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Emotion regulation in social interaction: Physiological and emotional responses associated with social inhibition

Stefanie Duijndam, Annemiek Karreman, Johan Denollet [1], Nina Kupper [*]

CoRPS – Center of Research on Psychological and Somatic Disorders, Tilburg University, the Netherlands

A R T I C L E   I N F O

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A B S T R A C T

Social inhibition may be associated with individual differences in emotion regulation. Mechanisms relating emotion regulation to social inhibition are largely unknown. We therefore examined how social inhibition is associated with emotional, sympathetic, and parasympathetic responses during sadness induction, and while employing emotion regulation strategies during social interaction after sadness induction. Undergraduate students ($N = 216$; 72% female) completed the Social Inhibition Questionnaire and participated in a sadness induction and emotion regulation (i.e., suppression and reappraisal) social interaction task, while emotional states, and sympathetic and parasympathetic reactivity were assessed. Repeated measures ANCOVAs showed that during sadness induction, social inhibition was unrelated to the emotional response, but social inhibition was associated with a blunted parasympathetic withdrawal response, due to an already withdrawn parasympathetic tone at rest. This may be suggestive of increased allostatic load with higher social inhibition, and may contribute to stress-related health risks. Both suppression and reappraisal tasks successfully diminished sadness, and this reduction was smaller with increasing levels of social inhibition. Physiological responses to emotion regulation efforts were independent of social inhibition. Elevated sadness in response to instructed emotion regulation in socially inhibited individuals may indicate more emotional distress during social interaction due to heightened threat sensitivity they experience.

1. Introduction

Social inhibition is a broad and stable personality trait, characterized by behavioral inhibition (e.g., difficulty talking to other people), interpersonal sensitivity (e.g., fear of negative evaluation), and social withdrawal (e.g., avoiding social interaction; Denollet, 2005; Denollet and Duijndam, 2019). Socially inhibited individuals have difficulties to engage in social situations. They feel insecure among other people, lack assertiveness, are less talkative, shy, and adopt self-enhancing strategies such as withdrawal (Denollet, 2005, 2013; Denollet and Duijndam, 2019; Grande et al., 2004). Research has shown that social inhibition in children is associated with later emotional problems (Caspi et al., 1996; Fox et al., 2005; Rapee, 2002). Socially inhibited individuals could have emotion regulation difficulties, which play an important role in social interaction (Gross and John, 2003).

It has been suggested that socially inhibited individuals use suppression as a self-enhancing strategy to cover up their emotional expression in social situations and to distance themselves from potential rejection of others (Asendorpf, 1993; Ayduk et al., 2000; Denollet, 2013; Denollet and Duijndam, 2019). Suppression is an emotion regulation strategy that is referred to as reducing, inhibiting or withdrawing emotion-expressive behavior once the individual is already in an emotional state (Gross, 2015). As a response-focused emotion regulation strategy, suppression occurs late in the process of emotion regulation, when the emotion is already there, which will not help to reduce the emotional experience (Gross and John, 2003). Instead, emotions will linger on and remain unresolved. It therefore takes more (cognitive) effort to suppress emotions, which was found to have negative effects on both mental and physical health (Graves et al., 1994; John and Gross, 2004). A recent study showed that expressive suppression distorts the experience of emotions, resulting in reduced control over emotions and a reduced capacity to regulate them effectively (Benita et al., 2020). Due to ineffective regulation of emotions, suppression has been associated with experiencing fewer positive and more negative emotions,

* Corresponding author at: Tilburg University, Department of Medical and Clinical Psychology, CoRPS – Center of Research on Psychological and Somatic Disorders, the Netherlands.

E-mail address: h.m.kupper@tilburguniversity.edu (N. Kupper).

[1] Prof. Dr. Johan Denollet passed away on October 26, 2019.

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avoidance of close relationships, and poorer well-being (e.g., more depressive symptoms; Cameron and Overall, 2018; Gross and John, 2003). In socially inhibited individuals, suppression during social interaction may result in increased negative emotional reactivity, which is suggested to induce withdrawal from social situations (Asendorpf, 1993; Denollet, 2013; Sheynin et al., 2013; Whelan and Zelenski, 2012).

Experimental studies have demonstrated that suppression is associated with sympathetic nervous system activation (Appleton et al., 2014; Butler et al., 2003; Gross and Levenson, 1995, 1997), explained by the increased experience of stress that goes together with maladaptive emotion regulation (Moore et al., 2008). Thus, due to the negative outcomes associated with suppression, this emotion regulation strategy may be considered maladaptive (Benita et al., 2020; Gross, 2015). To date, no study investigated the physiological consequences of suppression in socially inhibited individuals. The closest work is that of Messerli-Burgy et al. (2012) on Type D personality (the combination of high negative affectivity and high social inhibition (Denollet, 2005)), which found a strong relationship between Type D personality and maladaptive emotion regulation. In this study, a medium sized correlation was reported between social inhibition as measured with the DS14 and maladaptive emotion regulation. Whether the effects of the suppressive emotion regulation strategy on physiological functioning are affected by individual differences in social inhibition is as yet unknown.

In contrast to suppression, frequent use of the emotion regulation strategy reappraisal has been associated with experiencing and expressing more positive and less negative emotion, having closer relationships with friends due to sharing these emotions, and with well-being and greater self-esteem (Gross and John, 2003). Reappraisal is an antecedent-focused strategy referring to the reinterpretation of the meaning of the emotional stimulus, thereby altering the trajectory of the emotional response. Due to the positive emotional consequences, reappraisal is considered an adaptive emotion regulation strategy (Gross, 1998b). Thus far, no studies have investigated the relation between social inhibition and the employment of reappraisal. However, because individuals high in social anxiety report less frequent and efficient use of cognitive reappraisal (Kivity and Huppert, 2018; Morrison and Heimberg, 2013), and are more likely to be socially inhibited (Kupper and Denollet, 2014), it may be expected that socially inhibited individuals are less efficient in using reappraisal. Importantly, when socially anxious individuals are instructed to use reappraisal, this seems to be effective as extant research in socially anxious people shows larger reappraisal-related reduction in unpleasant emotions (Kivity and Huppert, 2018). Therefore, teaching reappraisal skills might be beneficial for socially anxious and socially inhibited individuals.

Because reappraisal is an effective method in down-regulating negative emotions, it has been suggested this should also be reflected in more adaptive physiological responding (e.g., Gross, 1998a). However, to date, mixed findings have been reported. Some report high reappraisal to be associated with greater cardiac output and ventricular contractility (Jamieson et al., 2012; Mauss et al., 2007), while other studies found reappraisal to be unrelated to physiological activation (Butler et al., 2003; Gross and Levenson, 1995, 1997). Whether social inhibition affects the reappraisal effect on emotional and physiological arousal remains to be investigated.

In order to fully understand the potential psychosomatic role suppression and reappraisal play in socially inhibited individuals, it is eminent to investigate responses of both the sympathetic and parasympathetic nervous system, not just their net effects (e.g., blood pressure, heart rate). Therefore, in the current study, we also assess sympathetic cardiac drive (i.e., pre-ejection period) and general sympathetic arousal (i.e., electro dermal activity), as well as heart rate variability (RMSSD) as a measure of parasympathetic activity.

In sum, there is a paucity of knowledge on individual differences in the emotional and physiological effects of emotion regulation processes, in particular in association with social inhibition. Social inhibition is considered a trait that can vary from normal functioning in social interactions to psychopathological levels of functioning. Because social inhibition reflects a personality trait rather than a disorder, high levels are presumably more prevalent compared to related psychopathologies (i.e., social anxiety disorder, avoidant personality disorder; Schneier et al., 2002; Stein et al., 2004). Identifying the impact of suppression and reappraisal on the psychophysiology of socially inhibited individuals may therefore offer an opportunity to improve the understanding of the consequences of emotion regulation in more serious conditions associated with social inhibition.

Therefore the aim of this study was to examine how social inhibition is related to emotional and physiological responses to specific emotion regulation instructions during social interactions. We (a) examined to what extent social inhibition was associated with the emotional (sadness and happiness) and physiological (sympathetic and parasympathetic) effects of sadness induction, and (b) investigated whether social inhibition was associated with emotional and physiological responses to instructed use of emotion regulation strategies during subsequent social interaction. Since previous studies indicate the presence of sex differences in emotional experience (Kelly et al., 2008), physiological responses (Hinojosa-Laborde et al., 1999; Maranon and Reckelhoff, 2013), and social inhibition (Denollet and Duijndam, 2019; Duijndam and Denollet, 2019), sex was an important covariate. In post-hoc analyses, we aimed to explore how the underlying facets of social inhibition (behavioral inhibition, interpersonal sensitivity, and social withdrawal) were associated with responses in emotion induction and instructed regulation.

