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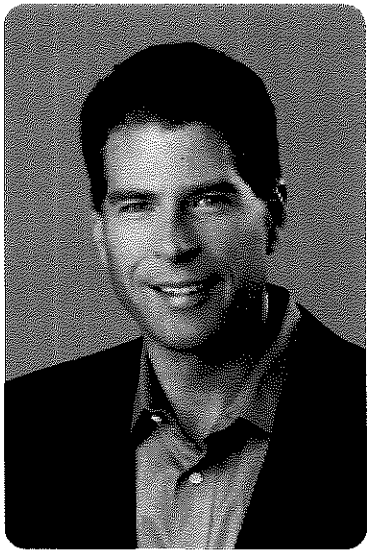

Why Inspiring Stories Make Us React: The Neuroscience of Narrative

By: Paul J. Zak, Ph.D.

Editor's Note: The man behind the discovery of the behavioral effect of a neurochemical in the brain called oxytocin wondered if the molecule might motivate people to engage in cooperative behaviors. In a series of tests using videos, his lab discovered that compelling narratives cause oxytocin release and have the power to affect our attitudes, beliefs, and behaviors.

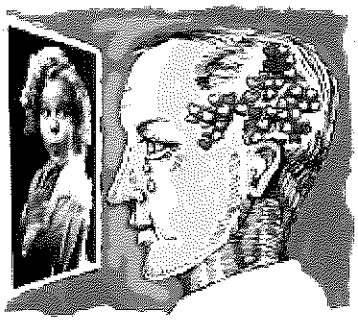

Illustration by William Hogan

During a night flight home to California after five days in Washington, D.C., I discovered that I am the last person you would want sitting next to you on a plane. Tired and unable to bang on my laptop in the turbulence at 40,000 feet, I decided to watch *Million Dollar Baby*. I hadn't seen it, but I figured a Clint Eastwood–directed film that had won the Oscar for Best Picture would be a deserved break for a hard week.

It is a wonderful film, and I became deeply absorbed in it. The narrative is circumscribed by a father-daughter story and concludes with an agonizing act. When the movie was over, the man next to me

said, "Sir, is there something I can do to help you?" I was crying. Well, not really crying, more like heaving big sloppy sobs out of my eyes and nose and mouth. Everyone around could hear me but I could not suppress my sadness.

After I recovered, I began to wonder what had happened to me. I was

character in the movie, as if one of my own daughters were the one suffering. I experienced heartache as the movie ended, but then it was only a story.

As a neuroscientist, I knew that movies changed our brain activity in some way, but how?

I soon realized I had stumbled on a potentially useful way to extend my studies of the social brain. My lab was the first to discover that the neurochemical oxytocin is synthesized in the human brain when one is trusted and that the molecule motivates reciprocation.[1][2][3] We found that the human oxytocin response was similar to that found in social rodents,[4] signaling that another person (or rodent) is safe and familiar. Perhaps most surprising, we found that in humans, this "you seem trustworthy" signal occurs even between strangers without face-to-face interactions.

Oxytocin is an astonishingly interesting molecule. It is a small peptide synthesized in the hypothalamus of mammal brains. It is made of only nine amino acids and is fragile. Oxytocin is classically associated with uterine contractions and milk-letdown for nursing. Animal studies have shown that under physiologic stress oxytocin is released in both brain and body.[5][6] This is unusual for a brain-derived neurochemical, but it provides a powerful way to study oxytocin: After a stimulus, changes in oxytocin in blood reflect changes in the brain's oxytocin.

For more than a decade, I have run human experiments measuring the endogenous release of oxytocin during social interactions. My colleagues and I have studied oxytocin release in the laboratory as well as in field studies spanning religious rituals, folk dances, weddings, and a traditional war dance by indigenous people in the rainforest of Papua New Guinea.[7] I also have demonstrated the causal effect of oxytocin on prosocial behaviors by safely infusing synthetic oxytocin into hundreds of people's brains through their noses.[8][9][10] Oxytocin infusion increases prosocial behaviors. It's like turning on a garden hose and watching the water spray out.

