Psychological Research
https://doi.org/10.1007/s00426-019-01143-z

ORIGINAL ARTICLE

Socially alerted cognition evoked by a confederate's mere presence: analysis of reaction-time distributions and delta plots

Michael B. Steinborn[1] · Lynn Huestegge[1]

Received: 28 September 2017 / Accepted: 2 January 2019

Abstract

We examined aspects of social alerting as induced through the presence of an attentive but non-evaluative confederate on mental efficiency. To this end, individuals were administered with a chained mental-arithmetic task (levels: low vs. high demand) in two contextual conditions (levels: alone vs. presence). In addition, we examined self-report measures of subjective state for purposes of control. As a result, the presence (vs. alone) condition improved (not hampered) processing speed (while error rate remained low overall), and this effect was differentially more pronounced for high (vs. low) demand. Reaction-time distributional analyses revealed that improvements in average performance actually originated from a selective speeding-up in the slower percentiles, indicating that social alerting promotes stability of information-processing throughput. These results challenge prevalent theoretical notions of mere-presence effects as individuals became consistently faster and less vulnerable to commit attention failure. Our findings indicate that social presence promotes not only processing speed but volitional steadiness.

Introduction

When individuals work continuously in the other's presence, a number of effects (occuring perspicuously) can be attributed to ideas generated on the basis of the other's pure attendance (cf. Bills, 1943; Burnham, 1910). These socially-implied ideas are not overtly communicated but covertly transmitted by either the others, the task, or contextual variables. One such situation is performing in the presence of an audience, which automatically induces the feeling of being evaluated (Guerin, 2009). When this aspect is overcome (e.g., when the individual has adapted to the situation), the audience is likely to turn into a stimulating factor. Other situations are those where individuals' performance is constantly monitored and evaluated by a superior person. For example, Kraepelin's (1902) famous work curve required individuals to perform as many addition-of-two-digits operations as possible within 60 min, and of particular relevance was his observation that supervisory monitoring of subordinates (e.g. psychiatric patients) by a test administrator improved performance speed and reduced performance fluctuations—even in the absence of consequences. Kraepelin concluded that supervisory monitored subordinates who act upon implied ideas are more likely to devote effort to the task than they would in the absence of monitoring (Brewer, 1995; Brewer & Ridgway, 1998; Harkins, 2006). Proceeding from this research, we examined the effect of mere presence on sustained attention in mental arithmetic in normal individuals, with a particular focus on assessing performance variability (cf. Langner & Eickhoff, 2013).

Effects of mere-presence: alerting, distraction, self-referential processing

Basically, the effect of social context is studied by means of an experimental set-up where a control (alone or single-context) condition is compared against a critical (presence or social-context) condition. Depending on the problem being addressed, this set-up is typically referred to as the co-actor paradigm, the audience paradigm or the mere-presence paradigm, depending on whether the focus is on mechanisms underlying competition, evaluation, or simply to study the alerting response imposed by the presence of other (mostly confederate) individuals (cf. Guerin, 2009). Historically, social-context effects were already debated since the late

✉ Michael B. Steinborn
michael.steinborn@uni-wuerzburg.de;
michael.b.steinborn@gmail.com

[1] Psychologie III, Universität Würzburg, Röntgenring 11, 97070 Würzburg, Germany

Published online: 08 January 2019

nineteenth century, mostly in the domains of sports and education. The classic example is the study of Triplett (1898), who observed that cyclists rode faster when racing together than when racing alone. His complete analysis implies that the mechanisms involved are enormously intricate, since not only social facilitation but also inhibition takes place under some circumstances (cf. Guerin, 2009). Another situation is when the others are not competitors but confederates that are merely in the same room (doing the same, similar, or even entirely different work). Allport (1920) examined whether the mere presence of others affects the speed and quality of produced verbal associations; he observed that more associations were produced (though this somewhat at the cost of quality) arguing that individuals' alertness level is increased in the presence of others as compared to when they are alone.

The finding of a sometimes facilitating and sometimes inhibiting influence in the co-actor paradigm on individuals' performance is very prevalent in the early empirical literature. For example, Thorndike (1922) already theorized on the general conditions for efficient learning of mental arithmetic in schoolchildren. Being a teacher, he was particularly interested in ways of providing recommendations for school psychologists concerning social context effects (group- vs. individual work, competitive vs. cooperative work, group size, etc.). In his view, the presence of others might be detrimental for acquisition (learning of new arithmetic facts) but best for the application of acquired competences (strengthening of existing arithmetic facts). Classically, Zajonc (1965) reported that the presence of a confederate (or an audience) facilitated performance on simple tasks but impairs performance on complex tasks. According to Zajonc (1965), even the mere presence of an attentive (but not overtly appraising or critical) confederate seems to be enough to increase the individual's level of alertness and to advance dominant responses. Later on, Manstead and Semin (1980) suggested to expound such performance effects by discerning the modus operandi, suggesting that routine tasks are processed automatically while complex tasks are processed in a controlled fashion. Accordingly, routine tasks are expected to be facilitated while complex tasks are expected to be hampered (cf. Bond & Titus, 1983; Geen & Gange, 1977; Guerin, 2009).

A rather different theoretical perspective was provided by Sanders and Baron (1975), who argued that the presence of a co-actor automatically increases both a state of preparedness to receive ongoing information from their social environment and the readiness to respond to it (cf. Bills, 1943; Burnham, 1910). This means that the presence of others basically promotes attentional focus and is thus expected to globally improve performance. However, a side effect of tonically increased readiness is that it makes the individual also vulnerable to distraction, potentially arising from the onset of events attracting attention or from the informational consequences of these events, irrespective of whether their origin is of physical or social nature (cf. Dolk et al., 2011; Folkard & Greeman, 1974; Hockey, 1997; Liepelt, 2014; Parmentier, 2014; Steinhauser, Maier, & Hübner, 2007). Connected with this aspect, Carver and Scheier (1977) suggested that the presence of an audience (in an evaluative) or a co-actor (in a competitive) context leads to an enhanced self-focus which increases the salience of a behavioral standard stored in memory (cf. Krishna & Strack, 2017; Mussweiler & Strack, 2000; Scheiter, Gerjets, & Heise, 2014; Strack & Deutsch, 2004). Accordingly, interference might potentially arise from two categorical sources, from the act of monitoring and comparing actual performance with an internal standard (or an external standard dictated by the co-actor's performance), and from subsequent self-worth related processes following comparative evaluation (cf. Carver & Scheier, 1982; Gray, 2011; Zajonc & Brickman, 1969, for further theorizing).

Effects on cognition: spare–utilized capacity threading

There is a popular assumption regarding the interplay of mere presence, processing demand, and performance output, along the following lines: The presence of a confederate is capable to elevate arousal, which in turn impacts on the efficiency of information processing and performance. According to the Yerkes–Dodson law, attention is undermined both under low and immoderately high levels of arousal, but there is an optimum somewhere between these extremes, resulting in performance as an inverted-u shaped function of arousal level. Arousal and information-processing demands, as is often argued, interact in a way such that the point of optimal arousal is lower for difficult as compared to easy processing demands, yielding the quintessential finding of a sometimes facilitating and othertimes inhibiting influence of mere-presence on performance. Regrettably, this simple story appears to be untrue. The fundamental problem lies in the complexity of the mechanisms underlying the interplay allying arousal and attention, with regard to the question of why the mild physical arousal imposed by the confederate's mere presence should not spill over into greater mental alertness in complex tasks to the same extent as it does in simple tasks. Thus, while the social-facilitation phenomenon can be accounted for by socially alerted cognition, models based on the arousal notion are on the whole not capable of explaining the social-inhibition phenomenon.

Our reasoning in this section will finally coalesce towards an integrated spare–utilized capacity threading model as a general framework (Steinborn & Huestegge, 2016, 2017). Two aspects are important. Regarding the social-facilitation phenomenon, we take the position that the mild alertness response imposed by mere-presence is globally beneficial (but never detrimental) to performance and worthwhile for both simple and complex versions of a particular task. This means we cannot just simply accept accounts based on the notion of an inverted–u shaped relation between arousal, task complexity and performance. Regarding the social-inhibition phenomenon, we take the position that any observed deterioration of performance can broadly be traced back to two categorical sources, event distraction and self-referential processing (cf. Wells & Matthews, 2015, Chap. 12). Given that these sources thrust their effects on performance not permanently but on some occasions, it follows that any observed performance decrement should originate not from a slowing of relevant processing operations but from an increase in the probability of attentional failure at these critical moments. This means we consider the notion of social-inhibition to be problematic with this respect, as performance should *not constantly* be inhibited but rather *occasionally* affected through distraction. Consequently, any observed decrement in average performance is not interpretable by itself as it potentially originates from increased performance fluctuations and thus requires variability analysis (cf. Steinborn, Langner, & Huestegge, 2017).

From this perspective, one would argue that the mild physical arousal imposed by a confederate's mere presence spills over onto greater mental alertness, supporting the mobilization of capacity. Kahneman (1973) assumes that resources are limited in two essential ways, namely that individuals can punctually engage in only one mental activity (Pashler, 1994), and that the system can run under full tilt only for a short period, which means that there is a limited time span for highly effective processing to be countered by renewed mobilization (Steinborn, Langner, Flehmig, & Huestegge, 2016, 2018). From this view, the term "sustained attention" is a misleading metaphor as attention (and task-relevant expectancies) cannot be sustained per se but must be periodically re-implemented (Langner & Eickhoff, 2013; Langner, Steinborn, Eickhoff, & Huestegge, 2018) and/or updated (Thomaschke, Bogon, & Dreisbach, 2017; Thomaschke & Dreisbach, 2015). If anything, capacity can only metaphorically be sustained, by constantly re-transforming spare to utilized capacity (Steinborn & Huestegge, 2016, 2017). Importantly, Kahneman (1973) distinguishes between the rate of utilized vs. spare capacity (operation vs. monitoring), and the spare–utilized capacity ratio is not constant but varies naturally across trials. Hence, as individuals engage in task operations, spare capacity is conveyed to utilized capacity and the corresponding increase in task focus would lead to a transitory decrease in monitoring. Failure to restart mobilization would thus lead to performance fluctuations; hence, a spare–utilized capacity view offers a natural way to explain fluctuations in continuous performance as reflected in distributional skewness (Steinborn & Huestegge, 2016, 2017).

