Title

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Journal
International journal of behavioral medicine, 25(4)

ISSN
1070-5503

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Publication Date
2018-08-01

DOI
10.1007/s12529-018-9720-5

Peer reviewed

International Journal of Behavioral Medicine (2018) 25:410–420
https://doi.org/10.1007/s12529-018-9720-5

Effects of Social Exclusion on Cardiovascular and Affective Reactivity to a Socially Evaluative Stressor

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Published online: 3 April 2018

Abstract

Purpose Socially disconnected individuals have worse health than those who feel socially connected. The mechanisms through which social disconnection influences physiological and psychological outcomes warrant study. The current study tested whether experimental manipulations of social exclusion, relative to inclusion, influenced subsequent cardiovascular (CV) and affective reactivity to socially evaluative stress.

Methods Young adults ($N = 81$) were assigned through block randomization to experience either social exclusion or inclusion, using a standardized computer-based task (Cyberball). Immediately after exposure to Cyberball, participants either underwent a socially evaluative stressor or an active control task, based on block randomization. Physiological activity (systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR)) and state anxiety were assessed throughout the experiment.

Results Excluded participants evidenced a significant increase in cardiovascular and affective responses to a socially evaluative stressor. Included participants who underwent the stressor evidenced similar increases in anxiety, but systolic blood pressure, diastolic blood pressure, and heart rate did not change significantly in response to the stressor.

Conclusions Results contribute to the understanding of physiological consequences of social exclusion. Further investigation is needed to test whether social inclusion can buffer CV stress reactivity, which would carry implications for how positive social factors may protect against the harmful effects of stress.

Keywords Social exclusion · Stress reactivity · Cyberball · Blood pressure · TSST

Introduction

Research demonstrates a robust link between social relationships and health [1–3]. Individuals who feel more interpersonally connected evidence better health outcomes, and those who feel disconnected from others fare worse on outcomes such as all-cause mortality, self-rated health, mental well-being, and cardiovascular (CV) function [4–8]. Considerable research has interrogated biobehavioral mechanisms for these links. One potential pathway through which social factors influence health is by modulating affective and physiological stress reactivity [9, 10]. Indeed, feelings of connectedness are theorized to reduce physiological responses, such as the activation of the sympathetic nervous system (SNS) and hypothalamic-pituitary-adrenal (HPA) axis, to stressors [7]. However, this hypothesis has been supported by correlational more than experimental research (for meta-analysis, see [8]), and the experimental studies have typically investigated whether positive social factors (e.g., giving or receiving support) reduce stress reactivity [11–14], as opposed to examining whether negative social factors (e.g., social exclusion) increase stress reactivity. Such an investigation may be important for understanding the physiological mechanisms through which chronic or repeated exposure to social adversity influences health [15–17]. Additionally, this research has tended to focus more on HPA than SNS responses to stress. The current experiment tests whether social exclusion, relative to social

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inclusion, influences CV responses and affective reactivity to a subsequent socially evaluative stressor.

Considerable research has investigated whether positive social factors influence stress physiology. Correlational findings indicate that higher social support is associated with lower blood pressure and better cardiovascular regulation to stress [8, 18]. Experimental research has demonstrated that giving support [11], the presence of a supportive person [12–14], and receiving support [19] reduces physiological stress responses. Less work, however, has examined whether social exclusion produces increases in physiological stress responses. Some experimental research shows that social exclusion can affect both immediate physiological activity as well as physiological responses to a subsequent stressor, but findings are mixed [20–24]. First, with regards to the effect of social exclusion on immediate physiological responses, most studies report that exclusion produces increases in neuroendocrine or CV responses only among a subset of participants [25–28], and others report null findings [29, 30] or opposite findings [31]. Thus, social exclusion itself does not appear to have a uniform response on immediate physiological activity. With regard to the effect of social exclusion on physiological responses to a subsequent stressor, most work has focused on HPA axis reactivity [24, 32, 33]. Across these studies, women evidenced a blunted cortisol response to social evaluation following social exclusion, relative to inclusion [24, 32, 33]. Among men, there was no effect of exclusion on cortisol responses to a subsequent stressor [32]. However, these studies did not include indicators of CV reactivity, which may be more sensitive measures of the effect of social exclusion on subsequent responses to a stressor.

CV reactivity may be particularly important to examine because higher CV stress reactivity predicts the development of preclinical and clinical disease [34], and meta-analytic findings indicate that exaggerated blood pressure reactivity to acute stress reliably predicts incident hypertension [35]. Importantly, CV reactivity to stress can be heightened by negative social factors such as harassment [36] and lowered by protective social factors such as giving or receiving support [11, 13]. Thus, it is plausible that experiences of social exclusion might influence subsequent CV responsiveness to a social stressor.

