Social stress in human-machine systems: opportunities and challenges of an experimental research approach

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Abstract

This article presents some deliberations on methodological approaches to researching the effects of work-related social stress on performance, with particular consideration being given to machine-induced social stress. The article proposes a broad methodological approach to examine such effects. A particular focus is placed on performance after-effects (e.g., unscheduled probe tasks), extra-role behaviour, and task management behaviour because of conventional performance measures (i.e. scheduled tasks) often being unimpaired by social stressors. The role of the 'performance protection mode' as an important concept is discussed. A distinction is made between three facets of after-effects: performance-related, behavioural, and emotional. Unscheduled probe tasks and voluntary tasks are proposed to measure performance-related and behavioural after-effects. Propositions for specific experimental scenarios are made, allowing for sufficiently realistic simulations of social stress at work. The availability of such lab-based simulations of work environments offers good opportunities for this line of experimental research, which is expected to gain in importance since highly automated systems may modify the impact of human-induced social stress or may even represent a social stressor themselves. Finally, the considerations presented in this article are not only of relevance to the domain of social stress but to experimental stress research in general.

Keywords: social stress; performance; after-effects; extra-role behaviour; organisational citizenship behaviour; performance protection mode;

Relevance to ergonomics / human factors theory

Based on theory-driven considerations, the present work makes some propositions of how the complex processes associated with social stress in human-machine systems can be examined

in a laboratory-based setting. A number of important concepts are proposed to allow a better assessment of the negative effects linked to different social stressors.

1 Introduction

In the field of ergonomics and human factors, there has been some interest in the topic of social stress (e.g., Demerouti, Veldhuis, Coombes and Hunter, 2019; Kluge, Silbert, Wiemers, Frank and Wolf, 2019; Sauer, Schmutz, Sonderegger and Messerli, 2019). Although social stress is not a recent topic in the field of ergonomics (e.g., Aarås, Horgen, Bjørset, Ro and Thoresen, 1998), this renewed interest may be partly due to the increasing possibility that highly automated machines (or algorithms) rather than humans may be the source of social stress (e.g., Thuillard et al, in press). Machines are expected to take over functions from humans in unprecedented ways, which may also include leadership functions (e.g., Wesche and Sonderegger, 2019) and of decision-making functions (e.g., Langer & Landers, 2021). While a substantial part of research on social stress (and indeed, research on stress in general) is carried out in the field (mainly relying on correlational studies and on using self-report measures), lab-based experimental studies represent an important complement in this research area. Experimental settings allow for a stronger focus on performance and other objective behavioural measures, which are usually difficult to collect in field research. Furthermore, the experimental method allows establishing cause-effect relationships.

The present article aims to propose a broad methodological approach to examine the work-related effects of social stress by means of the experimental method, with a particular emphasis being placed on machine-induced stress. The focus is on performance and work-related behaviours but also after-effects (i.e. effects that only appear after some delay). This article outlines several experimental protocols for social stressors, which may be implemented in experimental studies by adopting a modular approach.

2 The role of social stress at work

Social stressors have been defined as ‘poor social interactions with direct supervisors, co-workers, and others’ (Sonnentag and Frese, 2013, p. 562). Such interactions threaten the need to belong, which can be regarded as a basic human need, as specified, for instance, by Leary and Allen (2011) or by Deci et al (2017). The need to belong is satisfied to the extent to which humans receive messages that they are perceived as ‘likable, competent, attractive, and moral’ (Leary and Baumeister, 2000, p. 17). Thwarting of this need is stressful (Gerhardt et al., 2021; Semmer et al, 2019) and may initiate cognitive evaluative processes that result in lower self-esteem or social esteem (e.g., Gruenewald et al, 2004).

Many different concepts have been advanced that can be regarded as social stressors, such as ostracism (Williams, 2007), incivility (Pearson et al, 2001; Cortina et al, 2017), negative performance feedback (Holbrook, 2002), injustice (Jude and Colquit, 2004), bullying (Einarsen et al, 2020), negative interactions (Tepper and Henle, 2011), mistreatment (Hershcovis, 2011; Nixon et al., 2021), or harassment (Bowling and Beehr, 2006). A compilation of these social stressors may be found in Sauer et al (2019). Many studies have focused on such stressors individually. However, a number of authors noted that these concepts are overlapping and are often hard to distinguish, with many items being rather similar in the different scales assessing the concepts. Accordingly, it has been suggested subsuming them under a common term, such as aggression (Hershcovis, 2011), harassment (Bowling and Beehr, 2006), or disrespect (Lim and Cortina, 2005). In the most

comprehensive meta-analysis so far, Gerhardt et al (2021) showed that the different concepts have indeed much in common and are related to outcomes in a rather similar way. Gerhardt et al suggest using the term 'relational devaluation' (originally proposed by Leary and Allen, 2011), as it denotes the common element of different social stressors very aptly.

A devaluation implies an agent who sends a devaluing message. Although in the typical case this message is sent (or perceived as having been sent) in some social interaction, direct interaction is not necessary. Instead, such messages may also be sent indirectly. Such indirect messages may be found in inadequate job design (e.g., lack of autonomy signals lack of trust, tasks that are considered illegitimate signal disrespect) or in situations in which stress for others is induced by being inconsiderate (e.g., a colleague leaving a paper jam in the printer in the hall, management not providing tools of sufficient quality). Such messages have been investigated in the context of the 'Stress-as-Offense-to-Self' theory (Semmer et al, 2016; Semmer et al, 2019; Semmer et al, 2020).

While the sources and consequences of social stress have mostly been examined in interactions of two or more humans, an agent sending a devaluing message may also be a machine or may be seen in technical devices. For example, if a computer program is difficult to use, operators may blame those who programmed it, or the management who bought it. Through this attribution, the stress induced by the program may be perceived as having a social origin.

