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It just takes a text: Partner text messages can reduce cardiovascular responses to stress in females

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ABSTRACT

Despite the ubiquity of text messaging, little is known about the physiological impact of receiving texts. This study explored the cardiovascular effects of receiving text messages from romantic partners during a stressor. Seventy-five healthy females received either (1) scripted, supportive text messages from their partners, (2) scripted, mundane text messages from their partners, or (3) no text messages at all (control condition) prior to completing a laboratory stressor. Blood pressure and heart rate were monitored throughout the study. Analyses revealed that systolic blood pressure in response to the stressor was lowest in the mundane text message group and significantly lower than in the other two groups. However, the mundane text message group also exhibited systolic blood pressure that more slowly returned to baseline levels. These findings highlight one potential benefit of text messaging and signal a need for additional work to better understand texting.

1. Introduction

Text messaging is now central to social life. By some accounts, over six billion texts are sent per day in the U.S. (O'Grady, 2012). This is especially the case for young adults who send or receive an average of 109.5 messages per day (Smith, 2011)—often to provide social support to friends and romantic partners (Thurlow & Brown, 2003). One possible benefit of support provision via text is that it can be accessed during stressful situations when phone calls or in-person interactions are not possible. Under these circumstances, text messages may reduce potentially damaging responses to stressors. Although texting is a 20-year-old form of communication, whether supportive text messages are physiologically helpful or harmful during stressful experiences is an intriguing possibility that is unexplored.

1.1. Correlates and consequences of text messaging in everyday life

A growing body of literature has generated evidence that highlights the importance of text messaging in social relationships. Text messages are used to communicate emotionally laden and supportive messages to friends and romantic partners (Drouin & Landgraff, 2012; Thurlow & Brown, 2003). Research in this area has shown that those who prefer texting over talking report feeling closer to those with whom texts are exchanged (Reid & Reid, 2005). Similarly, in college women, texting was shown to facilitate attachment via communication (Lepp, Li, & Barkley, 2016). Preferring to text has also been associated with developing new friendships and participants reporting that texting added something new to existing friendships (Reid & Reid, 2005). Experimental work in this area has revealed that individuals asked via text message to think about someone who makes them feel "safe, secure, and comforted" reported higher felt security (Otway, Carnelley, & Rowe, 2014). This finding suggests that text messages can have a positive effect on psychological outcomes, although the design of this study may have elicited demand characteristics. Nevertheless, these findings illustrate that texting is related to positive aspects of social relationships.

Researchers have also identified a number of aversive correlates of text messaging. The receipt of text messages has been associated with poorer attention, recall, and GPA (Lepp, Barkley, & Karpinski, 2014; Rosen, Carrier, & Cheever, 2013; Rosen, Lim, Carrier, &

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Cheever, 2011). Text messaging has also been associated with poorer sleep, which is related to greater anxiety and depression and poorer executive function (Ferraro, Holfeld, Frankl, Frye, & Halvorson, 2015; Murdock, 2013; Van den Bulck, 2003). Several studies have also linked text messaging to higher anxiety in general (Lepp et al., 2014) and more social anxiety, greater loneliness (Reid & Reid, 2005), lower life satisfaction (indirectly; Lepp et al., 2014), and lower relationship satisfaction (Luo, 2014). These aversive correlates of texting may be due to the additional social demands of cell phones, which have been cited by participants as taxing (Lepp et al., 2014). This argument is supported by work showing that interpersonal stressors were only associated with burnout and worse emotional well-being when daily texting was high (Murdock, 2013). It may also be that the adverse consequences of texting are confounded with the use of Facebook on cell phones. Prior work shows that when including both texting and Facebook use, Facebook use is a more consistent predictor of adverse outcomes (Rosen, Whaling, Rab, Carrier, & Cheever, 2013).

Together these findings provide evidence not only that text messaging is a central feature of social life, but texting is also associated with a host of psychological and health-relevant outcomes—both good and bad. However, the majority of this work is correlational, and it is difficult to determine whether, for example, text messages contribute to anxiety or anxiety encourages the use of text messaging. Furthermore, the majority of this research focuses on the correlates of sending text messages or engaging in discussions via text, but not the correlates of receiving messages per se. Thus, research has yet to provide a clear answer to the question of whether receiving text messages during stress or otherwise has a psychological or physiological impact.