As emotion-eliciting films typically evoke subjective emotional responses (Rottenberg et al., 2007), and elevated physiological responses (Fernández et al., 2012) in experimental settings, we expected sadness induction (H_1) to successfully increase sadness and decrease happiness, and (H_2) to induce sympathetic and hemodynamic activation and parasympathetic withdrawal. Due to the tendency of socially inhibited individuals to suppress their emotions (Denollet, 2005; Denollet and Duijndam, 2019), (H_3) we expect more suppression regulation during sadness induction resulting in enhanced emotional experience for individuals with higher levels of social inhibition. With respect to emotion regulation, we hypothesized that individuals scoring high on social inhibition would show an enlarged response to instructed emotion suppression (Asendorpf, 1993; Denollet, 2005, 2013; Denollet and Duijndam, 2019), thus (H_4) showing increased sadness responses, decreased happiness responses, and (H_5) an altered sympathovagal balance favoring sympathetic nervous system activity (John and Gross, 2004). We further expected individuals scoring high on social inhibition to be less effective in their ability to use reappraisal. We expected higher social inhibition to be related to a more modest (H_6) emotional and (H_7) physiological response during the reappraisal task as compared to the sadness induction (Gross, 1998a).

2. Materials and methods

2.1. Participants

Participants were 223 undergraduate students, fluent in either Dutch ($N = 194$) or English ($N = 29$), who participated for course credit. Exclusion criteria for this study were individuals with heart disease and hypertension, due to the effects of these conditions on cardiovascular measures. Two participants were excluded either because of protocol irregularities ($n = 1$), or a pre-existing medical condition (i.e., recent brain surgery; $n = 1$). Five participants dropped out of the study prematurely (i.e., filled out the questionnaire, but did not show up for the experiment). The final sample consisted of 216 participants (Age $M = 20.6$, $SD = 2.8$; 72% female; 88% Dutch). All participants signed an informed consent form and the study was approved by the Tilburg School of Social and Behavioral Sciences ethics review board (EC-2016.26).

2.2. Design

After completion of the online questionnaires at home, participants were invited to the behavioral physiology lab (GO-Lab, Tilburg University) where they performed the emotion induction and regulation task. After informed consent was confirmed, participants were fitted with the physiological equipment. The experiment started with a ten-minute resting baseline, in which participants had to sit still while looking at neutral (landscape) images on the computer screen, to account for baseline physiological assessment. After the resting baseline, the test leader introduced a confederate to the participant, whom the participant had not met before. Following instructions, the participant and confederate performed the two subsequent emotion induction and regulation tasks (described below). The task instructions and film clips were presented on a desktop computer via E-Prime (E-Prime, 2002). The assignments for the participants and confederate were presented on an A4 paper in an envelope. An overview of the research design is presented in the supplemental materials (Fig. S1).

2.3. Emotion induction task

The emotion induction task involved watching three film clips (one neutral and two sad). We selected three film clips based on recommendations by Gross and Levenson (Gross and Levenson, 1995). The neutral clip was a 2 min and 16 s segment from the documentary *Alaska's Wild Denali*, in which the narrator explains about the national park in Alaska (Hardesty, 1997). One sad clip was a 2 min and 51 s segment from the movie *the Champ*, in which a boy watches his father die (Lovell and Zeffirelli, 1979). The other sad clip was a 3 min and 12 s segment from the Disney movie *Lion King*, in which a lion cub watches his father being murdered by his uncle (Hahn et al., 1994). The neutral film was always showed first, while the sad films (and accompanying discussion instructions, described below) were switched in order after 119 participants.

2.4. Emotion regulation task

After each sad film clip, the participant and confederate would converse about the subject of the sad film clips (i.e., loss) while being instructed to use different emotion regulation strategies (i.e., suppression vs. reappraisal). This emotion regulation task was based on the study protocol (made available by the authors) of an earlier study on emotion regulation in social interaction (Butler et al., 2006). About half of the participants ($N = 119$) were instructed to use suppression during the discussion about the first sad film clip (*Lion King)* and reappraisal during the conversation of the second sad film clip (*the Champ)*, while the other part ($N = 97$) were instructed to use reappraisal first and suppression second. The confederate was instructed to stay neutral during all conversations. All instructions were derived from the obtained study protocol (Butler et al., 2006). The suppression instructions for the participants during the conversation about the loss aspect of the *Lion King* were: "*discuss the non-emotional aspects of the film – focus on your thoughts rather than your feelings*" and "*try to maintain a non-emotional expression and tone of voice*". The confederate was instructed to "*try to act as neutral as possible and do not show any clear emotions*" during the conversation. During the conversation about *The Champ*, the reappraisal instructions for the participants were: "*discuss the positive aspects of the film – focus your thinking on the positive aspects rather than the negative*" and "*try to be optimistic and think positively about the situation*". The confederate was again instructed to try to act as neutral as possible and do not show any emotion during the conversation.

2.5. Measures

2.5.1. Social inhibition

To assess social inhibition, the 15-item Social Inhibition Questionnaire (SIQ-15; (Denollet and Duijndam, 2019; Duijndam and Denollet, 2019)) was used. Subjects rated their social inhibition tendencies on a 4-point Likert scale ranging from 0 (false) to 3 (true). The scale yields three subscale scores, for behavioral inhibition, interpersonal sensitivity, social withdrawal, and a total score. For presentation purposes (tables and figures), we divided the total social inhibition group in two, using median split. Cronbach's alpha in the current study yielded 0.93 for the total score, 0.92 for behavioral inhibition, 0.88 for interpersonal sensitivity, and 0.87 for social withdrawal.

2.5.2. Emotion regulation

The Emotion Regulation Questionnaire (ERQ; (Gross and John, 2003)) was used to assess the trait emotion regulation strategies suppression and reappraisal. Emotion regulation was rated on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Suppression was assessed with four items, and reappraisal with six items. Cronbach's alpha for the current study was 0.80 for suppression and 0.81 for reappraisal.

To examine which emotion regulation strategy participants used while watching the film clips, one suppression item (i.e., *During the film, I controlled my emotions by not expressing them*) and one reappraisal item (i.e., *During the film, I controlled my emotions by changing the way I think about the situation I'm in*) were assessed after watching each film clip.

2.5.3. Physiological measures

On the testing day in the GO-Lab, participants were fitted with the physiological measurement equipment (BIOPAC Instruments Inc., Goleta, CA). An electrocardiogram, impedance cardiogram, and electro dermal activity were recorded to obtain information on parasympathetic (root mean square of successive differences; RMSSD) and sympathetic cardiac activity (pre-ejection period (PEP), left ventricular ejection time (LVET)), and cardiovascular summary measures (inter-beat interval, and systolic and diastolic blood pressure). Because emotion induction is a passive task, sympathetic arousal may be picked up to a larger extent by skin conductance level, and non-specific skin conductance response (NSSCR). Measures of heart rate variability (Berntson et al., 1997), blood pressure (Shapiro et al., 1996), impedance cardiography (Sherwood et al., 1990), and electrodermal activity (Chaspari et al., 2015), were assessed, checked, and calculated as described by the according guidelines. Averages of all physiological variables were computed for each experimental period (neutral film, emotion induction, suppression conversation, and reappraisal conversation). Further details of the recordings and calculations of the physiological measures, can be found in the supplemental materials.

We lost some physiological data due to equipment failure and unresolvable artifacts. Due to movement artifacts or premature ventricular contractions (PVC), 7.6% of ECG data was unusable. The continuous BP device needed to be sent out for repairs halfway the study, and we did not have a replacement, which led to missing 57% of blood pressure data. We missed 10% of our electrodermal responses, which is in line with the fact that 10% of the population are skin conductance non-responders (Bernstein et al., 1982). Lastly, 17% of ICG data was missing, due to unresolvable movement artifacts.

2.5.4. Emotional responses

After each film clip and after each conversation, participants rated their emotional responses. Emotion experience was measured through a post film questionnaire which was used in previous research to validate film clips (Rottenberg et al., 2007). Participants had to rate their emotional responses to the film clips on a scale from 0 (not at all) to 4 (extremely). Emotional responses could be positive (e.g., happiness) or negative (e.g., sadness). In addition, they had to indicate whether they had already seen the movie, how unpleasant or pleasant they experienced the film (0 = unpleasant, 4 = pleasant), and whether they used suppression or reappraisal while watching the movie (0 = totally disagree with statement, 7 = totally agree with statement). For the purpose of the current study, we only used the sadness and happiness items. The confederate pretended to also rate his/her emotional experiences. After each conversation, the confederate rated whether and to what extent the participant had tried to stick to the assignment, and whether they discussed the discussion topics in the right order. Participants were also asked in retrospect whether they had understood all the instructions.

2.6. Statistical analysis

A priori power analysis indicated that for performing a repeated measures ANCOVA while expecting a less than medium effect size (f = 0.15; 95% power, and an alpha of 0.05, 2 repeated measures, correlation of 0.50) we would need 206 participants.

Baseline characteristics and resting baseline values are presented as descriptive statistics (means (SD) or median (IQR), and frequencies). Pearson's correlations were used to determine the association between social inhibition and suppression and reappraisal while watching the film clips. The scores on sadness and happiness for each period of the experiment were log transformed to account for the right skewness. With respect to the physiological parameters, RMSSD and skin conductance level were not normally distributed and a log transformation was used to improve the data distribution.