To some extent, however, technical devices themselves may be treated as if they were agentic, and humans often 'treat encounters with computers as social encounters' (Moon, 2003, p. 127). For instance, humans expect polite behaviour from technical devices, as shown by research on 'etiquette' (Sheridan and Parasuraman, 2006) in the sense that the system does not disrupt the user, does not give unwanted advice, and does not push for the next step to be taken. Furthermore, people react to technical devices in a way that corresponds to social scripts (theory of social response; Moon, 2003). For instance, they exhibit behaviours such as politeness or reciprocity corresponding to a computer's 'behaviour' (Nass and Moon, 2000), and they blame computers for making mistakes (Moon, 2003). Humans show these behaviours even though they are well aware that they make no sense vis-à-vis a computer, which is why Nass and Moon (2000) argue that such behaviour is not linked to anthropomorphic representation of the automated agent, referring to a 'mindless' application of social rules and expectations to computers.

Based on these considerations, we refer to social stressors as the transmission of a devaluing message. We contend that such messages need not involve direct social interaction but also may be transmitted indirectly (i.e., through actions that violate normative expectations with regard to rules, technical installations, job design, etc.). Furthermore, we contend that reactions induced by such messages (negative emotions, changes in performance) may also occur (though perhaps less strongly) if the message stems from a technical device (Hayes and Miller, 2011). In order to determine to what extent machine-transmitted devaluing messages have a negative effect on performance and well-being, the experiment is an extremely useful method, as it enables conclusions to be drawn about cause-effect relationships. In this regard, an important question is how to manipulate social stressors in an experimental setting and how to assess their consequences.

3 Categories of outcome variables

To measure the effects of social stress at work we propose an enlarged broadband approach. The term 'broadband approach' refers to a concept suggested by Hockey (1983) to distinguish it from the 'narrowband approach' in investigating the effects of stress. A broadband approach essentially means that a number of different outcome variables are assessed. This idea behind the broadband approach will be illustrated by including six different types of outcome variables. This does not mean that the largest possible number of measures is aimed for but rather that the right outcome measure has to be carefully selected within each type of outcome variable. The narrowband approach aims to make a comparison between different stressors (e.g., comparing ostracism, illegitimate tasks and incivilities) with regard to only a small number of outcome variables (e.g., stress hormones, self-reported emotions, or errors in tasks completion). By contrast, the broadband strategy enables gaining a better understanding of a specific stressor by measuring its impact on several groups of variables rather than making a comparison between several stressors. The outcome variables that may be used for the enlarged broadband approach are described in the next section, grouped into different categories.

3.1 Instant effects and after-effects

When examining effects that may ensue from social stress (or indeed from stress more generally), one may distinguish between two main types of effects: *instant effects* and *after-effects*. The two types obviously differ with regard to the moment at which the consequences of stress take effect (i.e. during or following the main task activities). Whereas some outcomes can be instantaneous or delayed (e.g., extra-role behaviour), some kinds of outcome measures are specific with regard to timing. For instant effects, this includes primary and secondary task performance, task management behaviour, subjective operator state, and psychophysiological operator state. For after-effects, this includes performance on tasks that follow (which may be scheduled or unscheduled), extra-role behaviour and emotional after-effects (self-reported affect and observable emotional manifestations).

Instant effects. We employ this term in this article for the sake of making a clear distinction between immediate consequences of stress and the so-called after-effects. Instant effects represent a set of outcome measures that have traditionally been used to measure the effects of stress. Our approach to measure instant effects builds on reflections already provided in earlier work (Sauer, Schmutz, Sonderegger and Messerli, 2019); however, these earlier ideas are considerably extended. We will use the concept 'performance protection mode' to describe a state in which adaptation processes allow the adoption of 'performance protection strategies' (see Hockey, 1996). It essentially describes a regulatory process that allows operators to remain effective when being faced with sub-optimal working conditions. Such regulatory processes have been referred to by Hockey (1997) in his 'model of compensatory control mechanisms'. The underlying idea of the 'performance protection mode' have been referred to by Plessow et al (2011) as the 'shielding of action goals'. Instant effects may then occur with regard to secondary tasks or low-priority aspects of the situation. Once operators have left this performance protection mode, they are more likely to show manifestations of strain, which is reflected in the concept of after-effects.

After-effects. It has been recognised for some time that effects of stress may persist beyond the immediate stress situation (e.g., Cohen, 1980; Frankenhaeuser, 1989; Glass and Singer, 1972; Hockey, 1997; MacEwen, 1998; Meijman and Mulder, 1998). More recently, this issue has been emphasised by authors such as Ganster and Rosen (2013) or Sonnentag (2018). Several mechanisms may be involved in such after-effects. First, extended effort expenditure

may deplete the capacity, and/or the motivation to expend effort, inducing an 'aversion to effort', and a tendency to employ strategies that require less effort but may entail risks (Hockey, 1997). Second, negative affect and the concomitant physiological arousal induced in stress situations cannot simply be 'shut off' but takes time to 'unwind' (Frankenhaeuser, 1989) and thus may persist beyond these situations (e.g., Eatough et al, 2016; Gerhardt et al, 2021; Marsland et al, 2017; Wirtz et al, 2013; Rau et al, 2001). Unwinding may be further prolonged by ruminating about the stressful situation (Blanco-Encomienda et al, 2020; Brosschot et al, 2016; Firoozabadi et al, 2018). In sum, 'when negative activation is high, it is more difficult to gain mental distance to negative events experienced at work' (Sonnentag, 2018, p. 175). Both these processes can have effects in several regards, not least because they affect attention. Once the performance-protection mode is left, its attention-focusing effect ceases, and low-effort strategies become more likely, which foster using shortcuts and employing heuristics rather than an exhaustive search of information. Persisting negative affective states reflect poorer well-being and require attention; they tend to be treated with priority (Matthews and Wells, 1999), and to induce the goal to end or alleviate this state (Gross, 2015; Tamir 2021). Humans therefore tend to be preoccupied with affective states, and the attentional resources focused on them are not available for performance on subsequent action requirements (Beal et al, 2005; Kanfer and Ackerman, 1999). As a result, effects are expected in several areas, such as performance, social behaviour, and affective states in situations following the stress situation.