1.2. Social support in health interventions via text message

Although the impact of receiving text messages is not well studied, the importance of texting in social life has led to the development of numerous interventions aimed at capitalizing on text messaging to improve health. Prior research has examined the effect of targeted text messages on a host of health-relevant outcomes including health behaviors and kept medical appointments. Text messages are also increasingly being used to improve medication adherence. For example, individuals who were HIV-positive who received weekly, text check-ins exhibited significantly lower viral loads after a year of receiving the intervention (King et al., 2017). A systematic synthesis of reviews of text-messaging interventions found evidence for the efficacy of text interventions for weight loss, physical activity, smoking cessation, diabetes management, and medication adherence for antiretroviral therapies (Hall, Cole-Lewis, & Bernhardt, 2015). However, few studies utilized theoretically informed strategies, and as a result, it is not clear what aspects of these text interventions are beneficial (Hall et al., 2015; Tomlinson, Rotheram-Borus, Swartz, & Tsai, 2013). Tomlinson et al. (2013) have suggested that text interventions are more likely to contribute to positive outcomes "when there is follow-up; when the message is personally tailored; when the frequency, wording, and content are highly relevant" (p. 2), but, to our knowledge, there is no empirical research that supports the use of these strategies. Research in this area illustrates the significant interest in texting for health interventions, but this research shows inconsistent use of psychological theory to guide study design. Theoretically guided study design could provide a deeper understanding of the impact of text messages. Furthermore, to our knowledge, no studies have examined the direct physiological impact of receiving text support—only the indirect, physiological effects of improved medication adherence, as a result of a text intervention, have been examined.

1.3. The pluses and pitfalls of social relationships during stressful experiences

1.3.1. Social support and stressors

The extensive, theoretically-guided literature on in-person social support provides some insight on the potential for text support to influence individuals and their responses to stressors. Feeling supported (i.e., feeling cared for, loved, and esteemed [Cobb, 1976]), has been shown to reduce psychological and physiological stress responses and protect individuals from the detrimental impact that stressors can have on health (Cohen & Wills, 1985; Uchino, Cacioppo, & Kiecolt-Glaser, 1996). Prior research has tested the impact of social support on cardiovascular responses to stressors (e.g., blood pressure) by experimentally manipulating in-person support in the laboratory. It is theorized that receiving support can improve the experience of stress by reducing the perception that a given event is threatening or stressful or by directly providing assistance with the stressful event (Cohen & Wills, 1985). For example, an upcoming presentation at work may be less stressful if a friend reminds the speaker that his/her boss will not be there for the presentation (reducing threat perception) or if a friend provides feedback that improves the presentation (directly helping with the stressor at hand). Prior research has shown that support provided prior to acute, laboratory stressors can reduce cardiovascular responses, which is health-protective (Thorsteinsson & James, 1999). Cardiovascular responses are often measured via blood pressure and heart rate, which quickly increases in response to stressors and decreases following stressors. Blood pressure responses to laboratory stressors are reliable predictors of future blood pressure (Carroll et al., 2001; Matthews, Woodall, & Allen, 1993), and, importantly, higher blood pressure is strongly associated with higher cardiovascular disease risk (Stamler, Stamler, & Neaton, 1993). Higher heart rate in response to stressors is also implicated in future cardiovascular disease (Bernston, Quigley, & Lozano, 2007).

However, the stress-buffering effects of support partly depends on the specific characteristics of support (see review by Thorsteinsson & James, 1999). One characteristic critical for whether support helps to reduce cardiovascular responses to a stressor is the extent to which the support is socially-evaluative. Social evaluation occurs when individuals feel that a valued part of their identity is being judged (Dickerson & Kemeny, 2004), and it has been tied with heightened physiological responses to stressors (e.g., Dickerson & Kemeny, 2004; Kirschbaum, Pirke, & Hellhammer, 1993). Prior research suggests that social support that communicates social evaluation can undermine self-efficacy and the benefits that support might otherwise provide (Bolger & Amarel, 2007). For example, in one study confederates provided the following support to participants preparing for a speech stress task: "Well, I can tell that you could use some help. I think it's best to summarize what you're going to say at the beginning of a speech and to end with a definite conclusion" (Bolger & Amarel, 2007, p. 465). Although intended to be helpful and supportive, when support goes wrong in this fashion, it can induce feelings of indebtedness, dependence, or incompetence in a recipient (Thoits, 2011). In that experiment, the receipt of this support was associated with greater distress (Bolger & Amarel, 2007). While support providers intend to be comforting and helpful, their presence and/or actions