The Current Study

To investigate the effects of social exclusion on CV and affective stress responsivity, we used a 2 (social exclusion: exclusion vs. inclusion) × 2 (stress: socially evaluative stress: active control) experimental design. We assessed systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), and state anxiety throughout the experimental session. First, we assigned participants through block randomization to either an acute experience of social exclusion or inclusion through Cyberball, a standard task used to manipulate social exclusion [37] and explored whether social exclusion, relative to inclusion, produced immediate increases in CV and affective responsiveness. Then, after completing the Cyberball task, participants were assigned to either undergo a socially evaluative stressor [32, 38] or an active control task (i.e., completing word searches), based on the block randomization. We hypothesized that participants would evidence increases in cardiovascular and affective responses to the socially evaluative stressor but that increases would be greater in socially excluded, as compared to included, participants. We also hypothesized that control participants, regardless of exclusion condition, would evidence no significant changes in CV and affective reactivity in response to the control task. Finally, participants sat quietly for 15 min following the stressor or control task, and we explored without directional hypotheses whether CV and affective responding returned to baseline levels during this recovery period as a function of social exclusion, stress, and/or their interaction.

Method

Participants

Participants ($N = 81$) were college students recruited by advertisements on campus. Exclusion criteria were feeling uncomfortable completing questionnaires in English or being under 18 years old. Participants were offered $5 compensation and were entered into a lottery to win one of four $25 gift cards.

Procedure

Upon arrival to the laboratory, participants provided written informed consent. Participants were instructed to abstain from exercising, drinking fluids, or eating within the hour before their appointment. After placement of a blood pressure cuff on their non-dominant arm, participants completed questionnaires on psychosocial characteristics (i.e., depressive symptoms, loneliness, social anxiety symptoms) during the 15-min baseline period. Next, participants were assigned through block randomization to an acute experience of social exclusion or inclusion through the Cyberball task. Following Cyberball task completion (15 min), participants completed the socially evaluative stressor (15 min) or the control condition, based on block randomization. Finally, participants sat quietly for 15 min of recovery. All procedures were approved by the Institutional Review Board at Pitzer College.

Social Exclusion Cyberball is a computer-based task that induces feelings of exclusion, relative to a social inclusion control condition [37]. Participants were assigned through block randomization to either a social exclusion or inclusion condition. Participants were asked to throw a virtual ball per mouse-click to the other "players" in the game as part of a "mental visualization task," and they were told that each thrower decides who receives the ball next. Included participants received an equal number of ball tosses as the rest of the "players," whereas socially excluded participants received significantly fewer ball tosses and stopped receiving the ball altogether during the game. The computerized players had gender-neutral names displayed on the computer screen alongside a cartoon avatar. Participants were led to believe that the computerized players were two other participants who were connected through computers at another location. Participants were instructed not to speak during the Cyberball task and did not receive feedback either during or immediately after the task. Effects of social exclusion are interpreted relative to the social inclusion condition [38].

Stress Task After completing Cyberball, participants were assigned through block randomization to complete a socially evaluative stressor or an active control task. The stressor task, a modified version of the Trier Social Stress Task (TSST) [39], consisted of anticipatory speech preparation (5 min; the speech prompt was "please discuss your positive and negative characteristics, how you view them, and how they have influenced your life"), speech performance (5 min), and verbal arithmetic performance (5 min; serially subtracting 13 from 1022). Used in previous research, this speech prompt elicits a robust biological stress response [32, 40]. The speech was delivered in front of a digital camera and an experimenter to increase social evaluative threat. Control participants were given three crossword puzzles to complete, each containing 20 words generated from a random word generator at or below a sixth grade reading level. A member of the research team instructed the control participants to take their time and that it was not necessary to finish the puzzles. No participant finished the crossword puzzles before time expired. Afterwards, participants sat quietly by themselves in the same room during the 15-min recovery period.

Randomization The randomization schedule was produced by a computer-generated program to create permuted random blocks of eight. Concealment was accomplished through the use of sequentially numbered files, which were stored on a password-protected database. Approximately equal numbers of participants were assigned to the four conditions ($n = 21$ excluded/TSST, $n = 21$ included/TSST, $n = 20$ excluded/control, $n = 19$ included/control).

Cardiovascular Measures

Throughout the experiment, blood pressure and heart rate were assessed continuously by a researcher trained in these methods with a Biopac NIBP100D blood pressure amplifier and then transmitted to a Biopac MP100 recording (Biopac Systems Inc., Goleta, CA). Data were sampled at 1000 Hz and were analyzed using ACQKnowledge 4.1.1 software. The researcher placed an arm cuff directly above the brachial artery on the participants' non-dominant arm so that they could write freely with their dominant hand, and a finger cuff was placed above the proximal joints of the index and middle fingers of the non-dominant hand. The participant's arm was placed on a table adjacent to the participant so that the hand with the finger cuff was placed at heart level. An initial brachial blood pressure measurement was used to calibrate the beat-by-beat CV monitoring, which was assessed through finger plethysmography continuously throughout the experimental session. Finger plethysmography has been validated and shown to provide accurate blood pressure measurements, as compared to auscultatory methods [41]. Average SBP, DBP, and HR values were generated across four intervals in the study [42, 43]: (a) during the 15-min baseline period after being connected to the CV equipment (baseline), (b) during the 15-min completion of the Cyberball task (Cyberball), (c) during the 15-min completion of either the TSST or control task (stressor), and (d) during the 15-min recovery period (recovery).