2.6.1. Emotion induction

First, we performed a manipulation check to confirm the emotion induction main effects on emotion and physiology, with a repeated measures ANCOVA. The dependent variables were the emotional (sad, happy) or physiological (e.g., systolic blood pressure) activation during the neutral film, and the averaged emotional or physiological activation to both emotion induction films (see Fig. S2 in the supplemental materials for an overview). The continuous score of social inhibition was added as the independent variable, to examine whether social inhibition was associated with the emotional and physiological emotion induction effect. In the adjusted model, we adjusted for the effects of sex.

2.6.2. Emotion regulation

We analyzed the change in emotional and physiological responses from emotion induction to the instructed emotion regulation task to gauge the effect of the respective emotion regulation task. This was considered the *emotion regulation response*. Repeated measures ANCOVA was used to examine whether social inhibition was associated with the emotional and physiological *emotion regulation response*. The dependent variables were the average emotional (sad, happy) or physiological (e.g., systolic blood pressure) activation level during sadness induction, and the average emotional or physiological activation during the emotion regulation manipulation (suppression or reappraisal; see Fig. S2 in the supplemental materials for a graphical overview). First, a univariate, unadjusted model was tested with only the social inhibition continuous total score. Then, the analysis was adjusted for the effect of sex and task order, which were added as between-subjects factors (i.e. categorical). Finally, as a post-hoc specification, the facets of social inhibition replaced the total social inhibition score, and were tested in a separate model while adjusting for the effects of sex and task order.

We used IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp (2013) for all analyses.

3. Results

3.1. Sample characteristics

All total group sample characteristics are displayed in Table 1. The participants were 20.6 years of age (SD = 2.8) on average, and the majority was female and Dutch. A small percentage underwent psychological treatment at the time of the experiment. Physiological baseline measures of the total sample are also displayed in Table 1.

Table 1
Descriptive statistics.

	Total group (n = 216)
Age *mean (SD)*	20.62 (2.74)
Sex (Female)	71.8% (155)
Language (Dutch)	87.5% (189)
Psychological treatment	12.5% (27)
Emotion regulation strategies	
Suppression (ERQ) *median (IQR)*	14.00 (8.0)
Reappraisal (ERQ) *median (IQR)*	29.50 (7.0)
Experiment related	
Task order (Lion King/Suppression first)	55.1% (119)
Non-adherence to pre-test health behavior rules	
Smoking 2 hour preceding test	1.9% (4)
Limit (≤3) alcohol consumption night before test	0.5% (1)
Coffee in 2 hour preceding test	8.8% (19)
Physiological baseline measures	
Systolic Blood Pressure *mean (SD)*	119.55 (12.67)
Diastolic Blood Pressure *mean (SD)*	68.60 (9.77)
Inter-beat Interval (in milliseconds) *mean (SD)*	790.26 (122.06)
RMSSD *mean (SD)*	44.27 (22.31)
PEP/LVET ratio *mean (SD)*	0.31 (0.06)
Skin conductance level *mean (SD)*	8.88 (7.02)
Non-Specific Skin Conductance Response *mean (SD)*	12.44 (11.68)

Note. SD = standard deviation; *IQR* = inter quartile range; *ERQ* = Emotion Regulation Questionnaire.

3.1.1. Social inhibition

The average SIQ15 total score was 15.7 (SD = 9.3; range 0–45). The average subscale scores were 4.8 (SD = 3.8; range 0–15) for behavioral inhibition, 5.9 (SD = 3.6; range 0–15) for interpersonal sensitivity and 5.0 (SD = 3.5; range 0–15) for social withdrawal. The subscale intercorrelations ranged between 0.49 and 0.65, indicating that multicollinearity will not be a problem in the ensuing RM-ANCOVA analyses. There were significant sex differences in the interpersonal sensitivity subscale (t = 2.86, p = .005), with women scoring higher than men ($M_{difference}$ = 1.5 (SE = 0.54)). There were no sex differences in the other two subscales or in the total score.

3.1.2. Habitual emotion regulation strategy

The median of ERQ subscales suppression and reappraisal were 14.00 (IQR = 8) and 29.5 (IQR = 7), respectively (Table 1). Social inhibition was positively related to the habitual use of suppression (ERQ; r = 0.44, p < .001), and negatively related to the use of reappraisal (ERQ; r = −0.24, p < .001). In addition, results showed that individuals scoring higher on social inhibition more often used suppression during both sadness inductions (*Lion King* (r = 0.14, p = .043); *The Champ* (r = 0.16, p = .022). Social inhibition was unrelated to the use of reappraisal during sadness induction (*Lion King* (r = 0.12, p = .081); *The Champ* (r = 0.12, p = .078).

3.1.3. Lifestyle behaviors and medication use

In total, 24 participants were non-adherent to the behavioral guidelines that were imposed with respect to consumption of coffee (n = 19) and cigarettes (n = 4) 2 hour preceding -, and alcohol consumption (n = 1) 24 hour preceding the experiment. Because lifestyle behaviors and psychotropic medication use may be possible confounders in the physiological responses, we tested whether these variables affected the physiology at baseline. Removing participants who use psychotropic medication, did not change the results. In addition, analyses without the non-compliant participants did not differ from analyses with non-compliant participants, except for coffee consumption and its effect on EDA. A positive correlation was found between caffeine consumption 2 h prior to testing and skin conductance level at baseline (r = 0.152, p = .034), and therefore we included caffeine consumption as a covariate in the analyses for skin conductance level.

3.2. Emotion induction effect

3.2.1. Test-retest reliability

As shown in Table 2, a high degree of reliability was found between sadness scores for the first emotion induction film and the second (ICC = 0.748), suggesting high conformity between the two induction responses. However, happiness scores were less consistent between the emotion induction films (ICC = 0.369), suggesting that one movie made them less happy than the other. All physiological outcome measures showed high reliability between the two emotion induction films (ICC > 0.77).

3.2.2. Emotional responses

There was a main emotion induction effect for both sadness and happiness reactivity. Compared to the neutral film, participants rated to have experienced more sadness (F (1,213) = 403.398, $p < .001$, η^2 = 0.654), and less happiness (F (1, 213) = 64.227, $p < .001$, η^2 = 0.232) during the sadness inductions, which is in accordance with our hypothesis (H_1). These results indicate that the emotion induction was successful.

In contrast with our hypothesis (H_3), social inhibition was unrelated to the emotional response to sadness induction (Table 3), with the exception of the behavioral inhibition facet. With higher behavioral inhibition, we observed a somewhat less pronounced sadness response (F (1, 213) = 3.029, p = .083, η^2 = 0.014). Additionally, women rated more sadness during both sadness-inductions than men (F (1, 213) = 17.485, $p < .001$, η^2 = 0.076). No sex related differences were observed for happiness.

3.2.3. Physiological responses

Sadness induction was associated with a parasympathetic withdrawal response (RMSSD: F (1, 203) = 10.705, p = .001, η^2 = 0.050), and increased sympathetic arousal (SCL: F (1, 181) = 5.195, p = .024, η^2 = 0.028; NSSCR: F (1, 195) = 21.448, $p < .001$, η^2 = 0.099), which was in line with our hypothesis (H_2).

Fig. 1 shows the course of parasympathetic activity as assessed with RMSSD, from baseline to sadness induction for high/low social inhibition (categorized using median split for presentation purposes). Social inhibition was inversely related to the sadness induction response of parasympathetic activity (Fig. 1; Table 3), such that responses were blunted in the high social inhibition group (due to a low baseline), while the below median group showed the expected withdrawal response. The parasympathetic withdrawal response was more prominent in women (F (1, 203) = 4.895, p = .028, η^2 = 0.024), but the sex by social inhibition interaction was not significant (F (1,202) = 0.062, p = .804, η^2 < 0.001). Other physiological measures showed no significant differences in association with social inhibition during emotion induction, indicating that our hypothesis is only partially accepted (H_3).

Table 2
Intra Class Correlations of all outcome measures between experimental periods.

	Emotion induction		Emotion regulation	
	ICC	95% CI	ICC	95% CI
Sadness	0.748	0.671–0.807	0.656	0.551–0.737
Happiness	0.369	0.175–0.517	0.567	0.433–0.669
SBP	0.778	0.565–0.858	0.754	0.610–0.844
DBP	0.800	0.688–0.871	0.870	0.795–0.918
IBI	0.961	0.948–0.970	0.960	0.947–0.969
RMSSD	0.916	0.889–0.936	0.925	0.902–0.943
PEP/LVET ratio	0.926	0.901–0.945	0.889	0.851–0.917
SCL	0.897	0.863–0.922	0.922	0.897–0.941
NSSCR	0.834	0.781–0.875	0.837	0.783–877

Note. Abbreviations: ICC = Intra Class Correlation; CI = Confidence Interval; SBP = systolic blood pressure; DBP = Diastolic blood pressure; IBI = interbeat interval; RMSSD = root mean square of successive differences; PEP = pre ejection period; LVET = left ventricular ejection time; SCL = skin conductance level; NSSCR = non-specific skin conductance response.

Table 3
Results from the RM-ANCOVAs of emotion induction effects associated with social inhibition.

