.62, p = .54, partial η^2 = 0.014; as well as the anger item; F (2, 87) = 1.58, p = .21, partial η^2 = 0.035. These results do not support Hypothesis 2b.

3.3.3. Justice

The Kruskall-Wallis test revealed significant differences in interpersonal human justice; H (2) = 12.42, p = .002. Bonferroni-corrected pairwise comparisons using Wilcoxon rank sum tests showed that participants in the control group evaluated the experimenter as significantly more just than the human group, p = .001. Fairness ratings in the machine group did not differ from the control group, p = .61, or from the human group, p = .11. No such differences were found for computer interpersonal justice; F (2, 87) = 0.25, p = .78, partial η^2 = 0.006.

Significant differences between conditions were detected for procedural justice; H (2) = 6.62, p = .036. Bonferroni-corrected pairwise comparisons using Wilcoxon rank sum tests showed that the control group was significantly higher than the human group, p = .036. The machine group did not differ from the control group, p = 1, or from the human group, p = .24.

The justice results overall only partially support Hypothesis 2c, in that only the human group showed an impairment of justice. Hypothesis 2d was not supported.

4. Discussion

The present study investigated whether human-induced and machine-induced social stress affect subsequent performance and subjective state by using a simulation of a complex work environment. Results indicated that the feedback was perceived as quite negative and relatively stressful, and that participants did feel excluded from the others by not being able to use the chat. This pointed towards a successful manipulation of social stress. Nevertheless, performance was unaffected by social stress. With regard to subjective state measures, social stress only partly influenced interpersonal and procedural justice, leaving other variables such as affect or state self-esteem unimpaired.

4.1. Performance

Based on Hockey's Compensatory Control Model, we expected that primary performance would be protected from social stress (H1a), but that performance on the secondary tasks would be impaired (H1b). No effect of social stress on any performance variable was detected, supporting H1a but not H1b. This pattern of nil effects could be seen as a case of the 'blank-out' mechanism (Sauer et al., 2019), in that participants managed to protect their performance from social stress. The present results might be seen as positive, indicating an ability from participants to shield their primary *and* secondary performance from both human-induced and machine-induced social stress. A possible 'blank-out' mechanism may have been observed in previous studies (Peifer et al., 2020; Sauer et al., 2021; Thuillard et al., 2022).

CAMS is a complex system requiring high cognitive resources to be operated. This high demand might simply have left no resources for rumination, thus preventing performance impairment despite the induction of social stress. In their meta-analysis, Kluger and DeNisi (1996) partly support this argument by showing that feedback has weaker effects on performance in complex tasks. This could mean that operators working on complex systems would be more protected from social stress due to the nature of their work. Compared to cognitively less demanding tasks, a stronger stress induction would be necessary to impair performance. Performance protection may also have caused physiological strain, as in Peifer et al. (2020). Physiological strain was not measured in the present study. It might however have potentially serious health consequences on the long term. Alternatively, according to Sauer et al. (2022), social stress may impair performance not on the main task but on unscheduled probe tasks for example, which is called performance after-effects. Such a phenomenon might have happened in the present study.

4.2. Subjective variables

We expected social stress to lower state self-esteem (H2a), affect (H2b) and justice (H2c) in the experimental groups compared to the control group. For interpersonal justice in particular, we expected the machine group to show the lowest score (H2d).

No effect of social stress on affect or state self-esteem were detected. Interpersonal and procedural justice were reduced in the human stress group only. Overall, subjective variables showed rather low support for our hypotheses. This relative absence of effect on subjective state is surprising in the sense that according to the Compensatory Control Model, performance protection is associated with some costs. Costs on mood or self-esteem have been identified in the literature before following potential 'blank-out' effects (Sauer et al., 2021; Thuillard et al., 2022). A link could be made with the emotion regulation literature. Different emotion regulation strategies have different effects at the physiological level (Webb et al., 2012). *Suppression* for example (i.e. not showing any feeling) is considered maladaptive and can lead to a higher sympathetic activation (Gross, 1998). This could be seen as a physiological cost of regulating social stress if participants used such a strategy to regulate their reaction. In the same line of argument, we could imagine that the protection mode may have been extended to subjective variables as well, with physiological strain being a sign of this protection.