Questionnaires

Post-Cyberball Questionnaire Immediately following Cyberball, participants completed a questionnaire used in previous studies of social exclusion [44]. A total of 20 items (each scored on a 1–5 Likert scale) assess feelings of belonging, control, self-esteem, and meaningful existence. Two additional items (i.e., "I felt ignored," "I felt excluded") served as a manipulation check for exclusion.

State Anxiety The 20-item State Anxiety Inventory [45] measured state anxiety directly after the baseline, Cyberball, stressor, and recovery phases of the experiment. Participants were asked to report feelings of anxiety during the preceding phase of the study. Ratings were endorsed on a 1–4 scale (1 = not at all, 2 = somewhat, 3 = moderately so, 4 = very much so) to capture the intensity of state anxiety. Items were reverse coded as appropriate and summed to create a total score, ranging from 20 to 80. Estimates of internal consistency were high (α's > .91).

Psychosocial Characteristics Depressive symptoms, loneliness, and social anxiety symptoms are independently related to social threat sensitivity [46–48]. Accordingly, we evaluated whether groups differed at baseline on measures of these psychosocial characteristics. The 20-item Center for Epidemiologic Studies-Depression Scale [49] was used to assess depressive symptoms. Each item has a 0–3 range, with higher total scores representing greater depressive symptom severity ($\alpha = .89$). The 20-item UCLA Loneliness Scale [50] was used to assess feelings of loneliness. Each item is rated on a 4-point scale, with higher total scores reflecting more loneliness ($\alpha = .91$). On the Social Anxiety Scale [51], participants rated a list of 24 situations that may induce feelings of social anxiety on both their fear and avoidance of each situation. Items range from 0 to 3, with higher scores reflecting more fear and avoidance of social situations ($\alpha = .92$).

Analytic Strategy

Baseline differences in self-reported and physiological variables between the experimental conditions were assessed with 2 (social exclusion: excluded, included) × 2 (stress: TSST, control) ANOVAs and chi-square tests where appropriate. Three multilevel models were conducted for each of the four dependent variables (i.e., SBP, DBP, HR, anxiety) to assess CV and affective responsiveness from baseline to Cyberball, baseline to stressor, and baseline to recovery, respectively. Specifically, CV and affective responsiveness were analyzed with 2 (social exclusion: excluded, included) × 2 (stress: TSST, control) × 2 (time: baseline, Cyberball/stressor/recovery) multilevel models. Planned a priori comparisons were conducted to evaluate within-group changes in CV and state anxiety over time. Significance testing for coefficients was conducted using z-scores, and results were identical when coefficients were tested using t tests with the Kenward-Roger method to estimate degrees of freedom, which uses an adjustment for estimating the covariance matrix that reduces bias from small sample sizes [52]. Tests of statistical significance did not differ when controlling for baseline or change in anxiety for all CV analyses.

Results

Baseline Comparisons

Across the experimental groups, participants did not significantly differ with regard to age, gender, year in college, race/ethnicity, and family income (ps > .083). At baseline, there were no significant differences as a function of social exclusion, stress condition, or their interaction on state anxiety, DBP, HR, social anxiety symptoms, depressive symptoms, or loneliness (ps > .076). A significant interaction was obtained between social exclusion and stress condition on baseline SBP, $F(1, 77) = 5.46$, $p = .022$. Baseline SBP was higher among excluded/control participants, as compared to included/control participants, $t(37) = 2.09$, $p = .043$. Baseline SBP values were not adjusted for the difference observed between included/control and excluded/control participants, because no substantive analyses were planned to compare the included/control and excluded/control conditions on SBP reactivity. Baseline SBP did not differ significantly among participants in the excluded/TSST and included/TSST conditions, $t(40) = -1.24$, $p = .222$. Correlations demonstrated that state anxiety at baseline was not associated significantly with any baseline CV variable (ps > .259). Table 1 provides sample characteristics.

Cyberball Manipulation Check

After Cyberball, excluded participants reported significantly higher levels of feeling ignored ($M = 4.23$, SD = 1.19), compared with included participants ($M = 1.93$, SD = 1.14), $t(78) = 8.83$, $p < .001$. Similarly, excluded participants reported feeling more excluded ($M = 4.02$, SD = 1.26), compared with included participants ($M = 1.83$, SD = 1.06), $t(79) = 8.51$, $p < .001$. Results from the post-Cyberball questionnaire demonstrate that socially excluded, as compared to included, participants evidenced lower feelings of belonging, self-esteem, meaningful existence, and control (ts > 4.30, ps < .001). Interestingly, included participants evidenced a significantly higher score ($M = 3.52$, SD = 0.87) than the neutral point on the belonging subscale ($t(39) = 3.81$, $p < .001$), indicating that the social inclusion condition produced feelings of belonging after Cyberball.

Effects of Social Exclusion on Affective and CV Responding

We first examined the effect of social exclusion, relative to inclusion, on affective and CV responding. Interactions between social exclusion (excluded, included) and time (baseline, Cyberball) were assessed for each outcome separately from baseline to the Cyberball phase. There was a nonsignificant social exclusion by time interaction on anxiety ($z = -1.74$, $p = .082$); planned a priori within-group comparisons showed that excluded participants evidenced a significant increase in anxiety ($z = 3.12$, $p = .002$) but included participants evidenced no significant change ($z = 0.66$, $p = .510$). Interaction effects, planned comparisons, and effect sizes are displayed in Table 2.