	Emotion induction		
	F (df)	p	η^2
	Emotional responses		
Sadness	2.355 (1, 213)	0.126	0.011
Happiness	0.314 (1, 213)	0.576	0.001
	Physiological responses		
Systolic blood pressure	2.545 (1, 70)	0.115	0.035
Diastolic blood pressure	0.689 (1, 70)	0.409	0.010
Inter-beat interval (IBI)	0.658 (1, 208)	0.418	0.003
RMSSD	6.750 (1,203)	**0.010**	0.032
PEP/LVET ratio	1.663 (1, 176)	0.199	0.009
Skin conductance level (SCL)[¥]	1.100 (1, 181)	0.296	0.006
Non-Specific Skin Conductance Response (NSSCR)	0.174 (1, 195)	0.677	0.001

Note. All analyses were corrected for sex. [¥]Skin conductance level was also corrected for caffeine consumption 2 h prior to testing. Boldface = significant at p < .05. The size of partial η^2 can be interpreted as small (0.01), medium (0.06), and large (0.14) (Miles and Shevlin, 2001).

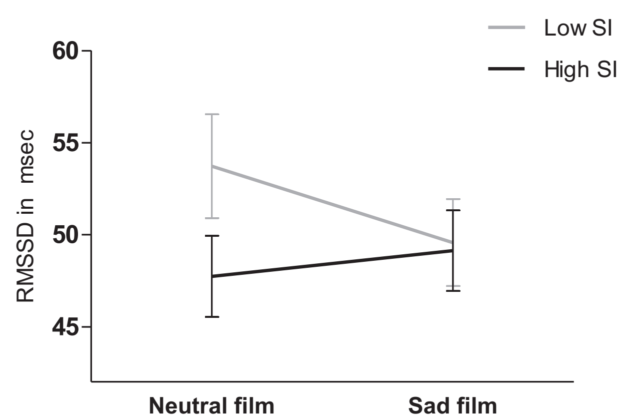

Fig. 1. Changes in RMSSD in milliseconds (msec) in response to sadness induction for low and high social inhibition (SI). In the Supplemental Materials a boxplot of the RMSSD data can be found (Fig. S1).

3.3. Emotion regulation effect: suppression task

3.3.1. Test-retest reliability

As shown in Table 2, both sadness and happiness scores were adequately reliable between the two conversations. In addition, all physiological outcome measures showed high reliability between the two emotion regulation conversations (ICC > 0.75).

3.3.2. Emotional responses

The suppression task reduced individuals' levels of sadness significantly (F (1,212) = 136.498, $p < .001$, partial η^2 = 0.392). Participants' happiness score did not change during suppression.

Higher social inhibition was associated with less reduction in sadness during the suppression task (Fig. 2a; Table 4), which is in contrast with our hypothesis (H_4). Post-hoc analysis showed that interpersonal sensitivity and social withdrawal, but not behavioral inhibition were showing this effect (see Table 4). Social inhibition did not affect the happiness response to suppression (Fig. 2b).

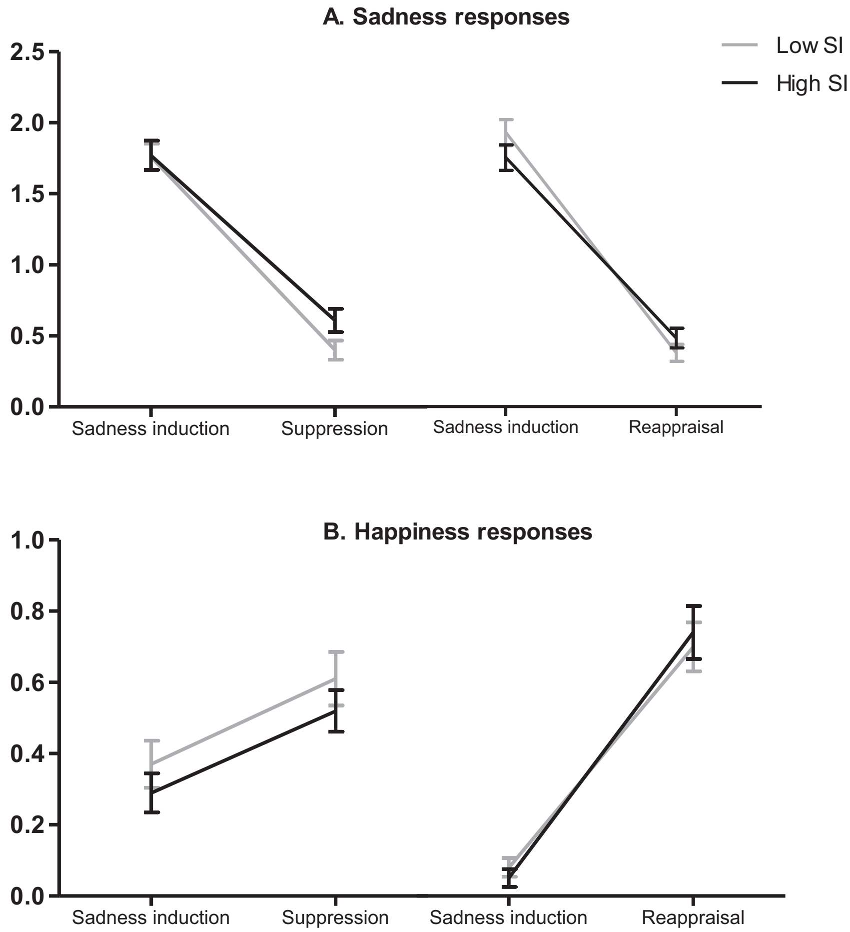

Fig. 2. Sadness (A) and happiness (B) responses of high and low social inhibition (SI) during the emotion regulation tasks. In the Supplemental Materials a boxplot of this data can be found (Fig. S2).

Table 4
Results from the RM-ANCOVAs of emotional emotion regulation effects.

		Suppression			Reappraisal		
		F (df)	P	η^2	F (df)	p	η^2
	Sadness						
A	SIQ15 total	6.965 (1, 212)	**0.009**	0.032	3.632 (1, 212)	*0.058*	0.017
B	Behavioral Inhibition	2.729 (1, 212)	0.100	0.013	6.388 (1, 212)	**0.012**	0.029
	Interpersonal Sensitivity	6.968 (1, 212)	**0.009**	0.032	4.512 (1, 212)	**0.035**	0.021
	Social Withdrawal	6.444 (1, 212)	**0.012**	0.029	0.036 (1, 212)	0.849	<0.001
	Happiness						
A	SIQ15 total	0.187 (1, 212)	0.666	0.001	0.368 (1, 212)	0.545	0.002
B	Behavioral Inhibition	0.024 (1, 212)	0.877	<0.001	0.234 (1, 212)	0.629	0.001
	Interpersonal Sensitivity	0.021 (1, 212)	0.886	<0.001	0.907 (1, 212)	0.342	0.004
	Social Withdrawal	0.712 (1, 212)	0.400	0.003	0.015 (1, 212)	0.903	<0.001

Note. All analyses were corrected for sex and task order. The size of partial η^2 can be interpreted as small (0.01), medium (0.06), and large (0.14) (Miles and Shevlin, 2001). Boldface = significant at $p < .05$.

Women generally showed larger reductions in sadness scores (F (1, 212) = 4.649, p = .032, partial η^2 = 0.021), a larger improvement in happiness scores (F (1, 212) = 5.065, p = .025, partial η^2 = 0.023), and women high in social inhibition report larger reduction in sadness than men high in social inhibition (F (1,211) = 4.440, p = .036, partial η^2 = 0.021). There was no sex by social inhibition interaction effect for happiness (F (1, 211) = 0.742, p = .390, partial η^2 = 0.004).

3.3.3. *Physiological responses*

Results showed a typical stress/performance response across measures in response to the suppression task. The instructed suppression elicited parasympathetic withdrawal (i.e., a decrease in RMSSD (F (1, 202) = 9.477, p = .002, partial η^2 = 0.045)) and sympathetic arousal (i.e., increase in PEP/LVET ratio (F (1, 180) = 10.813, p = .001, partial η^2 = 0.057), skin conductance level (F (1, 183) = 17.674, $p < .001$, partial η^2 = 0.088) and NSSCR (F (1, 192) = 51.956, $p < .001$, partial η^2 = 0.213)). As a consequence, inter-beat interval decreased significantly (i.e., suggestive of an increased heart rate; F (1, 207) = 87.373, $p < .001$, partial η^2 = 0.297) and diastolic blood pressure increased significantly (F (1, 81) = 11.748, p = .001, partial η^2 = 0.127).

With respect to the effect of social inhibition on physiological responses during suppression, no within-subject effects were found in relation to social inhibition or its facets (Table 5), which is in contrast with our hypothesis (H_5). Task order was not a significant confounder. Sex on the other hand showed main effects on cardiac reactivity (results not shown), but there were no significant interactions with social inhibition.