Participants in the human stress condition felt they were treated less fairly by the experimenter than the control group. When the same questions were asked about CAMS instead of the experimenter, no difference was detected. Procedural justice (i.e. how fair decision-making is), includes in the present study the decision to exclude someone from the chat. Interestingly, only the human stress group perceived the procedures as more unfair than the control group. This is different from

Table 3
Means and standard deviations/median and interquartile range of subjective state as a function of social stress.

Variable	Control group Mean/Median *(SD/IQR)*	Human social stress Mean/Median *(SD/IQR)*	Machine social stress Mean/Median *(SD/IQR)*
Affect: valence (1-9)	6.57 *(1.57)*	5.93 *(1.89)*	5.71 *(1.92)*
Affect: arousal (1-9)	4.7 *(1.98)*	4.55 *(1.64)*	4.84 *(2.03)*
State anger (1-9)	1.57 *(1.1)*	2.07 *(1.39)*	1.71 *(1.19)*
State self-esteem (20-140)	99.73 *(21.43)*	97.31 *(22.35)*	93.97 *(16.47)*
	*** (Control vs. Human)		
Human interpersonal justice (1-7)	7.00 *(.25)*	6.00 *(1.25)*	7.00 *(1.00)*
Machine interpersonal justice (1-7)	6.10 *(1.4)*	6.00 *(1.09)*	5.88 *(1.45)*
	* (Control vs. Human)		
Procedural justice (1-7)	6.25 *(.75)*	5.75 *(1.25)*	6.25 *(.875)*

Notes: * = $p < .05$; ** = $p < .01$; *** = $p < .001$.

Ötting and Maier (2018), who found no difference in procedural justice following decisions from a human, a robot or a computer system. Logg et al. (2019) found that people tend to accept algorithmic judgment more than human judgment. Participants might have accepted more easily to be removed from the chat by CAMS than by the experimenter.

Contrary to what was hypothesized, social stress did not influence state self-esteem. This is surprising since social stress acting through threats to self-esteem is at the core of the 'Stress as Offense to Self'-approach (Semmer et al., 2019). Additionally, social stress has been found in the literature to influence self-esteem (e.g. (Eatough et al., 2016; Sauer et al., 2021; Schulte-Braucks et al., 2019)). The SOS approach offers a possible explanation for this lack of effect on self-esteem: they hypothesize strategies to protect or restore self-esteem. In case of negative feedback for example, attributing it to a lack of fairness, or justice, of the supervisor may help protect self-esteem (Semmer et al., 2019). This lack of justice was found for the human stress group. Human-induced social stress would then be more threatening than machine-induced social stress, contrary to our hypothesis. In the present study, lower justice might have been a cost of protecting one's self against human-induced social stress. While a protection mechanism against threats to self-esteem appears to be a positive finding, it might have a negative side as well. According to Colquitt et al. (2013), lower justice may, in the long term, decrease positive work behaviour and increase negative work behaviour. The meta-analysis by Gerhardt et al. (2021) also underlines the importance of justice in the work domain, as they found lack of justice to be the social stressor with the strongest effects on attitudinal outcomes such as commitment or job satisfaction.

4.3. Limitations and future studies

Several limitations of this study should be stated: (a) We acknowledge that there are limitations with regard to the manipulation of ostracism used in the present study. It can be argued that the difference between the experimental groups and the control group regarding ostracism was relatively small, considering that participants in the control group were not able to use the chat either. Although it was necessary to prevent participants in the control group from using the chat, which naturally would have biased their performance, this limitation may explain some nil effects found in this study. Even though social stress was also induced using negative feedback, the manipulation could have been stronger with a different operationalization of ostracism. Future research aiming to use ostracism as a social stressor should design the manipulation with particular care. Ideally, future studies should use confederates who actively exclude participants so that the induction of social stress will be stronger. Using ostracism in combination with other social stressors, or repeatedly inducing social stress, are other options to increase the strength of the manipulation. (b) Several subjective variables could only be measured at the end of the experiment. It is possible that some transient effects, such as subjective stress, remained undetected due to the timing of the measurement. Similarly, we did not investigate performance after-effects. Future studies should measure subjective variables during the CAMS simulation (ideally combined with physiological measures), as well as performance after-effects. (c) The cover story used to present some questionnaires as originating from the ethics committee (section 2.4.3), which might have raised less suspicion towards the true purpose of the experiment, might at the same time have biased answers in favour of the experimenters. This could explain the small difference between conditions for the justice variables, which were presented under this cover story. (d) Social stress was only induced on one occasion. Our results do not provide information about the effects of repeated exposure to social stress in the long term. For example, long working hours can increase mental fatigue and lower performance in complex tasks (Chen et al., 2022), which might in turn make operators more vulnerable to social stress. Future research should compare different levels of intensity, frequency and duration of social stressors. (e) We could not use the same medium for social stress induction in both experimental conditions. It is possible this influenced the results in some way (see e.g. Alder and Ambrose, 2005). Future studies comparing human and machines as sources of social stress should aim to control for medium across experimental conditions. It would also be important that future research attempts to measure the 'blank-out', 'rumination' and 'increased motivation' mechanisms postulated in Sauer et al. (2019).