Provoking the Brain

Studies that only infuse oxytocin into participants and then make claims about human behavior are suspect. This approach does not identify what the brain itself is doing during social interactions, including neurochemical promotion and inhibition of oxytocin synthesis and dose-response relationships between oxytocin and behavior. The key question is whether the brain produces its own oxytocin during the behavior being studied; if so, the causal relationship between oxytocin and a particular behavior can be demonstrated via an infusion study. But the reverse is not true: Infusing oxytocin or any drug into the brain and observing a change in behavior does not mean that this is how the brain works–it simply means that a drug has changed behavior, as many drugs do. My studies complete the causal circle by measuring what the brain does naturally and then intervening in this system pharmacologically to show that the behavior can be provoked.

After years of experiments, I now consider oxytocin the neurologic substrate for the Golden Rule: If you treat me well, in most cases my brain will synthesize oxytocin and this will motivate me to treat you well in return. This is how social creatures such as humans maintain themselves as part of social groups: They play nice most of the time. (Why people do not play nice is a fascinating story we also have studied; see Zak, 2012 for evidence). But I'm a skeptic at heart, so I always want to measure the behavioral effects of oxytocin rather than simply ask people's opinions about how they feel.

The experience I had watching *Million Dollar Baby* caused me to wonder if movies, in addition to direct personal interactions, would cause oxytocin release. To test this, my colleague Jorge Barraza edited a set of a short video clips that we obtained with permission from St. Jude Children's Research Hospital. One version shows a father talking to the camera while his 2-year-old son, Ben, who has terminal brain cancer, plays in the background. The story has a classic dramatic arc in which the father is struggling to connect to and enjoy his son, all the while knowing that the child has only a few months to live. The clip concludes with the father finding the strength to stay emotionally close to his son "until he takes his last breath."

We also developed a video of the same father and son spending a day at the zoo. This version does not mention cancer or death, but the boy is bald (from his chemotherapy) and is called "miracle boy" once during the clip. This video lacks the tension induced by the typical story form but includes the same characters. This version was used as

a control story to see what the brain does when any video is being watched.

In our first study of narratives, we took blood before and after participants watched one of the two versions of the video. [11] We found that the narrative with the dramatic arc caused an increase in cortisol and oxytocin. Tellingly, the change in oxytocin had a positive correlation with participants' feeling of empathy for Ben and his father. Heightened empathy motivated participants to offer money to a stranger who was in the experiment. We connected a story to a feeling and then to a prosocial behavior. The "flat" narrative of Ben and his father at the zoo did not increase oxytocin or cortisol, and participants did not report empathy for the story's characters.

These findings suggest that emotionally engaging narratives inspire post-narrative actions–in this case, sending money to a stranger. But maybe this result only applied to videos of dying children. Also, we did not know for sure that oxytocin was the reason participants cared about the people in the video, just that oxytocin and empathy were correlated. So we rolled up our sleeves and ran more experiments.

Narrative Immersion

Our previous study pointed to oxytocin as the biological instrument that puts people in thrall to a story. To assess the causal impact of oxytocin on narrative immersion, we ran a study using public service announcements (PSAs) in which participants received intranasal infusions of synthetic oxytocin or a placebo. This time around, we decided to test a larger set of video narratives. We wanted stories that most people would not have seen before and ones that could elicit a prosocial action at a cost (such as a donation). This would allow us to measure objectively whether the story "got to you."

We found a rich trove of public service announcements from the United Kingdom that are well-produced and engaging. The experiment used sixteen PSAs that ran for thirty or sixty seconds on four topics: smoking, drinking to excess, speeding, and global warming. To incentivize people to pay attention to the videos, each of the participants was paid five dollars if they could correctly answer a factual question about the ad immediately after watching it. For example, "Was there a car in the video?" Then, our software asked participants if they would like to donate some of the five dollars they had just earned to a charity associated with the cause shown in the PSA. None of the PSAs solicited donations, they simply told stories about social issues. Computer software presented all the videos and

post-video questions and we used random participant identifiers so that one's donation behavior was kept private.

Forty people received either 40 IU of oxytocin or an equivalent amount of normal saline (placebo). Neither the experimenters nor the participants knew what substance had been administered. Participants started watching the videos after an hour-long period during which the synthetic oxytocin diffuses from the sinuses into the brain.

We found that those who received oxytocin donated, on average, 56 percent more money to charity compared with participants who received the placebo. [12] This confirmed the causal role of oxytocin on post-narrative prosocial behavior. But why did this happen? We discovered that participants who were given oxytocin showed substantially more concern for the characters in the PSAs. This increased concern motivated them to want to help by donating money to a charity that could alleviate the suffering these stories depicted.

