Social technology restriction alters state-anxiety but not autonomic activity in humans

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Durocher JJ, Lufkin KM, King ME, Carter JR. Social technology restriction alters state-anxiety but not autonomic activity in humans. Am J Physiol Regul Integr Comp Physiol 301: R1773–R1778, 2011. First published September 28, 2011; doi:10.1152/ajpregu.00418.2011.—Social technology is extensively used by young adults throughout the world, and it has been suggested that interrupting access to this technology induces anxiety. However, the influence of social technology restriction on anxiety and autonomic activity in young adults has not been formally examined. Therefore, we hypothesized that restriction of social technology would increase state-anxiety and alter neural cardiovascular regulation of arterial blood pressure. Twenty-one college students (age 18–23 yr) were examined during two consecutive weeks in which social technology use was normal or restricted (randomized crossover design). Mean arterial pressure (MAP), heart rate, and muscle sympathetic nerve activity (MSNA) were measured at rest and during several classic autonomic stressors, including isometric handgrip, postexercise muscle ischemia, cold pressor test, and mental stress. Tertile analysis revealed that restriction of social technology was associated with increases (12 ± 2 au; range 5 to 21; n = 7), decreases (–6 ± 2 au; range –2 to –11; n = 6), or no change (0 ± 0 au; range –1 to 3; n = 8) in state-anxiety. Social technology restriction did not alter MAP (74 ± 1 vs. 73 ± 1 mmHg), heart rate (62 ± 2 vs. 61 ± 2 beats/min), or MSNA (9 ± 1 vs. 9 ± 1 bursts/min) at rest, and it did not alter neural or cardiovascular responses to acute stressors. In conclusion, social technology restriction appears to have an interindividual influence on anxiety, but not autonomic activity. It remains unclear how repeated bouts, or chronic restriction of social technology, influence long-term psychological and cardiovascular health.

arterial blood pressure; cold pressor test; mental stress; muscle sympathetic nerve activity; psychological stress

Recent studies report that 95% of young adults in the United States own cellular phones and use them for multiple functions, such as talking, text messaging, and e-mail (22). Additionally, about 94% of college students report having an online social site, such as Facebook (3). The use of social technology has become a primary method of communication for a majority of young adults, and interrupting the use of these technologies can lead to increased levels of anxiety. Such anxiety may negatively influence an individual’s health, yet the extent of this potential anxiety has not been adequately quantified.

Increased levels of anxiety (21) are among the numerous factors that may significantly contribute to the development of cardiovascular disease. Augmented responses to autonomic stressors can be used as an early predictor of cardiovascular risk (4, 10, 11, 19, 20). For example, hypertensive adults demonstrate augmented sympathetic and pressor responses during isometric handgrip (IHG) and postexercise muscle ischemia (PEMI) compared with normotensive adults (2). Similarly, those with prehypertension demonstrate an augmented pressor response to mental stress (7, 16), and the extent of the blood pressure response to cold pressor test (CPT) is one predictor for the onset of hypertension (8, 20).

To date, no studies have examined the influence of social technology restriction on state-anxiety and autonomic regulation in humans. Therefore, the purpose of the present study was to simultaneously examine physiological and psychological responses to social technology restriction in young adults. We hypothesized that restriction of social technology for five consecutive weekdays would increase state-anxiety and alter neural cardiovascular control in humans. More specifically, we hypothesized that responses to IHG, PEMI, CPT, and mental stress would be augmented by social technology restriction.

Methods

Subjects. Twenty-one college students (10 males, 11 females; age 20 ± 0 yr, height 172 ± 2 cm, weight 70 ± 3 kg, body mass index 23 ± 1 kg/m²) that used multiple forms of social technology on a daily basis participated in this study. Further descriptive data (i.e., social technology use) based on the delta anxiety tertiles are described below. All participants were healthy, nonsmoking adults with no record of cardiovascular disease, and they abstained from exercise, caffeine, and alcohol for a minimum of 12 h prior to all testing sessions. We did not test females in a specific phase of the menstrual cycle, as testing occurred in a randomized order over a 2-wk period, which precluded controlling for this variable. The study was approved by the Institutional Review Board of Michigan Technological University, and all participants provided written informed consent.