4.4. Implications

Machine-induced social stress having no negative influence on participants could have serious implications, *if* these results were to be replicated. In the perspective of algorithmic management, these results could be seen as encouraging for the practice of delegating management tasks to automation. Indeed, human-induced stress had undesirable effects when machine-induced stress did not. This could be taken as an argument in favour of automation of management and the workplace in general. However, qualitative data from studies with samples of workers in actual platform-based gig work raised many issues with algorithmic management, such as low autonomy, transparency and control over working hours and tasks (Galière, 2020; Griesbach et al., 2019; Huang, 2022; Kellogg et al., 2018; Lee et al., 2015; Rosenblat and Stark, 2016; Uhde et al., 2020). It could be that machine-induced stress has a different effect depending on the type of work and tasks. As discussed above, operating CAMS is cognitively highly demanding, which might help shielding performance from social stress. It could mean that workers in similarly complex work environments (such as nuclear power plant operators, air traffic controllers or other safety-critical domains) might be less sensitive to machine-induced social stress as workers in platform-based gig work. More research is needed before recommendations on the implementation of automation at work could be made with a sufficient level of confidence.

4.5. Conclusion

The landscape of work has evolved and transformed at staggering speed and depth. Automation under different forms is increasingly prevalent in the workplace, and with it come new, complex forms of human-machine interactions able to induce social stress. Increasingly more people earn a living in platform-based gig work, effectively managed by algorithms. This phenomenon is likely to continue its growth and expand to more work settings, affecting more people. It is therefore crucial for research and the field of ergonomics and human factors in particular to better understand the effects of such complex interactions between humans and machines.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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7 General Discussion

7.1 Summary of main results

The main aim of this thesis was to investigate and compare the effects of human-induced and machine-induced social stress on subsequent performance and subjective state. To this end, three studies were conducted using the social stressors ITA, negative performance feedback, and ostracism.

The first study compared two scenarios to manipulate human-induced ITA in the lab. It identified one, namely, cleaning the desk, which was perceived as illegitimate. In this study, ITA did not affect performance but lowered affect and increased procedural injustice. Study two contained two experiments: the first comparing positive to negative human-induced feedback and the second comparing human and machine-induced negative feedback. None of the many performance measures used was impaired following negative feedback. Both human and machine-induced feedback increased anger and lowered affect. Interestingly, machine-induced feedback was perceived as more unfair than human-induced feedback. Study three compared human and machine-induced social stress using a combination of negative feedback and ostracism. This study improved on the previous ones on several levels, thanks to the use of CAMS. However, once again, social stress did not impair any performance measure. This time, justice measures were reduced by human-induced social stress and not by machine-induced social stress.

7.2 Discussion and integration of main results

Following recommendations from Hauser et al. (2018), manipulation checks were added to each study without giving away the purpose of the experiment. Overall, it appears that a considerable degree of confidence can be had in the manipulations of each presented study. In study one, the manipulation check and answers to open questions confirmed that the cleaning scenario was perceived as illegitimate. In the second experiment of study two, negative performance feedback appeared to increase state stress, anger, and negative mood, indicating a successful manipulation. Finally, in study three, which used both negative feedback and ostracism, results indicated that participants did feel ostracized and did perceive the received feedback as negative and relatively stressful.