3.4. Emotion regulation effect: reappraisal task

3.4.1. Emotional responses

As expected (H_1), the reappraisal task reduced the sadness level significantly (F (1, 212) = 166.688, $p < .001$, partial $\eta^2 = 0.440$) in the whole group (to the same extent as suppression did), and induced a significant happiness response (F (1, 212) = 53.128, $p < .001$, partial $\eta^2 = 0.200$). Like before, during suppression, sadness reduction due to the reappraisal task was larger in women (F (1, 212) = 8.984, $p = .003$, partial $\eta^2 = 0.041$).

Results showed a trend positive association between the social inhibition total score and the reappraisal induced reduction in sadness (Fig. 2a; Table 5), which is partially in line with our hypothesis (H_6). Importantly, facet analyses showed significant contributions of both behavioral inhibition and interpersonal sensitivity, but not of social withdrawal, explaining the net trend effect. Social inhibition was unrelated to the improvement of happiness (Fig. 2b).

3.4.2. Physiological responses

Contrary to expectations, reappraisal (compared to emotion induction level) increased sympathetic arousal (PEP/LVET ratio (F (1, 176) = 7.410, $p = .007$, partial $\eta^2 = 0.040$), skin conductance level (F (1, 180) = 19.052, $p < .001$, partial $\eta^2 = 0.096$) and NSSCR (F (1, 191) = 76.607, $p < .001$, partial $\eta^2 = 0.286$)), and reduced parasympathetic activity (RMSSD: (F (1, 204) = 11.205, $p = .001$, $\eta^2 = 0.052$)). We also observed an increase in diastolic blood pressure (F (1, 74) = 8.985, $p = .004$, partial $\eta^2 = 0.108$), and larger decreases in inter-beat interval (F (1, 207) = 161.280, $p < .001$, $\eta^2 = 0.438$). In contrast with our hypothesis (H_7), social inhibition was unrelated to the physiological responses in response to the reappraisal task (Table 5), and there were no significant interactions with sex and task order. There were main effects of sex and task order (data not shown).

4. Discussion

We investigated whether the trait of social inhibition explained individual differences in the emotional and physiological responses to sadness induction and subsequent emotion regulation tasks. Our results led to two primary conclusions. First, during sadness induction, social inhibition was associated with a blunted parasympathetic withdrawal response, due to an already withdrawn parasympathetic tone at rest. Social inhibition was unrelated to the emotional response. Second, both suppression and reappraisal tasks successfully diminished sadness, and this reduction was smaller with increasing levels of social inhibition. Physiological responses to emotion regulation efforts were independent of social inhibition.

Table 5
Results from the RM-ANCOVAs of physiological emotional regulation effects.

		Suppression			Reappraisal		
		F (df)	p	η^2	F (df)	p	η^2
	Systolic Blood Pressure						
A	SIQ15 total	0.487 (1, 81)	0.487	0.006	0.373 (1, 74)	0.543	0.005
B	Behavioral Inhibition	0.618 (1, 81)	0.434	0.008	0.419 (1, 74)	0.519	0.006
	Interpersonal Sensitivity	0.102 (1, 81)	0.750	0.001	1.733 (1, 74)	0.192	0.023
	Social Withdrawal	1.970 (1, 81)	0.164	0.024	0.183 (1, 74)	0.670	0.002
	Diastolic Blood Pressure						
A	SIQ15 total	0.010 (1, 81)	0.920	<0.001	0.055 (1, 74)	0.815	0.001
B	Behavioral Inhibition	0.003 (1, 81)	0.956	<0.001	0.501 (1, 74)	0.481	0.007
	Interpersonal Sensitivity	0.003 (1, 81)	0.959	<0.001	0.014 (1, 74)	0.907	<0.001
	Social Withdrawal	0.075 (1, 81)	0.785	<0.001	0.000 (1, 74)	0.991	<0.001
	Inter-beat Interval (IBI)						
A	SIQ15 total	0.016 (1, 207)	0.899	<0.001	1.265 (1, 207)	0.262	0.006
B	Behavioral Inhibition	0.510 (1, 207)	0.476	0.002	2.287 (1, 207)	0.132	0.011
	Interpersonal Sensitivity	0.033 (1, 207)	0.856	<0.001	1.665 (1, 207)	0.198	0.008
	Social Withdrawal	0.399 (1, 207)	0.528	0.002	0.001 (1, 207)	0.973	<0.001
	RMSSD						
A	SIQ15 total	0.357 (1, 202)	0.551	0.002	1.432 (1, 204)	0.233	0.007
B	Behavioral Inhibition	0.369 (1, 202)	0.554	0.002	1.681 (1, 204)	0.196	0.008
	Interpersonal Sensitivity	0.300 (1, 202)	0.584	0.001	1.187 (1, 204)	0.277	0.006
	Social Withdrawal	0.142 (1, 202)	0.707	0.001	0.440 (1, 204)	0.508	0.002
	PEP/Left Ventricular Ejection Time (LVET) ratio						
A	SIQ15 total	0.054 (1, 180)	0.816	<0.001	0.618 (1, 176)	0.433	0.003
B	Behavioral Inhibition	0.085 (1, 180)	0.772	<0.001	0.579 (1, 176)	0.448	0.003
	Interpersonal Sensitivity	0.016 (1, 180)	0.900	<0.001	0.083 (1, 176)	0.774	<0.001
	Social Withdrawal	0.029 (1, 180)	0.865	<0.001	0.914 (1, 176)	0.340	0.005
	Skin Conductance level (SCL)[¥]						
A	SIQ15 total	0.060 (1, 183)	0.806	<0.001	0.001 (1, 180)	0.988	<0.001
B	Behavioral Inhibition	0.017 (1, 183)	0.896	<0.001	0.060 (1, 180)	0.806	<0.001
	Interpersonal Sensitivity	0.301 (1, 183)	0.584	0.002	1.028 (1, 180)	0.312	0.006
	Social Withdrawal	0.002 (1, 183)	0.963	<0.001	0.692 (1, 180)	0.407	0.004
	Non-Specific Skin Conductance Response (NSSCR)						
A	SIQ15 total	0.390 (1, 192)	0.533	0.002	0.709 (1, 191)	0.401	0.004
B	Behavioral Inhibition	0.366 (1, 192)	0.546	0.002	2.493 (1, 191)	0.116	0.013
	Interpersonal Sensitivity	0.013 (1, 192)	0.910	<0.001	0.001 (1, 191)	0.978	<0.001
	Social Withdrawal	1.328 (1, 192)	0.251	0.007	0.332 (1, 191)	0.565	0.002

Note. All analyses were corrected for sex and task order. [¥]Skin conductance level was also corrected for caffeine consumption 2 h prior to testing. The size of partial η^2 can be interpreted as small (0.01), medium (0.06), and large (0.14) (Miles and Shevlin, 2001).

Physiologically, social inhibition was associated with a blunted parasympathetic withdrawal response to emotion induction, which seems to be due to the fact that already at baseline parasympathetic withdrawal was large (i.e., floor effect). The anticipation of social interaction may have triggered a stress response in socially inhibited individuals during the neutral condition, which could be attributed to them being concerned about having to interact with other people (Bibbey et al., 2015; Denollet and Duijndam, 2019). The parasympathetic withdrawal during rest and blunted reactivity to emotion induction may be reflective of allostatic load on the autonomic nervous system, which might contribute to stress-related health risks over time (Carroll et al., 2017; McEwen and Stellar, 1993).

Contrary to our hypothesis, emotional reactivity to the emotion induction was unrelated to social inhibition. Possibly, the passive nature of the emotion induction could explain why we did not find individual differences in emotional reactivity. Previous studies, in contrast, did report individual differences in affective experience after emotion induction. For example, neuroticism has been related to increased negative affect after negative emotion induction (Gross et al., 1998; Steenhaut et al., 2018; Thake and Zelenski, 2013), while extraversion has been related to increased positive affect after positive emotion induction (Gross et al., 1998). In sum, it seems that socially inhibited individuals are particularly autonomically aroused by anticipation of ensuing social interaction, and less by the emotion induction itself, while the emotional experience seemed unaffected by social inhibition.

Results further showed that both emotion regulation strategies elicited a reduction in sadness, which was progressively less reduced with increasing levels of social inhibition. The smaller decline in sadness possibly lies in the heightened threat sensitivity socially inhibited individuals experience during social interaction (Kret et al., 2011), leaving them more distressed during social interaction. Additionally, as predicted, individuals scoring high on social inhibition were less proficient in using reappraisal, and our results showed socially inhibited individuals to report higher sadness compared to individuals lower in social inhibition after the reappraisal task.

The suppression manipulation in our experiment did not significantly change the positive emotional experience after sadness induction, which is in accordance with the study of Kalokerinos et al. (2015). Although some research suggests that suppression reduces positive emotional experience (e.g., Dan-Glauser and Gross, 2011; Gross and John, 2003; Gross and Levenson, 1997), our results indicate that suppression is not necessarily related to decreased positive emotions. It has been suggested that long-term usage of suppression could lead to reduced positive emotion (e.g., Gross and John, 2003). Importantly, a meta-analysis showed that greater use of emotional suppression, regardless of the valence of the emotion, is associated with poorer social well-being (Chervonsky and Hunt, 2017). As expected, reappraisal successfully increased happiness, independent of the level of social inhibition. Even though socially inhibited individuals were less proficient in using reappraisal to down-regulate sadness, these findings suggest that socially inhibited individuals may benefit from instructed reappraisal as it helps to increase their happiness.