3.2 Instant effects: outcome measures

Primary and secondary task performance. This refers to the main task activities comprising several tasks with differing priorities. Such a multiple-task environment allows for assessing complex demands on the operator, which includes the flexible allocation of cognitive resources to the different task elements. Performance on primary tasks is often protected due to higher resource allocations (e.g., Hockey, 1997), which makes secondary tasks more vulnerable to high task demands. Therefore, secondary tasks represent a suitable indicator for measuring the effects of sub-optimal working conditions such as social stress on operator strain.

Task management behaviour. In addition to performance measures, there are task-related behavioural measures that provide important information about the manner in which the tasks are carried out (e.g., trial-and-error strategy or systematic exploration as a reflective strategy in task management; Van Der Linden, Sonnentag, Frese and Van Dyck, 2001). These task-related behavioural measures are distinct from performance measures because it often cannot be determined whether one type of behaviour is better than the other. Conversely, for a performance measure it is usually possible to state which of two scores is better. The two main variables measuring task management behaviour in human-machine interaction are *information sampling behaviour* and *control actions* (e.g., how often the operator checks a certain display and how often the operator adopts manual control, respectively). In work environments that are not dominated by human-machine systems, there are equivalent variables, such as the problem-solving strategy adopted. For example, experimental work showed that participants in charge of a fire brigade might adjust their task management behaviour when exposed to noise by moving from an 'analytical' style to a more activity-oriented style, without any impact on performance (Dörner and Pfeifer, 1993). Such adaptation processes are important because they may allow operators to match their way of working to their current operational state. For example, if working memory capacity is reduced, analytic reflections are more difficult, which might induce the operator to move from

a reflective, forward-planning approach to a 'trial-and-error'-approach. Another example refers to operators changing from the system management strategy of 'open-loop control' to one involving 'closed-loop control', with the latter requiring fewer cognitive resources (see Bainbridge, 1978).

Subjective operator state. A number of subjective variables may be of interest in the context of social stress, which may be grouped into variables that are related to the 'social self' and those that assess the general impact of work activities on the operator. Variables related to the 'social self' refer to the defining features of social stress, such as self-esteem (Gruenewald et al, 2004), social esteem (Semmer et al, 2020), affect (Van Katwyk et al, 2000), and self-confidence (e.g. the professional efficacy scale of the Maslach Burnout Inventory; Schaufeli et al, 1996). Outcome measures that assess the general impact of work activities on the operator include workload (e.g., NASA-task load index; Hart et al, 1988; Hart, 2006), fatigue (Van Hooff et al, 2007; Elfering et al, 2021), perceived strain (Semmer et al, 2020), work motivation (e.g., Pindek et al, 2019), and self-efficacy (Schyns et al, 2002). Other variables such as effort expenditure may be related to the type of active task management mode adopted (e.g., an active one by investing cognitive-energetical resources; Hockey, 1997). Finally, outcome variables that assess the subjective operator state also play an important role when verifying whether the experimental manipulation was successfully implemented (e.g., if negative feedback was actually perceived as negative or if an illegitimate task was actually considered illegitimate).

Psychophysiological operator state. The research literature suggests a number of psychophysiological measures to assess the operator state, which may be summarised into indicators of the *endocrine system* (e.g., cortisol), the *peripheral nervous system* (e.g., electrocardiogram, electrodermal activity, electromyography), and the *central nervous system* (e.g., EEG, fNIRS). With regard to indicators of the endocrine system, a considerable amount of work has been published based on the Trier Social Stress Test paradigm (Kirschbaum et al, 1993); it showed that social stress activates the hypothalamic-pituitary-adrenal axis, which can be measured by means of salivary, plasma or serum cortisol, and adrenocorticotrophic hormones (e.g., Kudielka et al, 2007). Further physiological correlates of social stress refer to the peripheral nervous system; they include the variability of cardiac activity using indicators such as heart rate variability (HRV; e.g. Hamidovic et al, 2020; Sonderegger and Sauer, 2009) and respiratory sinus arrhythmia (RSA; e.g., Butler et al, 2006; Lü et al, 2016). A further rather simple but useful way to capture the social stress is electrodermal activity (EDA; Critchley, 2002). Indicators based on facial muscular activity (electromyography, EMG) were also used to record muscular responses to the emotional experience of social stress (e.g. Lundberg et al, 1994). In the third category, recent but less common approaches have been employed to assess social stress by using electroencephalogram (EEG) as an indicator of the central nervous system. Especially interesting for our focus are indications of their potential in combination with computational methods such as machine learning and data mining (Lotfan et al, 2019; Mühl et al, 2014). Finally, functional near-infrared spectroscopy (fNIRS) has shown a link to social stress (e.g. Rosenbaum et al, 2018; Rhee et al, 2017).