7.2.1 Performance results

Considering that social stress was successfully manipulated in all experiments, it is surprising that across all studies, for all types of tasks used, not a single measure of performance was impaired by social stress. The results indicate that social stress, whether human or machine-induced, has globally no significant effect on performance. This constitutes a central result of the present work, which differs from some previous findings. For example, the Gerhardt et al. (2021) meta-analysis showed a negative relationship between social stress and performance. This discrepancy with the present results could be due to different methodologies and, more particularly, how performance was measured. In field studies, employees self-reporting their performance might perceive it to be lowered by social stress. At the same time, objective measures (such as in the present work) would reveal no significant differences. The nil results on performance are all the more surprising considering the number and diversity of tasks and measures used across the three studies. As explained in the introduction, the broadband approach that I used involves investigating multiple outcome measures to better understand the effect of social stress. This is why I chose to use several different types of performance tasks. Together, studies one and two used nine different tasks covering an extensive range of cognitive abilities (see Table 8 for a summary of performance measures and results), and study three included four additional performance measures. Sauer et al. (2019) expected the blank-out mechanism to be more strongly associated with safety-critical tasks. The present results may, however, suggest that blank-out happens with tasks that are not safety-critical as well. These results also appear unsupportive of the idea that social stress might have task-dependent effects, as was the case for negative feedback in Van Dijk & Kluger (2011). Despite the considerable number of tasks used across the three studies, social stress's (non-)effect appears to be quite consistent.

Several methodological elements may explain these nil results. In a lab context, performance tasks are highly salient. Participants take part in the experiment only to complete these tasks and have no other activities that may act as distractions, unlike real work contexts. The lab encourages participants to focus on the tasks given to them, which might make it easier to protect performance, even on secondary tasks, arguably less salient than primary ones. Performance tasks are also quite intensive because they already require considerable amounts of cognitive resources to be completed in normal circumstances. This may prevent any impairing effect of social stress from taking place. In Sauer et al. (2019), impaired performance is expected to happen due to rumination about the stressor. Tasks with high cognitive requirements may then block rumination as participants may simply not have the necessary resources to think about the stressor. Gerhardt et al. (2021) also explain that the variance of effects across different experiments of social stress may be due not to the stressor at play but rather to other characteristics such as the number of inductions, duration, or intensity of the stressor. It is possible that these characteristics, as they were used in the present studies, may have mitigated any possible effect of social stress.

Table 8. Summary of effects of social stress on performance measures (comparison to control group).

Study	Performance task	Task component	Effect on performance (Human social stress)	Effect on performance (Machine social stress)
Study 1	*Symbol coding*	-	n.s.	n/m
	Mental arithmetic	Speed	n.s.	n/m
		Accuracy	n.s.	n/m
	Memory span	-	n.s.	n/m
	Attention	Speed	n.s.	n/m
		Accuracy	n.s.	n/m
	Creativity	-	n.s.	n/m
Study 2				
Experiment 1	*Attention*	Speed	n.s.	n/m
		Accuracy	n.s.	n/m
	Backward counting	-	n.s.	n/m
	Symbol coding	-	n.s.	n/m
	Picture completion	Speed	n.s.	n/m
		Accuracy	n.s.	n/m
Experiment 2	*Attention*	Speed	n.s.	n.s.
		Accuracy	n.s.	n.s.
	Convergent creativity	-	n.s.	n.s.
	Divergent creativity	Fluency	n.s.	↑
		Originality	n.s.	n.s.
Study 3	*Parameter control failure*		n.s.	n.s.
	Malfunction diagnosis		n.s.	n.s.
	Reaction time		n.s.	n.s.
	Prospective memory		n.s.	n.s.

Note: n.s. = non-significant result, n/m = not measured, ↑ = performance increase.

Nil effects of stress on performance follow the performance protection mode in the CCM by Hockey (1997) and the blank-out mechanism in Sauer et al. (2019). In the CCM, when demands become too high for the lower level of regulation (such as when under stress), the system may either: increase effort and protect performance, or lower performance targets. Participants in the three studies may therefore have managed to protect their performance from social stress, regardless of the stressor or its source. While it could be reasonably expected that primary performance would be protected from social stress, as per the CCM, it is much more surprising that even secondary performance was unaffected. The CCM predicts costs to performance protection, which may typically be to sacrifice secondary tasks to focus on the primary ones. However, the third study using CAMS showed no effect on the two secondary tasks. While it might be interpreted as participants managing to protect both primary and secondary performance tasks from social stress, there are alternative explanations.

According to the CCM, other possible outcome variables may be subject to the costs of performance protection. One that was measured in the present work is affective responses. In the second experiment of study 2, both human and machine negative feedback increased anger and lowered affect. These reactions may hint at the costs of protecting performance from social stress. However, no such reactions were detected in the other studies. The expected costs may have impacted other variables that were not measured. In the category of instant effects (see Table 3), the outcome variables of task management behavior or psychophysiological state are other possibilities that could not be investigated in the present work. Alternatively, the costs of performance protection may lie as after-effects, be it in performance, subjective state, physiological state, or extra-role behavior. All these outcome variables that were not investigated in the present work should be interesting to include in future research on social stress.