In contrast to experimental studies that have shown that expressive suppression does not alleviate subjective experience of negative emotions (Butler et al., 2006; Campbell-Sills et al., 2006; Gross, 1998a; Gross and Levenson, 1997), we found that suppression was effective in decreasing the experience of sadness. A difference in design might explain these differences. We manipulated emotion regulation after induction and compared the emotional experience during induction with the experience during regulation. However, other studies manipulated emotion regulation during the induction (e.g., Campbell-Sills et al., 2006; Gross, 1998a; Kalokerinos et al., 2015), comparing emotional experience at baseline with that of the emotional experience during regulation/induction. In other words, expressive suppression after emotion induction may not alleviate subjective experience of negative emotions the same way as during emotion induction, as shown in prior research (Campbell-Sills et al., 2006; Gross, 1998a; Kalokerinos et al., 2015).

The physiological response to the suppression task mimicked a typical stress response (parasympathetic withdrawal combined with sympathetic activation) across physiological measures. In accordance, previous experimental studies have demonstrated that suppression is associated with sympathetic nervous system activation (Appleton et al., 2014; Butler et al., 2003; Gross and Levenson, 1995, 1997; Zaehringer et al., 2020), and the current study adds to these findings by also demonstrating parasympathetic withdrawal. Nevertheless, the size of the reactivity was unrelated to social inhibition. Notably, socially inhibited individuals use suppression on a regular basis (during social interaction), as indicated by their trait questionnaire data, suggesting that the physiological arousal associated with suppression occurs repeatedly and may become chronically altered. The association between greater suppression tendencies and poorer health (Graves et al., 1994) could therefore be explained by an increase of allostatic load on the response systems (McEwen and Stellar, 1993). In other words, the habitual use of suppression in socially inhibited individuals may contribute to the dysregulated stress responses in social situations (Bibbey et al., 2015) and thus to increased risk of cardiovascular disease (Cundiff and Smith, 2017).

With respect to physiological responses to reappraisal, our results revealed an increase in sympathetic arousal combined with parasympathetic withdrawal, but these were unrelated to social inhibition. Our hypothesis regarding physiological responses to reappraisal was therefore rejected. Even though some experimental studies found reappraisal to be unrelated to physiological activation (Butler et al., 2003; Egloff et al., 2006; Gross and Levenson, 1995, 1997), other studies suggest otherwise (e.g., Jamieson et al., 2012; Mauss et al., 2007). Additionally, a recent meta-analysis found reappraisal to be related to decreased heart rate, although the effects were rather small and heterogeneous across studies (Zaehringer et al., 2020). Using instructed reappraisal as a strategy in an unfamiliar setting such as the laboratory, involves active cognitive engagement and it therefore may increase sympathetic arousal (Gross and John, 2003), consistent with literature showing that reappraisal can increase physiological reactivity when there is high cognitive demand (e.g., Denson et al., 2014; Jamieson et al., 2013; Mauss et al., 2007). This sympathetic arousal is necessary to perform well on a task, and may help explain our findings. Importantly, previous research describes that using reappraisal for the first time may be effortful, but over longer cognitive training intervals, it may become less demanding, resulting in less sympathetic activation (e.g., Gaab et al., 2003). Whether this will benefit socially inhibited individuals as well, is worth investigating given the association of social inhibition and (mental) health-related problems (Denollet and Duijndam, 2019; Duijndam and Denollet, 2019).

Each underlying facet of social inhibition contributed differently to emotional reactivity during instructed emotion regulation. Behavioral inhibition was associated to the sadness response to reappraisal, but not suppression. As behaviorally inhibited individuals show decreased conversational behaviors (Asendorpf, 1993) and have difficulty providing input on ideas (Keltner et al., 2003), having to interact with a stranger might distract them from actually doing the instructed reappraisal. Interpersonal sensitivity was related to the change in sadness in response to both instructed suppression and reappraisal. This result makes conceptual sense, given that interpersonal sensitive individuals report more negative affect during stress (Herres et al., 2018), and anticipate negative reactions (Denollet and Duijndam, 2019). In a social stress study with 312 undergraduate students, social inhibition was associated with increased emotional reactivity, with behavioral inhibition and interpersonal sensitivity being particularly associated with the sadness response (Duijndam et al., 2020). Social withdrawal was only associated with changes in sadness scores in response to suppression. High scorers on social withdrawal have a tendency to suppress their emotions during social interactions, and suppression does not necessarily eliminate negative feelings but rather leaves them unresolved (John and Gross, 2004). During reappraisal however, which is a more adaptive emotion regulation strategy, social withdrawal was unrelated to the sadness response during reappraisal, which may indicate that reappraisal helps regulating the sad emotions more efficiently.

4.1. Limitations and implications

The results of this study should be viewed in light of its limitations and strengths. The sample was female-dominated (72%) and all participants were undergraduate psychology students, which possibly limits generalization of the results to other populations. Especially given that older adults tend to respond more strongly to negative mood induction (specifically interpersonal loss), which was something that we could not control for (Mather and Ready, 2020). Another limitation was that we lost some physiological data due to equipment failure and unresolvable artifacts. Additionally, it is uncertain whether the physiological response portrayed the regulation effect, or the stressfulness of talking about loss with a stranger. More research is necessary to examine this further. Furthermore, although participants were instructed to use specific strategies during the conversations, it is difficult to prove whether the correct strategies were used, and we had to rely on self-report.

A strength of this study is the large sample size, the use of standardized stimuli, and the fact that both emotional and physiological reactivity variables were taken into account. In addition, we investigated multiple regulatory subsystems to create a more complete illustration of the individual differences in physiological responses to emotion induction and regulation. Lastly, our analyses were performed while controlling for sex and task order.

Future research investigating the effects of social inhibition on emotion regulation should focus on manipulation studies aiming to increase skills in reappraisal, as emotion regulation strategies are learned strategies and not innate traits. Even though reappraisal was not as beneficial for socially inhibited individuals to down-regulate negative emotions compared to individuals low in social inhibition in our study, extensive training may enhance reappraisal resulting in less negative and more positive emotions, and less sympathetic nervous system activity in general (e.g., Gaab et al., 2003), which is important for health improvements. Several studies have found positive treatment effects of reappraisal in reducing unpleasant emotions in individuals with social anxiety disorder (for review, see Dryman and Heimberg, 2018), which was mostly related to the ability to use reappraisal effectively. A study in which a short intervention was performed in socially anxious individuals, showed promising results in effectively training participants in using reappraisal in stressful situations (Kivity and Huppert, 2016). Additionally, reappraisal was found to effectively reduce negative emotions following social threats in socially anxious individuals (Goldin et al., 2009). Even though social inhibition is a personality trait rather than a disorder, it is related to social anxiety (Kupper and Denollet, 2014), and there is reason believe that cognitive reappraisal training could benefit socially inhibited individuals in managing their sensitivity to threat (e.g., social evaluative concerns) and therefore decrease their emotional reactivity in social interaction.

4.2. Conclusion

Our results revealed that social inhibition was associated with a blunted parasympathetic withdrawal response to sadness induction. This suggests allostatic load already being present (McEwen and Stellar, 1993) and ongoing in those participants with higher social inhibition, which contributes to stress-related health risks. In addition, social inhibition was associated with a smaller reduction in sadness experience during instructed emotion regulation. Instructed suppression was, as expected, associated with a typical physiological stress response, without social inhibition affecting its size. However, as socially inhibited individuals habitually use suppression as an emotion regulation strategy, this may have negative consequences for their health (Graves et al., 1994). Reappraisal was less successful in reducing sadness in socially inhibited individuals, which may be due to their less proficient use of this emotion regulation strategy. Nonetheless, reappraisal boosted happiness, which was unrelated to social inhibition, and may indicate that individuals with high social inhibition may benefit from increasing their reappraisal skills.

Declaration of competing interest

None.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijpsycho.2020.09.013.

References

Appleton, A.A., Loucks, E.B., Buka, S.L., Kubzansky, L.D., 2014. Divergent associations of antecedent- and response-focused emotion regulation strategies with midlife cardiovascular disease risk. Ann. Behav. Med. 48 (2), 246–255. https://doi.org/10.1007/s12160-014-9600-4.

Asendorpf, J.B., 1993. Social inhibition: a general-developmental perspective. In: Traue, H.C., Pennebaker, J.W. (Eds.), Emotion, Inhibition, and Health. Hogrefe & Huber Publishers, Seattle, WA, pp. 80–99.

Ayduk, O., Mendoza-Denton, R., Mischel, W., Downey, G., Peake, P.K., Rodriguez, M., 2000. Regulating the interpersonal self: strategic self-regulation for coping with rejection sensitivity. J. Pers. Soc. Psychol. 79 (5), 776–792. https://doi.org/10.1037//0022-3514.79.5.776.