3.3 After-effects: outcome measures

Performance after-effects. As discussed above, people often protect performance in primary tasks by compensatory mechanisms. Although this performance protection mode may support performance, fatigue builds up during that process, which implies a growing preference for low-effort strategies (Hockey, 1997). Whereas such tendencies may be warded off for some time by the compensatory mechanisms (see Gollwitzer, 2012), low-effort strategies are likely

to dominate once the performance protection mode is left. Notably focused attention is likely to be lower in subsequent tasks, provided these do not constitute important primary tasks again, which would re-instate the performance protection mode. Lower performance and increased errors therefore should be more likely in tasks that do require attention but are perceived as routine, or as less important, than the original task. In line with these considerations, studies have shown that an increase in fatigue was related to impaired performance in a visual detection and a logical reasoning task (Fan and Smith, 2020). Similarly, Earle et al (2015) showed an effect of fatigue on a fault-finding task. Mental workload has been shown to be related to domestic falls (Elfering et al, 2013) and to risky commuting through cognitive failure (Elfering et al, 2012). Based on these considerations, 'probe tasks' (Hockey, 1997; Earle et al, 2015) that are presented to participants after the experimental task proper, are good candidates for showing such effects. An especially promising option seems to be using 'unscheduled probe tasks', that is, tasks that are presented without prior announcement and that appear as something that can quickly be completed without much attention (e.g., signing a form regarding participation in the experiment that contains some errors; not noticing these errors would be interpreted as an after-effect).

Extra-role behaviour. This group of variables refers to operator behaviour that is not directly related to the main tasks of the operator but refers to a set of activities that are important for the overall functioning of an organisation or a work team. The term 'extra-role behaviour' is used to describe discretionary behaviour that is (or is aimed to be) of benefit to the organisation, going beyond existing role expectations (Van Dyne, Cummings, and Parks, 1995). The term 'organisational citizenship behaviour' (OCB) describes the same phenomenon (e.g., Podsakoff, MacKenzie, Paine and Bachrach, 2000). Extra-role behaviour can be of a proactive and challenging nature but may also be characterised by cooperativeness (Van Dyne, Cummings, and Parks, 1995). Like task management behaviour, extra-role behaviour is considered a behavioural rather than a performance variable because it does not provide an indication of ranking the behaviour in terms of being better or worse. Extra-role behaviour is multidimensional (Carpini and Parker, 2017; Podsakoff et al, 2000; LePine et al, 2002), with the most important aspect in the context of the current paper being helping behaviour (often subsumed under OCB directed towards individuals, or OCB-I). Typical situations that are indicative of helping behaviour are situations in which someone else like a fellow operator is experiencing some difficulties and is offered help, for instance by providing information, by taking over some tasks, or by repairing a device that is not functioning well (e.g., a computer, a printer). Helping behaviour has also been investigated outside the work context (Lefevor, Fowers, Ahn, Lang, and Cohen, 2017). One would expect a reduced tendency to provide help when under stress (De Clercq and Belausteguigoitia, 2020; Eatough et al, 2011). We assume that this effect may continue after the stress situation is over. Confronting a participant with someone who needs help (e.g., someone who has dropped a bag with many items, the collection of which is cumbersome) would be an example, which suggests itself especially after the performance situation proper, as then there is no need to interrupt one's ongoing performance.

Affective after-effects. Affective after-effects include subjective states, psychophysiological states, and affective reactions. Measures for subjective states and psychophysiological states are the same that are discussed with regard to instant effects, as these states are postulated not to 'shut off' immediately but require unwinding. Affective reactions refer to a low threshold for and/or a higher intensity of reactions to frustrations or, as Baumeister et al (2019, p. 501) put it, 'things are bothering more than they usually would'. Thus, confronting participants with a bureaucratic and cumbersome procedure for obtaining the promised reimbursement for

their participation, or provoking them by a derogatory remark should induce an especially strong affective reaction after a stressful period. A typical affective reaction would entail showing anger, possibly combined with a retaliatory remark that characterises incivility (Cortina et al, 2017) or counterproductive work behaviour (Meier and Semmer, 2013).

3.4 Sensitivity of outcome measures

Having described the characteristics of the different categories of outcome variables, we may put forward hypotheses about the level of sensitivity of each outcome variable. Table 1 provides a description of the expected impact of social stress on different outcome variables, based on the literature reviewed by the authors, which is admittedly somewhat subjective in nature. We generally assume psychophysiological variables (providing the suitable ones are selected), subjective state variables (some of them also serving as a manipulation check) and after-effects are most sensitive to the effects of social stress. This is in contrast to performance variables related to the main task environment (in particular, primary task performance), which we would consider to have a lower level of sensitivity. However, it is still useful to measure primary task performance because we may detect the type of changes in task management (e.g., priority reversal) as a particularly maladaptive (but rare) form of responding to stress (e.g., the operator changes the status of the primary task to a secondary task). This reiterates the importance of adopting a broadband approach to measuring the effects of stress in general and social stress in particular.

Table 1: Estimated sensitivity of a selection of key outcome variables regarding the impact of social stress

Outcome variable	Description of expected impact	Key reference
Performance in main task environment		
Primary task performance	Low sensitivity due to performance protection on critical tasks	Hockey (1997)
Secondary task performance	Medium sensitivity due to cognitive-energetical resources being shifted to protect primary task performance	Hockey (1997)
Task management behaviour		
Information sampling behaviour	Medium sensitivity due to choosing less demanding information processing strategies (e.g. cutting corners by discontinuing the sampling of non-critical displays)	Hockey (1997)
System control actions	Medium sensitivity due to adopting a less resource-intensive strategy (e.g., changing from a reflective, forward-planning strategy or a trial-and-error approach)	Hockey (1997)
Subjective state		
'*Social self'-related variables*	High sensitivity because affected variables constitute essential elements of social stress	Gruenewald et al (2004)
General impact variables	Medium sensitivity is generally expected because affective reactions are less correlated in situational reactions, implying more differentiated reactions regarding specific situations	Brose et al (2015)
Psychophysiological state		
Endocrine system	High sensitivity for specific indicators (e.g. cortisol) though collecting such data is difficult, time-consuming and relatively expensive	Kirschbaum et al (1993)
Peripheral nervous system	High sensitivity for specific indicators (e.g. HRV and EDA), which allow for instantaneous and low-complexity collection and analysis of data	Cacioppo et al (2017)
Central nervous system	Possibly acceptable sensitivity levels for certain approaches but often low signal-to-noise ratio	Cacioppo et al (2017)
After-effects		
Performance after-effects	High sensitivity due to having left the performance protection mode	Hockey (1997)
Extra-role behaviour	High sensitivity due to the largely voluntary nature of such behaviour	Podsakoff et al (2000)
Affective after-effects	High sensitivity due to lowered threshold for affective reactions and more intense affective reactions after stressful period has terminated	Meier and Semmer (2013)

3.5 Moderating factors: attribution and individual differences

While we generally consider the outcome measures for after-effects to be sensitive to the effects of social stress, we will now point out the role of attribution and individual differences; both may decrease the manifestation of such effects.