Experimental design. Subjects reported to the Integrative Physiology Research Laboratory on two consecutive weeks. During 1 wk, subjects were restricted from using social technology Monday through Friday, while the alternate-week subjects were not restricted from use of social technology (randomized, crossover design). On Monday, Wednesday, and Friday of each week, resting blood pressure and heart rates were recorded at the same time of day following 5 min of rest, and subjects completed form Y-1 of the Spielberger State-Trait Anxiety Inventory (STAI) questionnaire (17). The STAI questionnaire has been used previously when examining reactivity to autonomic stressors (21). All testing sessions were performed at 2-h intervals between 8 AM and 4 PM, with participants reporting at the same time of day for all readings. On Friday of each week, following the resting blood pressure measurements and STAI questionnaire, height and weight were measured and participants were situated for autonomic testing in the supine position. The responses to three classic autonomic stressors were then assessed in the following order: 1) IHG and PEMI, 2) CPT, and 3) mental stress (i.e., arithmetic). Upon completion of the recorded recovery from each autonomic stressor, a minimum 5-min nonrecorded recovery was completed to allow for hemodynamic variables to stabilize.

IHG and PEMI. Participants performed two maximum voluntary contractions using a hand dynamometer after resting cardiovascular measurements were completed on each Friday before autonomic...
testing. Following a 5-min baseline, subjects held the dynamometer at 30% of their maximum voluntary contraction for 2 min or until fatigue. Time to fatigue was similar during the normal and social technology removal conditions (109 ± 4 vs. 111 ± 4 s). Immediately upon release of the handgrip dynamometer, PEMI was induced by inflating a cuff on the upper arm of the exercising limb to 220 mmHg for 2 min. Participants were asked to rate their perceived exertion (6–20 scale) and pain levels (6–20 scale) every 15 s during IHG and PEMI, respectively. Completion of PEMI was followed by 2 min of recorded supine recovery.

Cold pressor test. Following a 5-min baseline, participants immersed their hand up to the wrist in an ice bath (1–3°C) for 2 min. Perceived pain levels (6–20 scale) were reported every 15 s. The CPT was followed by a 2-min recorded supine recovery.

Mental arithmetic. Following a 5-min baseline, subjects performed mental stress (via mental arithmetic) for 3 min. The stress task involved subtracting a single digit number (6 or 7) continuously from random 2–3 digit numbers, while investigators verbally encouraged the subject to subtract faster. Completion of mental stress was followed by 3 min of recorded supine recovery. Perceived stress levels (0–4 scale) were recorded upon completion of the protocol (1).

Social technology restriction. Participants were assigned to a normal week of social technology use or a week of social technology restriction in a randomized order. During the restriction week, subjects were asked to restrict their use of social technology for the duration of 5 days (Monday through Friday). Restriction of social technologies included abstaining from the use of cell phones, Facebook, and socially related e-mail. Investigators retained cell phones for the 5-day duration under lock and key. A copy of each subject’s “inbox” and “sent” box was printed, stored, and justified by the participant to ensure no socially related e-mails were checked or sent during the 5 days. Socially related email was considered to be any email that was not from a professor (school-related) or employer (work-related). Facebook use was monitored by a designated investigator becoming a “friend” of the subject during the restriction of social technology week. Upon completion of the restriction week, the subject was free to remove the study investigator from their “friend” list. Cellular phones were returned upon completion of autonomic testing at the end of the social technology restriction week. During the normal week, participants used their social technologies without restriction.

Measurement techniques. Anxiety was measured using the STAI questionnaire for adults (17). The STAI form Y-1 was used to assess state-anxiety on Monday, Wednesday, and Friday during each of the two testing weeks. The 3 days were averaged to provide a mean state-anxiety score for each week (i.e., normal vs. restriction). State-anxiety is expressed as raw scores, as well as percentile and standard scores based on age and sex.