Present study: non-evaluative confederate monitoring

Our focus here was on the effects of the presence of a (non-evaluative, non-interfering, yet attentive) confederate on aspects of mental efficiency in (easy vs. hard) cognitive arithmetic. Based on the previous considerations, it seemed possible to make a distinction between presently debated mechanisms of how alerting generated by the sole presence of a confederate affects performance. According to a mere–effort account, social alerting increases mental focus and in this way firmly promotes mental concentration. In theoretical terms, it encourages the immediate mobilization (and sustainable maintenance) of processing resources by biasing the ratio between utilized and spare capacity in favour of the former over the latter. From this theoretical vantage point, it can be prognosticated that social alerting globally capacitates efficient information processing through increased focus on goal-directed processing operations at the expense of task-irrelevant processing such as environmental monitoring (i.e., gathering social cues) or self-referential processing (i.e., worrying or mind wandering). Critically, the mere-effort model makes the straightforward prediction that social alerting unequivocally facilitates both automatic and controlled components of information processing. We see no reason why alertness elevated mildly by mere presence of a confederate should have any detrimental effect on hard (relative to easy) mental arithmetic. Henceforward, we expected to observe a corresponding performance improvement in easy (low workload) as well as in hard (high workload) mental arithmetic (Brewer, 1995; Brewer & Ridgway, 1998; Thorndike, 1922).

According to the event–distraction account, as put forward by Baron and colleagues (Baron, Moore, & Sanders, 1978; Sanders & Baron, 1975), the presence of a confederate is assumed to enhance a state of general preparedness, which does not only affect task-relevant processing but also the disposition to receive ongoing information from the social environment and the inclination to respond to it (cf. Eder, Rothermund, & Proctor, 2010; Ohman & Mineka, 2001). In other words, the tonically augmented readiness makes the individual vulnerable to distraction (cf. Folkard & Greeman, 1974). Hence, the presence of distractors could occasionally urge the spare–utilized capacity ratio in exactly the opposite direction on some occasions. Most importantly, the changeover is in favor of (task-irrelevant) environmental monitoring over (task-relevant) running (mental-operation) processes. In other words, the event–distraction account predicts occasionally intensified monitoring at the cost of operating-task processes. However, since the event–distraction account is not very specific with regard to the exact trigger conditions or the occurrence frequency of distractor events, precise predictions cannot be derived from this theorizing. If anything, one might expect a destabilization (due to occasional distractions) as reflected in measures of performance variability, which might be differentially more pronounced for hard (relative to easy) mental arithmetic.

In the present study, we compared individuals' performance in a mixed within-subject design to enable a comparison of two critical experimental conditions, an alone (single-context) condition and a presence (social-context) condition. Decidedly, we investigated the effect of mere presence on both easy and hard mental-arithmetic demand, which served as a proxy for assessing aspects related to automatic and controlled information-processing (or low vs. high workload, respectively). In order to truly meet the conditions specified to study the effect of *mere* presence on performance, we further aimed to minimize any potentiality for social distraction. That is, we took all preventive measures to prevent distraction and/or evaluative cognition (e.g., through fast motions or direct gaze) potentially evoked by the experimenter (e.g., Eder et al., 2010; Gamer, Hecht, Seipp, & Hiller, 2011; Kunde, Weller, & Pfister, 2018, for a wider theoretical background). It was thus indispensable to us to configure the confederate in a way that he/she is observant without at the same time capturing the participant's attention. Put differently, we envisaged to gauge the true effect of confederate monitoring unconfounded by any kind of interference by social or non-social agents, or events, respectively. Thence, our prevailing expectation was in favor of a mere–effort model. We expected to observe that the presence (vs. the alone) condition globally improves processing speed, which should be observed for both easy and hard demand in a similar way, and that this improvement (at least) partially originates from reduced performance fluctuations as revealed by distributional and delta plot analysis (Belletier et al., 2015; Sharma, Booth, Brown, & Huguet, 2010).

Method

Participants

A sample of 80 psychology students (mean age = 22.7 years, SD = 4.7; 82% female) took part in the experiment (40 in experimental group, 40 in control group). Participants were mostly right-handed (96%), in standard (good health) condition, and had normal or corrected-to-normal vision. They obtained credit points for their participation.

Ethical statement

Informed consent was obtained from the participants regarding their agreement with their participation in this research. Our study was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All authors declare that there are no conflicts of interests.

Apparatus and stimuli

The experiment was programmed using Psychopy (2009). Participants sat about 60 cm in front of the screen. To mimic the characteristic (i.e., self-regulated) features of active continuous mental work, we used mental arithmetic as one of the primary cultural techniques (Bills, 1943; Thorndike, 1922), practiced among identifiable cultural groups, and tractable to sophisticated psychometric analysis (Pieters, 1983, 1985; Rasch, 1980; Van Breukelen et al., 1995). Note that mental arithmetic is not merely one of the most important cultural techniques but by nature permits the creation of a substantial number of elementary-trial events. This is an advantage against other commonly used chronometric (RT-based) paradigms. By constrast, there are only four unique trial events in the Erikson flanker task and the Simon task, which are commonly used in similar contexts (e.g., Barker, Troller-Renfree, Pine, & Fox, 2015; Voegler et al., 2018). Over prolonged periods of work, these paradigms are at disadvantage because the participants become prone to monotony and because the unique-trial events are repeated very often. Specifically, we utilized a variant of the mental-addition and verification task including both easy and hard items, using a short response–stimulus interval of 50 ms, which is particularly suitable to examine performance fluctuations (Flehmig, Steinborn, Langner, & Westhoff, 2007; Flehmig, Steinborn, Westhoff, & Langner, 2010; Jentzsch & Leuthold, 2005; Miller & Ulrich, 2013; Notebaert & Soetens, 2006). In each trial, an addition term together with the result is presented and participants indicated whether the outcome is either correct or incorrect. They were instructed to verify a correct result by pressing the right key (right index finger) and to falsify an incorrect result by pressing the left key (left index finger). The task contained easy and difficult items differing with respect to the chain length. Items categorized as easy included simple additions (e.g., $4+5=9$; $4+5=8$) while items categorized as difficult included chained additions (e.g., $4+5+1+2=12$; $4+5+1+2=11$). There were 24 easy items and 24 hard elementary trial events (items) which were presented randomly and equally often, amounting to total of 864 trials.

Automatic and controlled processing components

In the present study, we used easy (chain length = 1) and hard (chain length = 4–5) mental-addition items as a proxy for automatic vs. controlled processing components in a chronometric task using mental arithmetic. It is clear that the use of this nomenclature only makes sense when the context where these terms are employed is also specified (Logan, 1988, pp. 493–495). According to Logan (1988), there are two distinct modes of solving mental-addition problems of this kind, a calculation-based mode and one that is based on memory retrieval. He considered performance as automatic when it is based on single-step, direct-access retrieval of solutions from memory, while he considered performance as controlled when it is based on algorithmic processing mechanisms such as counting, addition, memorizing, or borrowing (Ashcraft, 1992; Groen & Parkman, 1972; Imbo, Vandierendonck, & Vergauwe, 2007). Crucial is that each particular trial is finally solved by either the retrieval or the algorithmic process, which means that in this conception, automatic and controlled processing are conceptualized as categorically dinstinct modes, not as a continuum.

Self-report measures

We administered self-report measures before and after each of the experimental sessions. The Dundee Stress State Questionnaire (DSSQ), developed and psychometrically examined by Matthews et al. (2002), assesses the three fundamental dimensions of subjective state: task engagement, distress, and worry. The instrument has successfully been applied to task situations that comprise a performance context (Helton, Funke, & Knott, 2014; Helton, Matthews, & Warm, 2009; Matthews, Warm, Reinerman-Jones, et al., 2010), and is sensitive to energetical variables such as fatigue and sleep deprivation (Bratzke, Rolke, Steinborn, & Ulrich, 2009; Bratzke, Steinborn, Rolke, & Ulrich, 2012; Steinborn, Flehmig, Westhoff, & Langner, 2010). Here we used the short version of the DSSQ (Helton & Naeswall, 2015) in the German version (Langner, Eickhoff, & Steinborn, 2011; Langner, Steinborn, Chatterjee, Sturm, & Willmes, 2010). The questionnaire consists of 30 items, which assess different facets of mental state on 5-point Likert-type rating scales. We aimed to use these measures to check for potential influences of the critical manipulation on the participants' stress state, particularly engagement and distress. For example, several studies have examined effects of social observation on behavioral and neurophysiological output measures related to social (evaluation) anxiety, demonstrating that the presence of an (oftentimes evaluative) observer elevates levels of stress and discomfort (e.g., Barker et al., 2015; Bartis, Szymanski, & Harkins, 1988; Peterburs et al., 2017; Voegler et al., 2018). Hence, these self-report measures served purposes of control and exploration and might be useful in comparison with other studies on self-reported experience (Helton et al., 2014; Helton et al., 2009; Langner et al., 2010; Matthews & Zeidner, 2012; Shaw et al., 2010; Warm, Parasuraman, & Matthews, 2008).

General design and procedure

The goal of this study was to contrast individuals' performance in an alone (single-context) and a present (social-context) experimental condition. The experimental group went through the experimental blocks in a way that enabled both a within-subject and a between-subject comparison (ABABA, with A = alone and B = confederate present), and so that the length of these blocks (i.e., the number of trials) are equal for both conditions. The control group went through exactly the same experimental blocks, however, they were only administered with the alone condition (AAAAA, with A = alone). This configuration of two (experimental vs. control) groups and experimental blocks (ABABA vs. AAAAA) allowed for a combined within-subject and between-subject comparison at exactly the same block positions. It further permits the control of several potential confounds and ancillary conditions.