The perception of the social stressor may play an important role. If an operator believes that he/she is the target of social stress due to bad intent (e.g., my fellow operators ignore me because they are sexist or racist) or to carelessness (e.g., leaving a mess for others), he/she will be expected to show less extra-role behaviour ('Why should I be helpful to someone who has not been nice to me?'). Conversely, if an operator believes that he/she is the target of social stress because of previous mistakes or inappropriate behaviour of his/her own, the operator may wish to show extra-role behaviour to compensate (e.g., my teammates have ignored me for some time because I cocked up the team bonus due to a severe error of mine; see Tangney et al, 2007).

Individual differences between operators are to be acknowledged. For instance, narcissism might augment the reaction to perceived devaluation (Meier and Semmer, 2012), and so might neuroticism (Semmer and Meier, 2009), whereas stable high self-esteem might 'immunise' against it (Meier et al, 2009). Furthermore, individuals may differ in their behavioural manifestations with which they respond to social stress, as there are many possibilities to defend the self (Tesser, 2001). For example, some operators may concentrate on the secondary rather than the primary task to maintain the delusion of operational effectiveness (e.g., Trumbo and Milone, 1971). Alternatively, operators may focus on extra-role behaviour rather than work performance to compensate for deficiencies in work performance. We consider the issue of individual differences of being of considerable complexity. We cannot provide a detailed account of this issue in this article, but we wish to emphasise that it needs to be addressed in theoretical as well as empirical work in the future.

4 Development of experimental scenarios

4.1 Using a cover story

When conducting research on social stress, there is usually a need to use some degree of deception (e.g., giving fake performance feedback, dissimulating the real purpose of the experiment) in order to bring participants into a state in which their self-esteem or social esteem is threatened. This usually requires a good cover story (e.g., Brehmer, Leplat and Rasmussen, 1991), which helps putting participants in such a state of mind that they behave in a similar way as they would in a real work environment. If the experimental scenario consists of several elements, the cover story requires a sufficient level of consistency within the experimental protocol.

When examining social stress, administrating subjective state measures may involve the risk of giving away the real purpose of the study. Therefore, it may be problematic to take measurements prior to task completion (e.g., baseline measure of self-esteem before experimental manipulation) without taking some precaution. In particular, if psychology students with considerable experience of being tested take part in such studies, they may start to engage in guessing the real purpose of the study. Therefore, using non-psychology students is advisable.

Certain manipulations of social stress (e.g., illegitimate task assignment, negative performance feedback) may require an assessment of experimenter behaviour by the participant. For example, did the participant perceive the task assigned or the performance feedback given by the experimenter to be appropriate? Posing these questions in the experiment might give away the real purpose of the study. Furthermore, participants might be hesitant to provide an honest answer to such a question because they are concerned that the

experimenter will find out who gave this answer at some point. These problems can be circumvented by informing participants that they will be asked to answer some confidential questions from the ethics committee about experimenter behaviour with a view to verifying the appropriateness of experimenter behaviour in the psychology department. This part of the cover story aims to measure critical variables without revealing the purpose of the experiment, and to obtain more accurate participant ratings of experimenter behaviour.

4.2 Using a modular approach

When designing an experimental scenario to examine social stress, one may make use of a modular approach. This involves combining various elements (some of them may be considered essential, others may be considered optional), which may be treated as separate modules that can be combined with each other. We propose that the following modules may be employed: experimental manipulation, main task scenario, assessment of subjective state, measurement of psychophysiological state, unscheduled probe task, voluntary task, post-experimental provocation, and post-experimental interviewing.

The modules proposed are not implemented in the chronological order in which they are presented in this article. Instead, they may be interwoven to some extent (e.g., subjective measurement is made while the participant has briefly interrupted her main task activity).

4.2.1 Experimental manipulation (Module I)

The main purpose of this module is to implement the experimental manipulation of social stress successfully. Depending on the type of social stressor, this often requires a cover story. For example, social stress cannot be induced by means of negative feedback without deceiving the participant. The intensity of social stress can be manipulated by combining several stressors or by increasing frequency of exposure (for more details, see section 4.6). An important part of this module represents the manipulation check. However, it may have to be measured in a later phase of the experiments rather than immediately following the manipulation to avoid that participants guess the purpose of the study. The manipulation checks usually differ considerably as a function of the social stressor implemented. However, the assessment of self-esteem may be used as a standard manipulation check since the conceptualisation of social stress assumes that self-esteem is being affected.

4.2.2 Performance on main task scenario (Module II)

The scenario may consist of a multiple-task environment (usually a simulation of a technical work environment or a managerial decision-making environment) in which the participant has to complete several activities simultaneously (e.g., system stabilisation and fault rectification). This allows the measurement of both performance and task-related behaviour as important elements for determining instant effects of social stress. Furthermore, it allows a distinction to be made between primary and secondary tasks (i.e. attaching differing priorities to tasks) but also permits the use of a range of different cognitive tasks (e.g., reaction time, prospective memory) to determine differential effects of social stress. An example of such a dynamic multiple-task environment is described in Sauer and Chavaillaz (2018). Alternatively, the main task scenario may also consist of a series of consecutive tasks (e.g., a battery of ability tests), though this approach does not allow gauging task-related behaviour.