If you think about it, the donations are quite odd. The narrative is over, but the effects linger. It is as if the brain is lazy and is using a "monkey see, monkey do" approach to assess appropriate social behaviors. (Indeed, the brain seeks to conserve energy by using default pathways –a kind of "laziness.") The PSAs seemed to persuade viewers that (for example) nowadays the humans are very concerned about drinking too much, so as a human, I, too, should be concerned. And I should demonstrate that concern by donating money to charity. Such responses are what social creatures with social brains do. And yet, participants understand that the stories are fictional and are portrayed by professional actors. The money donated to charity cannot help these actors out of their fictional binds. The money might help prevent the harm depicted in the PSAs from happening to an unknown other person, but this is a big "if." Nevertheless, oxytocin makes people want to help others in costly and tangible ways.

In another experiment,[12] we sought to replicate our earlier study by taking blood samples before a group of forty-two participants (who were not in the oxytocin infusion study) watched one of the UK PSAs. We measured the change in oxytocin and in a fast-acting arousal hormone with a long name that is abbreviated ACTH.

When the PSA elicited an increase in both ACTH and oxytocin, donations were 261 percent higher than when one or both of these biomarkers did not rise. The change in ACTH correlated with the

amount of attention people paid to the story. This finding makes sense: If we do not attend to a story, it will not pull us into its narrative arc. Attention is a scarce neural resource because it is metabolically costly to a brain that needs to conserve resources. If a story does not sustain our attention, then the brain will look for something else more interesting to do.

We also found that the change in oxytocin was associated with concern for the characters in the story, replicating our earlier finding. If you pay attention to the story and become emotionally engaged with the story's characters, then it is as if you have been transported into the story's world. This is why your palms sweat when James Bond dodges bullets. And why you stifle a sniffle when Bambi's mother dies.

Attention-getting

Narratives that cause us to pay attention and also involve us emotionally are the stories that move us to action. This is what a good documentary film does. More generally, stories with a dramatic arc fit the requirements for high-impact narratives. This structure sustains attention by building suspense while at the same time providing a vehicle for character development. The climax of the story keeps us on the edge of our neural seats until the tension is relieved at the finish.

Theorists including Aristotle (*Poetics*, 335 BCE), Gustav Freytag (*Die Technik des Dramas*, 1863), and Joseph Campbell (*The Hero with a Thousand Faces*, 1949) have contended that the rising and falling tension of dramatic performances facilitate the audience's emotional connection to the characters. Hollywood writers call this creating "surprising familiarity." Every story is different but somehow the same.

Now let's get down to brass tacks: Why are there so many dreadful movies? Humans have known about the three-act structure and mythos, pathos, and ethos for 2,500 years. This is where the neuroscience hits the flickering screen.

Like all experiments, we had to start small.

To answer these questions, we needed to measure attention and oxytocin responses rapidly–second by second, or even faster. Blood draws would not do. At the same time, the U.S. Department of Defense wanted to know why narratives are persuasive and

supported our research and that of other labs as well. Attention is easy to measure rapidly, via a quickened heartbeat or sweat coming from eccrine glands in the skin. But was there a way to measure oxytocin rapidly? Nature provided a solution. While we were mostly interested in oxytocin in the brain, the stimulus-induced co-release of oxytocin in the brain and blood meant we could measure changing activity in regions with densities of oxytocin receptors. The vagus nerve (the longest cranial nerve, which innervates the heart and gut) is chock-full of oxytocin receptors. With a bit of algorithmic fiddling, scientists can measure the activity of the vagus using an electrocardiogram (ECG). We confirmed that the change in oxytocin in blood correlates with changes in vagus nerve activity. Voilà, we had a measurement technique. But would it predict behavior?

We returned to the story of the dying child Ben because it is a reliable way to stimulate oxytocin release. This time we measured cardiac activity using an ECG and sweat using an electrodermal sensor on the fingers. Because we were developing a system that might be used in a war zone, we built in redundancies. Attention was measured using both heart rate and skin conductance changes from sweat on the fingers; emotional resonance was quantified using two measures of changes in the brain's relaxation response driven by the vagus nerve. The exciting part was that we could measure both effects up to one thousand times a second with off-the-shelf wireless technologies.