Benita, M., Benish-Weisman, M., Matos, L., Torres, C., 2020. Integrative and suppressive emotion regulation differentially predict well-being through basic need satisfaction and frustration: a test of three countries. Motiv. Emot. 44 (1), 67–81. https://doi.org/10.1007/s11031-019-09781-x.

Bernstein, A.S., Frith, C.D., Gruzelier, J.H., Patterson, T., Straube, E., Venables, P.H., Zahn, T.P., 1982. An analysis of the skin conductance orienting response in samples of American, British, and German schizophrenics. Biol. Psychol. 14 (3), 155–211. https://doi.org/10.1016/0301-0511(82)90001-1.

Berntson, G.G., Bigger, J.T., Eckberg, D.L., Grossman, P., Kaufmann, P.G., Malik, M., VanderMolen, M.W., 1997. Heart rate variability: Origins, methods, and interpretive caveats. Psychophysiology 34 (6), 623–648. https://doi.org/10.1111/j.1469-8986.1997.tb02140.x.

Bibbey, A., Carroll, D., Ginty, A.T., Phillips, A.C., 2015. Cardiovascular and cortisol reactions to acute psychological stress under conditions of high versus low social evaluative threat: associations with the type D personality construct. Psychosom. Med. 77 (5), 599–608. https://doi.org/10.1097/psy.0000000000000194.

Butler, E.A., Egloff, B., Wilhelm, F.H., Smith, N.C., Erickson, E.A., Gross, J.J., 2003. The social consequences of expressive suppression. Emotion 3 (1), 48–67. https://doi.org/10.1037/1528-3542.3.1.48.

Butler, E.A., Wilhelm, F.H., Gross, J.J., 2006. Respiratory sinus arrhythmia, emotion, and emotion regulation during social interaction. Psychophysiology 43 (6), 612–622. https://doi.org/10.1111/j.1469-8986.2006.00467.x.

Cameron, L.D., Overall, N.C., 2018. Suppression and expression as distinct emotion-regulation processes in daily interactions: longitudinal and meta-analyses. Emotion 18 (4), 465–480. https://doi.org/10.1037/emo0000334.

Campbell-Sills, L., Barlow, D.H., Brown, T.A., Hofmann, S.G., 2006. Effects of suppression and acceptance on emotional responses of individuals with anxiety and

