The Heart of the Story:

Peripheral Physiology During Narrative Exposure Predicts Charitable Giving

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Abstract

Emotionally laden narratives are often used as persuasive appeals by charitable organizations. Physiological responses to a narrative may explain why some people respond to an appeal while others do not. In this study we tested whether autonomic and hormonal activity during a narrative predict subsequent narrative influence via charitable giving. Participants viewed a brief story of a father's experience with his 2- year old son who has terminal cancer. After the story, participants were presented with an opportunity to donate some of their study earnings to a related charity. Measures derived from cardiac and electrodermal activity, including HF-HRV, significantly predicted donor status. Time-series GARCH models of physiology during the narrative further differentiated donors from non-donors. Moreover, cardiac activity and experienced concern were found to covary from moment-to-moment across the narrative. Our findings indicate that the physiological response to a stimulus, herein a narrative, can predict influence as indexed by stimulus-related behavior.

Can bodily states predict costly behavior? The brain exerts control on the body via neural (autonomic) and hormonal (neuroendocrine) systems (Janig, 2003). Likewise, these systems relay information about bodily states (the "internal environment") back to the brain. Neural states as people are processing information can be observed without intruding on the experience of process itself (Falk et al., 2010), and have been associated with objective influence outcomes (Falk, Berkman, & Lieberman, 2012). In this research we examine how reactivity in these peripheral systems can predict whether someone will behaviorally respond to a related stimulus.

Recent work has associated the neuroactive hormones adrenocorticotropin hormone (ACTH) and oxytocin (OT) with cognitive (attention) and affective engagement (empathic concern) while viewing public service announcements (Lin et al., 2013). [1] ACTH has long been affiliated with attention toward environmental stimuli (e.g., Born, Fehm, & Voigt, 1986). Other steroidal hormones are linked to social behaviors. For instance, cortisol is hypothesized to motivate action in response to the factors in the environment (see Dickerson & Kemeny, 2004), including social stimuli (Rahe, Rubin, & Gunderson, 1972). Testosterone has been shown respond to social challenges (Bos, Panksepp, Bluthe, & van Honk, 2012) and in the absence of social threats increases prosocial behavior (Boksem et al., 2013).

An extensive research suggests that both sympathetic and parasympathetic systems are indicative of attention and affective engagement. People are more likely to attend to stimuli eliciting sympathetic arousal (see Boucsein, 2012; Kensinger, 2004; MacLeod & Matthews, 2004). Activity in both sympathetic and parasympathetic systems, via electrodermal and cardiac activity, has been shown to occur in response to emotional stories (Eisenberg, Fabes, et al., 1988; Eisenberg, Fabes, Schaller, Miller, et al., 1991; Eisenberg, Schaller, et al., 1988). A key component

of the parasympathetic nervous system, the vagus nerve, is proposed to be central to the mammalian "social-engagement system" (Porges, 2007). Whereas resting vagal activity is associated with affective experiences, notably empathic concern (e.g., Oveis, Cohen, Gruber, Shiota, Haidt, & Keltner, 2009), changes in vagal activity (reactivity) are used as situational indicators of vagal control (Beauchaine, 2001).

The Present Research

The present research examines if reactivity in autonomic and neuroendocrine systems predict whether someone will act in response to a narrative. As our stimulus, we selected a 100-second narrative. Narratives can serve as vehicles for transmitting influence by conveying a desired way to feel, think, or act (Gerrig, 1993). Narratives promote attitude congruence (story-consistent beliefs; e.g., Appel & Richter, 2010; Busselle & Bilandzic, 2009; Green, 2004; Green & Brock, 2000), a positive evaluation of information within the narrative (Escalas, 2004; Paharia, Keinan, Avery, & Schor, 2010), and identification with fictional groups in a story (Gabriel & Young, 2011). Narratives are successful at motivating costly behavior. For instance, character-based appeals are found to be a more effective tool for eliciting donations than an information-based rhetorical appeal (Small & Loewenstein, 2003). A narrative from a charitable organization was selected as it provides a straightforward behavioral outcome measure: a monetary donation. Moreover, a charity narrative permits us to make explicit predictions about the psychological and physiological processes involved in narrative influence. We evaluated whether cardiac vagal control, heart rate (which reflects both sympathetic and vagal influences), and electrodermal activity as people experienced an influential narrative would differ between the responders and non-responders to a subsequent donation appeal. Furthermore, we examined several candidate

hormones hypothesized to be associated with attention to the narrative.

Method

Participants and Procedure

We recruited 163 participants (68 female) from Claremont colleges and the surrounding community through mass e-mails, posted fliers, and an existing online recruitment pool (ages 18-52, M= 20.91, SD= 5.20). The general sample size was determined assuming a medium effect size prior to start of data collection. Participant earnings varied with the number of correctly answered post-narrative questions and charitable donations made; maximum possible earnings were $40. Study sessions were conducted at the Center for Neuroeconomics Studies at Claremont Graduate University in Claremont, CA. Claremont Graduate University's Institutional Review Board and the U.S. Army Medical Research and Materiel Command's Office of Research Protections, Human Research Protection Office approved this study.

Prior to consent, participants were informed that the purpose of the study was to investigate what happens in your body when you are exposed to emotional stories. The consent form further informed participants that they would see one of several stories selected by the researchers, though all participants viewed the same story. After obtaining written informed consent, 12ml of blood was drawn by a qualified phlebotomist from an antecubital vein to establish basal hormone levels and participants were fitted with autonomic physiology sensors. Participants completed a questionnaire that included demographic items and a number of state and trait measures. Once finished, participants were seated privately in a dimly lit room in front of a 15" MacbookPro© laptop (Apple, Inc.) equipped with headphones. All proceeding tasks, including the donation task, were presented in MATLAB© (Mathworks, Inc.), using the

Psychophysics Toolbox extensions (Brainard, 1997).