can actually heighten responses to the stressor (Taylor et al., 2010). Non-evaluative support may be similar to "invisible social support," which is support that an individual is unaware of but that someone else reports providing (Bolger & Amarel, 2007; Bolger, Zuckerman, & Kessler, 2000). This type of support has been described as indirect and subtle, or as deemphasizing the support recipient role (Girme, Overall, & Simpson, 2013) and has been associated with positive relational and psychological outcomes. For example, providers might use unrelated humor as a form of invisible support (Girme et al., 2013). In sum, research on in-person social support suggests that carefully worded social support may confer cardiovascular benefits to recipients during stress.

1.3.2. Relational reminders and stressors

Other research illustrates that supportive words or behaviors may not be what benefits recipients, but instead, that benefits could be derived from the symbolic reminders of social connection that providers bestow. That is, simply feeling socially connected may also help reduce physiological responses to a stressor. The "emotional comfort" of being reminded of supportive others or spending time with supportive others (Taylor, Welch, Kim, & Sherman, 2007) has been shown to activate knowledge and memories of an individual's social network (Ferguson & Bargh, 2004). This, in turn, may confer physiological benefits. For example, looking at a picture of a romantic partner reduced reports of experimentally manipulated pain unpleasantness more than actually holding a partner's hand during a stressor (Master et al., 2009). Prior research has also demonstrated that thinking about supportive ties is associated with lower cardiovascular reactivity in response to a stressor (Smith, Ruiz, & Uchino, 2004; van Well & Kolk, 2008). Finally, using pets as support providers or preventing support providers from hearing the participant completing the stressor (e.g., by having the provider wear headphones playing white noise) predicted lower cardiovascular responses to acute stressors (Allen, Blascovich, & Mendes, 2002; Fontana, Diegnan, Villeneuve, & Lepore, 1999; Kors, Linden, & Gerin, 1997). Together this research demonstrates the potential for symbolic reminders of social connection that are not explicitly supportive to ameliorate cardiovascular responses to stress.

1.4. Text messaging, social support, and responses to stressors

Research to date does not provide a consistent picture of how the receipt of supportive text messages might influence how individuals respond to stressors, and there are several possible outcomes. The literature on in-person social support illustrates the potential for carefully worded/provided text support to mitigate cardiovascular increases in response to a stressor, but it is possible that the factors that undermine the benefits of in-person support may also undermine text support. Unsolicited support may make individuals feel that they are perceived as less competent, and it may also foster feelings of indebtedness, shame, or incompetence (Bolger et al., 2000). Text messages relevant to the stressor at hand may also further focus recipients on the stressor, thereby *increasing* the impact of the stressor on cardiovascular outcomes.

On the other hand, related research shows that social cues or symbolic reminders of supportive others may contribute to *lower* cardiovascular responses to a stressor. Text support that individuals receive may activate knowledge and memories of their social networks (Ferguson & Bargh, 2004) and signal belonging, acceptance, and companionship (Pettigrew, 2009; Thoits, 2011), thereby reducing cardiovascular stress responses. Furthermore, text messages that are not about the stressor may draw recipients' attention away from the stressor and, therefore, reduce its impact on recipients' stress responses. Finally, prior work suggests that text messages can be distracting (e.g., Rosen et al., 2011), and this may prove beneficial in the context of a stressor.

In sum, text messages that are supportive or that remind recipients of their social networks both have the potential to influence, and even reduce, cardiovascular responses to stressors. Nevertheless, the immediate impact of receiving text messages is not well studied. Only one study, to our knowledge, has experimentally tested the direct psychological effect of receiving text messages (see Otway et al., 2014). Experimental studies of texting have largely only examined the psychological impact of texts in relation to changes in health behaviors (for review see Hall et al., 2015). Furthermore, we are not aware of any studies that have examined the direct, physiological effect of receiving texts. Prior research has only examined changes in physiology due to improved medication adherence, which was targeted via text intervention. Namely, empirical studies have demonstrated that text interventions can increase antiretroviral-therapy adherence and reduce viral load (Hall et al., 2015; King et al., 2017). Finally, we know of no studies that have examined the direct impact of receiving text messages when the recipient is experiencing stress.