mood disorders. Behav. Res. Ther. 44 (9), 1251–1263. https://doi.org/10.1016/j.brat.2005.10.001.
Carroll, D., Ginty, A.T., Whittaker, A.C., Lovallo, W.R., de Rooij, S.R., 2017. The behavioural, cognitive, and neural corollaries of blunted cardiovascular and cortisol reactions to acute psychological stress. Neurosci. Biobehav. Rev. 77, 74–86. https://doi.org/10.1016/j.neubiorev.2017.02.025.
Caspi, A., Moffitt, T.E., Newman, D.L., Silva, P.A., 1996. Behavioral observations at age 3 years predict adult psychiatric disorders - longitudinal evidence from a birth cohort. Arch. Gen. Psychiatry 53 (11), 1033–1039. Retrieved from ://WOS:A1996VR82200007.
Chaspari, T., Tsiartas, A., Stein, L.I., Cermak, S.A., Narayanan, S.S., 2015. Sparse representation of electrodermal activity with knowledge-driven dictionaries. IEEE Trans. Biomed. Eng. 62 (3), 960–971. https://doi.org/10.1109/tbme.2014.2376960.
Chervonsky, E., Hunt, C., 2017. Suppression and expression of emotion in social and interpersonal outcomes: a meta-analysis. Emotion 17 (4), 669–683. https://doi.org/10.1037/emo0000270.
Cundiff, J.M., Smith, T.W., 2017. Social status, everyday interpersonal processes, and coronary heart disease: a social psychophysiological view. Soc. Personal. Psychol. Compass 11 (4), 20. https://doi.org/10.1111/spc3.12310.
Dan-Glauser, E.S., Gross, J.J., 2011. The temporal dynamics of two response-focused forms of emotion regulation: experiential, expressive, and autonomic consequences. Psychophysiology 48 (9), 1309–1322. https://doi.org/10.1111/j.1469-8986.2011.01191.x.
Denollet, J., 2005. DS14: standard assessment of negative affectivity, social inhibition, and Type D personality. Psychosom. Med. 67 (1), 89–97. https://doi.org/10.1097/01.psy.0000149256.81953.49.
Denollet, J., 2013. Interpersonal sensitivity, social inhibition, and type D personality: how and when are they associated with health? Comment on Marin and Miller (2013). Psychol. Bull. 139 (5), 991–997. https://doi.org/10.1037/a0033537.
Denollet, J., Duijndam, S., 2019. The multidimensional nature of adult social inhibition: inhibition, sensitivity and withdrawal facets of the SIQ15. J. Affect. Disord. 245, 569–579. https://doi.org/10.1016/j.jad.2018.11.035.
Denson, T.F., Creswell, J.D., Terides, M.D., Blundell, K., 2014. Cognitive reappraisal increases neuroendocrine reactivity to acute social stress and physical pain. Psychoneuroendocrinology 49, 69–78. https://doi.org/10.1016/j.psyneuen.2014.07.003.
Dryman, M.T., Heimberg, R.G., 2018. Emotion regulation in social anxiety and depression: a systematic review of expressive suppression and cognitive reappraisal. Clin. Psychol. Rev. 65, 17–42. https://doi.org/10.1016/j.cpr.2018.07.004.
Duijndam, S., Denollet, J., 2019. Social inhibition in population-based and cardiac patient samples: robustness of inhibition, sensitivity and withdrawal as distinct facets. Gen. Hosp. Psychiatry 58, 13–23. https://doi.org/10.1016/j.genhosppsych.2019.02.004.
Duijndam, S., Karreman, A., Denollet, J., Kupper, N., 2020. Physiological and emotional responses to evaluative stress in socially inhibited young adults. Biol. Psychol. 149, 107811 https://doi.org/10.1016/j.biopsycho.2019.107811.
Egloff, B., Schmukle, S.C., Burns, L.R., Schwerdtfeger, A., 2006. Spontaneous emotion regulation during evaluated speaking tasks: associations with negative affect, anxiety expression, memory, and physiological responding. Emotion 6 (3), 356–366. https://doi.org/10.1037/1528-3542.6.3.356.
E-Prime, 2002. Version 2.0. Psychology Softwar Tools Inc.
Fernández, C., Pascual, J.C., Soler, J., Elices, M., Portella, M.J., Fernández-Abascal, E., 2012. Physiological responses induced by emotion-eliciting films. Appl. Psychophysiol. Biofeedback 37 (2), 73–79. https://doi.org/10.1007/s10484-012-9180-7.
Fox, N.A., Henderson, H.A., Marshall, P.J., Nichols, K.E., Ghera, M.M., 2005. Behavioral inhibition: linking biology and behavior within a developmental framework. In: Annual Review of Psychology, vol. 56. Annual Reviews, Palo Alto, pp. 235–262.
Gaab, J., Blattler, N., Menzi, T., Pabst, B., Stoyer, S., Ehlert, U., 2003. Randomized controlled evaluation of the effects of cognitive-behavioral stress management on cortisol responses to acute stress in healthy subjects. Psychoneuroendocrinology 28 (6), 767–779. https://doi.org/10.1016/s0306-4530(02)00069-0.
Goldin, P.R., Manber, T., Hakimi, S., Canli, T., Gross, J.J., 2009. Neural bases of social anxiety disorder: emotional reactivity and cognitive regulation during social and physical threat. Arch. Gen. Psychiatry 66 (2), 170–180. https://doi.org/10.1001/archgenpsychiatry.2008.525.
Grande, G., Jordan, J., Kummel, M., Struwe, C., Schubmann, R., Schulze, F., Herrmann-Lingen, C., 2004. Evaluation of the German type D scale (DS14) and prevalence of the type D personality pattern in cardiological and psychosomatic patients and healthy subjects. Psychotherapie Psychosomatik Medizinische Psychologie 54 (11), 413–422. https://doi.org/10.1088/s-2004-828376.
Graves, P.L., Mead, L.A., Wang, N.Y., Liang, K.Y., Klag, M.J., 1994. Temperament as a potential predictor of mortality - evidence from a 41-year prospective-study. J. Behav. Med. 17 (2), 111–126. https://doi.org/10.1007/bf01858100.
Gross, J.J., 1998a. Antecedent- and response-focused emotion regulation: divergent consequences for experience, expression, and physiology. J. Pers. Soc. Psychol. 74 (1), 224–237. https://doi.org/10.1037/0022-3514.74.1.224.
Gross, J.J., 1998b. The emerging field of emotion regulation: an integrative review. Rev. Gen. Psychol. 2 (3), 271–299. https://doi.org/10.1037/1089-2680.2.3.271.
Gross, J.J., 2015. Emotion regulation: current status and future prospects. Psychol. Inq. 26 (1), 1–26. https://doi.org/10.1080/1047840x.2014.940781.
Gross, J.J., John, O.P., 2003. Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. J. Pers. Soc. Psychol. 85 (2), 348–362. https://doi.org/10.1037/0022-3514.85.2.348.
Gross, J.J., Levenson, R.W., 1995. Emotion elicitation using films. Cognit. Emot. 9 (1), 87–108. https://doi.org/10.1080/02699939508408966.
Gross, J.J., Levenson, R.W., 1997. Hiding feelings: the acute effects of inhibiting negative and positive emotion. J. Abnorm. Psychol. 106 (1), 95–103. https://doi.org/10.1037//0021-843x.106.1.95.
Gross, J.J., Sutton, S.K., Ketelaar, T., 1998. Relations between affect and personality: support for the affect-level and affective-reactivity views. Personal. Soc. Psychol. Bull. 24 (3), 279–288. https://doi.org/10.1177/0146167298243005.
Hahn, D., Allers, R., Minkoff, R., 1994. The lion king [Motion Picture]. Walt Disney Pictures, United States.
Hardesty, T., 1997. Alaska's Wild Denali: Summer in Denali National Park [MotionPicture]. Alaska Video Postcards, United States.
Herres, J., Caporino, N.E., Cummings, C.M., Kendall, P.C., 2018. Emotional reactivity to daily events in youth with anxiety disorders. Anxiety Stress Coping 31 (4), 387–401. https://doi.org/10.1080/10615806.2018.1472492.
Hinojosa-Laborde, C.M., Chapa, I., Lange, D., Haywood, J.R., 1999. Gender differences in sympathetic nervous system regulation. Clin. Exp. Pharmacol. Physiol. 26 (2), 122–126. https://doi.org/10.1046/j.1440-1681.1999.02995.x.
Jamieson, J.P., Nock, M.K., Mendes, W.B., 2012. Mind over matter: reappraising arousal improves cardiovascular and cognitive responses to stress. J. Exp. Psychol. Gen. 141 (3), 417–422. https://doi.org/10.1037/a0025719.
Jamieson, J.P., Mendes, W.B., Nock, M.K., 2013. Improving acute stress responses: the power of reappraisal. Curr. Dir. Psychol. Sci. 22 (1), 51–56. https://doi.org/10.1177/0963721412461500.
John, O.P., Gross, J.J., 2004. Healthy and unhealthy emotion regulation: personality processes, individual differences, and life span development. J. Pers. 72 (6), 1301–1333. https://doi.org/10.1111/j.1467-6494.2004.00298.x.
Kalokerinos, E.K., Greenaway, K.H., Denson, T.F., 2015. Reappraisal but not suppression downregulates the experience of positive and negative emotion. Emotion 15 (3), 271–275. https://doi.org/10.1037/emo0000025.
Kelly, M.M., Tyrka, A.R., Anderson, G.M., Price, L.H., Carpenter, L.L., 2008. Sex differences in emotional and physiological responses to the Trier Social Stress Test. J. Behav. Ther. Exp. Psychiatry 39 (1), 87–98. https://doi.org/10.1016/j.jbtep.2007.02.003.
Keltner, D., Gruenfeld, D.H., Anderson, C., 2003. Power, approach, and inhibition. Psychol. Rev. 110 (2), 265–284. https://doi.org/10.1037/0033-295x.110.2.265.
Kivity, Y., Huppert, J.D., 2016. Does cognitive reappraisal reduce anxiety? A daily diary study of a micro-intervention with individuals with high social anxiety. J. Consult. Clin. Psychol. 84 (3), 269–283. https://doi.org/10.1037/ccp0000075.
Kivity, Y., Huppert, J.D., 2018. Are individuals diagnosed with social anxiety disorder successful in regulating their emotions? A mixed-method investigation using self-report, subjective, and event-related potentials measures. J. Affect. Disord. 236, 298–305. https://doi.org/10.1016/j.jad.2018.02.029.
Kret, M.E., Denollet, J., Grezes, J., de Gelder, B., 2011. The role of negative affectivity and social inhibition in perceiving social threat: an fMRI study. Neuropsychologia 49 (5), 1187–1193. https://doi.org/10.1016/j.neuropsychologia.2011.02.007.
Kupper, N., Denollet, J., 2014. Type D personality is associated with social anxiety in the general population. Int. J. Behav. Med. 21 (3), 496–505. https://doi.org/10.1007/s12529-013-9350-x.
Lovell, D., Zeffirelli, F., 1979. The champ [Motion picture]. MGM/Pathe Home Video, United States.
Maranon, R., Reckelhoff, J.F., 2013. Sex and gender differences in control of blood pressure. Clin. Sci. 125 (7–8), 311–318. https://doi.org/10.1042/cs20130140.
Mather, M.A., Ready, R.E., 2020. Greater negative affect and mixed emotions during spontaneous reactions to sad films in older than younger adults. Eur. J. Ageing 15. https://doi.org/10.1007/s10433-020-00565-8.
Mauss, I.B., Cook, C.L., Cheng, J.Y.J., Gross, J.J., 2007. Individual differences in cognitive reappraisal: experiential and physiological responses to an anger provocation. Int. J. Psychophysiol. 66 (2), 116–124. https://doi.org/10.1016/j.ijpsycho.2007.03.017.
McEwen, B.S., Stellar, E., 1993. Stress and the individual. Mechanisms leading to disease. Arch. Intern. Med. 153 (18), 2093–2101.
Messerli-Burgy, N., Barth, J., von Kanel, R., Schmid, J.P., Saner, H., Znoj, H., 2012. Maladaptive emotion regulation is related to distressed personalities in cardiac patients. Stress. Health 28 (4), 347–352. https://doi.org/10.1002/smi.2420.
Miles, J., Shevlin, M., 2001. Applying Regression and Correlation: A Guide for Students and Researchers, 1st ed. SAGE Publications Ltd, London.
Moore, S.A., Zoellner, L.A., Mollenholt, N., 2008. Are expressive suppression and cognitive reappraisal associated with stress-related symptoms? Behav. Res. Ther. 46 (9), 993–1000. https://doi.org/10.1016/j.brat.2008.05.001.
Morrison, A.S., Heimberg, R.G., 2013. Social anxiety and social anxiety disorder. In: NolenHoeksema, S. (Ed.), Annual Review of Clinical Psychology, Vol 9, vol. 9. Annual Reviews, Palo Alto, pp. 249–274.
Rapee, R.M., 2002. The development and modification of temperamental risk for anxiety disorders: prevention of a lifetime of anxiety? Biol. Psychiatry 52 (10), 947–957. https://doi.org/10.1016/s0006-3223(02)01572-x.
Rottenberg, J., Ray, R.D., Gross, J.J., 2007. Emotion elicitation using films. In: Coan, J. A., Allen, J.J.B. (Eds.), The Handbook of Emotion Elicitation and Assessment. Oxford University Press, London.
Schneier, F.R., Blanco, C., Antia, S.X., Liebowitz, M.R., 2002. The social anxiety spectrum. Psychiatr. Clin. N. Am. 25 (4), 757–774. https://doi.org/10.1016/s0193-953x(02)00018-7.
Shapiro, D., Jamner, L.D., Lane, J.D., Light, K.C., Myrtek, M., Sawada, Y., Steptoe, A., 1996. Blood pressure publication guidelines. Psychophysiology 33 (1), 1–12. https://doi.org/10.1111/j.1469-8986.1996.tb02103.x.
Sherwood, A., Allen, M.T., Fahrenberg, J., Kelsey, R.M., Lovallo, W.R., Vandoornen, L.J. P., 1990. Methodological guidelines for impedance cardiography. Psychophysiology 27 (1), 1–23. https://doi.org/10.1111/j.1469-8986.1990.tb02171.x.

Sheynin, J., Shikari, S., Gluck, M.A., Moustafa, A.A., Servatius, R.J., Myers, C.E., 2013. Enhanced avoidance learning in behaviorally inhibited young men and women. Stress Int. J. Biol. Stress 16 (3), 289–299. https://doi.org/10.3109/10253890.2012.744391.

Steenhaut, P., Demeyer, I., De Raedt, R., Rossi, G., 2018. The role of personality in the assessment of subjective and physiological emotional reactivity: a comparison between younger and older adults. Assessment 25 (3), 285–301. https://doi.org/10.1177/1073191117719510.

Stein, D.J., Ono, Y., Tajima, O., Muller, J.E., 2004. The social anxiety disorder spectrum. J. Clin. Psychiatry 65, 27–33. Retrieved from ://WOS:000225732300006.

Thake, J., Zelenski, J.M., 2013. Neuroticism, BIS, and reactivity to discrete negative mood inductions. Personal. Individ. Differ. 54 (2), 208–213. https://doi.org/10.1016/j.paid.2012.08.041.

Whelan, D.C., Zelenski, J.M., 2012. Experimental evidence that positive moods cause sociability. Soc. Psychol. Personal. Sci. 3 (4), 430–437. https://doi.org/10.1177/1948550611425194.

Zaehringer, J., Jennen-Steinmetz, C., Schmahl, C., Ende, G., Paret, C., 2020. Psychophysiological effects of downregulating negative emotions: insights from a meta-analysis of healthy adults. Front. Psychol. 11, 28. https://doi.org/10.3389/fpsyg.2020.00470.