After a 5-minute baseline acquisition period for autonomic nervous system (ANS) measures, participants watched a 100-second video obtained with permission from St. Jude's Children's Research Hospital of a father who has a 2-year old son who is dying of brain cancer (used previously in Barraza & Zak, 2009). Peripheral nervous system activity was recorded throughout the stimulus. Post-stimulus, participants were asked to rate their emotions using 12 adjectives previously used to assess empathic concern and personal distress (Batson et al., 1997), emotions also believed to be important in narrative experience (Mar, Oatley, Djikic, & Mullin, 2011). Immediately after these ratings, participants received another 12ml blood draw in an adjacent room. Participants returned to their seats and were asked to answer five questions related to the narrative, earning $5 for each correct answer. These earnings were added to the $15 base participation payment. The earnings task was designed so that participants earned money in the study based on effort rather than receiving a windfall. Questions were made to be simple such that a large majority of participants answered all questions correctly. Participants were next informed that the preceding story was produced by St. Jude's Children's Research Hospital and were given a brief description regarding their activities. The option to donate none, some, or all of their participation earnings to St. Jude's was next presented to participants in private and with a reminder of their anonymity. After the donation decision, participants were privately paid their earnings and dismissed. There was no deception of any kind in this study and donated money was sent to St. Jude's at the conclusion of the study.

Self-Report Measures

We employed the Ten-Item Personality Inventory (TIPI; Gosling, Rentfrow, & Swann,

2003), to assess broad personality dimensions (extraversion, agreeableness, conscientiousness, neuroticism, openness). Item scores ranged from 1 ‘‘strongly disagree” to 7 ‘‘strongly agree”. Each subscale consists of two items; scale scores were computed by averaging the respective item scores. The four subscales in the Interpersonal Reactivity Index (IRI; Davis, 1983) were used to measure empathic personality dimensions (empathic concern, personal distress, perspective-taking, fantasy). Item scores ranged from 1 ‘‘does not describe me well” to 7 ‘‘describes me very well.” Subscales were computed by averaging the seven items per subscale. State negative and positive affect was assessed using the Positive And Negative Affect Schedule (PANAS, Watson et al., 1988). Item scores ranged from 1 ‘‘not at all” to 5 ‘‘extremely.” Positive affect and negative affect subscales were computed by averaging the ten items per subscale.

Autonomic Measures

Cardiac (sampling rate 1 kHz) and electrodermal activity (sampling rate 250 Hz) were collected using a Biopac MP150 data acquisition system and BioNomadix® transmitters and recorded with AcqKnowledge® software version 4.2 (Biopac Inc., Goleta, California). To measure cardiac activity, participants were fitted with three disposable Ag-AgCl electrocardiogram (ECG) electrodes using a Lead III configuration. To measure skin conductance, two disposable Ag-AgCl electrodermal (EDA) electrodes were placed on participants’ distal phalanx surfaces of the middle and index fingers of their non-dominant hand. Before placement of EDA electrodes, participants washed hands with non-detergent bar soap.

Following data collection, the data were manually inspected in AcqKnowledge® software version 4.2 (Biopac Inc., Goleta, California). Skin conductance waveforms were visually inspected for brief periods of signal loss, and data drop-offs shorter than 1 s in length were replaced with

averages from adjacent parts of the waveform. Additionally, waveform noise due to experimenter-observed movement was smoothed using mean-value replacement from adjacent parts of the waveform. Next, a 10-Hz low-pass filter was applied to the waveform to remove high-frequency noise (Norris, Larsen, & Cacioppo, 2007), and a square root transformation was applied to adjust for skew inherent to skin conductance data (Dawson, Schell, & Filion, 1989; Figner & Murphy, 2011). After transformations, average skin conductance level (SCL) was extracted for the final 2 min of the baseline and for the 100 s time-span of the narrative. These values were used to calculate percent change in SCL from baseline to the narrative. For time series analyses, 1 s segments of SCL were taken from baseline and narrative stimulus. Non-specific skin conductance responses (NS-SCRs) were identified using a threshold of .01 μS, and NS-SCR counts were taken for baseline, and narrative. Following extraction of NS-SCR counts, these values were used to calculate rate of NS-SCRs/min for baseline, narrative, and the three narrative segments.

Cardiac data from 23 participants were excluded due to problems with data collection, thus leaving a total of 141 participants for further analysis. ECG artifacts were manually removed from the data. Data were further passed through the band-pass finite impulse response (FIR) filter, to remove both high- and low-frequency noise, and then smoothed. R-R intervals were identified and extracted from Biopac and imported into Kubios software (http://kubios.uef.fi) for derivation of heart rate variability (HRV) measures, including the high frequency (HF) component as the measure of vagal control. Linear trend components were removed from the data prior to HRV analysis. The HF power was extracted from 0.12-0.4 Hz band and then log-transformed as suggested by Lewis and colleagues (2012).

Hormone Measures

Three hormones were assessed at baseline and immediately after narrative exposure: adrenocorticotropin hormone (ACTH), cortisol (CORT), and testosterone (T). Sessions were run in the afternoon when diurnal variations in CORT are relatively stable.[2] Two 8-mL, EDTA (ethylenediaminetetraacetic acid) whole-blood tubes and one 8-mL, serum-separator tube were drawn while maintaining a sterile field and using a Vacutainer butterfly needle (BD, Franklin Lakes, NJ, USA) at baseline and post-stimulus. Following the draw, whole-blood tubes were rocked to facilitate mixing and prevent coagulation, and immediately placed onto ice. Within 15 min of the draw, plasma tubes were transferred from the ice to centrifuge at 1500 rpm for 12 min at 4◦C. Serum tubes were also rocked following the draw, and they were placed at room temperature for 30 minutes. Serum tubes were then transferred to the centrifuge, where they were spun at 2300 rpm for 10 min. Plasma and serum were removed from the tubes with disposable pipettes and placed into 2-mL microtubes with screw caps. These tubes were immediately placed on dry ice and stored at −80◦C until assay.