Results indicated no significant social exclusion by time interaction for SBP, DBP, or HR (ps > .256). A significant effect of time on DBP indicated that all participants evidenced a small yet significant decrease in DBP ($z = -3.46$, $p = .001$). There were no significant effects of social exclusion or time on any other outcome (ps > .085).

Effects of Social Exclusion and Socially Evaluative Stress on Affective and CV Responding

Baseline to Stressor Next, we examined the effect of social exclusion, relative to inclusion, on affective and CV responses to the stress task. Interactions between social exclusion (excluded, included), stress (TSST, control), and time (baseline,

Table 1 Descriptive statistics for participants ($N = 81$ young adults)

	Excluded/TSST ($n = 21$)		Included/TSST ($n = 21$)		Excluded/control ($n = 20$)		Included/control ($n = 19$)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (in years)	20.43	0.87	20.57	1.03	21.30	2.76	19.95	1.18
Depressive symptoms	11.85	8.77	16.30	9.79	13.45	8.99	12.37	6.73
Baseline state anxiety	27.92	5.87	36.54	11.88	32.42	10.00	33.25	7.88
Baseline SBP	123.86	16.56	129.64	13.50	132.34	16.04	122.96	11.43
Baseline DBP	81.75	12.43	81.86	10.46	82.44	9.21	79.65	7.16
Baseline heart rate	76.58	16.48	84.46	16.48	83.33	15.21	80.98	14.74
Loneliness	33.92	7.71	42.00	9.70	38.75	9.24	39.00	7.35
Social anxiety symptoms	45.92	19.50	46.38	19.52	52.83	20.56	38.00	14.77
	n	%	*n*	%	*n*	%	*n*	%
Gender								
Male	3	14.29%	2	9.52%	7	35.00%	6	31.58%
Female	18	85.71%	19	90.48%	13	65.00%	13	68.42%
Year in school								
First year	0	0%	0	0%	1	5.00%	4	21.05%
Second year	6	28.57%	7	33.33%	6	30.00%	3	15.79%
Third year	10	47.62%	5	23.81%	6	30.00%	4	21.05%
Fourth year	5	23.81%	9	42.86%	7	35.00%	8	42.11%
Family income								
Less than $15,000	0	0%	0	0%	1	5.00%	1	5.26%
$15,001–$45,000	4	19.05%	0	0%	1	5.00%	3	15.79%
$45,001–$75,000	4	19.05%	2	9.52%	4	20.00%	3	15.79%
$75,001–$99,999	4	19.05%	8	38.10%	6	30.00%	5	26.32%
More than $100,000	7	33.33%	11	52.38%	8	40.00%	6	31.58%
Did not respond	2	9.52%	0	0%	0	0%	1	5.26%
Race/ethnicity								
White	11	52.38%	17	80.95%	9	45.00%	11	57.89%
Other race/ethnicity	10	47.62%	4	19.05%	11	55.00%	8	42.11%

No significant differences were observed between any of the baseline variables with the exception of baseline SBP. Post hoc comparisons indicated that baseline SBP was higher among excluded/control participants, as compared to included/control participants. No differences were observed in baseline SBP between the other groups

TSST Trier Social Stress Task, *SBP* systolic blood pressure, *DBP* diastolic blood pressure

stressor) were assessed for each outcome separately from baseline to the stressor phase. The overall pattern of effects is displayed in Fig. 1.

First, with regard to affective responding, there was no significant three-way interaction on anxiety ($z = 1.49$, $p = .137$). However, there was a significant interaction between stress and time ($z = -3.47$, $p = .001$), such that TSST participants evidenced significant increases in anxiety ($M = 11.12$, SE = 1.97, $z = 5.63$, $p < .001$) whereas control participants did not evidence any significant change ($z = 0.67$, $p = .503$). There were no other interaction effects (*p*s > .106; see Table 2).

With regards to CV responding, there was a significant three-way interaction between social exclusion, stress, and time on SBP responding ($z = 2.76$, $p = .006$) and a nonsignificant three-way interaction on DBP responding ($z = 1.67$, $p = .095$). Decomposing these effects with planned a priori contrasts, among subjects who went through the TSST, social exclusion led to bigger increases in SBP and DBP compared to inclusion (*p*s < .011). More specifically, within-group contrasts from baseline to the stressor phase showed that excluded/TSST participants evidenced a significant increase in SBP ($z = 4.65$, $p < .001$) and DBP ($z = 5.13$, $p < .001$), whereas included/TSST participants evidenced no significant change in SBP ($z = 0.39$, $p = .697$) or DBP ($z = 1.54$, $p = .124$), suggesting that inclusion may have a dampening effect on subsequent stress reactivity or that the analysis is underpowered to capture changes in SBP or DBP. For control participants, SBP and DBP reactivity did not differ significantly between excluded and included groups (*p*s > .353).