4.2.3 Assessment of subjective state (Module III)

Subjective state is typically assessed by means of questionnaires. These are mainly standard questionnaires assessing important concepts. In the context of social stress research, this may include measures of self-esteem (SSES; Heatherton and Polivy, 1991), affect (PANAS;

Watson, Clark, and Tellegen, 1988) and workload (NASA-TLX; Hart and Staveland, 1988; Hart, 2006). However, it is sometimes necessary to develop scales for the purpose of a specific experiment if appropriate standard scales are not available. Such purpose-built scales are particularly required if stressor-specific manipulation checks are to be carried out. Short scales are clearly preferable to avoid having negative effects on participant motivation. In the vast majority of cases, verbal scales are employed but under certain circumstances, pictorial scales may be helpful (Baumgartner et al, 2019). Such states can be assessed before, during, or after the experimental procedure, but they need to be embedded in a plausible cover story.

4.2.4 Measurement of psychophysiological state (Module IV)

Based on Boucsein and Backs (2000) and assuming that emotional demands are strongly associated with social stress, the assessment of indicators of the endocrine system (e.g., cortisol) can be considered a suitable approach. However, their assessment is rather expensive, complex (e.g., measures depend on circadian and hormonal rhythm of participants) and time-consuming (e.g., saliva samples have to be sent to specialised laboratories, which report the results back with considerable time delay). In contrast, recording indicators of the peripheral nervous system is more direct. The indicators based on this data (e.g. tonic and phasic skin conductivity, heart rate variability and respiratory sinus arrhythmia) can be considered relatively simple, inexpensive, instantaneous and robust. In contrast, the assessment of indicators of the central nervous system (e.g., electroencephalogram and functional Near-Infrared Spectroscopy) suffers from a relatively low signal-to-noise ratio despite the availability of inexpensive high-quality technology and open-source software (e.g., OpenBCI, Brainbay). Furthermore, there is an influence of hard-to-control artefacts (e.g., participant movement, muscular activity).

4.2.5 Performance on unscheduled probe task (Module V)

Compared to the main task activities, the unscheduled probe task should generally be of a simpler and more routine nature to make it more vulnerable to lapses of concentration and attention. If the unscheduled probe task were of a critical nature, the operator may return to the ‘performance protection’-mode. For example, if a surgeon is asked to sign a form to discharge a patient after a difficult operation, he/she may not be very attentive to the details of this procedure (is it the right patient, etc.), with an error being easily committed. Conversely, if the same surgeon was called to an emergency after having finished the scheduled operation, he/she is very likely to return to the ‘performance protection’-mode, with full attention being given to the task.

4.2.6 Voluntary task behaviour (Module VI)

This module refers to a set of tasks that allows measuring extra-role behaviour extra-role behaviour (e.g., Van Dyne & LePine, 1998). These tasks are strictly voluntary in nature in that they are not assigned to the participant. This type of task involves either an explicit or an implicit request. The explicit request involves a polite question without putting pressure on the participant (e.g., experimenter asks participants whether he/she would be willing to help). The implicit request puts the participant into a situation that indicates a need to act (e.g., experimenter is in obvious difficulties while the participant is in a position to help). This voluntary task does not provide a measure of performance but rather a behavioural measure representing an indicator of participant engagement or motivation.

We propose a distinction between two types of tasks referring to the degree of reflection being involved. The first type of task refers to ‘spontaneous reactions’, in which the operator has to decide within seconds of what to do. For example, if a fellow operator accidentally drops a

pile of papers that are scattered over the floor, the operator has to decide immediately whether he/she will help pick them up or not. The second type of task refers to 'considered responses', in which the operator has some time to consider his/her way of reacting. For example, a fellow operator asks for some assistance in overhauling an unreliable machine at the following weekend. The research literature has examined both forms of task without making this conceptual distinction. For example, 'spontaneous reactions' were measured in the form of a confederate feigning to have lost a contact lens (Cohen and Spacapan, 1978), the experimenter dropping a stack of books or pens (Porath and Erez, 2007), or by the number of times the participant said 'thank you' when the experimenter opened doors for him or her (DeBono, Shmueli, and Muraven, 2011). 'Considered responses' were examined by asking participants to help an experimenter by pretesting materials to be used for a study (Sherrod and Downs, 1974). The conceptual distinction may be important because the two types may not be vulnerable to the same degree. More specifically, we would expect spontaneous reactions being more sensitive because it is socially more difficult to deny an explicit request rather than ignoring someone's difficult situation, at least as long as the request is within reasonable boundaries with regard to the effort required.

4.2.8 Reactions to post-experimental provocation (Module VII)

As discussed above, humans might react more strongly to additional provocations after a stressful task. Such provocations might consist of having participants to fill in very bureaucratic forms in order to be reimbursed for taking part in the experiment, or a confederate making a derogatory remark, such as 'Are you also one of those people who completed the stupid tasks in that experiment and did not dare to tell them how stupid they were?'. The reactions to post-experimental provocation may be measured by means of observation or questionnaire items.

4.2.7 Post-experimental interviewing (Module VIII)

The post-experimental interview represents the final module in the experimental procedure. It is important because it provides the opportunity to collect qualitative data from participants providing some insight into their perception of the social stressor. A semi-structured interview mainly comprising open questions is employed to identify the participants' attitude towards the social stressor and to understand their reasons for behaving in certain ways. This may include questions such as 'Why were you upset by the behaviour of the machine?' or 'In what way would you have felt different if you had been dealing with a human rather than a machine?'. A major benefit of the data collected in the module is that it allows an easier interpretation of the data collected in the other modules.