Four hormones were assayed using either radioimmunoassay (RIA) or enzyme immunoassay (EIA) kits. Adrenocorticotropin hormone (ACTH) was assayed from plasma using two RIA kits produced by DiaSorin, Inc. (Stillwater, MN, USA). The inter- and intra-assay coefficients of variation for the first kit were 15.40% at 38.70 pg/mL and 8.63% at 16.03 pg/mL (10 replicates), and for the second kit they were 9.83% at 111.87 pg/mL and 2.94% at 87.77 pg/mL (10 replicates). Cortisol was assayed from serum using an RIA kit produced by Diagnostic Systems Laboratories (Webster, TX, USA). This assay was performed using a LC-MS method developed by the Biomarkers Core Laboratory. Samples were treated with the internal standard

d4-Cortisol provided by CDN Isotopes (Pointe-Claire Quebec, Canada). Testosterone was assayed from plasma using two EIA kits produced by ALPCO, Inc. (Salem, NH, USA). The inter- and intra-assay coefficients of variation for the first kit were 4.73% at 1.19 ng/mL and 10.66% at 1.08 ng/mL, and for the second kit they were 9.07% at 3.83 ng/mL and 8.89% at 3.48 ng/mL. After acetonitrile extraction, OT was assayed from plasma using an RIA kit produced by Bachem, Inc. (Torrance, CA, USA). The inter- and intra-assay coefficients of variations for OT were 4.58% and 4% at 4.69 pg/mL, respectively. ACTH, cortisol, and testosterone were assayed at the Endocrine Core Laboratory of the Yerkes National Primate Research Center at Emory University (Atlanta, GA). Oxytocin (OT) was assayed at the Reproductive Endocrine Research Laboratory at the University of Southern California (USC, Los Angeles, CA). Due to the high number of values falling outside of the typical range seen in the literature (see McCullough, Churchland, & Mendez, 2013) and a high number of values falling below detectable range (1 pg/mL), we concluded that OT values were not reliable to be included in the analysis.

Results

Donations, Personality, and Post Narrative Affect

Overall, 52% percent of participants made donations (average donation $6.94, SD = $6.99). There were no gender differences in the decision to donate or the amount donated (ps > .10). Donors rated themselves higher on the five-factor agreeableness dimension (M=4.94, SD=1.13) than non-donors (M= 4.53, SD= 1.26; p = 0.032, *d*= .35). Differences were also found in trait measures of empathy, with donors scoring higher on empathic concern (donors M= 5.36, SD= 0.85; non-donors M= 4.88, SD= 1.11; p = 0.002, *d*= .49) and perspective-taking (donors M= 5.09,

SD= 0.82; non-donors M= 4.72, SD= 1.00; p =0.013, *d*= .41). Donors also reported greater affect in response the narrative. After the narrative, donors reported greater concern (donor M= 5.80, SD= 1.27; non-donors M= 4.52, SD= 1.43; p =0.011, *d*= .96), and distress (donor M= 5.76, SD= 1.06; non-donor M= 5.33, SD= 1.18; p = 0.02, *d*= .39) than non-donors. About half of participants earned the full amount of 40 dollars USD (53%; mean earnings = 37.53, SD= 2.75). Donors and non-donors did not significantly differ in their earnings (donors M= 37.62, SD= 2.74; non-donors M= 37.43, SD= 2.78; p =0.67).

Narrative Physiology

Mixed model analysis of variance was used in order to examine differences in the physiology of donors and non-donors during narrative exposure, with age entered as a covariate (see Figure 1). For cardiac measures, main effects show the narrative accelerated heart rate, significantly decreasing R-R interval across groups, $F(1, 136) = 12.9$, $p < .001$, $\eta^2 = .09$, and decreasing HF-HRV, $F(1, 122) = 8.5$, $p < .01$, $\eta^2 = .07$. There were no significant interaction for donation status (donor/non-donor). For electrodermal measures, main effects results reveal the narrative significantly increased average skin conductance level across groups, $F(1, 147) = 89.99$, $p < .001$, $\eta^2 = .38$, and increased skin conductance responses, $F(1, 145) = 92.73$, $p < .001$, $\eta^2 = .39$. Interactions indicate that, compared to non-donors, donors had higher sympathetic activation in both SCL, $F(1, 147) = 4.90$, $p < .05$, $\eta^2 = .03$, and NS-SCR $F(1, 145) = 12.86$, $p < .001$, $\eta^2 = .08$, during narrative exposure, but not at baseline. Across all hormone measures (cortisol: pre-narrative M= 15.83, SD= 7.94, post-narrative M= 13.14,SD= 6.95; ACTH: pre-narrative M= 38.79, SD= 22.76, post-narrative M= 42.12, SD= 27.89; testosterone: pre-narrative M= 4.10, SD= 4.02, post-narrative M= 4.09, SD= 4.08), the only significant effect was a decline in cortisol from

baseline to narrative, F(1, 147) = 19.01, p < .001, η^2 = .12. The average change in cortisol did not have a significant difference between donor and non-donor groups (p > .10).