But it is not so simple to isolate the effects of a story from everything else the brain is doing to keep you upright, breathing, and conscious. All neuroscience studies need to extract the neurologic signal produced by a stimulus during an experiment from the background noise of all other neural activity. To give you a sense of the scope of this problem, for every thirty people we test for an hour each, we collect a terabyte of peripheral neurologic data. Most of this data is not relevant to understanding why people respond to stories, but the faint traces that are relevant must be extracted and processed with extraordinary care. Once we did all this, the data told us several interesting things.[13]

First among them is that the brain does not work like the hypothetical story structure known as Freytag's pyramid, in which strictly rising action leads to a climax, and then strictly falling action occurs as the story resolves. Even for the one-hundred-second "Ben" video, one's attention waxes and wanes. The brain is attending to the story and then doing a quick search of the rest of the environment, and then refocusing on the story as the tension rises. Nevertheless, the peak attentional response occurs in the climax, when Ben's father reveals

that Ben is dying. That's a bombshell to which people pay attention.

The oxytocin response lags behind the attentional spike as the story begins. After about thirty seconds, vagal activity begins to increase as viewers get to know and then begin to empathize with Ben and his father. Attention to the story provides a reason viewers should care about the characters.

Not only were we able we track what the brain is doing millisecond by millisecond during a story, we used the neurologic data to build a predictive model of donations to a childhood cancer charity–our measure of story impact. The statistical model we built predicts whether a participant would donate money with 82 percent accuracy. That is, by measuring how your peripheral nervous system responds to a story, we can almost perfectly predict what you'll do before you do it.

The participants who, for whatever reason, either lost interest in the video or didn't form an emotional connection to Ben and his father almost never donated money to charity. But we are still left with a mystery: Why donate money at all? The money will not save Ben and it won't offer relief to his father. It seems that once we are attentive and emotionally engaged, our brains go into mimic mode and mirror the behaviors that the characters in the story are doing, or might do. As social creatures we are biased toward engaging with others, and effective stories motivate us to help others.

Truth be told, Ben's story is as near to a perfect high-impact narrative as there is. We wondered if neurologic data could identify bad stories, too. And what about stories that may be distasteful but that are still desirable to watch? I watched Steven Spielberg's Holocaust movie *Schindler's List* once. I'm glad I did, but I don't have much desire to watch it again. It was just overwhelming emotionally.

Our next study tested stories about "hot-button" issues to see how people reacted to potentially disagreeable topics. We used first-person narratives from StoryCorps, a nonprofit that collects and distributes personal stories. We choose six stories on racism, gun control, and the terrorist attacks of September 11. Each anecdote lasted from two to four minutes. For our "narrative impact" measure, we invited participants to donate some of their earnings to a charity associated with the topic of the story.

These stories were challenging to analyze because they varied substantially in structure and content. The peripheral neurologic data

we collected reflected these variations. Just as in the "Ben" story, we confirmed that stories that sustain attention and generate emotional resonance produce post-narrative donations–even stories on difficult topics. To the brain, good stories are good stories, whether first-person or third-person, on topics happy or sad, as long as they get us to care about their characters.

Psycholinguists have shown that effective stories induce "transportation" into the narrative.[14] Transportation happens when one loses oneself in the flow of the story–just like I did while watching *Million Dollar Baby*. To understand the psychological effects of stories, we included surveys of narrative transportation and concern for story characters in the StoryCorps study. Both narrative transportation and concern predicted post-story donations. This shows why stories affect behavior after the story has ended: we have put ourselves into the narrative. Even a week after the experiment, accurate story recall was predicted by a single measure: narrative transportation.

Do We Know a Good Story When We See One?

You may be thinking that we have a money-centric approach to assessing when people are moved by a story. Fair enough. Let's try a different approach: We'll have thousands of people rate stories instead. The stories we used were TV commercials. Conveniently, this is just what *USA Today* asks readers to do on Super Bowl Sunday: vote for the commercials they like the best. About five thousand people voted for their favorite commercials in 2014, and the style and content of these short narratives vary from the unusual to poignant to just plain silly. This gave us a chance to further refine our algorithms and test them against what people say they like.