1.5. The current study

This study builds on the theoretically-guided, in-person social support literature to examine how text messages influence responses to stressors. In this experiment, we tested the potential for text messages from romantic partners to attenuate cardiovascular responses to a stressor in females. We examined the impact of both **supportive** and **mundane** text messages on cardiovascular responses to an acute stressor compared to a no-text control condition. Supportive text messages were carefully crafted messages designed to be explicitly supportive to participants, but not evaluative. Mundane messages, on the other hand, were designed to be free of explicit support and relatively neutral in content in order to test the possibility that merely receiving any communication from a partner, and therefore being reminded of her partner, might confer cardiovascular benefits during the stressor. We tested the following hypotheses:

Hypothesis 1.1. Supportive text messages will be associated with lower cardiovascular responses to the stressor than the no-text (control) condition.

Hypothesis 1.2. Mundane text messages will be associated with lower cardiovascular responses to the stressor than the no-text (control) condition.

2. Methods

2.1. Participants

The study design, recruitment procedures, and experimental protocol were IRB approved. Couples were recruited via university campus flyers. Eligible couples ($N = 75$; $n = 25$ per condition) were 18–30 years of age, in a heterosexual, monogamous relationship for at least three months, fluent in English, and able to send and receive text messages. Couples were told that the purpose of this study was to "assess the effectiveness of text messages as an instructional tool in research" and that the female member was randomly selected to complete the stressor task. However, only females completed the

stressor task, and therefore, must have also been free of psychological or cardiovascular disorders in order to participate (mean age = 20.21; 84% European American; 1.35% married)[1]. Prior research informed our decision for only female participants to complete the acute stress procedures. There are established gender differences in the effects of received support (e.g., Lepore, Mata Allen, & Evans, 1993; van Well & Kolk, 2008) and young adult females text more frequently than males (Faulkner & Culwin, 2005; Reid & Reid, 2005).

2.2. Procedures

Partners were separated into different rooms, and males received instructions about the text message manipulation if assigned to a texting condition and completed surveys unrelated to this investigation alone in a quiet room. Female participants ("participants" hereafter) were fitted with a blood pressure cuff, which was used to record blood pressure and heart rate throughout the study. Experimenters blind to study condition asked participants to place their phones next to them with the volume on and were told that they would receive text messages from the experimenter as part of the study. Participants were told that they were allowed to read text messages from the experimenter and their partner, but they were asked not to respond to any messages. Next, participants sat alone in a quiet room and completed surveys, and then they began a 10-minute resting, **baseline period** to establish a cardiovascular baseline (see Fig. 1). Participants were instructed to "sit back and relax" during this time.

Following the baseline period, participants completed additional surveys not examined for this investigation. After completing surveys, the two-minute **text period** began and those in a text condition received the first of their two text messages. Participants were randomly assigned to receive either supportive text messages from their partner, mundane text messages from their partner, or no text messages from their partner (control). The first supportive message was: *"Don't worry. It's just a psych study. You'll be fine :)."* The first mundane message was, *"It's cold in here."*

Next, a blind-to-condition, male evaluator provided information to participants about the upcoming stressor, which was a shortened, one-evaluator version of the Trier Social Stress Test that included public speaking and mental math (Kirschbaum et al., 1993), and he instructed participants to begin preparing their speeches. During the **speech preparation period**, participants sat alone for four minutes in a quiet room to prepare their speech. Participants received a second text from their partner half way through the speech preparation period. In the support condition they received, *"You could talk about how hard working you are."* In the mundane condition, they received, *"I'm filling out surveys."* After the second messages were sent, the stressor tasks began.

The stressor tasks—the speech and math tasks—began when the evaluator entered the room, turned on a large video camera, and told the participant to start her speech. The evaluator maintained a stoic facial expression and prompted the participant to continue speaking when she stopped. At the end of the three-minute speech, the math task began. During this task, the evaluator instructed the participant to count backwards from 2372 by 13 as fast as possible. This task lasted a minute, and at least once, the evaluator told the participant to speed up or that she was making too many errors.