Predicting Donations

The decision to donate to the narrative-aligned charity was associated with baseline-corrected autonomic and hormonal measures in a logistic regression (Table 1). Given that most autonomic measures had a significant change from baseline during narrative stimulus, we entered autonomic variables in the first step (model 1). Hormone measures were added to the second step to examine if there was added variance explained. As expected, HF-HRV significantly predicted the decision to donate, odds ratio (OR) = 1.01, *p* = .046. In addition, heart rate (R-R interval), OR = 1.79, p = .022, and skin conductance responses (NS-CSR), OR = 1.41, p = .022, were predictive of the decision to donate within the same model. None of the endocrine measures significantly predicted the decision to donate (*p* >.05). The results remained significant when controlling for agreeableness (β = .26, *p* = .11), empathic concern (β = .52, *p* = .02), perspective-taking (β = .63, *p* = .01), gender (β = -.62, *p* = .16), or age (β = -.02, *p* = .65).

Experienced Affect

Given that the R-R interval was the strongest physiologic predictor of the decision to donate within the regression model, we set to explore the relationship between heart rate and narrative experience further. Participants from a separate study (N= 45; age M= 24.47, SD= 5.89; 63.3% female) viewed the story in 5-second segments, providing a rating for how much concern they felt at every segment (i.e., “how much concern do you feel”). The item was rated on Likert-type scale ranging from 1 (“did not feel this way at all”) to 7 (felt this way very much”). Mean R-R interval levels and concern were strongly correlated from segment to segment (*r* = .68, *p* = .001;

see Figure 2). Concern reported after the narrative was positively associated with the decision to donate (r = .20, p = .005) and the amount donated (r = .19, p = .009). Experienced narrative distress was not associated with donation behavior (ps > .10).

Time Series Analysis

In order to further examine the physiological differences between donors and non-donors, we examined the cardiac (R-R interval) physiologic time series averaged for each group (e.g., Bollerslev, 1986; Greene, 2012; Hamilton, 1994). The data were baseline-corrected and interpolated into one- second epochs to reduce noise. We estimated both traditional (autogressive integrated moving average, ARIMA) and more recent (generalized autoregressive conditional heteroskedasticity, GARCH) time series models until a best-fit model was identified (see Figure 3). We also tested for a structural break on narrative onset in order to test if cardiac activity immediately following narrative presentation differed between donors and non-donors.

The entire time series was tested for stationarity using a Dickey-Fuller test, which showed the data were stationary ($p = .02$ and $p < .001$, respectively rejects the null hypothesis of a unit root). The best fitting model for the donor group was an ARIMA(1,7), ARCH(1) EGARCH(1,2), with a significant structural break at stimulus onset. The AIC fit measure for this model was - 1618, with all coefficients significant ($p < 0.01$) and no significant autocorrelations. The best fitting model for the non-donor group was similar, an ARIMA(1,2), ARCH(1) EGARCH(1,2,3,4). This model's AIC value was -1506 and all estimated coefficients were significant ($p \leq 0.08$). The time series models show that cardiac activity in both donors and non-donors has autoregressive feedback and volatility clustering. The differences components of the best-fit time-series models are not interpretable. Nevertheless, these models show that physiologic arousal at stimulus

onset differed between donors and non-donors.

Discussion

The present research examined the connection between autonomic and hormonal systems and behavioral responses to a persuasive narrative. Both sympathetic and parasympathetic reactivity during narrative exposure significantly and independently predicted charitable giving. These findings persisted when controlling for personality traits. Importantly, as shown by modeling the cardiac time series, autonomic measures differed significantly across donors and non-donors *within* the narrative itself, indicating different reactions to particular elements of the narrative.

Studies have reported heart rate acceleration during exposure to stimuli that elicit positive affect (Lang et al., 1993 and Bradley and Lang, 2000). One might expect that donors would experience greater concern and thus show increased cardiac activity compared to non-donors, especially since empathic concern is classified as a positive emotion (Condon & Barrett, 2013; Goetz, 2010). Empathic concern, however, is associated with heart rate deceleration (Eisenberg et al., 1988). Heart rate deceleration is also observed during evocative films for children who were more willing to help bring homework or donate some of their participation earnings to a child in need (Eisenberg et al., 1989). In our study, while heart rate accelerated relative to baseline for our sample, heart rate appeared to decelerate as the narrative progressed, as indexed by an increase in the R-R interval. Moreover we found that across the narrative the R-R interval was positively correlated with ratings of concern from an independent sample.

While vagal control appeared to decline significantly during the narrative for donors and non-donors, we found that vagal control significantly predicted donor status. Prior research

suggests that higher resting vagal activity is associated with positive emotions (Kok & Fredrickson, 2010; Oveis et al., 2009) and perceptions of helpfulness by others (Eisenberg et al., 1996). It is important to note that our behavioral outcome was a positive social behavior (charitable giving), rather than tonic positive emotions as previous studies. However, resting vagal activity, which can be interpreted as trait-like, was not associated with our outcome measure. Whereas tonic vagal activity may be associated with dispositions toward emotionality (e.g., coping, emotional regulation, see Appelhans & Luecken, 2006), phasic vagal control may be a better indicator of responding to a specific stimulus (e.g., Friedman, Stephens, & Thayer, 2014; Stephens, Christie, & Friedman, 2010).

Electrodermal activity significantly increased during narrative exposure, and this increase was more pronounced in the donor group. Moreover, our results show that SCR was significantly associated with donor status, but not SCL. Both of these measures were significantly and positively correlated in this study (r= .32) consistent with the literature (reported correlations range from r = 0.44 to r = 0.75; Bouscein, 2012). However, there is evidence that SCL and SCR are not identical in their relation to stimuli. For instance, SCRs may reflect the general presence of highly arousing, negatively-tuned cognitive activity while SCL may indicate general arousal (e.g., Nikula, 1991). There is some indication that SCRs are better indicators of anticipatory responses than SCLs (e.g., Phillips, Evans, & Fearn, 1986). Our regression model indicates that the differences in SCL between donors and non-donors during the stimulus may be due to phasic SCR activity.