Resting arterial blood pressure and heart rate were recorded using an automated sphygmomanometer (Omron HEM-907XL, Omron Health Care) on Monday, Wednesday, and Friday of each week. During autonomic testing, beat-to-beat arterial pressure was measured continuously via Finometer (Finapres Medical Systems, Amsterdam, The Netherlands) during the baseline, intervention, and recovery of each trial. Finometer baseline blood pressures were normalized to a 3-reading average from the automated sphygmomanometer separated by 1-min intervals in the supine position. These readings were taken just prior to each baseline during autonomic testing, and the averages of these supine blood pressures are reported in Fig. 1 and Table 3. Heart rate was measured continuously via a 3-lead electrocardiogram.

Muscle sympathetic nerve activity (MSNA) was recorded directly via microneurography. A tungsten microelectrode was inserted into the peroneal nerve of the leg, and a reference electrode was inserted subcutaneously 2–3 cm away from the recording electrode. The electrodes were connected to a preamplifier, which was further attached to an amplifier. Nerve activity was amplified (gain 80,000, band-pass filtered (700–2,000 Hz), and integrated (time constant, 0.1) to obtain a mean voltage recording of nerve activity. Recordings were deemed satisfactory when spontaneous pulse synchronous bursts were detected and increased during end-expiratory apnea, but not with auditory stimuli (i.e., yelling and clapping).

Data analysis. Arterial blood pressure, heart rate, and MSNA were imported and analyzed using WinCPRS software program (Absolute Aliens, Turku, Finland). R-waves were marked in the time series. Bursts of MSNA were automatically detected using amplitude to determine a signal-to-noise ratio of 3:1, within a 0.5-s search window centered on a 1.3-s expected burst peak latency from the previous R-wave. The average burst area during baseline was normalized to a mean value of 100, and activity was expressed as bursts per minute, bursts per 100 heart beats, and total MSNA (i.e., the sum of the normalized burst areas per minute). All nerve activity was analyzed by a single investigator who was blinded to the treatment (i.e., normal vs. restriction).

Statistical analysis. Data were analyzed using commercial statistical analysis software (SPSS 18.0, SPSS, Chicago, IL). Paired t-tests were utilized to compare resting and baseline variables between the normal and social technology restriction conditions. Two-way repeated-measures ANOVA (condition × time) were utilized to determine changes in mean arterial pressure (MAP), heart rate, and MSNA (using mean values for baseline, intervention, and recovery). Statistically significant results were further compared using paired t-test post hoc analyses. The change in raw state-anxiety from the normal to restriction week were further ranked by tertile analysis, and the delta anxiety tertiles were then used as a between-subjects factor in the repeated-measures ANOVA to determine whether responses to autonomic stressors were dependent on the degree of anxiety induced by the treatment (i.e., normal or restricted use of social technologies).

Three consecutive automated sphygmomanometer resting blood pressures were taken in the supine position prior to each trial, and average values were used to calibrate the Finometer. Means were considered significantly different when P < 0.05. Results are expressed as means ± SE. All data represent 21 participants unless otherwise specified in our tables and figures (i.e., MSNA).

RESULTS

Restriction of social technology did not alter state anxiety (31 ± 2 vs. 32 ± 2 au), MAP (74 ± 1 vs. 73 ± 1 mmHg), heart rate (62 ± 2 vs. 61 ± 2 beats/min), or MSNA (9 ± 1 vs. 9 ± 1 bursts/min) at rest. Daily and weekly state-anxiety levels are shown in Table 1. A more detailed tertile analysis revealed that social technology restriction was associated with a decrease

| Table 1. State-anxiety levels during the normal and social technology restriction weeks |
|-----------------------------------------------|-----------------|-----------------|--------------------|
| Variable                      | Normal Condition | Restriction Condition |
| State-anxiety, raw            | 30 ± 2 | 29 ± 1 | 32 ± 2 | 31 ± 2 | 32 ± 2 | 32 ± 2 | 34 ± 3 | 32 ± 2 |
| State-anxiety, %tile          | 15 ± 2 | 15 ± 2 | 15 ± 2 | 15 ± 2 | 14 ± 2 | 15 ± 2 | 16 ± 2 | 15 ± 2 |
| State-anxiety, std.           | 44 ± 2 | 44 ± 2 | 47 ± 2 | 45 ± 2 | 46 ± 2 | 48 ± 3 | 48 ± 3 | 47 ± 2 |