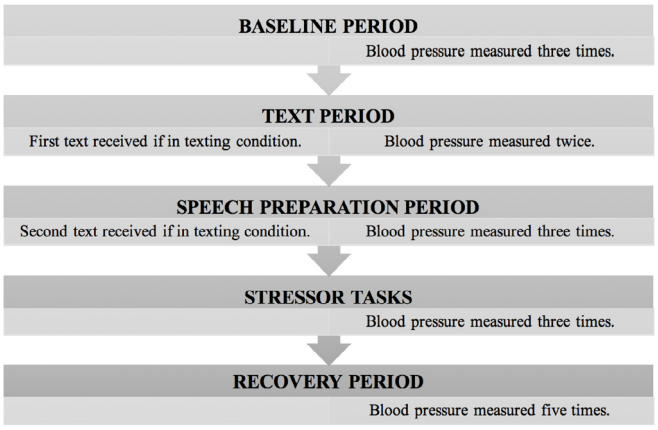

Fig. 1. Study timeline with timing of texts and blood pressure measurements detailed.

Following the stressor tasks, participants reported how supported, loved, and cared for they felt, completed a 10-minute **recovery period** where they sat alone in a quiet room, and then completed additional questionnaires. Couples were then reunited, debriefed, and compensated with $20.

2.3. Measures

2.3.1. Demographic and health information

Age and ethnicity were collected prior to the baseline period. An experimenter measured participants' heights and weights with a flexible tape measure and physician's mechanical beam scale, and these measurements were used to calculate Body Mass Index (BMI). Also prior to the baseline period, participants indicated if they had smoked that day ($n = 1$). Group means are reported in Table 1.

2.3.2. Cardiovascular responses to the stressor

Systolic and diastolic blood pressure and heart rate were assessed over the course of the study with a Dinamap oscillometric automated cuff. Blood pressure was assessed at four, six, and eight minutes during the 10-minute baseline resting period. An average of the three baseline blood pressure measurements was used as a covariate in all analyses in order to account for variation in individual resting physiology (Carroll et al., 2001).

Blood pressure was also recorded twice during the text period, three times during the speech preparation period, three times during the stressor tasks, and five times during the recovery period. To best model the quadratic shape of cardiovascular responses to the stressor, the final speech preparation blood pressure measurement (immediately prior to the start of the speech), the three stressor task measurements, and the first recovery measurements were used. The four recovery blood pressure measurements not used were excluded because cardiovascular activity had largely returned to baseline levels by the first recovery timepoint. Thus, the last speech preparation timepoint, the timepoints during the stressor tasks, and the first recovery timepoint were used to measure the typical rise and fall of cardiovascular activity in response to a stressor.

Cardiovascular responses to a stressor are characterized by an

[1] Three participants were excluded from the analyses for the following reasons: one due to physiological equipment malfunction, one opted not to complete the stressor tasks, and one due to distress during the stressor tasks (total $N = 78$). Due to a machine malfunction, two participants were missing a baseline cardiovascular measure, without which an average baseline blood pressure could not be calculated. These participants were excluded from cardiovascular analyses.

[2] In the initial model for systolic blood pressure, the residuals were non-normally distributed. In order to adjust for this, a second model was run with robust standard errors. This adjustment did not alter the findings. All values reported are from the model with robust standard errors (see Table 2).

[3] In this second model, the support condition was the reference group.

Table 1
Differences between demographic/health information and blood pressure by experimental condition ($N = 75$).

	No-Text Control ($n = 25$)			Supportive ($n = 25$)			Mundane ($n = 25$)		
	M	SD	95% CI	M	SD	95% CI	M	SD	95% CI
Age	20.36	1.93	[19.56, 21.16]	20.00	1.61	[19.20, 20.81]	20.28	2.42	[19.48, 21.08]
Body Mass Index	24.91	8.35	[22.52, 27.30]	23.76	4.16	[21.34, 26.15]	22.63	4.58	[20.24, 25.03]
Average BL SBP	110.49	8.78	[107.19, 113.80]	107.86	9.02	[104.49, 111.23]	108.63	6.84	[105.25, 112.00]
Average BL DBP	62.72	8.42	[59.66, 65.78]	63.79	8.42	[60.66, 66.92]	62.96	6.10	[59.83, 66.09]
Average BL HR	69.93	9.14	[65.23, 74.64]	71.90	13.45	[67.10, 76.71]	72.57	12.47	[67.77, 77.47]