Endocrine measures (basal or reactive) did not appear to be associated with behavioral responses. We were unable to replicate the significant increase in ACTH after an influential

message reported in Lin and colleagues (2013). Although found an increase in ACTH from baseline to post-narrative, the change did not reach significance (baseline = 38.79 pg/ml, narrative = 42.16 pg/ml; two-tailed t-test, p = .15). This non-replication could be due to the larger age distribution (Lin et al, age range = 18-35) or differences in the stimulus (a self-relevant, visceral, and negative stimulus in Lin et al.).

The current research contributes to the emerging literature on the neurobiology of influence and persuasion. Previous research has shown that central nervous system activity (BOLD activity in medial prefrontal cortex) during presentation of an anti-smoking public service ads (PSAs) is a better predictor of population level success of the PSA than subjective smoker ratings or even ratings from professionals (Falk, Berkman, & Lieberman, 2012). We show here that peripheral physiology can serve the same function. From a practical standpoint, autonomic measures are much easier to collect and can be done inside and outside of the lab. However, autonomic physiology does not provide a fine-grained view of particular psychological processes that may be involved (e.g., affective versus cognitive). Yet, since peripheral neural systems coordinate interactions with the environment, these measures may be as successful in capturing influence that leads to an action. In short, physiological resonance with the environment may be able to differentiate when some may act where others sit idly by.

Author Contributions

J. A. Barraza and P. J. Zak developed the study concept and design. Protocol testing, data collection, and data preparation was performed by J. A. Barraza, L. E. Beavin, V. Alexander, and E. Terris. Data analysis was performed by V. Alexander in consultation with J. A. Barraza and P. J. Zak. The manuscript was written by J.A. Barraza and P. J. Zak, with contributions to methods and

results sections by V. Alexander. All authors approved the final submitted version of the manuscript.

Notes

1. Unlike with Lin et al., (2013), we were unable to include oxytocin in our analysis as we encountered a substantial proportion of missing data due to the assay process. The remaining data had such large between- and within-subject variation that they were not included in the analyses.

2. Though each hormone follows a different time course (e.g., de Wied, 1990; Dickerson & Kemeny, 2004; Rowe, Lincoln, Racey, et al., 1974), we collected blood for assay within 1-5 minutes of the narrative stimulus conclusion. The collection point was selected given the rapidity of changes in both oxytocin (Fabian et. al., 1969) and ACTH (de Wied, 1990).

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The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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References

Appel, M., & Richter, T. (2010). Transportation and need for affect in narrative persuasion: A mediated moderation model. *Media Psychology*, *13*(2), 101-135.

Appelhans, B. M., & Luecken, L. J. (2006). Heart rate variability as an index of regulated emotional responding. *Review of General Psychology*, *10*(3), 229–240. doi:10.1037/1089-2680.10.3.229

Barraza, J. A., & Zak, P. J. (2009). Empathy toward strangers triggers oxytocin release and subsequent generosity. *Annals of the New York Academy of Sciences, 1167*, 182-189.

Batson, C. D., Sager, K., Garst, E., Kang, M., Rubchinsky, K., & Dawson, K. (1997). Is empathy-induced helping due to self–other merging?. *Journal of Personality and Social Psychology*, *73*(3), 495.

Beauchaine, T. (2001). Vagal control, development, and Gray's motivational theory: Toward an integrated model of autonomic nervous system functioning in psychopathology. *Development and Psychopathology, 13*(2), 183-214.

Boksem, M. A., Mehta, P. H., Van den Bergh, B., van Son, V., Trautmann, S. T., Roelofs, K., ... & Sanfey, A. G. (2013). Testosterone inhibits trust but promotes reciprocity. *Psychological Science*, *24*, 2306-2314.

Bollerslev, T. (1986). Generalized autoregressive conditional heteroskedasticity. *Journal of Econometrics, 31*, 307–327.

Born, J., Fehm, H. L., & Voigt, K. H. (1986). ACTH and attention in humans: a review. *Neuropsychobiology*, *15*, 165-186.

Bos, P. A., Panksepp, J., Bluthé, R. M., & Honk, J. V. (2012). Acute effects of steroid hormones and neuropeptides on human social–emotional behavior: a review of single administration studies. *Frontiers in Neuroendocrinology*, *33*, 17-35.

Boucsein, W. (2012). *Electrodermal activity*. Boston, MA: Springer Science & Business Media. doi:10.1007/978-1-4614-1126-0

Bradley, M. M., & Lang, P. J. (2000). Measuring emotion: Behavior, feeling, and physiology. *In: Lane, R.D., & Nadel, L. (Eds.), Cognitive neuroscience of emotion* (pp.242-276). New York, NY: Oxford University Press.

Brainard, D. H. (1997) The Psychophysics toolbox. *Spatial Vision, 10*, 433-436.

Busselle, R., & Bilandzic, H. (2009). Measuring narrative engagement. *Media Psychology, 12(4)*, 321-347.

Condon, P., & Barrett, L.F. (2013). Conceptualizing and experiencing compassion. *Emotion, 13*, 817-821.

Eisenberg, N., Fabes, R. A., Bustamante, D., Mathy, R. M., Miller, P. A., & Lindholm, E. (1988). Differentiation of vicariously induced emotional reactions in children. *Developmental Psychology, 24*, 237-246.

Eisenberg, N., Schaller, M., Fabes, R. A., Bustamante, D., Mathy, R. M., Shell, R., et al. (1988). Differentiation of personal distress and sympathy in children and adults. *Developmental Psychology, 24*, 766-775.

Eisenberg, N., Fabes, R. A., Schaller, M., Miller, P., Carlo, G., Poulin, R., et al. (1991). Personality

and socialization correlates of vicarious emotional responding. *Journal of Personality and Social Psychology, 61*, 459-470.