4.3 Ethical considerations

When conducting experimental research on social stress, there are obvious concerns about ethical issues surrounding deception of the participant or the risk of the participant being harmed. These concerns limit the strength of the manipulation to a level that is not harmful or may be part of people's daily lives that participants are accustomed to. Indeed, social stressors are part of daily life. This suggests that the exposure to social stress in an experiment is not too dissimilar to what participants may have already experienced (e.g., being socially excluded by fellow workers or fellow students, receiving negative feedback by supervisors or teaching staff, being assigned tasks that they considered to be inappropriate). However, in an experimental setting, stressor intensity has to be kept lower and may not involve high-intensity stressors such as direct insults, even if one has to cope with such events in one's daily life. In addition to limiting stressor intensity, a number of measures can be implemented in the procedure to reduce the risk of participants feeling uneasy after having completed the

experiment. The main measure to achieve this is to offer a detailed debriefing after the experiment has been completed. This should provide full explanation of the real purpose of the experiment, outlining the need to use some degree of deception to obtain important scientific data. This point should be emphasised to the participant by providing good examples. For instance, the experiment could point the importance of knowing about the risk of performance decrements (resulting from being exposed to a social stressor) in safety-critical professions such as an airline pilot during a flight or a surgeon during an operation. If confederates were used (e.g., when simulating ostracism), they should also be involved in the debriefing session to allow for some direct interaction between the participant and the confederates to demonstrate to the participant that the behaviour shown by confederates was part of the experimental procedure rather than being rooted in personal animosity. In the debriefing session, the experimenter needs to make sure that the participant is fine before leaving the laboratory. As a last safety net, the possibility of immediately contacting psychotherapy or counselling services should be arranged so that such an eventuality is catered for. It needs to be stressed that in the view of the authors such an eventuality is extremely unlikely to happen. Generally, it helps to have a sufficient number of dry runs of the experimental protocol, with fellow researchers playing the role of the participant to improve it further with regard to ethical considerations but also concerning the methodological quality of the study. Based on these considerations, it is highly problematic to employ devaluation related to characteristics such as sex, ethnicity, and age, or to use personal insults.

In contrast, it is possible to use messages of devaluation that are of lower intensity. One may distinguish between two types of messages: verbal and behavioural. Both types may be employed in experimental scenarios. Verbal messages are conveyed in negative performance feedback. Of particular interest may be the concept of 'subtly offending feedback' (Krings et al, 2015). This type of feedback is very polite in tone but implies a negative evaluation of the recipient with regard to competence or motivation. Therefore, the type of attribution makes negative feedback offending (Krings et al, 2015). This may include the strategies of 'banalisation' (suggesting that it would have been easy to avoid a given mistake), 'overkill' (dwelling on small mistakes), and 'exaggeration' (exaggerating the possible negative consequences of mistakes). All these strategies imply a lack of competence or diligence, and thus constitute an offense to the operator's self. Another example for a devaluing verbal message is the lack of politeness (or incivility), which may be characterised by using harsh language (Cortina et al, 2017). A final example refers to the concept of 'lack of etiquette' (Hayes and Miller, 2011). This may refer to inappropriate interruptions, 'suggestions' that come across as orders, lack of patience, and lack of explanations. Behavioural messages as the second type are conveyed in the case of ostracism (Williams, 2007), which may involve ignoring a person. Another example of devaluing behavioural messages represents unfair treatment (e.g., allocating resources in an unfair way, a supervisor being less responsive to one operator than all others, or closing a door just as the participant is about to walk through).

Taking these considerations into account, certain social stressors are more likely to be amenable to be implemented in experimental scenarios than others. Table 2 provides an overview of the social stressors referred to in the research literature. The table presents examples of how the stressor can be manipulated in an experimental setting (providing that it is ethically feasible). The result of this evaluation (which is based on the assessment of the authors) proposes a number of promising candidates for experimental manipulations.

Table 2: Examples for inducing social stressors induced by humans and/or machines in an experimental setting

Social stressor	Example for implementation in experiment	Alternative or related concepts	Comments
Ostracism (Williams, 2007)	Two confederates interact with one another while excluding the participant	Social exclusion; rejection (Pereira et al., 2013; Williams, 2007)	
Illegitimate tasks (Semmer et al., 2015)	Participant is requested to make copies of personal documents of the experimenter		
Negative feedback (Holbrook, 2002)	Providing feedback that performance of participant is clearly below average	Negative performance feedback (Holbrook, 2002)	Destructive feedback might violate ethical principles
	Providing feedback that participant's mistake has not yet been observed before on this task	Subtly offending feedback (Krings et al., 2015)	
	Providing feedback that the participant is totally incompetent	Destructive negative feedback (Baron, 1988	
Incivility (Pearson et al, 2001; Cortina et al, 2017)	Rude remarks, such as - dismissing something the participant did or said as nonsense - 'We will now explain it again for everybody who still has not got it' - 'If you really pay attention, you will avoid such mistakes next time' - behaviour by the participant is commented on as 'strange', 'overly sensitive', 'inattentive', etc.	Aggression (in a broad sense, e.g., Hershcovis, 2011) Harassment (Bowling & Beehr, 2006) Negative interactions (Tepper & Henle, 2011) Mistreatment (Hershcovis, 2011; Nixon et al., 2021) Interactional injustice (Judge & Colquitt, 2004) Relational devaluation (Gerhardt et al., 2021)	List of possible behaviours in this domain is almost endless, as long as it is demeaning but of low intensity and not clearly intended to harm the participant
Etiquette (Sheridan & Parasuraman, 2006)	- Participant is asked to work faster - Experimenter comments that participant should already be well doing the next task by now	Conceptual overlap with incivility	
Injustice (Judge & Colquitt, 2004)	A confederate is allocated a much better computer or screen than the participant	Distributive injustice (Judge & Colquitt, 2004)	Interactional injustice may also be classified as incivility
	A confederate is being treated with exceptional politeness, the participant in a neutral and distanced way	Interactional injustice (Judge & Colquitt, 2004)	
	A mistake by a confederate that is comparable to a mistake by the participant is dismissed as only 'minor'	Procedural injustice (Judge & Colquitt, 2004)	
Aggression (in a strict sense; Neuman & Baron, 2005)	Clear insults	Violence	Ethically not feasible in experimental settings, as it implies intent to harm
Bullying (Nielsen et al., 2015)	Any of the behaviours listed above if they are clearly targeted and occur repeatedly over a longer period (i.e. typically for at least 6 months)	Mobbing	Neither practically nor ethically feasible in experimental settings