Experimental protocol

The following research protocol was applied for the *experimental group*: The participant was first welcomed and assigned to the laboratory room. Then he/she was first administered with the pre-task DSSQ. Before the start of the session, the experimenter instructed the participant in the usual manner, that is, to respond as fast and accurately as possible. Then the participant was administered with the experimental conditions (ABABA, A = alone, B = present), and then he/she was administered with the post-task DSSQ. At the end of the entire experiment, the participant was informed about the goals of this study but was committed to maintain in confidence what has happened in this experiment. The protocol for the *control group* was basically the same except that the participants were not administered with any presence condition but instead with the alone condition throughout (AAAAA).

Implementation of the mere-presence condition

In order to meet the definition of the effect of the mere presence of a confederate, we used the experimenter as confederate, not a previously unknown person. In some way, recruiting the experimenter is the most proper way of experimentally manipulating a "mere-presence" condition because the attitude towards the experimenter is relatively neutral, although directed towards compliance with the instruction of the experiment. We admit that the issue of what constitutes a neutral confederate has been debated since the beginning of the twentieth century and a final solution is not in sight so far. (1) We explicitly aimed to minimize event distraction by intrusive events that may capture attention too strongly and thus are capable of interrupting ongoing task activity. We further aimed to minimize any transmission of social cues that might be capable of activating self-discrepancies (e.g., social comparison), which in turn activate self-referential processing (cf. Wells & Matthews, 2015, Chap. 12). Note that under these circumstances, the participant is likely to be in a state of public rather than private self-focus, so that attention to social cues is particularly enhanced, as for example, was the case in the study of Conty et al. (2010). (2) In the alone condition (block A), the experimenter went out of the room so that the participant was alone in the laboratory room, while in the presence condition (block B), the experimenter remained in the room (sitting on the same large table next to the participant, reading a study book). This was not further explained to the participant since we decided not to use any cover story to justify the presence condition as was used in previous research (cf. Sharma et al., 2010, p. 54). Instead, we aimed to keep the situation as natural as possible and to avoid any disruption of situational flow. (3) During the experimental trials, the confederate was reading a book but occasionally (about every 30 s, the confederate was trained beforehand) looked around and at the participant, then continued reading.

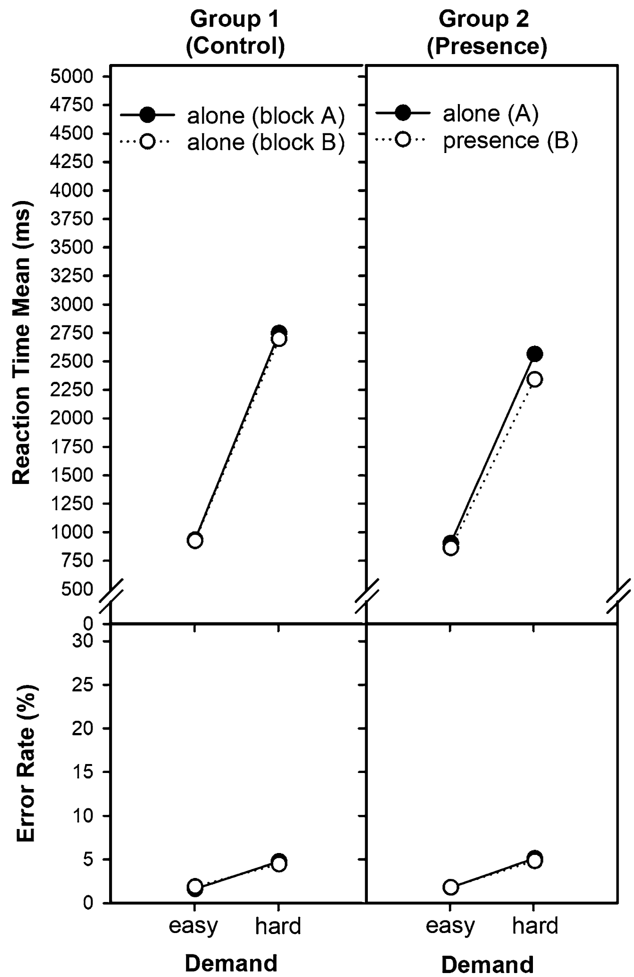

Fig. 1 Reaction time mean (RTM) and error rate (ER) as a function of the factors group (controls vs. presence), social context (alone vs. presence), and demand (easy vs. hard) in speeded mental arithmetic

Results

Data treatment

Incorrect responses were defined errors and correct responses shorter than 100 ms were defined outliers and discarded from RT analysis. Since our hypotheses implied an analysis of the entire RT distribution, specific criteria were applied to excessively long respones. We only used a smart trimming method by relegating the two slowest reactions for each of the experimental conditions, according to the recommendation of Ulrich and Miller (1994). For each experimental condition, we calculated the reaction time mean (RTM) from the correct responses to index average response speed and the RT coefficient of variation (RTCV) to index relativized response-speed variability, according to Flehmig et al. (2007) and in line with our previous use of this method (Steinborn & Huestegge, 2016, 2017). RTCV is a classic measure of intra-individual performance variability and computed by dividing the standard deviation of response times of an individual by the mean of response times of that individual in a particular experimental condition. Error percentage (EP) indicated the rate of incorrect responses (Fig. 1).

Distributional analysis

To analyze the distribution of responses, we estimated the vincentized interpolated cumulative distributive function (CDF) of responses with 19 percentiles for each of the experimental conditions according to Ulrich et al. (2007), and in conformity with our own and others previous use of this method. We would like to caution the reader at this point not to confuse our method with the ranked-RT bins approach, which is a simplified way of looking at the slowest and fastest parts of an RT distribution, often used in clinical and applied-research contexts. By contrast, we adopted a more intricated psychometric technique, utilizing a 5% percentile-point cumulative distributive function with equally spaced probabilities (resulting in 19 obtained percentiles of

Table 1 Mean reaction time (RT) and error percentage (EP) as a function of the factors "social context" and "processing demand", separately for group 1 and group 2 (control vs. experimental)

Factor levels			Group 1				Group 2			
	Context	Demand	RTM (ms)		EP (%)		RTM (ms)		EP (%)	
			M	CI	M	CI	M	CI	M	CI
1	1	1	935	50.8	1.63	0.44	906	50.8	1.80	0.44
2	1	2	2748	195.9	4.78	1.14	2565	195.9	5.15	1.14
3	2	1	925	50.2	1.91	0.59	862	50.2	1.82	0.59
4	2	2	2699	192.0	4.48	1.36	2343	192.0	4.85	1.36

N = 80; RTM = reaction-time mean; EP = error rate (%); *M* and *CI* are population parameters

05, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95), following accepted standards for percentile estimation (cf. Gilchrist, 2000). To provide a brief description, assume that a sample $[x_1, x_2, x_3, \ldots, x_n]$ of n RTs has been collected in a certain experimental condition for a given participant. In a first step, the RTs were ordered to obtain step-function estimates which are then used to calculate a corresponding cumulative-frequency polygon. Then, by means of linear interpolation, new polygons are generated between adjacent (neighbouring) midpoints until the cumulative frequency can directly be read off for any value of this function. Finally, percentiles are estimated separately for every participant and every experimental condition $[p_{\mathrm{i}} = (i - 0.5)/np$, for $i = 1, \ldots, np]$. By means of this method, we were able to know whether the observed effects on mean RT were due to a generic slowing of all responses or alternatively due to a selective slowing of the long percentiles of the CDF. We adopted an ex-Gaussian model to our data according to the methodical rules provided by Lacouture and Cousineau (2008), interpreting μ as an indicator of central tendency (i.e., processing speed) and τ as an indicator of variability (i.e., attentional lapsing) in terms of distributional skewness. Note that we utilized the ex-Gaussian model only as a descriptive model to adequately address the characteristics of empirical RT distributions, following previous theoretical considerations (Heathcote, Popiel, & Mewhort, 1991; Schwarz, 2001; Steinhauser & Huebner, 2009).

Experimental effects on RTM

The three-factorial GLM mixed within-subject design contained the factors group (control vs. experimental), block type (A vs. B), and demand (easy vs. hard). Complete statistical results are referred to in Table 1. The main effect of the factor group is not independently interpretable (only in interaction with the factor block type) and not further considered. The main effect of the factor demand indicates that performance was faster for easy than for hard mental-arithmetic $[F(1,78) = 870.8,\ p < 0.001]$, and served as manipulation check. The main effect of the factor block indicates that performance became globally faster with repeated testing $[F(1,78) = 90.3,\ p < 0.001]$. Critically, the group × block interaction effect $[F(1,78) = 36.6,\ p < 0.001]$ indicates that this speed-up was relatively more pronounced for the experimental (vs. the control) group. There was a group × block × demand interaction effect $[F(1,78) = 18.9,\ p < 0.001]$, indicating that the relative advantage of the experimental group (vs. controls) in the critical block comparison tended to be differentially larger for hard than for easy mental-arithmetic demand. In sum, these findings indicate that performance became faster (not slower) through mere presence, and this effect occurred both for easy and hard demand. Notably, error rate remained low overall and there were no effects on error rate that could compromise any interpretation.

Experimental effects on variability indices

Complete statistical results are referred to in Tables 1 and 2. The main effect of the factor demand on RTCV indicates that performance was less variable for easy than for hard mental-arithmetic $[F(1,78) = 206.7,\ p < 0.001]$. There was a main effect of the factor block type on RTCV $[F(1,78) = 44.2,\ p < 0.001]$ and a group × block type interaction effect on RTCV $[F(1,78) = 16.4,\ p < 0.001]$, indicating an effect of mere presence not only on average response speed but on response-speed variability. No group × block × demand interaction effect on RTCV was observed. There was a main effect of the factor block type on the ex-Gaussian τ parameter $[F(1,78) = 36.1,\ p < 0.001]$ and a group × block type interaction effect ex-Gaussian τ $[F(1,78) = 7.5,\ p < 0.01]$. There was only a tendency towards a group × block × demand interaction effect on the ex-Gaussian τ parameter.