Escalas, J. E. (2004). Narrative processing: Building consumer connections to brands. *Journal of Consumer Psychology*, *14*(1), 168-180.

Falk, E. B., Rameson, L., Berkman, E. T., Liao, B., Kang, Y., Inagaki, T. K., & Lieberman, M. D. (2010). The neural correlates of persuasion: A common network across cultures and media. *Journal of Cognitive Neuroscience*, *22*(11), 2447-2459.

Falk, E. B., Berkman, E. T., & Lieberman, M. D. (2012). From neural responses to population behavior: Neural focus group predicts population-level media effects. *Psychological Science*, *23*(5), 439–445.

Friedman, B. H., Stephens, C. L., & Thayer, J. F. (2014). Redundancy analysis of autonomic and self-reported, responses to induced emotions. *Biological Psychology*, *98*, 19–28. doi:10.1016/j.biopsycho.2013.12.006

Gerrig, R. J. (1993). *Experiencing narrative worlds: On the psychological activities of reading*. New Haven: Yale University Press.

Goetz, J. L., Keltner, D., & Simon-Thomas, E. (2010). Compassion: an evolutionary analysis and empirical review. *Psychological Bulletin*, *136*(3), 351-374.

Gosling, S. D., Rentfrow, P. J., & Swann Jr, W. B. (2003). A very brief measure of the Big-Five personality domains. *Journal of Research in Personality*, *37*(6), 504-528.

Green, M.C. (2004). Transportation into narrative worlds: The role of prior knowledge and perceived realism. *Discourse Processes, 38(2)*, 247-266.

Green, M.C., & Brock, T.C. (2000). The role of transportation in the persuasiveness of public

narratives. *Journal of Personality and Social Psychology, 79(5)*, 701-721.

Greene, W. H. (2012). *Econometric Analysis* (7th ed). Upper Saddle River, NJ: Prentice Hall.

Hamilton, J. D. (1994). *Time Series Analysis*. Princeton: Princeton University Press

Janig, W. (2003). The autonomic nervous system and its coordination by the brain. In R. J. Davidson, K. R. Scherer, & H. H. Goldsmith (Eds.), Handbook of affective sciences (pp. 135–186). New York, NY: Oxford University Press.

Kensinger, E. A. (2004). Remembering emotional experiences: The contribution of valence and arousal. *Reviews in the Neurosciences*, *15*(4), 241-252.

Kok, B. E., & Fredrickson, B. L. (2010). Upward spirals of the heart: Autonomic flexibility, as indexed by vagal control, reciprocally and prospectively predicts positive emotions and social connectedness. *Biological Psychology*, *85*(3), 432-436.

Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, A. O. (1993). Looking at pictures: Affective, facial, visceral, and behavioral reactions. *Psychophysiology, 30*, 261–273.

Lewis GF, Furman SA, McCool MF, Porges SW. (2012). Statistical strategies to quantify respiratory sinus arrhythmia: Are commonly used metrics equivalent? *Biological Psychology, 89*, 349-364.

Lin, P.-Y., Grewal, N. S., Morin, C., Johnson, W. D., & Zak, P. J. (2013). Oxytocin increases the influence of public service advertisements. *PLoS ONE*, *8*(2), e56934.

MacLeod, C., & Mathews, A. (2004). Selective memory effects in anxiety disorders: An overview of research findings and their implications. In D. Reisberg, & P. Hertel (Eds.), *Memory and emotion*, New York, NY: Oxford University Press.

Mar, R. A., Oatley, K., Djikic, M., & Mullin, J. (2011). Emotion and narrative fiction: Interactive

influences before, during, and after reading. *Cognition & Emotion*, *25*, 818-833.

Nikula, R. (1991). Psychological correlates of nonspecific skin conductance responses. *Psychophysiology*, *28*, 86-90.

Oveis, C., Cohen, A. B., Gruber, J., Shiota, M. N., Haidt, J., & Keltner, D. (2009). Resting respiratory sinus arrhythmia is associated with tonic positive emotionality. *Emotion*, *9*, 265–270. doi:10.1037/a0015383

Paharia, N., Keinan, A., Avery, J., Schor, J. (2011). The underdog effect: The marketing of disadvantage through brand biography. *Journal of Consumer Research, 37*, 775-790.

Phillips, K. C., Evans, P. D., & Fearn, J. M. (1986). Heart rate and skin conductance correlates of monitoring or distraction as strategies for "coping". IN D. Papakostopoulos, S. Butler, & I. Martin (Eds.), *Clinical and Experimental Neuropsychophysiology*, 486-499. Dover: Croom Helm.

Porges, S. W. (2011). *The Polyvagal Theory: Neurophysiological Foundations of Emotions, Attachment, Communication, and Self-regulation (Norton Series on Interpersonal Neurobiology)*. WW Norton & Company.

Rahe, C. R. H., Rubin, R. T., & Gunderson, E. E. (1972). Measures of subjects' motivation and affect correlated with their serum uric acid, cholesterol, and cortisol. *Archives of General Psychiatry*, *26*(, 357-359.

Rowe, P. H., Lincoln, G. A., Racey, P. A., Lehane, J., Stephenson, M. J., Shenton, J. C., & Glover, T. D. (1974). Temporal variations of testosterone levels in the peripheral blood plasma of men. *Journal of Endocrinology*, *61*, 63-73.

Small, D. A., Loewenstein, G., & Slovic, P. (2007). Sympathy and callousness: The impact of

deliberative thought on donations to identifiable and statistical victims. *Organizational Behavior and Human Decision Processes*, *102*(2), 143-153.