Values are expressed as means ± SE; raw, raw state-anxiety scores in arbitrary units; %tile, percentile state-anxiety scores; std., standard state-anxiety scores.
(−5.8 ± 1.5 au; range −2 to −11) in raw state-anxiety for six participants (tertile 1), no change (0.3 ± 0.4 au; range −1 to 3) in eight participants (tertile 2), and an increase (12.2 ± 2.4 au; range 5 to 21) for seven participants (tertile 3). Figure 1 reveals that resting MAP, heart rate, and MSNA were similar within each tertile during the normal and social technology restriction weeks. Resting systolic and diastolic arterial blood pressures were also similar within each tertile during the two experimental weeks (data not shown). Amounts of overall social technology use were not different between tertiles as shown in Table 2.

Table 2. Self-reported normal social technology use according to each anxiety tertile

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tertile 1</th>
<th>Tertile 2</th>
<th>Tertile 3</th>
<th>Ave.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell phone, h/day</td>
<td>3.2 ± 0.5</td>
<td>1.3 ± 0.5</td>
<td>2.6 ± 0.5</td>
<td>2.4 ± 0.3</td>
</tr>
<tr>
<td>Facebook, h/day</td>
<td>1.1 ± 0.3</td>
<td>0.9 ± 0.2</td>
<td>1.2 ± 0.2</td>
<td>1.0 ± 0.1</td>
</tr>
<tr>
<td>Social e-mail, h/day</td>
<td>0.5 ± 0.2</td>
<td>0.3 ± 0.1</td>
<td>0.4 ± 0.1</td>
<td>0.4 ± 0.1</td>
</tr>
<tr>
<td>Average, h/day</td>
<td>4.8 ± 0.7</td>
<td>2.5 ± 0.6</td>
<td>4.1 ± 0.7</td>
<td>3.8 ± 0.4</td>
</tr>
</tbody>
</table>

Values are expressed as means ± SE; Tertile 1, participants that decreased state-anxiety (normal vs. restriction week); Tertile 2, participants that had no change in state-anxiety (normal vs. restriction week); Tertile 3, participants that increased state-anxiety (normal vs. restriction week). *Tertile 2 significantly lower than Tertiles 1 and 3 (P < 0.05). Average (h/day) was not significantly different between tertiles (P = 0.07).

The responses to IHG, PEMI, CPT, and mental arithmetic were similar during the normal and social technology restriction conditions, and they were similar for each anxiety tertile (P > 0.05; treatment × anxiety tertile). Raw baseline values preceding each of these autonomic stressors were similar during the normal and social technology restriction week, as shown in Table 3. Figure 2 depicts IHG and PEMI responses during the normal and social technology restriction conditions. IHG increased MAP (Δ17 ± 2 vs. Δ17 ± 1 mmHg), heart rate (Δ30 ± 3 vs. Δ27 ± 4 beats/min), and MSNA (Δ13 ± 2 vs. Δ14 ± 2 bursts/min) to a similar extent during the normal and restricted conditions. Increases in MAP (Δ18 ± 3 vs. Δ20 ± 2 mmHg), heart rate (Δ10 ± 2 vs. Δ8 ± 3 beats/min), and MSNA (Δ16 ± 2 vs. Δ16 ± 2 bursts/min) from baseline to PEMI were also similar during each condition. MAP (Δ12 ± 1 vs. Δ13 ± 1 mmHg), heart rate (Δ13 ± 2 vs. Δ11 ± 2 beats/min), and MSNA (Δ14 ± 2 vs. Δ17 ± 2 bursts/min) responses to CPT were comparable during normal conditions and social technology restriction as shown in Fig. 3. Finally, mental stress increased MAP (Δ8 ± 1 vs. Δ7 ± 1 mmHg), heart rate (Δ21 ± 2 vs. Δ20 ± 2 beats/min), and MSNA (Δ2 ± 2 vs. Δ2 ± 2 bursts/min) to similar levels in each condition as demonstrated in Fig. 4.