USA Today does not simply provide a ranking of commercials; it has its readers rate them on a one to ten scale. Good idea! My group derived a quantification of narrative engagement using neurologic data so we, too, could rate story quality. We estimated the relative contribution of attention and emotional resonance on story impact from our corpus of studied stories. We call this measure a story's ZEST (for Zak Engagement STatistic). By estimating each Super Bowl ad's ZEST, we could compare the *USA Today* readers' ad likability with the ZEST measure of brain activity.

Three days after the 2014 Super Bowl, sixteen participants watched the top ten Super Bowl commercials in random order in my lab while we measured their peripheral neurologic activity. The results were astounding. There was no correlation at all between what *USA Today*

readers said they liked and a commercial's ZEST. Either we had made a big mistake, or we had discovered something important. So we ran another study using *USA Today's* top ten 2013 Super Bowl commercials and found exactly the same thing: zero correlation.

These findings suggest that people are unable to articulate what they like and do not like. But their brains reveal what is engaging for them to watch. Perhaps this should not surprise us. In a classic study, psychologist and economics Nobel laureate Daniel Kahneman found that people's preferences for things they have not experienced are largely unformed.[15]

Watching the Super Bowl commercials myself, I sensed why it is hard to articulate what one likes. The best Super Bowl commercial in 2014, according to *USA Today* readers, was called "Puppy Love," produced for Budweiser beer. In the first ten seconds, one sees a puppy nuzzling the nose of a Clydesdale horse. One immediately recognizes the Clydesdale as the Budweiser icon, and this tells viewers what they can expect from the ad. The suspense is gone, and our neurologic measures show that people's attention wanders starting fifteen seconds into the commercial. Without attention, the hoped-for emotional resonance with the ad's characters (and presumably the brand) fails to occur.

But ask people what they like and, gosh, they see puppies and horses and wide open country and, well, of course we love these images. But the brain does not lie. The commercial is dull.

In all our studies we ruled out effects that might influence ZEST, including movement, cars, buildings, attractive men and women, and many other factors. They don't matter; it all comes down to story.

The U.S. Department of Defense's funding of the emerging science of narrative jump-started the field.[16] [17] Storytellers have always known that attention and emotion are important to develop during a narrative, but now we have ways to measure these responses directly rather than rely on incohate impressions such as "entertaining" or "fascinating." Yet, even with millennia of practice, creating a great story is difficult. The emerging science of narrative can guide the art, but it cannot replace it. Humans are just too complex for an algorithm to generate art. And this is where the artist comes in. The narrator in *Million Dollar Baby* describes the heroine, Maggie's, desire to be a boxer as " ... the magic of risking everything for a dream that nobody sees but you. " Artists who create worlds we cannot help but enter do the same.

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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.

1. Introduction

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, Grewal, Morin, Johnson, & Zak, 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 & Mathews, 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, Schaller et al., 1988; Eisenberg et al., 1991). 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,

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[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.

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notably empathic concern (e.g., Oveis et al., 2009), changes in vagal activity (reactivity) are used as situational indicators of vagal control (Beauchaine, 2001).

2. 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, 2011), 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.

3. Method

3.1. Participants and procedure

We recruited 163 participants (68 females) 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, 12 mL 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-min baseline acquisition period for autonomic nervous system (ANS) measures, participants watched a 100-s 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 12 mL 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.

3.2. 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.

3.3. 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, CA). 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, CA). 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, 2001). 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 0.01 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 to 0.4 Hz band and then log-transformed as suggested by Lewis, Furman, McCool, and Porges (2012).

3.4. 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

[2] Though each hormone follows a different time course (e.g., de Wied, 1990; Dickerson & Kemeny, 2004; Rowe et al., 1974), we collected blood for assay within 1–5 min 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).

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 min. 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.

4. Results

4.1. Donations, personality, and post narrative affect

Overall, 52% percent of participants made donations (average donation $6.94, *SD* = $6.99). There were no gender differences in the decision to donate or the amount donated (*ps* > 0.10). Donors rated themselves higher on the five-factor agreeableness dimension ($M = 4.94$, $SD = 1.13$) than non-donors ($M = 4.53$, $SD = 1.26$; $p = 0.032$, $d = 0.35$). 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 $M = 4.88$, $SD = 1.11$; $p = 0.002$, $d = 0.49$) and perspective-taking (donors $M = 5.09$, $SD = 0.82$; non-donors $M = 4.72$, $SD = 1.00$; $p = 0.013$, $d = 0.41$). 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 $M = 4.52$, $SD = 1.43$; $p = 0.011$, $d = 0.96$), and distress (donor $M = 5.76$, $SD = 1.06$; non-donor $M = 5.33$, $SD = 1.18$; $p = 0.02$, $d = 0.39$) 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 $M = 37.43$, $SD = 2.78$; $p = 0.67$).