Stephens, C. L., Christie, I. C., & Friedman, B. H. (2010). Autonomic specificity of basic emotions: Evidence from pattern classification and cluster analysis. *Biological Psychology, 84*, 83–93. doi:10.1016/j.biopsycho.2010.03.014

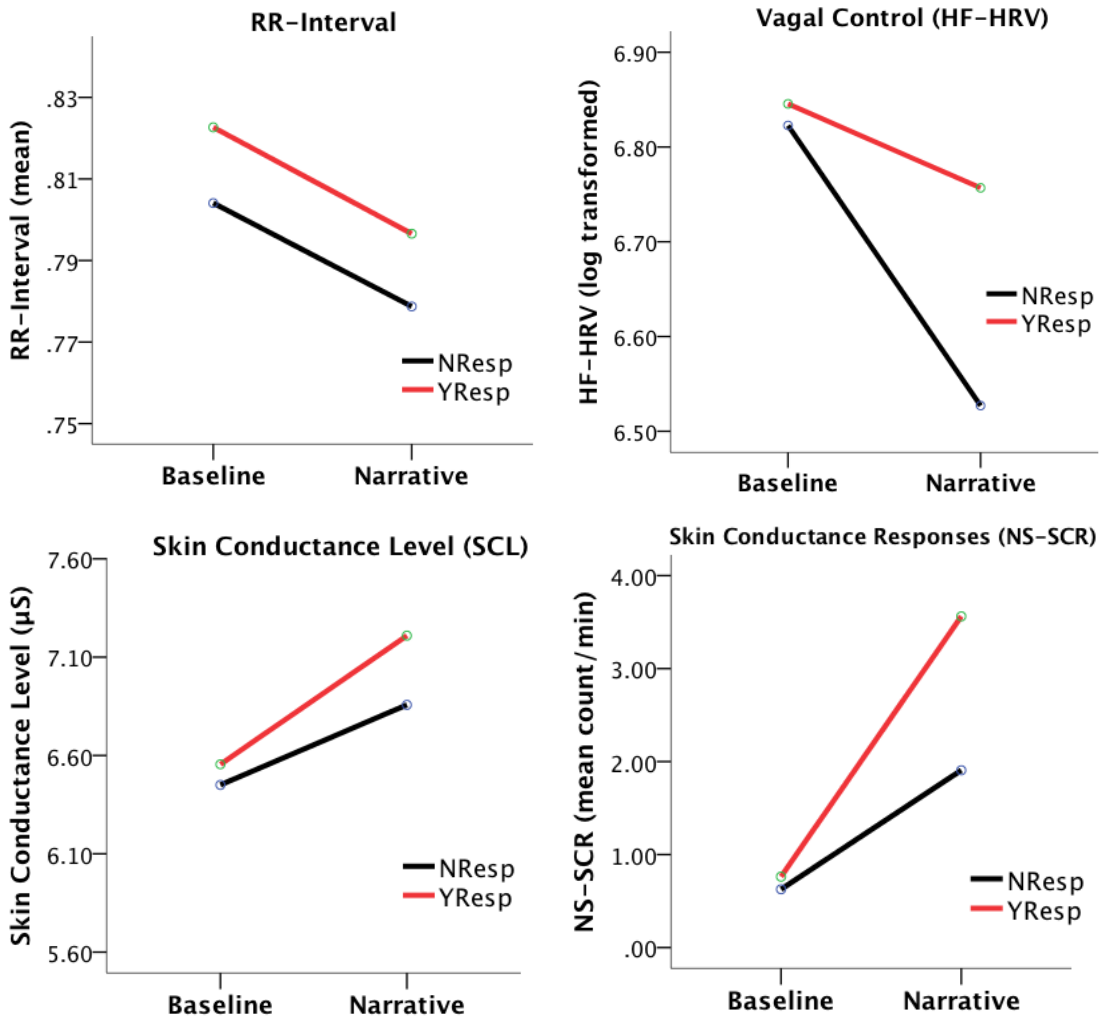

Figure 1. Mean physiology at baseline and during narrative exposure for donors (YResp) and non-donors (NResp).

Table 1.

Logistic regression model predicting donations with delta change in physiology

Model and predictor	β	*SE* (β)	Wald statistic	*p*	Odds ratio
Model 1					
RR interval	0.58	0.25	5.41	0.020	1.90
HF-HRV	0.01	0.01	4.24	0.039	1.01
NS-SCR	0.29	0.14	4.66	0.031	1.34
SCL	-2.94	0.32	1.14	0.286	0.05
Model 2					
RR interval	0.59	0.26	5.25	0.022	1.79
HF-HRV	0.01	0.01	3.99	0.046	1.01
NS-SCR	0.34	0.15	5.24	0.022	1.41
SCL	-3.64	2.88	1.60	0.206	0.03
ACTH	-0.01	0.01	0.31	0.578	1.00
Cortisol	-0.03	0.36	2.97	0.085	0.97
Testosterone	-0.11	0.22	0.02	0.881	0.89