Ratings of perceived exertion were similar for the normal and social technology restriction testing days during IHG (14.9 ± 0.4 vs. 14.8 ± 0.3 au), and perceived pain levels were similar during PEMI in each condition (15.0 ± 0.5 vs. 14.9 ± 0.6 au). Perceived pain during CPT was also similar between conditions (14.5 ± 0.4 vs. 14.5 ± 0.5 au). Finally, perceived stress during mental arithmetic was similar during the normal and social technology restriction (3.0 ± 0.2 vs. 2.9 ± 0.1 au).

**DISCUSSION**

The present study examined the influence of social technology restriction on both physiological and psychological responses in young, healthy adults. Three primary findings have emerged. First, restriction of social technology for 1 wk in college students has an interindividual influence on state-anxiety, with participants reporting increases, decreases, or no change. Second, resting MAP, heart rate, and MSNA were not altered by the restriction of social technology. Third, social technology restriction did not alter the neural, cardiovascular, or psychological responses to classic autonomic stressors. Our findings indicate that restriction of social technology for 5 days can influence anxiety, but it does not produce substantial
changes in neural cardiovascular control at rest or during acute stress.

Our premise that restriction of social technology would result in altered neural and cardiovascular control in humans was based on anecdotal evidence of heightened anxiety during social technology interruption. The use of social technology has dramatically increased in recent years, and in some cases, this technology has become a way to avoid the potential anxiety of face-to-face communication (12). Several online websites speak of “disconnect anxiety”, but peer-reviewed sources that quantify the degree of anxiety are lacking. Related anecdotal perceptions indicate that some people associate Facebook use with negative effects on one’s personal image. However, Ellison et al. (3) have recently noted that undergraduate Facebook users, for the most part, increase their “social capital” and sense of community through the use of Facebook. Lack of social communication can be deleterious to health, as those with smaller social networks are reported to have a greater incidence of coronary artery disease, and an inverse relationship exists between the degree of social support and future cardiac events (14). Thus, decreasing social communication and support through social technology restriction could induce anxiety and have cardiovascular implications. To date, the effects of social technology restriction on autonomic function in humans has not been examined.

Contrary to our hypothesis, restriction of social technologies did not consistently increase state-anxiety or alter autonomic regulation. However, state-anxiety did increase in 7 of 21 participants using a tertile analysis. Thus, restriction of social technology appears to have an interindividual influence on state-anxiety. Increases in state-anxiety are often associated with increases in heart rate and blood pressure (18). Moreover, increases in state-anxiety induced during the days leading up to end of semester exams have been shown to correlate with changes in sympatho-vagal balance, as estimated by pulse rate variability (15). This evidence suggests that increases in heart rate and blood pressure with state-anxiety may be associated with elevated MSNA. However, the effect of state-anxiety on blood pressure and heart rate remain equivocal, as other research has demonstrated no difference based on state-anxiety levels (21). Our findings lend new insight to this field by indicating that resting MAP, heart rate, and MSNA were remarkably similar between conditions and across anxiety tertiles. These results are consistent with a study by Lambert et al. (6), who demonstrated that clinically diagnosed patients with panic disorder had significantly higher state and trait

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Table 3. Mean values for the three supine resting baselines during the normal and restriction of social technology autonomic tests

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normal Condition</th>
<th>Restriction Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base 1</td>
<td>Base 2</td>
</tr>
<tr>
<td>SAP, mmHg</td>
<td>105 ± 2</td>
<td>106 ± 2</td>
</tr>
<tr>
<td>DAP, mmHg</td>
<td>57 ± 2</td>
<td>58 ± 2</td>
</tr>
<tr>
<td>MAP, mmHg</td>
<td>73 ± 2</td>
<td>74 ± 1</td>
</tr>
<tr>
<td>HR, beats/min</td>
<td>61 ± 2</td>
<td>62 ± 2</td>
</tr>
<tr>
<td>MSNA, bursts/min</td>
<td>9 ± 1</td>
<td>9 ± 1</td>
</tr>
<tr>
<td>MSNA, bursts/100hb</td>
<td>14 ± 2</td>
<td>15 ± 2</td>
</tr>
</tbody>
</table>