4.2. 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 Fig. 1). For cardiac measures, main effects show the narrative accelerated heart rate, significantly decreasing R-R interval across groups, $F(1, 136) = 12.9$, $p < 0.001$, $\eta^2 = 0.09$, and decreasing HF-HRV, $F(1, 122) = 8.5$, $p < 0.01$, $\eta^2 = 0.07$. There was 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, $F(1, 147) = 89.99$, $p < 0.001$, $\eta^2 = 0.38$, and increased skin conductance responses, $F(1, 145) = 92.73$, $p < 0.001$, $\eta^2 = 0.39$. Interactions indicate that, compared to non-donors, donors had higher sympathetic activation in both SCL, $F(1, 147) = 4.90$, $p < 0.05$, $\eta^2 = 03$, and NS-SCR, $F(1, 145) = 12.86$, $p < 0.001$, $\eta^2 = 0.08$, 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, $F(1, 147) = 19.01$, $p < 0.001$, $\eta^2 = 0.12$. The average change in cortisol did not have a significant difference between donor and non-donor groups ($p > 0.10$).

Table 1
Logistic regression model predicting donations with delta change in physiology.

Model and predictor	β	$SE(\beta)$	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

4.3. 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, $p = 0.046$. In addition, heart rate (R-R interval), OR = 1.79, $p = 0.022$, and skin conductance responses (NS-CSR), OR = 1.41, $p = 0.022$, were predictive of the decision to donate within the same model. None of the endocrine measures significantly predicted the decision to donate ($p > 0.05$). The results remained significant when controlling for agreeableness ($\beta = 0.26$, $p = 0.11$), empathic concern ($\beta = 0.52$, $p = 0.02$), perspective-taking ($\beta = 0.63$, $p = 0.01$), gender ($\beta = -0.62$, $p = 0.16$), or age ($\beta = -0.02$, $p = 0.65$).

4.4. 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-s 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 ($r = 0.68$, $p = 0.001$; see Fig. 2). Concern reported after the narrative was positively associated with the decision to donate ($r = 0.20$, $p = 0.005$) and the amount donated ($r = 0.19$, $p = 0.009$). Experienced narrative distress was not associated with donation behavior (*ps* > 0.10).