Table 2 Effects of social exclusion (vs. inclusion) and socially evaluative stress (vs. control) on affective and cardiovascular responsiveness: interactive effects, planned comparisons, and effect sizes

	Systolic blood pressure		Diastolic blood pressure		Heart rate		State anxiety	
Baseline to Cyberball	b (SE)	95% CI	b (SE)	95% CI	b (SE)	95% CI	b (SE)	95% CI
Exclusion × Time interaction	− 0.41 (1.65)	[− 2.83, 3.65]	1.22 (1.58)	[− 3.32, 0.88]	− 0.16 (1.73)	[− 3.22, 3.54]	− 2.84 (1.63)	[− 6.04, 0.36]
Planned within-group time contrasts	ΔM (SE)	95% CI	ΔM (SE)	95% CI	ΔM (SE)	95% CI	ΔM (SE)	95% CI
Exclusion	− 1.98 (1.16)	[−4.26, 0.29]	*− 2.61 (0.75)*	*[− 4.08, − 1.13]*	− 0.42 (121)	[− 2.80, 1.95]	*3.60 (1.15)*	*[1.34, 5.86]*
Inclusion	− 1.57 (1.17)	[− 3.87, 0.73]	*− 3.82 (0.76)*	*[− 5.32, − 2.33]*	− 0.26 (1.23)	[− 2.67, 2.14]	0.76 (1.15)	[− 1.50, 3.02]
Baseline to stressor	b (SE)	95% CI	b (SE)	95% CI	b (SE)	95% CI	b (SE)	95% CI
Three-way interaction	*16.24 (5.89)*	*[4.70, 27.78]*	7.04 (4.22)	[− 1.23, 15.30]	6.54 (4.27)	[− 1.83, 14.91]	8.47 (5.70)	[− 2.70, 19.64]
Exclusion × time interaction	*− 12.30 (4.08)*	*[− 20.31, −4.30]*	*− 7.43 (2.92)*	*[− 13.17, −1.70]*	*− 8.52 (2.96)*	*[− 14.32, − 2.72]*	− 6.38 (3.95)	[− 14.12, 1.35]
Exclusion × stress interaction	*− 15.16 (7.28)*	*[− 29.43, −0.88]*	−2.90 (5.28)	[− 13.25, 7.46]	− 10.24 (6.67)	[− 23.32, 2.84]	− 7.78 (6.16)	[− 19.85, 4.28]
Stress × time interaction	*− 22.66 (4.14)*	*[− 20.31, −4.30]*	*− 12.87 (2.96)*	*[− 18.67, −7.06]*	*− 8.49 (3.00)*	*[− 14.37, − 2.61]*	*− 13.97 (4.03)*	*[− 21.87, − 6.08]*
Planned within-group time contrasts	ΔM (SE)	95% CI	ΔM (SE)	95% CI	ΔM (SE)	95% CI	ΔM (SE)	95% CI
Exclusion/TSST	*13.43 (2.89)*	*[7.77, 19.09]*	*10.62 (2.07)*	*[6.56, 14.67]*	*8.32 (2.09)*	*[4.22, 12.42]*	*14.31 (2.79)*	*[8.84, 19.78]*
Inclusion/TSST	1.12 (2.89)	[− 4.54, 6.78]	3.18 (2.07)	[− 0.87, 7.24]	− 0.20 (2.09)	[− 4.30, 3.91]	*7.92 (2.79)*	*[2.45, 13.40]*
Exclusion/control	*− 9.23 (2.96)*	*[− 15.03, − 3.43]*	− 2.25 (2.12)	[− 6.41, 1.90]	− 0.17 (2.15)	[− 4.38, 4.03]	0.33 (2.91)	[− 5.36, 6.03]
Inclusion/control	−5.30(3.04)	[−11.25, 0.66]	−2.65(2.17)	[−6.91, 1.61]	−2.15(2.20)	[−6.47, 2.16]	2.42(2.91)	[−3.28, 8.11]
Baseline to recovery	b (SE)	95% CI	b (SE)	95% CI	b (SE)	95% CI	b (SE)	95% CI
Three-way interaction	*18.52 (7.47)*	*[3.88, 33.16]*	6.06 (6.94)	[− 7.54, 19.65]	5.53 (4.48)	[− 3.25, 14.30]	3.35 (3.58)	[− 3.68, 10.37]
Exclusion × time interaction	*−11.51 (5.18)*	*[− 21.67, − 1.36]*	− 3.82 (4.81)	[− 13.25, 5.62]	*− 7.50 (3.09)*	*[− 13.56, − 1.45]*	− 3.85 (2.48)	[− 8.71, 1.02]
Exclusion × stress interaction	− 15.16 (8.00)	[− 30.84, 0.52]	− 2.90 (5.80)	[− 14.27, 8.47]	*− 10.24 (6.61)*	*[− 23.19, 2.72]*	− 7.78 (5.66)	[− 18.87, 3.31]
Stress × time interaction	*− 22.27 (5.24)*	*[− 32.55, − 11.99]*	− 7.15 (4.87)	[− 16.70, 2.40]	− 2.72 (3.16)	[− 8.92, 3.49]	*− 7.44 (2.53)*	*[− 12.40, − 2.47]*
Planned within-group time contrasts	ΔM (SE)	95% CI	ΔM (SE)	95% CI	ΔM (SE)	95% CI	ΔM (SE)	95% CI
Exclusion/TSST	7.07 (3.66)	[− 0.11, 14.25]	2.85 (3.40)	[− 3.82, 9.52]	2.13 (2.18)	[− 2.15, 6.41]	*4.77 (1.76)*	*[1.33, 8.21]*
Inclusion/TSST	− 4.43 (3.66)	[− 11.62, 2.74]	− 0.97 (3.40)	[− 7.64, 5.70]	*− 5.38 (2.18)*	*[−9.66, −1.10]*	0.93 (1.76)	[− 2.52, 4.36]
Exclusion/control	*− 15.20 (3.75)*	*[− 22.56, − 7.84]*	− 4.30 (3.49)	[− 11.14, 2.53]	− 0.59 (2.29)	[− 5.08, 3.90]	− 2.67 (1.83)	[− 6.25, 0.92]
Inclusion/control	*− 8.19 (3.85)*	*[− 15.74, − 0.64]*	− 2.06 (3.58)	[− 9.07, 4.95]	− 2.57 (2.30)	[− 7.07, 1.93]	− 3.17 (1.83)	[− 6.75, 0.42]