4.4 Varying the intensity of social stress

If there is a need to increase the intensity of a social stressor while staying within ethically acceptable levels to demonstrate an effect, there may be three principal ways of doing so. (a) Stressors can be combined with each other. Such combinations of stressors may also be encountered in the real world (e.g., targets of ostracism may also be assigned illegitimate tasks; recipients of negative performance feedback may also by ostracised by better performers). There is lab-based research that has successfully implemented combinations of social stressors such as ostracism and negative performance feedback (Sauer, Jeanneret, Smargiassi and Thuillard, 2020). Since we assume the same underlying mechanisms to take effect for all social stressors (i.e. threat to self-esteem and social esteem), it would be possible to test these mechanisms by combining stressors to make them more intense. (b) The intensity of the stressors can be increased horizontally by increasing exposure time. This refers first to the time between the first exposure to the stressor and the debriefing. Furthermore, it refers to the frequency of exposure, which refers to the distinction between single, intermittent and continuous exposure. In single exposure, the stressor may be applied once at the beginning of the experiment (e.g., negative performance feedback is given to participant). In intermittent exposure, the stressor is presented on several occasions during the experiment (e.g., negative

performance feedback is given several times). In continuous exposure, the stressor is continuously present during the experiment (e.g., negative feedback is continuously given on a computer screen showing current performance levels). We assume that the stressor will be experienced in a more intense way when exposure frequency is increased. (c) The intensity of the stressors can be increased vertically (i.e. increase intensity of a single exposure). The three dimensions of manipulating the intensity of the social stressor are considered independent of each other. Since it is difficult to estimate the resulting intensity of the social stressor, empirical testing is required. Overall, the challenge consists of implementing a manipulation of social stress that is sufficiently large to produce an effect but does not put the participant at risk.

4.5 Practical points to consider when manipulating social stress

Based on our previous experience in implementing different types of social stressors in lab-based research, we would argue that it is by no means straightforward to achieve a successful experimental manipulation of social stress. For example, when trying to implement illegitimate tasks, even such manipulations as being asked to produce analyses that subsequently were – visible for the participant – thrown into the dustbin, yielded only very small effects. As illegitimate tasks have frequently been shown to be associated with strain, we attribute such results to a tendency among (psychology) students to accept many, even rather strange, requests when participating in an experiment. The 'demand characteristics' of the experimental situation induce test participants to assume that this request must serve a 'legitimate purpose' (Orne, 1962, p. 777). Careful piloting is therefore required to ensure that tasks are not 'legitimised' in this way. Our research group is currently developing scenarios in which illegitimate tasks are presented in a different context, such as a seminar in which a series of absolutely legitimate tasks, like giving presentations, is unexpectedly followed by an illegitimate task, such as making copies of personal documents for the teaching assistant.

4.6 Concluding considerations

The considerations expressed in this article refer to several issues that are related to the successful implementation of social stress in a laboratory context. Figure 1 provides an overview of the key elements of our methodological approach, indicating how these elements are related to each other. It highlights the possibilities for creating different social stressors (induced by devaluing messages from a human or a machine) in a lab-based context by following the modular approach to create an appropriate cover story while taking into account ethical constraints. In the context of work activities of the human while being (or just having been) exposed to these devaluing messages, a broad assessment of outcome variables is required to detect negative effects of social stressors.

We acknowledge that there also limitations of using a lab-based experimental approach to examine the multiple impact of social stressors despite the many advantages associated with this approach. The intensity of social stress is expected to be higher in the field due to its more natural setting, which makes it necessary to carry out research in real work environments, too. Only the combination of well-designed lab-based simulations of real work in combination with field research will provide advancements in the present research domain.

5 Outlook and conclusion

In the future, we expect that the importance of social stress is going to grow and that increasing automation will not stop or reverse this trend. This is partly due to the increased prevalence of hybrid teams, that is, humans and machines (or algorithms) working very

closely together. We believe that this might increase the frequency of humans being exposed to social stress despite some attempts (which we also very much hope for) to adopt measures to reduce the prevalence of social stress following the knowledge gained from research about its negative impact. For example, one may even envisage scenarios of humans being the victim of sex discrimination by machine algorithms. This may happen when machine algorithms have adopted such practices from observing interactions within human-only teams, in which the team leader assigns more weight to contributions of male team members than female team members.

Future research on social stress may also take into account the positive effects of social support (e.g., Kossek, Pichler, Bodner & Hammer, 2011) by combining the two concepts into the same empirical study. Social support may function as a kind of antagonist to social stress, which makes it a primary intervention to attenuate the effects of stress. Of particular interest is also the potential of machine-based social support (e.g., Bemelmans, Gelderblom, Jonker & De Witte, 2012), which may dovetail well with human and machine-induced social stress.

In this article, we aimed to provide an overview of several relevant issues in the field of work-related social stress. We provided some preliminary answers but also posed new questions. Given the increasing importance of the research topic (which is relevant beyond the domain of work-related social stress), there is a need to carry out more lab-based work making use of the experimental method. This will allow us to measure performance and other behavioural indicators to obtain a fuller picture of instantaneous and after-effects of such stressors. We are well aware that our presentation is limited because we could cover only the most pressing issues. Furthermore, our treatise represents our personal views and many of our assumptions require empirical testing. Nevertheless, we hope the methodological ideas presented in this article may help design such studies and stimulate further deliberation of how to advance the field.

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