Note. BL = baseline. SBP = systolic blood pressure. DBP = diastolic blood pressure. HR = heart rate. There were no significant differences in these variables by condition.

increase in activity during the stressful event or task that is followed by a decline toward pre-event activity after the event is over (Allen, Kennedy, Cryan, Dinan, & Clarke, 2014). We predicted that the supportive and mundane conditions would attenuate the trajectory of cardiovascular responses to the stressor tasks, and therefore, we modeled cardiovascular responses before (speech preparation), during, and after (recovery) the stressor tasks with multilevel models. We were primarily interested in the cross-level interaction between the quadratic form of time and condition (time*time*condition) in the fixed portion of the model, which represented the effect of condition on the entire trajectory of blood pressure and heart rate responses. STATA version 13IC was used for all multilevel models. The linear effect of time was included as a random effect, which means the linear slope of each individual was allowed to vary randomly, and an unstructured covariance matrix was specified (Rabe-Hesketh & Skrondal, 2012, p. 298).

2.3.3. Post-stressor state perceptions of support

Immediately after the stressor, participants were asked to indicate how accurate the following words were in describing how they currently felt: loved, cared for (Cobb, 1976), and supported. Participants rated these words on a scale from zero (*not at all accurate*) to four (*extremely accurate*).

3. Results

3.1. Hypothesis 1.1. and 1.2

Controlling for average baseline systolic blood pressure (Carroll et al., 2001), the time*time*condition interaction was significant, $\chi^2(2) = 6.66$, $p = .04$; full model $\chi^2(9) = 449.2$, $p < .001$. Those in the mundane condition exhibited a trajectory of systolic blood pressure over the course of the study that was significantly different from those in the no-text control group (reference group), $\gamma = 1.06$, $z = 1.99$, $p = .047$, 95% CI [0.01, 2.11], (see Fig. 2 and Table 2).[2] The mundane condition trajectory was also significantly different than the support condition trajectory, $\gamma = -1.33$, $z = -2.45$, $p = .01$, 95% CI [-2.39, −0.27].[3] Specifically, those in the mundane condition showed lower systolic blood pressure responses to the stressor tasks compared to those in the support and no-text control conditions, supporting our second hypothesis. The support and no-text control conditions did not significantly differ from each other in their trajectories of systolic blood pressure. However, those in the mundane condition also exhibited systolic blood pressure during recovery that took longer to return to resting values than those in the other two conditions. There were no significant effects of condition on the trajectory of diastolic blood pressure or heart rate.

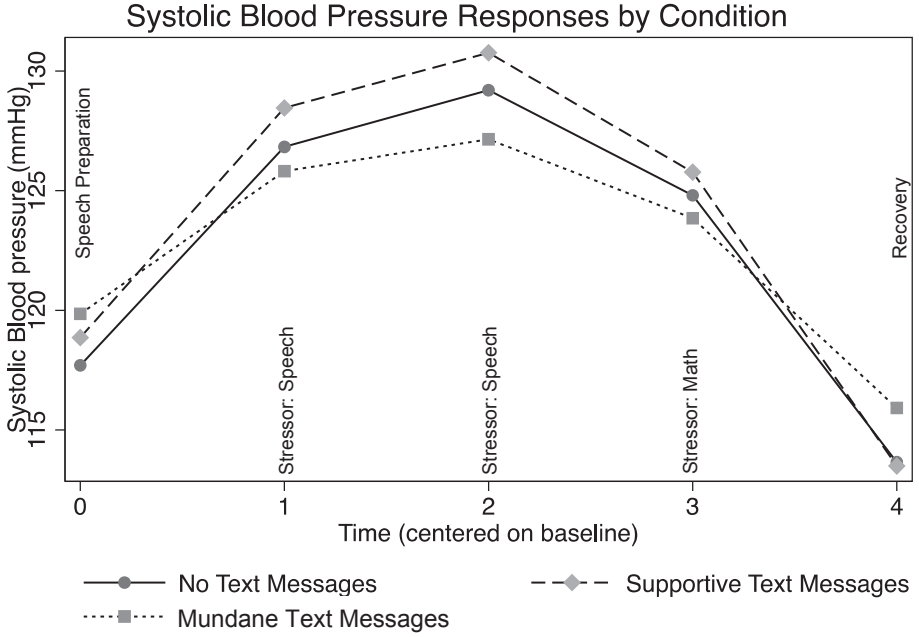

Fig. 2. Predicted systolic blood pressure responses during speech preparation, the stressor tasks, and recovery ($n = 25$ per condition).