Italicized statistics are statistically significant at $p < .05$

b unstandardized regression coefficient, *SE* standard error, *CI* confidence interval, Δ*M* average change, *TSST* Trier Social Stress Task

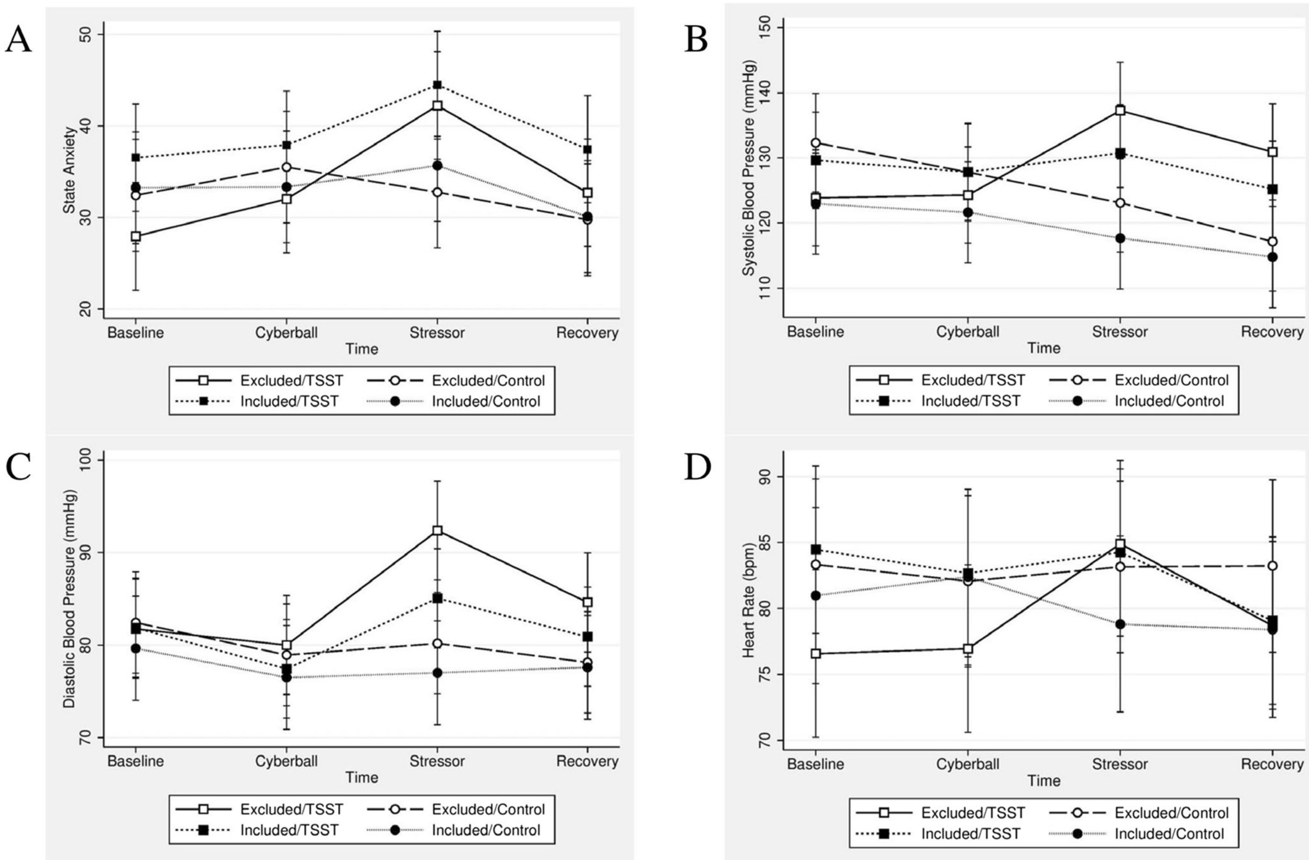

Fig. 1 State anxiety (**a**), systolic blood pressure (**b**), diastolic blood pressure (**c**), and heart rate (**d**) activity over time. Error bars reflect standard errors. *TSST* Trier Social Stress Task, *mmHg* millimeters of mercury, *BPM* beats per minute