Supplemental analyses

For purposes of control, we performed a supplemental GLM analysis, comparing performance of the control group with the experimental group at exactly the same block positions

Table 2 Results of the global mixed within-subject GLM: experimental effects of the factors group, block type, and demand on speeded mental arithmetic performance

	Source	*df*	RTM			EP			RTCV		
			F	*P*	η^2	*F*	*P*	η^2	*F*	*P*	η^2
1	Group	1,78	3.7	0.059	0.05	0.1	0.704	0.00	2.2	0.140	0.03
2	Block type	1,78	90.3	0.000	0.54	0.3	0.596	0.00	44.2	0.000	0.36
3	Demand	1,78	870.8	0.000	0.92	68.1	0.000	0.47	206.7	0.000	0.73
4	Group × block	1,78	36.6	0.000	0.32	0.2	0.659	0.00	16.4	0.000	0.17
5	Group × demand	1,78	3.8	0.054	0.05	0.2	0.649	0.00	0.3	0.582	0.00
6	Block × demand	1.78	46.5	0.000	0.37	2.2	0.209	0.65	0.4	0.551	0.01
7	Group × block × demand	1,78	18.9	0.000	0.19	0.2	0.666	0.00	0.3	0.593	0.00

Effect size: partial η^2; experimental factors: group (controls vs. experimental), block type (A vs. B), Demand (easy vs. hard mental arithmetic)

RTM reaction time mean, *EP* error percentage, *RTCV* relativized reaction time standard deviation

Table 3 Results of the global mixed within-subject GLM on ex-Gaussian parameters: experimental effects of the factors group, block type, and demand on speeded mental arithmetic performance

	Source	*df*	Mue (μ)			Sigma (σ)			Tau (τ)		
			F	*p*	η^2	*F*	*p*	η^2	*F*	*p*	η^2
1	Group	1,78	1.1	0.303	0.01	0.2	0.627	0.00	4.6	0.035	0.06
2	Block type	1,78	0.0	0.888	0.00	0.1	0.735	0.00	36.1	0.000	0.32
3	Demand	1,78	803.9	0.000	0.91	326.7	0.000	0.81	268.5	0.000	0.78
4	Group × block	1,78	1.4	0.244	0.02	0.3	0.575	0.00	7.5	0.008	0.09
5	Group × demand	1,78	0.5	0.490	0.01	0.1	0.743	0.00	5.5	0.022	0.07
6	Block × demand	1.78	0.0	0.879	0.00	0.1	0.794	0.00	16.1	0.000	0.17
7	Group × block × demand	1,78	1.04	0.311	0.01	0.0	0.829	0.00	3.0	0.090	0.04

Effect size: partial η^2; experimental factors: group (controls vs. experimental), block type (A vs. B), Demand (easy vs. hard mental arithmetic). Mue (μ) = parameter of central tendency; Sigma (σ) = parameter of dispersion (around the mean); Tau (τ) = parameter of skewness

[i.e., A**A**A**A**A vs. A**B**A**B**A][1]. The two-factorial *between-subject* design contained the factors group (alone vs. presence) and demand (easy vs. hard). The main effect of the factor group on RTM [$F(1,78) = 6.6$, $p < 0.05$] indicates that responses were globally faster for the presence (vs. alone) condition. The group × demand interaction effect on RTM [$F(1,78) = 6.5$, $p < 0.05$] indicates that this effect was differentially larger for hard than for easy items (Tables 3, 4). Error rate was low overall and is not further considered.

Self-report measures

We collected pre-task and post-task measures of subjective state for purposes of control and for exploratory purposes (Table 5). Of particular relevance is the main effect of the factor time on task (TOT) on task engagement [$F(1,78) = 6.2$, $p < 0.05$], and on worry [$F(1,78) = 4.3$, $p < 0.05$], indicating a decrease in the former and a slight increase in the latter (Fig. 4; Table 6).

Discussion

Summary

The mere presence of a confederate yielded a speed-up of mental-arithmetic performance while error rate remained

[1] One reviewer was curious of whether the performance in mere-presence (A) blocks is influenced by their mixing in alone (B) blocks. If participants maintain their focus in a more stable way in B blocks due to the presence of the experimenter, what do they do in the A blocks in between B blocks? The reviewer speculated that the exercising of effort and the resulting benefit in a mere-presence (A) block could potentially have yielded costs in the subsequent alone (B) block. In response to this request, we performed an extensional GLM analysis, comparing RT performance in alone (A) blocks immediately after a presence (B) block in the experimental group with exactly the same (A) block position in the control (AB**A**B**A** vs. AA**A**A**A**) group. The result of this extensional analysis does not indicate that the participants relax their performance (or are even depleted) after a presence condition. Quite the contrary, participants were relatively faster (not slower) after a mere-presence block (i.e., BA sequence) as compared to after an alone block (i.e., AA sequence, $p < 0.01$). This indicates that attentional control settings are affected by effort mobilization (not resource depletion) due to social alerting. Admittedly, the precise mechanism underlying this after effect cannot be determined here. Future research might elucidate whether this effect originates from (1) a simple carry-over of attentional-control settings, or alternatively, (2) from the individual's mental representation of "pure potentiality" of a confederate's presence (cf. Krishna & Strack, 2017, pp. 152–158; Kurzban, Duckworth, Kable, & Myers, 2013, pp. 663–667). We do, however, want to make it quite clear that this aspect of our study is exploratory and requires further study in future research. Hence, we will not further expand on this issue at this point.

Table 4 Results of the between-subject GLM analysis: effects of the factors context (group: alone vs. presence) and demand (easy vs. hard) on speeded mental arithmetic performance

	Source	*df*	RTM			EP			RTCV		
			F	*P*	η^2	*F*	*P*	η^2	*F*	*P*	η^2
1	Context	1,78	6.6	0.012	0.08	0.1	0.806	0.00	6.3	0.000	0.96
2	Demand	1,78	802.8	0.000	0.91	37.7	0.000	0.33	166.2	0.000	0.68
3	Context × demand	1,78	6.5	0.013	0.08	0.3	0.611	0.00	0.1	0.752	0.00

Effect size: partial η^2; experimental factors (between-subject): context (group: alone vs. present), demand (easy vs. hard mental arithmetic)

RTM reaction time mean, *EP* error percentage; *RTCV* relativized reaction time standard deviation

Table 5 Results of the between-subject GLM analysis on ex-Gaussian parameters: effects of the factors context (group: alone vs. presence) and demand (easy vs. hard) on mental arithmetic performance

	Source	*df*	Mue (μ)			Sigma (σ)			Tau (τ)		
			F	*p*	η^2	*F*	*p*	η^2	*F*	*p*	η^2
1	Context	1,78	1.6	0.215	0.020	0.5	0.507	0.01	8.1	0.000	0.80
2	Demand	1,78	684.6	0.000	0.90	250.6	0.000	0.76	188.3	0.000	0.71
3	Context × demand	1,78	0.9	0.351	0.011	0.1	0.706	0.00	7.4	0.000	0.09

Effect size: partial η^2; experimental factors (between-subject): context (group: alone vs. present), demand (easy vs. hard mental arithmetic)

Table 6 Results of the mixed within-subjects GLM analysis: effects of context (group: alone vs. present) and time on task (pre-test vs. post-test) on the fundamental dimensions of subjective state

	Source	*df*	Task engagement			Distress			Worry		
			F	*p*	η^2	*F*	*p*	η^2	*F*	*p*	η^2
1	Group	1,78	6.4	0.014	0.08	1.9	0.171	0.02	0.1	0.832	0.00
2	TOT (pre–post)	1,78	6.2	0.015	0.07	1.2	0.272	0.02	4.3	0.042	0.05
3	Group × TOT	1,78	0.8	0.363	0.01	4.2	0.043	0.05	0.8	0.769	0.00

Effect size: partial η^2; experimental factors: context (group: alone vs. present), time on task (TOT: pre-test vs. post-test)

low overall. This speed-up was relatively larger for hard than for easy items, indicating that socially alerted cognition enhanced not only automatic (chain length = 1, low workload) but also controlled information processing (chain length = 4–5, high workload). Both the global as well as the demand-specific improvement in average performance speed originated partly from a stabilization of performance consistency. An extensional analysis revealed that the presence (vs. the alone) condition considerably decreased distributional skewness (i.e., it reduced mental lapsing). In addition, we assessed self-report measures of subjective state (engagement, distress, and worry), which have previously been applied to similar task situations comprising a performance context (Helton et al., 2014; Helton et al., 2009; Matthews, Warm, Reinerman-Jones, et al., 2010). We were particularly interested in the assessment of task engagement which, according to Matthews et al. (2010), represents a mode of adaptation to task demand signaling a commitment to the investment of effort on task performance (i.e., the readiness for impending intensive attention). Task engagement (motivation) declined over the experimental session. This is also in line with the metaphorical idea that resources (and experienced motivation as a phenomenological by-product) are depleted after immoderate use (Hagger, Wood, Stiff, & Chatzisarantis, 2010; Inzlicht & Schmeichel, 2012; Muraven & Baumeister, 2000; Schmeichel, 2007).

Methodological issues

At the first glance, the present findings seem unusual given that the theorizing in this domain still adheres to the opinion that easy tasks are facilitated while more difficult tasks should be hampered by the mere presence of others. Notwithstanding, the majority of studies does not provide any substantial evidence to support this claim as empirical findings provide a rather inconsistent picture. Whereas several studies have found evidence for both positive and negative effects of social context on aspects of performance, oftentimes weak or even absent effects have been reported (Bond & Titus, 1983; Geen & Gange, 1977; Guerin, 2009, for a review of findings). An obvious reason for the divergence of empirical findings might lie in the great heterogeneity of context, design, and the implementation of critical means and measures. Moreover, there are substantial methodological weaknesses and inadequacies of many reported studies in this domain (cf. Guerin, 2009). In some studies, for example, there was no clearly defined "alone" condition since the experimenter was constantly present in the laboratory, and the "presence" condition was manipulated by an additional (i.e., a redundant third-party) person as part of a cover story (e.g., Sharma et al., 2010). Other studies used arbitrary tasks and/or unreliable or unaudited performance measures (cf. Kiesel et al., 2010; Koch, Poljac, Müller, & Kiesel, 2018, for a methodologically oriented tutorial), or simply an insufficient number of trials (cf. Miller & Ulrich, 2013; Rothermund & Wentura, 2010, pointing on this critical aspect). For example, task difficulty was often conceptualized in terms of demonstrable categories that *only seem to* reflect aspects of automatic vs. controlled processing but were actually completely different with respect to underlying processes.