Table 2
Multilevel between-person effects of the experimental condition on systolic blood pressure responses before, during, and after a stressor.

Variable	Coefficients (Robust SE)	95% CI
Intercept	117.70(1.82)***	[114.14, 121.27]
Average Baseline SBP	0.93(0.08)***	[0.78, 1.00]
Time	12.51(1.32)***	[9.93, 15.09]
Time*Time	−3.38(0.36)***	[−4.09, −2.67]
Condition[a]		
Supportive Texts	1.16(2.37)	[−3.48, 5.80]
Mundane Texts	2.15(2.66)	[−3.05, 7.35]
Time*Condition[a]		
Supportive Texts	0.73(2.05)	[−3.29, 4.75]
Mundane Support	−4.23(1.97)*	[−8.08, −0.38]
Time*Time*Condition[a]		
Supportive Texts	−0.27(0.52)	[−1.29, .76]
Mundane Texts	1.06(.54)*	[.01, 2.11]
Covariance Parameters	**Estimate (Robust SE)**	
Random Intercept ($\tilde{\sigma}_o^2$)	75.10(14.62)	[51.28, 109.99]
Random Slope ($\tilde{\sigma}_1^2$)	0.97(0.40)	[0.43, 2.16]
Covariance ($\tilde{\sigma}_{01}$)	−8.51(2.41)	[−13.23, −3.79]
Residual Variance	33.92(3.05)	[27.70, 41.53]

Note: Based on 73 participants with 362 longitudinal records. *$p < .05$ **$p < .01$ ***$p < .001$.
[a] The control condition is the comparison group.

3.2. Post-stressor state perceptions of support

In terms of subjective experience, those in the support condition reported feeling more supported, $F(2,70) = 6.86$, $p = .002$, $\eta^2 = .16$, loved, $F(2,71) = 5.54$, $p = .006$, $\eta^2 = .13$, and cared for, $F(2,71) = 4.44$, $p = .02$, $\eta^2 = .11$, compared to those in the other two conditions, which rules out the possibility that those in the supportive text condition did not feel supported.

4. Discussion

This study is the first to demonstrate that text messages from a partner can confer cardiovascular benefits in response to a stressor. In partial support of our hypotheses, those who received mundane text messages from their partners exhibited smaller cardiovascular increases in response to a stressor. This is consistent with prior research suggesting that the mental activation of a supportive network member can buffer cardiovascular responses to a stressor (Smith et al., 2004; van Well & Kolk, 2008). Potential mechanisms linking mundane texts with reduced cardiovascular responses may be the activation of social network memories (Ferguson & Bargh, 2004), the signaling of acceptance (Thoits, 2011), or distraction. Those in the mundane condition exhibited slower recovery from the stressor than those in the support or no-text control conditions. This may suggest that the mundane texts provided a distraction from the stressor, but additional support may be needed later to quicken cardiovascular recovery from the stressor. It is also possible that different types of text messages may have differential effects on various phases of stressor responses (i.e., initial responses versus post-stressor recovery). Each of these potential mechanisms linking mundane text messages to cardiovascular responses to a stressor merits systematic examination in future studies.

While mundane text messages were associated with lower systolic blood pressure responses to stress, they were not associated with lower diastolic blood pressure or heart rate in response to the stressor. Experimental studies examining the impact of receiving in-person support and thinking about social ties demonstrate stress buffering for an array of cardiovascular measures; however, prior work does not always demonstrate effects for all measures. For example, as in this study, Kors et al. (1997) found stress buffering of systolic blood pressure responses to a stressor from non-evaluative, in-person support but no effects on diastolic blood pressure or heart rate. Systolic blood pressure reflects ventricular contractility and vascular resistance, whereas diastolic blood pressure and heart rate reflect other cardiovascular subsystems (Allen, 2000). Thus, it is possible that systolic blood pressure may reflect cardiovascular subsystems more sensitive to the social manipulation in this study. Our findings are consistent with this previous work and understanding of the function of specific cardiovascular subsystems. Future research should examine the impact of receiving text messages on additional measures of cardiovascular responses to stressors, as well as other physiological responses to stressors.