Although no effects of social stress on performance were observed, it could be argued that long-term exposure to social stress may have more negative effects. In the CCM, Hockey (1997) explains that chronic stress can lower the effort budget. A lower effort budget means fewer resources to protect performance from stress when necessary, which should be more likely to lead to impaired performance. It remains to be seen whether the stressors used in the present work may impact performance in the long term. It would be congruent with the idea of Gerhardt et al. (2021) that characteristics of the stressors, such as duration or repeated exposure, influence outcome consequences.

7.2.2 Subjective state results

Another surprising result is that in none of the three studies did social stress impair state self-esteem (see Table 9 for a summary of subjective state measures and results). According to the 'Stress as Offense to Self' approach (SOS), social stress should threaten the self, either personal self-esteem or social self-esteem. Even though the instrument used had three subscales related to both types of self-esteem (performance, social or appearance-related self-esteem), no effects were found on the subscales either. There are several possible explanations for these results. For example, a *threat* to self-esteem does not necessarily result in *impaired* self-esteem, which could explain why no effects were detected on the scale used. Stronger inductions of stress may be required to have a noticeable impact. Alternatively, the student sample may have made it more difficult to find an effect. According to the SOS, people tend to see their professional roles as part of their identity, which is why a threat to this role can be stressful. However, a lab experiment is different from a real professional context. Therefore, it is difficult to say whether students' professional roles were activated and threatened in the experiment context. It seems that stressors such as ostracism, used in study three, could reach beyond the professional role and threaten the self at a more personal level. However, no such effect was detected. The reason might be that self-esteem may be protected from stress, just as performance in the CCM. Semmer et al. (2019) mention that people can "ward off attacks to the self and restore their self-esteem" (p. 225). They may use several strategies to this end, such as derogating others, switching to counterproductive behavior, or making self-serving attributions. Participants may have used such strategies to protect their self-esteem from social stress, for example, in negative feedback, by attributing it to a lack of justice.

Table 9. Summary of effects of social stress on subjective state measures (comparison to control group).

Study	Subjective state measure	Effect on subjective state (HSS)	Effect on subjective state (MSS)
Study 1	*Affect*	↓	n/m
	State self-esteem	n.s.	n/m
	Interpersonal injustice	n.s.	n/m
	Procedural injustice	n.s.	n/m
Study 2			
Experiment 1	*Affect*	n.s.	n/m
	State anxiety	n.s.	n/m
Experiment 2	*Affect*	↓	↓
	State self-esteem	n.s.	n.s.
	Interpersonal justice	n.s.	↓
Study 3	*Affect*	n.s.	n.s.
	State self-esteem	n.s.	n.s.
	Interpersonal justice	↓	n.s.
	Procedural justice	↓	n.s.

Note: n.s. = non-significant result, n/m = not measured, ↑ = score increase, ↓ = score decrease.

It could be argued that one of the main findings of the present work is how social stress and justice appear to be linked. It is remarkable that across all three studies, an effect of social stress on a form of justice was found. In the first study, ITA increased procedural injustice (although not compared to the control group). In study two, interpersonal fairness was lower after machine negative feedback than after human negative feedback. In study three, human-induced social stress caused lower interpersonal and procedural justice compared to the control group. The effects were not always the same and varied between interpersonal and procedural justice or between human and machine-induced social stress. Still, the fact that an effect was found each time gives some confidence that there is a relationship between social stress and justice. As explained in the previous paragraph, this could be seen as a strategy to ward off a threat to the self. Being on the receiving end of ITA, negative feedback, or ostracism, all different forms of relational devaluation, can be quite stressful. Deciding that this is not due to some form of one's own insufficiency but rather to the unfairness of an experimenter or machine might help protect self-esteem. These results do not represent direct evidence that the participants' self was actually threatened but might be interpreted as indirect support of this mechanism and the SOS model.