We predict that the present results could easily be replicated and even extended as far as a few but critical methodical rules are considered, which in the following will be discussed. *First*, a mandatory requirement in mere-presence studies is to configure the confederate in a way that he/she is attentive without simultaneously capturing the participant's attention too strongly and too often (cf. Brewer & Ridgway, 1998; Guerin, 2009). The confederate in this situation is *per definitionem* neither overtly competitive nor evaluative, which, of course, can never be guaranteed. This means that one can never be certain that socially relevant information is not implicitly transmitted by either the confederate, aspects of task demand, or context (cf. Ashcraft & Kirk, 2001; Gray, 2011; Oatley & Johnson-Laird, 1987; Scheier & Carver, 1977). *Second*, the task must be applicable to a mere-presence condition. It is possible that the task itself is capable to trigger evaluative tendencies within the participant (cf. Brewer, 1995; Brewer & Ridgway, 1998). For example, any kind of problem-solving tasks that require a single solution obtained by sudden insight is likely to induce evaluative tendencies within the participant because it enables instantaneous feedback about success or failure in an all-or-none style (Ashcraft & Kirk, 2001; Beilock & Carr, 2001). *Third*, the task must allow for a reliable performance measurement. This condition is routinely met for most of the chronometric paradigms, provided that sufficient trials are collected, and that performance can precisely and adequately be measured (cf. Miller & Ulrich, 2013; Steinborn et al., 2018).

Fourth, and connected with the previous aspect, it is important that exactly those aspects of performance are registered and interpreted which are subject of theorizing, given that the event–distraction account clearly implies a methodology beyond measures of central tendency. At present, only two studies have addressed this important point in mere-presence research by additionally assessing performance variability via distributional and delta-plot analyses (Belletier et al., 2015; Sharma et al., 2010). We would like to nudge the reader at this intersection point that our theorizing is based on the idea that socially alerted cognition should be reflected in a reduction of attentional fluctuations as indicated by reduced distributional skewness, which was the case for both easy and hard mental-arithmetic demand. Without considering distributional shape, effects on average performance speed cannot be interpreted appropriately (Steinborn et al., 2017; Ulrich, Schroeter, Leuthold, & Birngruber, 2015). *Fifth*, task difficulty (easy vs. hard items) must be spaced as far apart as possible (cf. Miller & Ulrich, 2013). In general, a mere-presence condition can effectively be implemented for most of the cultural techniques (e.g., reading, writing, arithmetic), given that task demand is manipulated within the same task (not between different tasks that are regarded as either easy or difficult), and further, it is desireable that the difficulty conditions can flexibly be contrasted, as is the case for versions of a mental-arithmetic paradigm.

Theoretical implications

In the contemporary literature on social-context effects on cognition, two competing machinery are currently reviewed as to their wherewithal and legitimacy to explain social facilitation and inhibition phenomena, which are put forward here as the mere–effort model and the event–distraction account. Given these theoretical positions, our results are markedly in support of the former but in opposition to the latter, since from the former, an amelioration in both speed and steadiness is predicted (cf. Steinborn et al., 2017). This exactly occurred in our study. On top of that, the presence (vs. the alone) condition yielded a response speed-up for both easy and hard mental arithmetic, which was even more pronounced for the hard (vs. the easy) demand condition. From the vantage point of a spare–utilized capacity threading model of sustained-attention performance, this pattern is perfectly in line with the mere–effort model; however, it is completely at odds with the event–distraction account, since the former prognosticates an enhanced focus on operating processes at the cost of environmental monitoring, while the latter portends the opposite at least during moments of distraction. The CDF analysis corroborates this position (Fig. 2), denoting that individuals' performance became faster through an increase in steadiness (i.e., a reduction in attentional fluctuations), apparent in the right tail of an empirically observed RT distribution (Steinborn et al., 2016, 2018).

This imparts implications as to the actual mechanism underlying social-context effects on cognition, as information processing did not singly "speed-up" but rather "stabilized" processing throughput (Humphreys & Revelle, 1984; Steinborn et al., 2018; Szalma & Teo, 2012; Thorne, 2006).

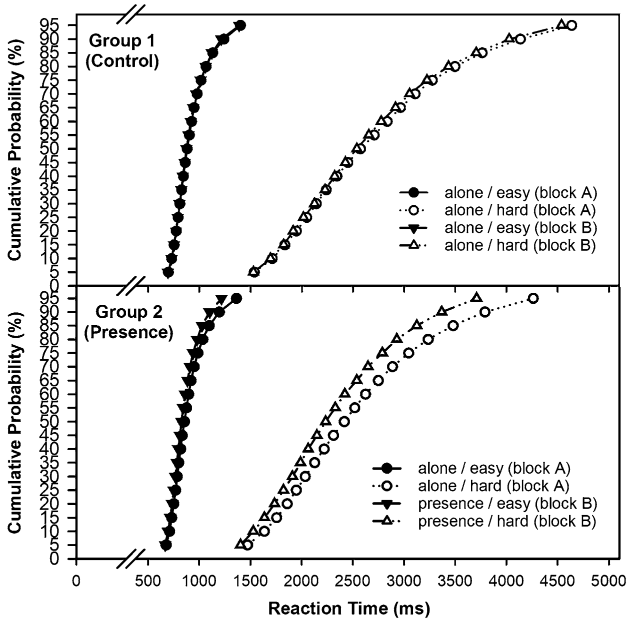

Fig. 2 Vincentized interpolated (percentile-point) cumulative distributive function (CDF) of reaction times for each combination of the factors group (controls vs. presence), social context (alone vs. presence) and demand (easy vs. hard) in speeded mental arithmetic

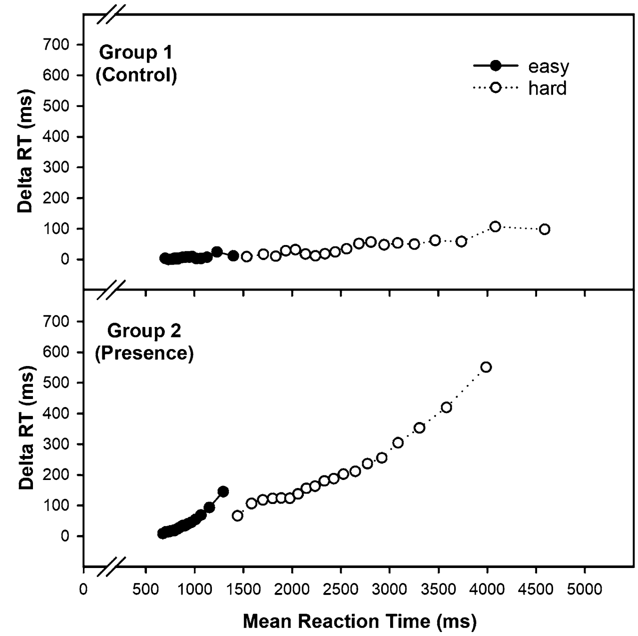

Fig. 3 Delta plot of the mere-presence effect as a function of the factor demand (easy vs. hard) in speeded mental arithmetic, comparably displayed for the control and the experimental group

Note that any decrement on RT mean is not interpretable by itself if the effect emerges from a selective speed up of responses at long CDF percentiles (cf. Miller, 2006, p. 93), given that this selective speed-up is beyond mere-scaling variability (Ulrich & Miller, 1994; Wagenmakers & Brown, 2007). It becomes apparent from Fig. 2 that the experimental conditions (alone vs. presence) are not vastly different at short CDF percentiles while their difference increase remarkably towards long percentiles. Figure 3 displays a delta plot of the mere-presence effect, comparably for the control group vs. the experimental group. This is obtained by plotting the RT difference (for each percentile) as induced by a critical manipulation (condition A vs. B) against the mean of both conditions for each of the percentiles (De Jong, Liang, & Lauber, 1994; Ridderinkhof, 2002; Ulrich et al., 2015). By this means, the effects of social context can be evaluated for each percentile relative to the mean level of performance, signalling that individuals were not decidedly faster overall but more persistent. This demonstrates that delta plots provide an expedient streamlining of the relatively intricate information presented in the CDFs (Schwarz & Miller, 2012, 2014).

Taken together, the important message that our study delivers is that the presence of an attentive not overtly evaluative confederate during continuous mental arithmetic does not only unambiguously improve information-processing speed (rather than hamper performance during high-demand processing), but rather makes participants more reliable and less susceptible to attention failure. In this way, our results are in line with the findings of Sharma et al. (2010) who showed that the presence of a confederate reduces interference in the color-word (Stroop) conflict task in terms of both speed and variability. However, Sharma et al. argued that social facilitation is expected to occur only in situations where the preparatory interval (i.e., the foreperiod) is predictable and optimal in length (RSI = 1000 ms) but not in self-paced situations (RSI = 32 ms). The authors argued that efficient attentional control in the latter (32 ms) situation is impossible since participants are prevented from adequately preparing for the imperative moment (Harkins, 2006; Huestegge, Pieczykolan, & Koch, 2014; Huguet, Galvaing, Monteil, & Dumas, 1999; Klauer, Herfordt, & Voss, 2008; Steinborn et al., 2017; Wühr & Huestegge, 2010), thwarting any benefit of social presence on performance. Our results argue against this claim, both on theoretical grounds (cf. Steinborn & Langner, 2011; Steinborn & Langner, 2012) and by presenting evidence for social facilitation (not inhibition) in self-paced (RSI = 50 ms) speeded mental arithmetic, both for easy and hard demand. In this way, our study contributes to the understanding of effects of mere presence on cognition (Fig. 4).