Although they felt supported, loved, and cared for, those in the support condition did not exhibit attenuated cardiovascular responses. One of the other few experimental studies of the immediate effects of receiving text messages found that asking individuals via text message to think about someone who makes them feel "safe, secure, and comforted," compared to being asked to think about their routes home, was related to higher felt security (Otway et al., 2014). However, in this study, supportive texts may have simultaneously communicated support *and* threatened the self in ways that undermined potential cardiovascular benefits. While it may be possible to convey support via text message without social evaluation, the supportive messages used in this study may not have achieved this as they indicated that the male partner was aware of the stressful task. Although we attempted to craft carefully-worded support, the supportive messages may have inadvertently increased evaluative threat. This may have also led to reduced self-efficacy (important for support transactions; Bolger & Amarel, 2007) due to the subtle suggestion that the participant *needed* assistance. This is echoed in research on participants of similar backgrounds (college undergraduates) showing poorer outcomes in response to received support (Bolger & Amarel, 2007). These threats may be minimized when a support recipient has requested support (Bolger & Amarel, 2007). It may also be that there was a support mismatch. Past work illustrates the importance of support being responsive to needs (Maisel & Gable, 2009), and participants simply may not have found the texts helpful despite reporting that they were supportive. Supportive messages may also have induced greater feelings of obligation to respond to the texts, and this arousal may have interfered with stress-buffering processes (Lepp et al., 2014). In daily life, the effects of text support are further complicated by the potential for individuals to receive multiple messages from multiple sources and these messages may have competing influences on physiological processes. Naturalistic, observational research of received text messages may shed light on these complex processes and the relative influence of supportive, mundane, or other types of received text messages while individuals are experiencing a stressor.

4.1. Limitations and future directions

Participants in this study were predominately white college undergraduates. Research suggests that these individuals are more likely to be independent and more self-focused (Markus & Kitayama, 1991), and, therefore, they may be particularly reactive to threats to self-efficacy embedded in received support. Understanding how these individuals respond to text messages prior to a stressor is an important first step in examining the impact of support and text messaging on well-being, but there are few studies in this area thus far, and these results should only be generalized to those with similar backgrounds. Future work should explore the effects of texting in groups that vary in their approach to close

relationships (e.g., those from various cultural background groups).

In this study, we also exclusively examined female responses to a stressor. We chose to focus on female responses for several reasons. First, there are established gender differences in the effects of received support (e.g., Lepore et al., 1993; van Well & Kolk, 2008), and others have theorized that females may be especially sensitive to supportive interactions when faced with a stressor (Taylor et al., 2000). Furthermore, young adult females are known to more frequently text as compared to males (Faulkner & Culwin, 2005; Reid & Reid, 2005). Thus, we felt that an initial study of social support via text messages would be best conducted with females, but future work should also examine the effects of text support in large samples that include males.

Our work shows promise for social connection messages to be helpful during acute stress for females, but future research is needed. Studies should explore individual differences, relationship factors, different stressor types, and support perceptions that may influence the effectiveness of support via text message. Moreover, it will be important to consider the influence of these messages on an acute stressor versus a chronic stressor (i.e., they may prove most effective during acute, as opposed to chronic, stressors). This is especially important for studies currently using text-messaging interventions to improve health.

5. Conclusion

Text messaging is central to social life, but little research has explored the impact of these messages on recipients facing stress. This study demonstrated that mundane texts from partners influence blood pressure responses to a stressor, which mirrors research on in-person support demonstrating that subtle forms of support may be more psychologically and physiologically beneficial. While more research is needed to determine the health and clinical implications of these findings, in-lab blood pressure responses to stress have been shown to predict future cardiovascular health (Carroll et al., 2001; Matthews et al., 1993; Stamler et al., 1993). Thus, to the extent that these findings represent real-world responses to texts received during inevitable, daily stress, this form of communication may have the potential to influence biological and physical well-being. Text messaging is an integral part of the daily lives of millions, and it is critical that we continue theoretically informed research on the effects of texting to better understand how phones might be used to help one another.

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