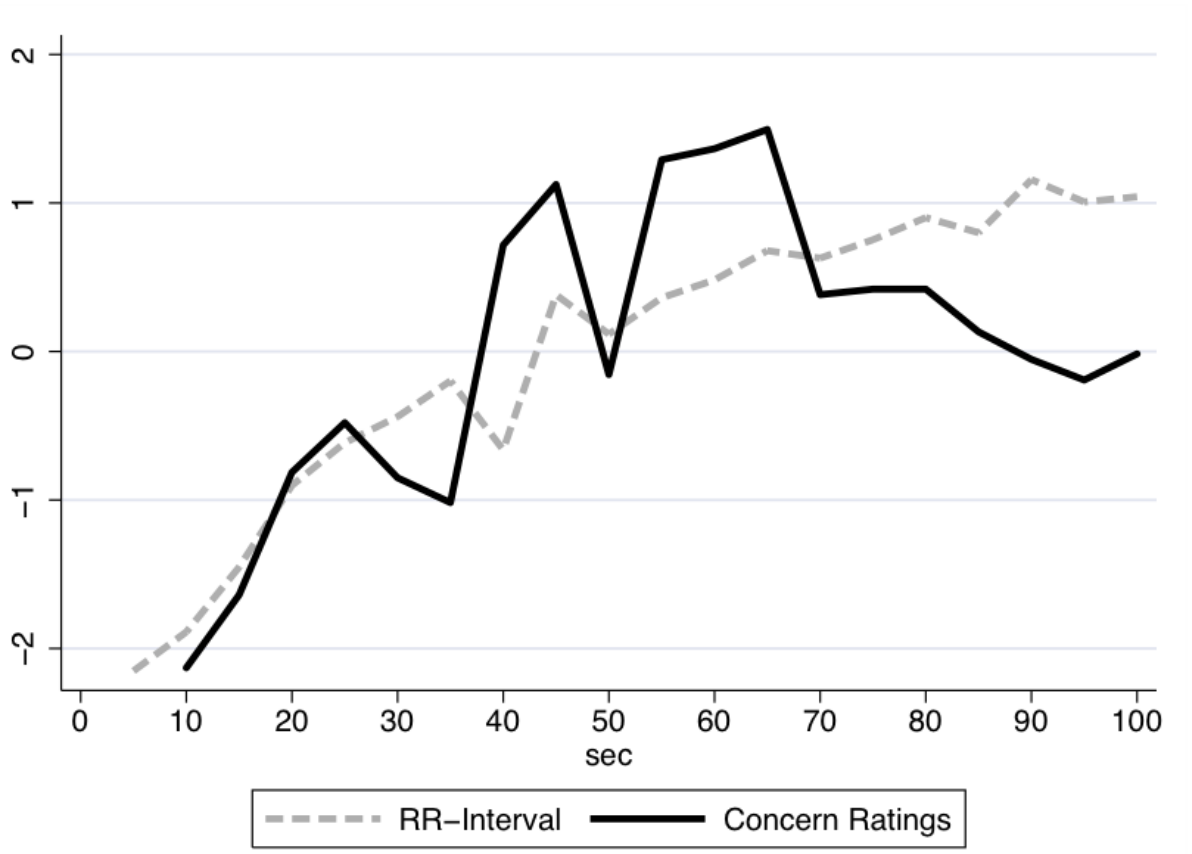

Figure 2. Mean standardized RR-interval (with a 5-second lag) and concern scores across narrative.

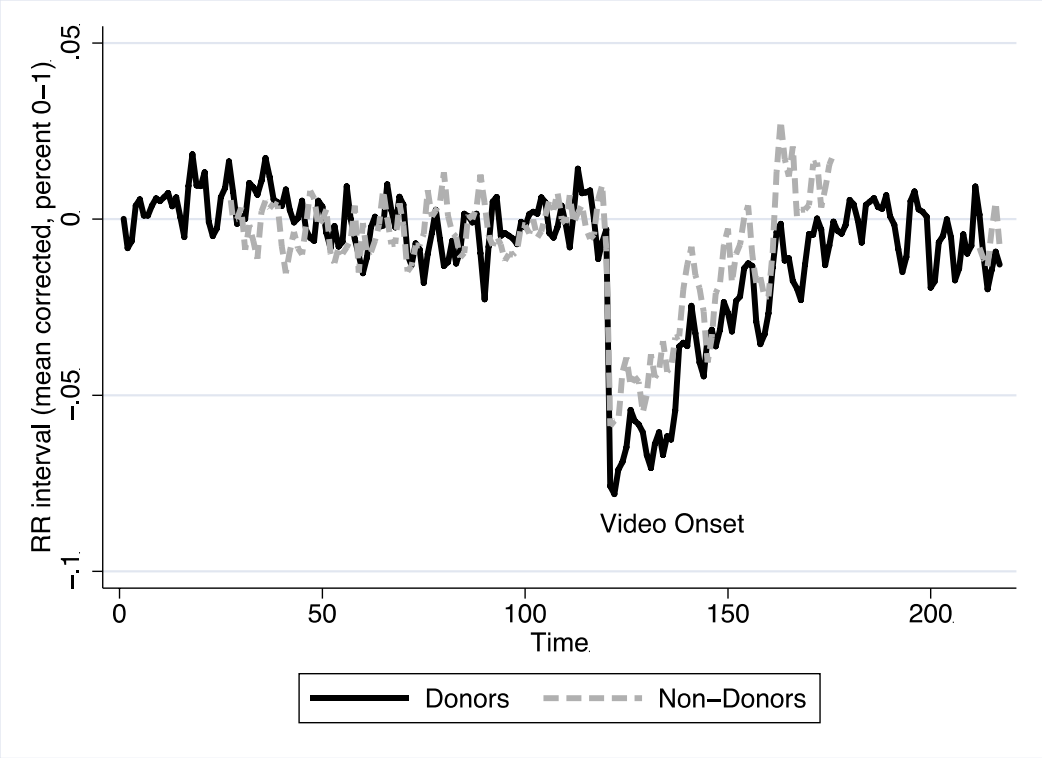

Figure 3. Timeseries of the RR-interval for donors and non-donors across baseline and narrative video (baseline mean corrected by percent from -1 to +1).

Research Highlights

The Heart of the Story:

Peripheral Physiology During Narrative Exposure Predicts Charitable Giving

Barraza, Alexander, Beavin, Terris, & Zak

- Autonomic reactivity to a narrative is associated with narrative-aligned behavior
- Autonomic activity varies by both behavior classification and narrative events
- Cardiac activity and experienced concern covary across the narrative