Final conclusion

The key contribution of our study comprises two aspects, methodology of design and experimental set-up, and

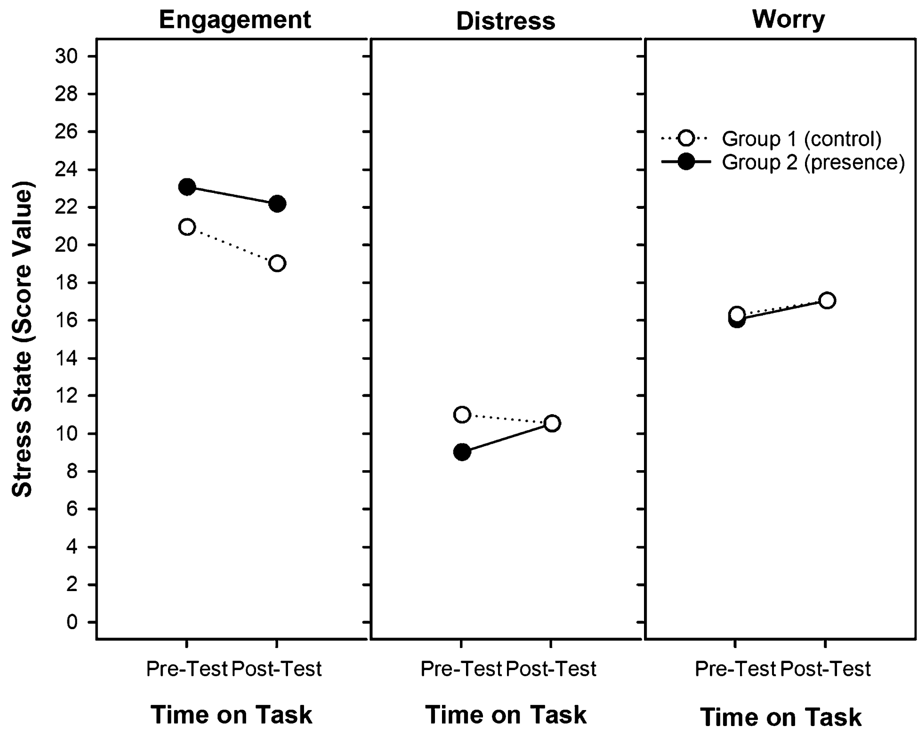

Fig. 4 Fundamental dimensions of subjective stress state (task engagement, distress, and worry) as a function of the factors group (controls vs. experimental) and time on task (pretest vs. posttest)

advanced measurement technology. The foremost important goal was to manipulate social presence largely unbiased from any potential instances of event distraction (by social or non-social agents) and self-referential processing (evaluation and comparison activities, worrying) and gauging hypothesized effects with high precision by analyzing the entire RT distribution instead of only analyzing RT means (Belletier et al., 2015; Sharma et al., 2010). This is a clear progress compared to previous studies in this domain. Our results imply that the mere presence of a confederate amplifies an individual's alertness, and by this means, the capability of attaining and maintaining a state of enhanced mental efficiency, as indicated by improvements of processing speed and volitional steadiness. These improvements were observed for both easy and hard mental-arithmetic demand, indicating that componential aspects related to automatic and controlled information-processing are improved (not hampered) by socially alerted cognition. Thus, a particular key characteristic of our study might be that of creating connections between cognitive-experimental and social-psychological research along the concept of a spare–utilized capacity threading model to explain performance variability. In subsequent research, we aim to work out the specific mechanism underlying the mobilization of exceptional effort related to social alerting, considering important interaction variables and contextual conditions.

Acknowledgements We would like to thank the following student research assistants for help with data collection at our lab: Julia Böhme, Kristina Stanzel, Laura Heubeck, Viktoria Dueck, Wiebke Herter.

Compliance with ethical standards

Informed consent Informed consent was obtained from the participants regarding their agreement with their participation in this research.

Ethical standards Our study was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Conflict of interest All authors declare that there are no conflict of interests.

References

Allport, F. H. (1920). The influence of the group upon association and thought. *Journal of Experimental Psychology, 3*, 159–182. https://doi.org/10.1037/h0067891.

Ashcraft, M. H. (1992). Cognitive arithmetic—A review of data and theory. *Cognition, 44*(1–2), 75–106. https://doi.org/10.1016/0010-0277(92)90051-i.

Ashcraft, M. H., & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. *Journal of Experimental Psychology: General, 130*(2), 224–237. https://doi.org/10.1037/0096-3445.130.2.224.

Barker, T. V., Troller-Renfree, S., Pine, D. S., & Fox, N. A. (2015). Individual differences in social anxiety affect the salience of errors in social contexts. *Cognitive Affective & Behavioral*

Neuroscience, 15(4), 723–735. https://doi.org/10.3758/s13415-015-0360-9.

Baron, R. S., Moore, D., & Sanders, G. S. (1978). Distraction as a source of drive in social facilitation research. *Journal of Personality and Social Psychology, 36*, 816–824. https://doi.org/10.1037/0022-3514.36.8.816.

Bartis, S., Szymanski, K., & Harkins, S. G. (1988). Evaluation and Performance: A two-edged knife. *Personality and Social Psychology Bulletin, 14*(2), 242–251. https://doi.org/10.1177/0146167288142003.

Beilock, S. L., & Carr, T. H. (2001). On the fragility of skilled performance: What governs choking under pressure? *Journal of Experimental Psychology: General, 130*(4), 701–725. https://doi.org/10.1037/0096-3445.130.4.701.

Belletier, C., Davranche, K., Tellier, I. S., Dumas, F., Vidal, F., Hasbroucq, T., & Huguet, P. (2015). Choking under monitoring pressure: Being watched by the experimenter reduces executive attention. *Psychonomic Bulletin & Review, 22*(5), 1410–1416. https://doi.org/10.3758/s13423-015-0804-9.

Bills, A. G. (1943). *The psychology of efficiency: A discussion of the hygiene of mental work*. New York: Harper & Brothers Publishers.

Bond, C. F., & Titus, L. J. (1983). Social facilitation—A meta-analysis of 241 studies. *Psychological Bulletin, 94*(2), 265–292. https://doi.org/10.1037/0033-2909.94.2.265.

Bratzke, D., Rolke, B., Steinborn, M. B., & Ulrich, R. (2009). The effect of 40 h constant wakefulness on task-switching efficiency. *Journal of Sleep Research, 18*(2), 167–172. https://doi.org/10.1111/j.1365-2869.2008.00729.x.

Bratzke, D., Steinborn, M. B., Rolke, B., & Ulrich, R. (2012). Effects of sleep loss and circadian rhythm on executive inhibitory control in the Stroop and Simon tasks. *Chronobiology International, 29*(1), 55–61. https://doi.org/10.3109/07420528.2011.635235.

Brewer, N. (1995). The effects of monitoring individual and group-performance on the distribution of effort across tasks. *Journal of Applied Social Psychology, 25*(9), 760–777. https://doi.org/10.1111/j.1559-1816.1995.tb01774.x.

Brewer, N., & Ridgway, T. (1998). Effects of supervisory monitoring on productivity and quality of performance. *Journal of Experimental Psychology: Applied, 4*(3), 211–227. https://doi.org/10.1037/1076-898X.4.3.211.

Burnham, W. H. (1910). The group as a stimulus to mental activity. *Science, 31*, 761–767.

Carver, C. S., & Scheier, M. F. (1982). Control theory—A useful conceptual framework for personality, social, clinical, and health psychology. *Psychological Bulletin, 92*(1), 111–135. https://doi.org/10.1037//0033-2909.92.1.111.

Conty, L., Gimmig, D., Belletier, C., George, N., & Huguet, P. (2010). The cost of being watched: Stroop interference increases under concomitant eye contact. *Cognition, 115*(1), 133–139. https://doi.org/10.1016/j.cognition.2009.12.005.

De Jong, R., Liang, C. C., & Lauber, E. (1994). Conditional and unconditional automaticity: A dual-process model of effects of spatial stimulus-response correspondence. *Journal of Experimental Psychology: Human Perception and Performance, 20*(4), 731–750. https://doi.org/10.1037/0096-1523.20.4.731.

Dolk, T., Hommel, B., Colzato, L. S., Schutz-Bosbach, S., Prinz, W., & Liepelt, R. (2011). How “social” is the social Simon effect? *Frontiers in Psychology, 2*, 84. https://doi.org/10.3389/fpsyg.2011.00084.

Eder, A. B., Rothermund, K., & Proctor, R. W. (2010). The prepared emotional reflex: Intentional preparation of automatic approach and avoidance tendencies as a means to regulate emotional responding. *Emotion, 10*(4), 593–598. https://doi.org/10.1037/a0019009.

Flehmig, H. C., Steinborn, M. B., Langner, R., Scholz, A., & Westhoff, K. (2007). Assessing intraindividual variability in sustained attention: Reliability, relation to speed and accuracy, and practice effects. *Psychology Science, 49*, 132–149.

Flehmig, H. C., Steinborn, M. B., Langner, R., & Westhoff, K. (2007). Neuroticism and the mental noise hypothesis: Relation to lapses of attention and slips of action in everyday life. *Psychology Science, 49*, 343–360.

Flehmig, H. C., Steinborn, M. B., Westhoff, K., & Langner, R. (2010). Neuroticism and speed-accuracy tradeoff in self-paced speeded mental addition and comparison. *Journal of Individual Differences, 31*(3), 130–137. https://doi.org/10.1027/1614-0001/a000021.

Folkard, S., & Greeman, A. L. (1974). Salience, induced muscle tension, and ability to ignore irrelevant information. *Quarterly Journal of Experimental Psychology, 26*(3), 360–367. https://doi.org/10.1080/14640747408400425.

Gamer, M., Hecht, H., Seipp, N., & Hiller, W. (2011). Who is looking at me? The cone of gaze widens in social phobia. *Cognition & Emotion, 25*(4), 756–764. https://doi.org/10.1080/02699931.2010.503117.

Geen, R. G., & Gange, J. J. (1977). Drive theory of social facilitation—12 years of theory and research. *Psychological Bulletin, 84*(6), 1267–1288. https://doi.org/10.1037//0033-2909.84.6.1267.

Gilchrist, W. G. (2000). *Statistical modelling with quantile functions*. Boca Raton: Chapman & Hall/CRC.

Gray, R. (2011). Links between attention, performance pressure, and movement in skilled motor action. *Current Directions in Psychological Science, 20*(5), 301–306. https://doi.org/10.1177/0963721411416572.

Groen, G. J., & Parkman, J. M. (1972). Chronometric analysis of simple addition. *Psychological Review, 79*(4), 329–343. https://doi.org/10.1037/h0032950.

Guerin, B. (2009). *Social facilitation*. Cambridge: Cambridge University Press.