Additionally, there was no significant three-way interaction on HR reactivity ($z = 1.53$, $p = .126$). However, there was a significant stress by time interaction for HR reactivity ($z = 2.83$, $p = .005$), such that TSST participants evidenced significant increases in HR ($M = 4.11$, SE = 1.48, $z = 2.78$, $p = .005$), whereas control participants did not evidence any significant change (ps > .455). There was also a significant social exclusion by time interaction on HR ($z = 2.88$, $p = .004$). Specifically, within-group analyses showed that excluded participants evidenced significant increases in HR ($M = 4.23$, SE = 1.50, $z = 2.82$, $p = .005$), whereas included participants evidenced no significant change ($M = -1.14$, SE = 1.52, $z = -0.75$, $p = .453$). Exploratory analyses indicated that this effect was driven by excluded/TSST participants. Excluded/TSST participants evidenced a significant increase in HR ($z = 3.97$, $p < .001$), whereas all other groups evidenced no significant change (ps > .328). Furthermore, HR increases in excluded/TSST participants were greater than those of included/TSST participants ($z = 2.88$, $p = .004$), but HR responding did not differ between excluded/control and included/control participants ($z = 0.64$, $p = .520$).

Baseline to Recovery Next, we examined the effect of social exclusion, relative to inclusion, on affective and CV responses to the TSST during the recovery phase. Interactions among social exclusion (excluded, included), stress (TSST, control), and time (baseline, recovery) were assessed for each outcome separately from baseline to the recovery phase.

First, with regard to affective responding, there was no three-way interaction between social exclusion, stress, and time on anxiety ($z = 0.93$, $p = .350$). However, there was a significant interaction between stress and time on anxiety ($z = 2.93$, $p = .003$).Within-group analyses showed that anxiety was higher at recovery than at baseline for TSST participants ($M = 2.85$, SE = 1.24, $z = 2.29$, $p = .022$) and lower at recovery than at baseline for control participants ($M = -2.92$, SE = 1.29, $z = -2.26$, $p = .024$).

With regard to CV responding, there was a significant three-way on SBP ($z = 2.48$, $p = .013$) but not on DBP or HR (ps > .217). For those who went through the stress task, social exclusion led to higher SBP at recovery than at baseline, compared to those who went through inclusion ($z = 2.22$, $p = .026$; see Table 2). However, for those who went through the control task, there was no difference in SBP at recovery, compared to baseline, for included vs. excluded participants ($z = 1.30$, $p = .193$). There was also a significant social exclusion by time interaction ($z = 2.42$, $p = .015$) and a stress by time interaction ($z = -2.83$, $p = .005$) on HR, but not on DBP

($ps > .142$). Within-group analyses showed that HR was significantly lower at recovery than at baseline for included/TSST participants ($z = -2.46$, $p = .014$), but there was no significant difference among all other groups ($ps > .264$).

Discussion

First, we investigated the effects of social exclusion, relative to inclusion, on immediate CV and affective responsiveness. Consistent with previous research on social exclusion and affective responses [31, 33, 53], social exclusion, relative to inclusion, produced a significant increase in state anxiety. CV reactivity did not differ between the two conditions, however. It is difficult to directly compare this finding to previous studies, which often report moderated effects of exclusion on biological responsiveness by factors such as sex, self-esteem, and sensitivity rejection [25, 26, 31]. Within-group analyses indicated that excluded participants evidenced a significant increase in state anxiety in response to the Cyberball task, whereas included participants evidenced no significant change.

Next, we investigated whether manipulations of social exclusion, relative to inclusion, influenced physiological and affective responses to a subsequent social stressor (vs. an active control task) from baseline to the immediate post-task assessment points and to recovery. In partial support of our hypothesis, excluded/TSST participants, compared to included/TSST participants, evidenced significantly greater increases in SBP and DBP in response to the stressor. Contrary to hypothesis, however, within-group analyses showed that included/TSST participants evidenced no significant change in SBP and DBP in response to the stressor. Similar within-group findings emerged for HR reactivity, such that excluded/TSST participants evidenced significant increases in HR from baseline to the stressor, but included/TSST participants evidenced no significant change. Whether social exclusion produced a potentiated or normative response to subsequent stress is unclear. When comparing the mean levels of the outcomes to those found in other studies, however, it appears that the observed values among participants in the present excluded/TSST condition were similar to values among participants who completed a socially evaluative stressor without any prior manipulation [54–56]. There were no significant influences of social exclusion, relative to inclusion, on affective reactivity. However, there was a significant effect of stress such that TSST participants, compared to control participants, evidenced greater increases in state anxiety in response to the stressor.