Interestingly, lack of justice is, in itself, a social stressor. Protecting one's self from social stress by attributing it to a lack of justice may, therefore, have unexpected consequences. Colquitt et al. (2013) showed that lower perceived justice might influence work behavior in the long term, for example, by decreasing organizational citizenship behavior or increasing counterproductive work behavior. In their meta-analysis, Gerhardt et al. (2021) found the same effects on work behavior. Additionally, they found lack of justice to be positively associated with negative emotions, burnout, turnover, and absenteeism, and negatively associated with mental well-being, performance, commitment, and job satisfaction. Overall, lack of justice even was the individual social stressor with the most potent effects. This raises the question of whether using this strategy to protect the self may have worse effects than the original stressor in the first place. This strategy might be efficient in the short term but might have strong side effects in the long term that one should be wary of. A parallel can be made here with the CCM. It could be that just as there are costs to performance protection in the CCM, there might be costs to protection from threats to the self in the SOS.

7.3 Human vs machine-induced social stress

The most original contribution of the present work to the literature was to compare the effects of human and machine-induced social stress. This was done in studies two and three. The results show that, overall, both sources of social stress have very similar effects (or lack thereof). The main lesson from the results is that machines can induce social stress. In study two, participants perceived machine negative feedback as just as stressful as human feedback. When negative feedback was used again in study three, it was perceived as negative and stressful in both human and machine social stress groups. Participants also felt similarly ostracized when social exclusion was induced by a human or by a machine. It appears that machines may induce at least two different social stressors, namely negative performance feedback and ostracism. Due to their increasing use in society and technological progress (Rahwan et al., 2019), it appears likely that machines will induce more social stressors in time. Based on the lists in Gerhardt et al. (2021) or Sauer et al. (2019), I could imagine machines to be able to induce the following stressors: illegitimate task assignment, injustice, incivility, and possibly some forms of mobbing or harassment (see e.g. algorithmic despotism in Griesbach et al., 2019).

Both sources appear to not affect performance, with the exception, in study two, of machine-induced negative feedback increasing performance in a subscale of a divergent creativity task. I could interpret these results in the sense that performance may be protected from machine social stress just as well as from human social stress. If this is the case, it would represent a positive finding for employees in hybrid teams and in gig work with algorithmic management. Human and machine-induced social stress also have similar consequences on affect. In study two, human and machine negative feedback induced a similar amount of anger and negative affect. While in study three, no effect of social stress on anger or affect was observed, this was the case for both sources of social stress. No effect on state self-esteem for both sources was found in studies two and three. In summary, in the present work machine and human-induced social stress had similar effects on performance, affect, and self-esteem. Such results raise the question of to which extent the CCM and SOS models (Hockey, 1997; Semmer et al., 2019), developed for human interactions, also fit human-machine interactions.

Interestingly, differences were found between human and machine-induced social stress in justice measures. In study two, machine social stress was perceived as less fair, while in study three, it was the case for human social stress only. It is difficult to say whether one of these two effects is the "true" one and whether one of these two sources of social stress is actually perceived as less fair than the other. If machine-induced social stress is perceived as less fair overall than its human counterpart, there could be significant implications for the dynamics of automation of the workplace. As explained in the introduction, human resources in some organizations make decisions based on algorithms on whom to hire, fire, promote, or put to work in a team (Gal et al., 2020). If such decisions were perceived as unfair, it could potentially reduce trust or acceptance of such decisions. This could lead to conflicts that may not happen if the same decisions were taken only by humans. In such cases, one could ask whether it would be better for organizations not to communicate that algorithms make decisions. Issues could also arise in algorithmic management when almost all interactions of an employee with management are automated. Such a work environment may therefore increase the perceived lack of justice from the employees, which could, in turn, increase the risks of absenteeism, burnout, or turnover (Colquitt et al., 2013). It should be said, however, that people's perceptions of algorithms can evolve relatively fast. As explained in the introduction of study 2, people might rely more and more on algorithms for several aspects of daily life (Logg et al., 2019; Rahwan et al., 2019). It might be that people that are less used to algorithms perceive them as unfair, but these perceptions evolve with time towards increasing algorithm reliance.