Hagger, M. S., Wood, C., Stiff, C., & Chatzisarantis, N. L. D. (2010). Ego depletion and the strength model of self-control: A meta-analysis. *Psychological Bulletin, 136*(4), 495–525. https://doi.org/10.1037/a0019486.

Harkins, S. G. (2006). Mere effort as the mediator of the evaluation-performance relationship. *Journal of Personality and Social Psychology, 91*(3), 436–455. https://doi.org/10.1037/0022-3514.91.3.436.

Heathcote, A., Popiel, S. J., & Mewhort, D. J. K. (1991). Analysis of response time distributions—An example using the Stroop task. *Psychological Bulletin, 109*(2), 340–347. https://doi.org/10.1037/0033-2909.109.2.340.

Helton, W. S., Funke, G. J., & Knott, B. A. (2014). Measuring workload in collaborative contexts: Trait versus state perspectives. *Human Factors, 56*(2), 322–332. https://doi.org/10.1177/0018720813490727.

Helton, W. S., Matthews, G., & Warm, J. S. (2009). Stress state mediation between environmental variables and performance: The case of noise and vigilance. *Acta Psychologica, 130*(3), 204–213. https://doi.org/10.1016/j.actpsy.2008.12.006.

Helton, W. S., & Naeswall, K. (2015). Short stress state questionnaire factor structure and state change assessment. *European Journal of Psychological Assessment, 31*(1), 20–30. https://doi.org/10.1027/1015-5759/a000200.

Hockey, G. R. J. (1997). Compensatory control in the regulation of human performance under stress and high workload: A cognitive-energetical framework. *Biological Psychology, 45*(1–3), 73–93. https://doi.org/10.1016/S0301-0511(96)05223-4.

Huestegge, L., Pieczykolan, A., & Koch, I. (2014). Talking while looking: On the encapsulation of output system representations.

Cognitive Psychology, 73, 72–91. https://doi.org/10.1016/j.cogpsych.2014.06.001.

Huguet, P., Galvaing, M. P., Monteil, J. M., & Dumas, F. (1999). Social presence effects in the stroop task: Further evidence for an attentional view of social facilitation. *Journal of Personality and Social Psychology, 77*(5), 1011–1025. https://doi.org/10.1037//0022-3514.77.5.1011.

Humphreys, M. S., & Revelle, W. (1984). Personality, motivation, and performance—A theory of the relationship between individual-differences and information-processing. *Psychological Review, 91*(2), 153–184. https://doi.org/10.1037/0033-295x.91.2.153.

Imbo, I., Vandierendonck, A., & Vergauwe, E. (2007). The role of working memory in carrying and borrowing. *Psychological Research Psychologische Forschung, 71*(4), 467–483. https://doi.org/10.1007/s00426-006-0044-8.

Inzlicht, M., & Schmeichel, B. J. (2012). What is ego depletion? Toward a mechanistic revision of the resource model of self-control. *Perspectives on Psychological Science, 7*(5), 450–463. https://doi.org/10.1177/1745691612454134.

Jentzsch, I., & Leuthold, H. (2005). Response conflict determines sequential effects in serial response time tasks with short response-stimulus intervals. *Journal of Experimental Psychology: Human Perception and Performance, 31*(4), 731–748. https://doi.org/10.1037/0096-1523.31.4.731.

Kahneman, D. (1973). *Attention and effort*. London: Prentice Hall.

Kiesel, A., Steinhauser, M., Wendt, M., Falkenstein, M., Jost, K., Philipp, A. M., & Koch, I. (2010). Control and interference in task switching—A review. *Psychological Bulletin, 136*(5), 849–874. https://doi.org/10.1037/a0019842.

Klauer, K. C., Herfordt, J., & Voss, A. (2008). Social presence effects on the Stroop task: Boundary conditions and an alternative account. *Journal of Experimental Social Psychology, 44*(2), 469–476. https://doi.org/10.1016/j.jesp.2007.02.009.

Koch, I., Poljac, E., Müller, H., & Kiesel, A. (2018). Cognitive structure, flexibility, and plasticity in human multitasking—An integrative review of dual-task and taskswitching research. *Psychological Bulletin, 144*, 557–583.

Kraepelin, E. (1902). Die Arbeitskurve [the work curve]. *Philosophische Studien, 19*, 459–507.

Krishna, A., & Strack, F. (2017). Reflection and impulse as determinants of human behavior. In P. Meusburger, B. Merlen & L. Suarsana (Eds.), *Knowledge and action, knowledge and space* (pp. 145–167). Berlin: Springer.

Kunde, W., Weller, L., & Pfister, R. (2018). Sociomotor action control. *Psychonomic Bulletin & Review, 25*(3), 917–931. https://doi.org/10.3758/s13423-017-1316-6.

Kurzban, R., Duckworth, A., Kable, J. W., & Myers, J. (2013). An opportunity cost model of subjective effort and task performance. *Behavioral and Brain Sciences, 36*(6), 661–679.

Lacouture, Y., & Cousineau, D. (2008). How to use MATLAB to fit the ex-Gaussian and other probability functions to a distribution of response times. *Tutorials in Quantitative Methods for Psychology, 4*(1), 35–45.

Langner, R., & Eickhoff, S. B. (2013). Sustaining attention to simple tasks: A meta-analytic review of the neural mechanisms of vigilant attention. *Psychological Bulletin, 139*(4), 870–900. https://doi.org/10.1037/a0030694.

Langner, R., Eickhoff, S. B., & Steinborn, M. B. (2011). Mental fatigue modulates dynamic adaptation to perceptual demand in speeded detection. *PLoS One, 6*(12), e28399. https://doi.org/10.1371/journal.pone.0028399.

Langner, R., Steinborn, M. B., Chatterjee, A., Sturm, W., & Willmes, K. (2010). Mental fatigue and temporal preparation in simple reaction-time performance. *Acta Psychologica, 133*(1), 64–72. https://doi.org/10.1016/j.actpsy.2009.10.001.

Langner, R., Steinborn, M. B., Eickhoff, S. B., & Huestegge, L. (2018). When specific action biases meet nonspecific preparation: Event repetition modulates the variable-foreperiod effect. *Journal of Experimental Psychology: Human Perception and Performance*. https://doi.org/10.1037/xhp0000561.

Liepelt, R. (2014). Interacting hands: The role of attention for the joint Simon effect. *Frontiers in Psychology, 5*, 1462. https://doi.org/10.3389/fpsyg.2014.01462.

Logan, G. D. (1988). Toward and instance theory of automatization. *Psychological Review, 95*(4), 492–527. https://doi.org/10.1037//0033-295x.95.4.492.

Manstead, A. S. R., & Semin, G. R. (1980). Social facilitation effects: Mere enhancement of dominant response? *British Journal of Social and Clinical Psychology, 19*, 119–136. https://doi.org/10.1111/j.2044-8260.1980.tb00937.x.

Matthews, G., Campbell, S. E., Falconer, S., Joyner, L. A., Huggins, J., Gilliland, K., et al. (2002). Fundamental dimensions of subjective state in performance settings: Task engagement, distress, and worry. *Emotion, 2*(4), 315–340. https://doi.org/10.1037//1528-3542.2.4.315.

Matthews, G., Warm, J. S., Reinerman, L. E., Langheim, L. K., & Saxby, D. J. (2010). Task engagement, attention, and executive control. In *Handbook of individual differences in cognition* (pp. 205–230). New York: Springer.

Matthews, G., Warm, J. S., Reinerman-Jones, L. E., Langheim, L. K., Washburn, D. A., & Tripp, L. (2010). Task engagement, cerebral blood flow velocity, and diagnostic monitoring for sustained attention. *Journal of Experimental Psychology: Applied, 16*(2), 187–203. https://doi.org/10.1037/a0019572.

Matthews, G., & Zeidner, M. (2012). Individual differences in attentional networks: Trait and state correlates of the ANT. *Personality and Individual Differences, 53*(5), 574–579. https://doi.org/10.1016/j.paid.2012.04.034.

Miller, J. (2006). A likelihood ratio test for mixture effects. *Behavior Research Methods, 38*(1), 92–106. https://doi.org/10.3758/bf03192754.

Miller, J., & Ulrich, R. (2013). Mental chronometry and individual differences: Modeling reliabilities and correlations of reaction time means and effect sizes. *Psychonomic Bulletin & Review, 20*(5), 819–858. https://doi.org/10.3758/s13423-013-0404-5.

Muraven, M., & Baumeister, R. F. (2000). Self-regulation and depletion of limited resources: Does self-control resemble a muscle? *Psychological Bulletin, 126*(2), 247–259. https://doi.org/10.1037//0033-2909.126.2.247.

Mussweiler, T., & Strack, F. (2000). The "relative self": Informational and judgmental consequences of comparative self-evaluation. *Journal of Personality and Social Psychology, 79*(1), 23–38. https://doi.org/10.1037/0022-3514.79.1.23.

Notebaert, W., & Soetens, E. (2006). Sustained suppression in congruency tasks. *Quarterly Journal of Experimental Psychology, 59*(1), 178–189. https://doi.org/10.1080/17470210500151360.

Oatley, K., & Johnson-Laird, P. (1987). Towards a cognitive theory of emotions. *Cognition and Emotion, 1*, 29–50.

Ohman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review, 108*(3), 483–522. https://doi.org/10.1037//0033-295x.108.3.483.

Parmentier, F. B. R. (2014). The cognitive determinants of behavioral distraction by deviant auditory stimuli: A review. *Psychological Research Psychologische Forschung, 78*(3), 321–338. https://doi.org/10.1007/s00426-013-0534-4.

Pashler, H. (1994). Overlapping mental operations in serial performance with preview. *Quarterly Journal of Experimental Psychology, 47A*(1), 161–191. https://doi.org/10.1080/14640749408401148.