Finally, we explored whether CV and affective responses returned to baseline levels during the recovery period as a function of social exclusion and stress condition. For those who went through the stress task, Cyberball exclusion led to higher SBP (but not DBP or HR) at recovery than at baseline, compared to included participants. It is unclear why there are disparate findings in relation to SBP and DBP recovery. Other studies indicate that social manipulations influence SBP but not DBP responsiveness [e.g., 11, 13]. SBP is related to higher variability in measurement across time, whereas DBP is generally more stable [57]; as such, it is possible that the effect size for social manipulations needs to be larger to produce changes in DBP recovery from stress.

To our knowledge, three studies have investigated effects of social exclusion on physiological reactivity to a subsequent stressor [24, 32, 33], which demonstrated a blunting effect of social exclusion, relative to inclusion, on neuroendocrine (but not catecholaminergic) reactivity to stress. A direct comparison of these findings is difficult, because we did not assess neuroendocrine or catecholaminergic markers. The present experiment produced a different pattern of results, in which socially excluded participants evidenced significant increases in SBP, DBP, and HR in response to a stressor, whereas included participants evidenced no significant change in SBP, DBP, or HR. It is important to note that the HPA axis and SNS are differentially engaged by various psychological experiences [58], and it is possible that social exclusion produces distinct effects on these systems. Specifically, acute feelings of social exclusion are associated with neural activity in regions responsible for detecting danger and threat (e.g., dorsal anterior cingulate cortex), which are important for the regulation of SNS responding [58–60]. In contrast, exclusion produces feelings of low self-esteem and low control, which in conjunction are related to HPA axis non-responsiveness to stress [61].

The Cyberball paradigm is widely used to manipulate social exclusion, using the inclusion condition as a control group. After Cyberball, however, socially included participants reported significantly higher feelings of belonging than the neutral point. It is possible that the social inclusion condition functions to produce feelings of belonging and connectedness, suggesting that it is not a neutral control group. Future research is needed to further evaluate whether Cyberball inclusion can be used as a neutral control group, relative to exclusion, or serves as an active manipulation of belonging and connectedness.

We found that socially excluded, compared to included, participants evidenced greater CV reactivity to a socially evaluative stressor. Surprisingly, however, these results were driven, in part, by null changes in SBP, DBP, and HR from baseline to the stressor phase among socially included participants. These findings suggest that social inclusion may attenuate CV reactivity in response to a socially evaluative stressor, but it is also possible that the absence of significant changes reflects an underpowered analysis. Although further research is needed to evaluate whether social inclusion buffers CV reactivity to stress, the pattern of results is consistent with those of previous studies which demonstrate that positive social manipulations reduce CV reactivity to stress [11–14, 19]. Chronic or repeated SNS reactivity is associated with several negative long-term health consequences, including hypertension [62, 63] and CV disease risk [35]. Thus, future experimental findings demonstrating that social inclusion can buffer SNS-related responding to stress would carry importance for preventive efforts to reduce CV disease risk, particularly for those who confront chronic or repeated stressors.

The current study did not include a condition in which participants completed the social stressor without a prior manipulation of social exclusion or inclusion. A study design with such a condition would allow for a direct test of whether social exclusion produced a potentiated or normative response to a subsequent socially evaluative stressor. Furthermore, in light of the characteristics of the current sample, findings may not generalize to other populations. The sample was composed of primarily Caucasian students of higher socioeconomic backgrounds than the general population. Investigations in a more diverse community sample are needed. Additionally, the administration of questionnaires during the baseline period may have affected baseline SBP, DBP, HR, and state anxiety; however, baseline values in the current study are comparable to those obtained in studies that did not use post-questionnaire measurements [54, 63]. Finally, statistical tests for interactive effects were likely underpowered.

Future research should include both neuroendocrine and CV assessments as well as a measure of social integration to further evaluate the impact of social inclusion and exclusion on subsequent responsiveness to stress. In conclusion, experimental manipulations of social exclusion prior to a socially evaluative stressor (vs. an active control) demonstrated that excluded participants evidenced significant increases in SBP, DBP, and HR following social evaluation and that included participants did not evidence any significant change in SBP, DBP, or HR in response to the stressor, suggesting a buffering effect of social inclusion on CV reactivity to socially evaluative stress. Results bolster the understanding of the physiological mechanisms through which experiences of social exclusion relate to health outcomes. Additional investigations are needed to test whether feelings of social inclusion can buffer CV stress reactivity, which would carry implications for how positive social factors may protect against the deleterious effects of stress.

Acknowledgements We are grateful to Norma Rodriguez and Anne Blackstock-Bernstein for their comments on an earlier version of this manuscript as well as to Andy Lin for providing statistical consultation. We are also thankful to Taylor Kawakami and Jennifer Burleigh for their assistance with data collection. Timothy J. Williamson acknowledges support from a National Institute of Mental Health Predoctoral Research Fellowship (MH 15750). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. There are no other financial disclosures.

Funding This study was funded in part by the National Institute of Mental Health (MH 15750, Williamson). There are no other financial disclosures.

Compliance with Ethical Standards

Conflicts of Interest The authors declare that they have no conflict of interest.

Ethics Approval and Consent to Participate All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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