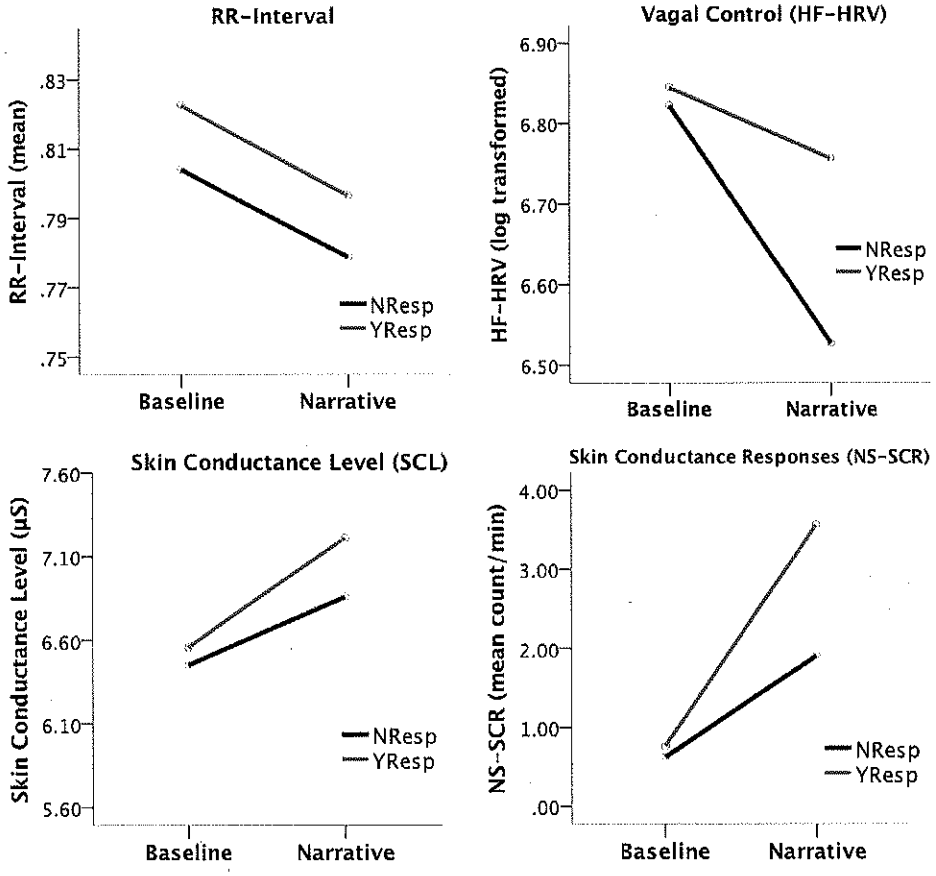

Fig. 1. Mean physiology at baseline and during narrative exposure for donors (YResp) and non-donors (NResp).

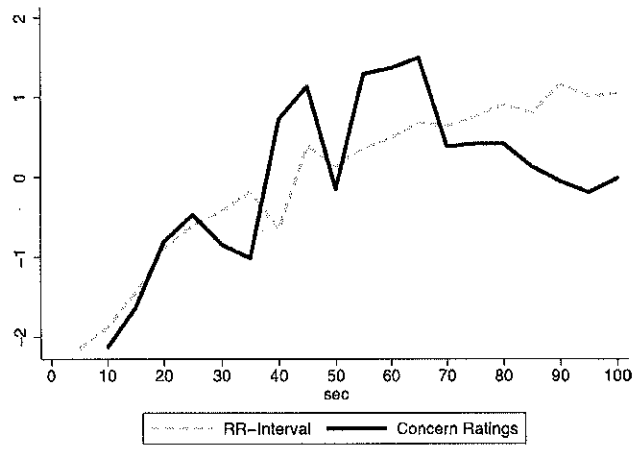

Fig. 2. Mean standardized RR-interval (with a 5-s lag) and concern scores across narrative.

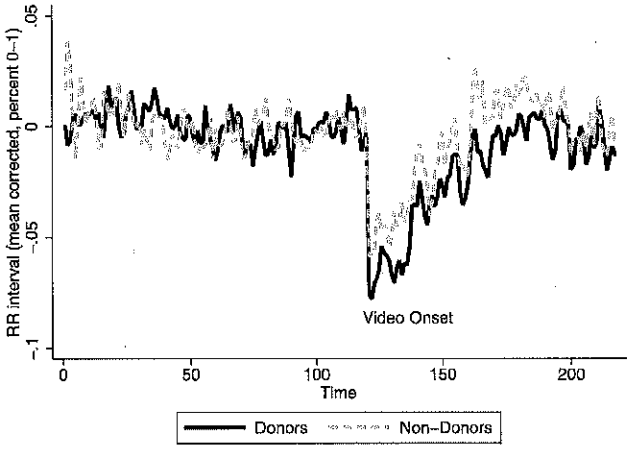

Fig. 3. Time series of the RR-interval for donors and non-donors across baseline and narrative video (baseline mean corrected by percent from −1 to +1).

4.5. 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 1-s epochs to reduce noise. We estimated both traditional (autoregressive integrated moving average, ARIMA) and more recent (generalized autoregressive conditional heteroskedasticity, GARCH) time series models until a best-fit model was identified (see Fig. 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 ($p = 0.02$ and $p < 0.001$, 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.

5. 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, Greenwald, Bradley, & Hamm, 1993 and Bradley & 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, Keltner, & Simon-Thomas, 2010). Empathic concern, however, is associated with heart rate deceleration (Eisenberg, Fabes et al., 1988; Eisenberg, Schaller 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 ($r = 0.32$) consistent with the literature (reported correlations range from $r = 0.44$ to $r = 0.75$; Boucsein, 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 et al. (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, $p = 0.15$). 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 et al., 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's contribution

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.

Declaration of conflicting interests

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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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.biopsycho.2015.01.008.

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