Peirce, J. W. (2009). Generating stimuli for neuroscience using PsychoPy. *Frontiers in Neuroinformatics, 2*, 10. https://doi.org/10.3389/neuro.11.010.2008.
Peterburs, J., Voegler, R., Liepelt, R., Schulze, A., Wilhelm, S., Ocklenburg, S., & Straube, T. (2017). Processing of fair and unfair offers in the ultimatum game under social observation. *Scientific Reports, 7*, 44062. https://doi.org/10.1038/srep44062.
Pieters, J. P. M. (1983). Sternberg additive factor method and underlying psychological processes - Some theoretical considerations. *Psychological Bulletin, 93*(3), 411–426. https://doi.org/10.1037/0033-2909.93.3.411.
Pieters, J. P. M. (1985). Reaction time analysis of simple mental tasks: A general approach. *Acta Psychologica, 59*, 227–269. https://doi.org/10.1016/0001-6918(85)90046-0.
Rasch, G. (1980). *Probabilistic models for some intelligence and attainment tests*. Chicago: The University of Chicago Press.
Ridderinkhof, K. R. (2002). Micro- and macro-adjustments of task set: Activation and suppression in conflict tasks. *Psychological Research Psychologische Forschung, 66*(4), 312–323. https://doi.org/10.1007/s00426-002-0104-7.
Rothermund, K., & Wentura, D. (2010). It's brief but is it better? An evaluation of the brief Implicit Association Test. *Experimental Psychology, 57*(3), 233–237. https://doi.org/10.1027/1618-3169/a000060.
Sanders, G. S., & Baron, R. S. (1975). Motivating effects of distraction on task performance. *Journal of Personality and Social Psychology, 32*(6), 956–963. https://doi.org/10.1037//0022-3514.32.6.956.
Scheier, M. F., & Carver, C. S. (1977). Self-focused attention and experience of emotion—Attraction, repulsion, elation, and depression. *Journal of Personality and Social Psychology, 35*(9), 625–636. https://doi.org/10.1037//0022-3514.35.9.625.
Scheiter, K., Gerjets, P., & Heise, E. (2014). Distraction during learning with hypermedia: Difficult tasks help to keep task goals on track. *Frontiers in Psychology, 5*, 268. https://doi.org/10.3389/fpsyg.2014.00268.
Schmeichel, B. J. (2007). Attention control, memory updating, and emotion regulation temporarily reduce the capacity for executive control. *Journal of Experimental Psychology: General, 136*(2), 241–255. https://doi.org/10.1037/0096-3445.136.2.241.
Schwarz, W. (2001). The ex-Wald distribution as a descriptive model of response times. *Behavior Research Methods Instruments & Computers, 33*(4), 457–469. https://doi.org/10.3758/bf03195403.
Schwarz, W., & Miller, J. O. (2012). Response time models of delta plots with negative-going slopes. *Psychonomic Bulletin & Review, 19*(4), 555–574. https://doi.org/10.3758/s13423-012-0254-6.
Schwarz, W., & Miller, J. O. (2014). When less equals more: Probability summation without sensitivity improvement. *Journal of Experimental Psychology: Human Perception and Performance, 40*(5), 2091–2100. https://doi.org/10.1037/a0037548.
Sharma, D., Booth, R., Brown, R., & Huguet, P. (2010). Exploring the temporal dynamics of social facilitation in the Stroop task. *Psychonomic Bulletin & Review, 17*(1), 52–58. https://doi.org/10.3758/pbr.17.1.52.
Shaw, T. H., Matthews, G., Warm, J. S., Finomore, V. S., Silverman, L., & Costa, P. T. Jr. (2010). Individual differences in vigilance: Personality, ability and states of stress. *Journal of Research in Personality, 44*(3), 297–308. https://doi.org/10.1016/j.jrp.2010.02.007.
Steinborn, M. B., Flehmig, H. C., Westhoff, K., & Langner, R. (2010). Differential effects of prolonged work on performance measures in self-paced speed tests. *Advances in Cognitive Psychology, 5*, 105–113. https://doi.org/10.2478/v10053-008-0070-8.
Steinborn, M. B., & Huestegge, L. (2016). A walk down the lane gives wings to your brain: Restorative benefits of rest breaks on cognition and self-control. *Applied Cognitive Psychology, 30*(5), 795–805. https://doi.org/10.1002/acp.3255.
Steinborn, M. B., & Huestegge, L. (2017). Phone conversation while processing information: Chronometric analysis of load effects in everyday-media multitasking. Frontiers in Psychology, *8*, 896. https://doi.org/10.3389/fpsyg.2017.00896.
Steinborn, M. B., & Langner, R. (2011). Distraction by irrelevant sound during foreperiods selectively impairs temporal preparation. *Acta Psychologica, 136*(3), 405–418. https://doi.org/10.1016/j.actpsy.2011.01.008.
Steinborn, M. B., & Langner, R. (2012). Arousal modulates temporal preparation under increased time uncertainty: Evidence from higher-order sequential foreperiod effects. *Acta Psychologica, 139*(1), 65–76. https://doi.org/10.1016/j.actpsy.2011.10.010.
Steinborn, M. B., Langner, R., Flehmig, H. C., & Huestegge, L. (2016). Everyday life cognitive instability predicts simple reaction time variability: Analysis of reaction time distributions and delta plots. *Applied Cognitive Psychology, 30*(1), 92–102. https://doi.org/10.1002/acp.3172.
Steinborn, M. B., Langner, R., Flehmig, H. C., & Huestegge, L. (2018). Methodology of performance scoring in the d2 sustained-attention test: Cumulative-reliability functions and practical guidelines. *Psychological Assessment, 30*(3), 339–357. https://doi.org/10.1037/pas0000482.
Steinborn, M. B., Langner, R., & Huestegge, L. (2017). Mobilizing cognition for speeded action: Try-harder instructions promote motivated readiness in the constant-foreperiod paradigm. *Psychological Research Psychologische Forschung, 81*, 1135–1151. https://doi.org/10.1007/s00426-016-0810-1.
Steinhauser, M., & Huebner, R. (2009). Distinguishing response conflict and task conflict in the Stroop task: Evidence from Ex-Gaussian distribution analysis. *Journal of Experimental Psychology: Human Perception and Performance, 35*(5), 1398–1412. https://doi.org/10.1037/a0016467.
Steinhauser, M., Maier, M., & Hübner, R. (2007). Cognitive control under stress—How stress affects strategies of task-set reconfiguration. *Psychological Science, 18*(6), 540–545. https://doi.org/10.1111/j.1467-9280.2007.01935.x.
Strack, F., & Deutsch, R. (2004). Reflective and impulsive determinants of social behavior. *Personality and Social Psychology Review, 8*(3), 220–247. https://doi.org/10.1207/s15327957pspr0803_1.
Szalma, J. L., & Teo, G. W. L. (2012). Spatial and temporal task characteristics as stress: A test of the dynamic adaptability theory of stress, workload, and performance. *Acta Psychologica, 139*(3), 471–485. https://doi.org/10.1016/j.actpsy.2011.12.009.
Thomaschke, R., Bogon, J., & Dreisbach, G. (2017). Timing affect: Dimension-specific time-based expectancy for affect. *Emotion, 18*(5), 646–669. https://doi.org/10.1037/emo0000380.
Thomaschke, R., & Dreisbach, G. (2015). The time-event correlation effect is due to temporal expectancy, not to partial transition costs. *Journal of Experimental Psychology: Human Perception and Performance, 41*(1), 196–218. https://doi.org/10.1037/a0038328.
Thorndike, E. L. (1922). *The psychology of arithmetic*. New York: Macmillan.
Thorne, D. R. (2006). Throughput: A simple performance index with desirable characteristics. *Behavior Research Methods, 38*(4), 569–573. https://doi.org/10.3758/bf03193886.
Triplett, N. (1898). The dynamogenic factors in pacemaking and competition. *The American Journal of Psychology, 9*(4), 507–533. https://doi.org/10.2307/1412188.
Ulrich, R., & Miller, J. (1994). Effects of truncation on reaction time analysis. *Journal of Experimental Psychology: General, 123*(1), 34–80. https://doi.org/10.1037//0096-3445.123.1.34.
Ulrich, R., Miller, J., & Schroeter, H. (2007). Testing the race model inequality: An algorithm and computer programs. *Behavior*

Research Methods, 39(2), 291–302. https://doi.org/10.3758/bf03193160.

Ulrich, R., Schroeter, H., Leuthold, H., & Birngruber, T. (2015). Automatic and controlled stimulus processing in conflict tasks: Superimposed diffusion processes and delta functions. *Cognitive Psychology, 78*, 148–174. https://doi.org/10.1016/j.cogpsych.2015.02.005.

Van Breukelen, G. J. P., Roskam, E. E. C. I., Eling, P. A. T. M., Jansen, R. W. T. L., Souren, D. A. P. B., & Ickenroth, J. G. M. (1995). A model and diagnostic measures for response-time series on tests of concentration—Historical background, conceptual framework, and some applications. *Brain and Cognition, 27*(2), 147–179. https://doi.org/10.1006/brcg.1995.1015.

Voegler, R., Peterburs, J., Lemke, H., Ocklenburg, S., Liepelt, R., & Straube, T. (2018). Electrophysiological correlates of performance monitoring under social observation in patients with social anxiety disorder and healthy controls. *Biological Psychology, 132*(2), 71–80. https://doi.org/10.1016/j.biopsycho.2017.11.003.

Wagenmakers, E. J., & Brown, S. (2007). On the linear relation between the mean and the standard deviation of a response time distribution. *Psychological Review, 114*(3), 830–841. https://doi.org/10.1037/0033-295X.114.3.830.

Warm, J. S., Parasuraman, R., & Matthews, G. (2008). Vigilance requires hard mental work and is stressful. *Human Factors, 50*(3), 433–441. https://doi.org/10.1518/001872008x312152.

Wells, A., & Matthews, G. (2015). *Attention and emotion: A clinical perspective*. Hove: Psychology Press.

Wühr, P., & Huestegge, L. (2010). The impact of social presence on voluntary and involuntary control of spatial attention. *Social Cognition, 28*(2), 145–160. https://doi.org/10.1521/soco.2010.28.2.145.

Zajonc, R. B. (1965). Social facilitation. *Science, 149*(3681), 269–274. https://doi.org/10.1126/science.149.3681.269.

Zajonc, R. B., & Brickman, P. (1969). Expectancy and feedback as independent factors in task performance. *Journal of Personality and Social Psychology, 11*(2), 148–156. https://doi.org/10.1037/h0026887.