7.4 Implications

At the theoretical level, the results appear to support the CASA theoretical framework. More precisely, the fact that a machine can induce stress and negative affect and be perceived as unfair, just like a human, could support the idea that machines were perceived as social actors by the participants. Interpersonal fairness is particularly relevant since it is about the personal relationship with another person, or in this case, the machine. According to the CASA (Nass et al., 1994; Nass & Moon, 2000; Sundar & Nass, 2000), this would mean that the machines used in studies two and three fulfilled the required criteria to be perceived as social actors, namely exhibiting a sufficient amount of social cues and being considered an autonomous source of communication. I could imagine that a machine has to be perceived first as a social actor for social stress to be induced by a machine. Alternatively, it could be that the machine, as soon as it induces social stress, becomes a social actor. Overall, the results appear to support the CASA paradigm, which is particularly relevant in the context of hybrid teams and algorithmic management. In a context of increasing automation at work, it is essential to realize that a single human working with machines is actually in a hybrid team comprising other social actors.

The main implication of this work for organizations and practitioners is that machine-induced social stress should be avoided as much as human-induced social stress. While machines appear not to be worse than humans as a source of social stress, it is critical to note that they are not better either. Humans tend to see machines as social actors and can have complex work interactions with them. These work interactions can be affected by relational devaluation in the form of social stress, which can have consequences on the human employee, at least at the affective level. Machines and algorithms should therefore be designed to limit the induction of social stress as much as possible. In the case of negative performance feedback, for example, it should be formulated constructively. Rules could also be implemented in algorithms to avoid leaving employees out when forming teams, or to avoid assigning tasks to someone that she or he should not do. This would first require raising awareness about social stress in organizations developing and using such automated tools to design them in a non-stressful way.

7.5 Limitations and future research

The present work has several limitations to consider:

(a) One main limitation concerns the protection of performance from social stress. While this mechanism represents a plausible explanation of the results, it is essential to note that the present work cannot provide direct evidence of performance protection since it was not directly measured. For example, open questions may have helped clarify how social stress was perceived and whether participants felt they had to change something to maintain performance.

(b) The present work covered a limited number of categories of outcome variables (see Table 3). Future research should investigate the remaining categories. These other outcome variables might reveal effects of social stress that could not be detected in the present work, such as the costs of performance protection as predicted by Hockey (1997). Following Sauer et al. (2022), this would include task management behavior and psychophysiological state in the instant effects category. Task management behavior is interesting since, according to Hockey, one might switch strategies in a task to protect performance. In addition, physiological measures such as cortisol or heart rate should be added as objective measures of stress. Then, after-effects outcome variables represent an exciting direction that has not been investigated yet in social stress research. This includes performance, subjective and physiological after-effects, and extra-role behavior.

(c) Using three different stressors, individually or combined, constitutes a strong point of the present work as it varies the induction of social stress. However, it cannot be ruled out that other stressors may have different effects in different directions, even though they all share the same core concept of relational devaluation. Therefore, future research should continue to use different social stressors.

(d) Different variations of social stress induction could have also been used. According to Gerhardt et al. (2021), differences in intensity, duration, or number of social stress induction may influence the effects in various directions. Therefore, the induction of social stress in future studies should be varied accordingly to those criteria, for example to investigate the effects of social stress in the long term.

(e) While the lab setting and the student samples offer several advantages, they also have inherent reduced ecological validity, as the experiments were not done in a workplace with employees. I could imagine more substantial effects when using employee samples since social stress related to their work should be more threatening to their self-esteem.

(f) Finding ways to alleviate the effects of social stress would be crucial. One possibility that should be examined is social support. Since machines can induce social stress, it would be interesting to investigate whether they can induce social support as well, for example via chatbots. It would then be possible to compare the efficiency of human and machine-induced social support in reducing the adverse effects of social stress.

7.6 Conclusion

The main question of this thesis was whether human and machine-induced social stress influence subsequent performance and subjective state and whether they do it differently. Three different studies provided the following answers. First, neither source of social stress impacted subsequent performance. Second, both human and machine-induced social stress had an effect on some subjective state variables, such as affect, stress, or justice. I interpreted these results as possible clues of a performance protection mechanism that bears costs at the subjective state level. I also pointed out that other types of costs of protecting performance may have been undetected. The main message from the present work is that machines can induce social stress, and that social stressors induced by humans and machines can have surprisingly similar effects. The notion that human-machine interactions can be social and possibly stressful should not be overlooked, nor should the harmful potential of machines in the workplace be underestimated. This is particularly crucial in the current context of an increasingly fast and global automation of society. Research on such new forms of social interactions between humans and machines is extremely recent, and there is still much to be investigated on the negative impacts of machines. That said, even less is known about whether interactions with machines may have positive effects, such as providing social support. If we are to live with machines, research has to examine and inform on both sides of the medal.

8 References

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