Values are expressed as means ± SE. Base 1, baseline preceding isometric handgrip; Base 2, baseline preceding cold pressor test; Base 3, baseline preceding mental stress; SAP, systolic arterial blood pressure; DAP, diastolic arterial blood pressure; MAP, mean arterial blood pressure; HR, heart rate; MSNA, muscle sympathetic nerve activity; hb, heart beats. MSNA data, n = 16.
anxiety levels than healthy controls, but similar levels of resting MSNA.

Chronic psychological stress has been linked to the development of essential hypertension (4), atherosclerosis (14), and myocardial infarction (13). Previous studies have also linked augmented acute stress responses to increased cardiovascular risk (2, 7, 8, 10, 11, 16, 20). Specifically, augmented MSNA or blood pressure responses to IHG (2, 10), CPT (8, 20), and mental stress (7, 11, 16) are associated with increased risk of cardiovascular disease. In the present study, we measured neural and cardiovascular responses to each of these classic stressors during normal and social technology-restricted conditions. Responses to each of these autonomic stressors remained unaltered by the restriction of social technology, providing some indication that risk for cardiovascular disease may not be significantly increased by relatively short-term social technology restriction. Moreover, neural and cardiovascular responses were not different between anxiety tertiles. These findings are consistent with those of Mauss et al. (9), who report that humans with high and low social anxiety demonstrated similar autonomic control during and following stressful speech tasks.

We acknowledge three potential limitations. First, access to social technology was only restricted for 5 days. It is possible that longer periods of restriction may have a more dramatic influence on autonomic regulation of blood pressure. Second, it remains possible that social technology restriction may have a more dramatic impact on extreme (more than 12 h/day) social anxiety levels than healthy controls, but similar levels of resting MSNA.

Fig. 3. Mean arterial pressure (MAP; top), heart rate (HR; middle), and muscle sympathetic nerve activity (MSNA; bottom) responses to cold pressor test (CPT) were not altered by the restriction of social technology. MSNA data, n = 13.

Fig. 4. Mean arterial pressure (MAP; top), heart rate (HR; middle), and muscle sympathetic nerve activity (MSNA; bottom) responses to mental stress (MS) were not altered by the restriction of social technology. MSNA data, n = 10.
technology users (5). However, all of our participants used multiple forms of social technology daily, and 18 of our 21 participants were classified as "medium" to "high" users for one or more of the social technologies (5). Finally, if social technology use is interrupted without warning, it could elicit a different response than that experienced by volunteers in a study that has specific study parameters and timelines defined. However, this limitation could be difficult to overcome without serious ethical considerations (i.e., informing participants about the study design before they provide consent).

In summary, state-anxiety appears to increase, decrease, or not change with social technology restriction. However, despite this interindividual variability, resting MAP, heart rate, and MSNA were not changed. Moreover, restriction of social technology did not alter acute neural or cardiovascular responses to classic autonomic stressors. Because of the interindividual anxiety responses to restriction of social technologies, the influence of this restriction on cardiovascular health deserves further attention.

**Perspectives and Significance**

The present study examined young, healthy college students. While social technology use remains highest in this demographic, middle-age and elderly adults have also embraced the recent social technology revolution. As such, they are likely to be equally susceptible to potential anxiousness when those technologies are interrupted. Although the present study revealed no altered autonomic activity during social technology restriction in young adults, it is possible that middle-aged and elderly individuals have different autonomic responses to such restriction. Moreover, these populations are at heightened risk for cardiovascular complications that could be exacerbated by short-term anxiety. The explosion of social technologies over the past decade warrants further investigations on the psychological and physiological implications of social technology interruptions. This might be particularly important in individuals with an “addiction” to social technology and/or populations at risk for adverse cardiovascular events.

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**DISCLOSURES**

No conflicts of interest, financial or otherwise, are declared by the authors.

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