RESEARCH ARTICLE

Changes in Human Health Parameters Associated With a Touch Tank Experience at a Zoological Institution

John M. Sahrmann,[1] Amy Niedbalski,[1] Louise Bradshaw,[2] Rebecca Johnson,[3] and Sharon L. Deem[4]*

[1]*Department of Audience Research, Saint Louis Zoo, Saint Louis, Missouri*
[2]*Department of Education, Saint Louis Zoo, Saint Louis, Missouri*
[3]*Research Center for Human Animal Interaction, University of Missouri College of Veterinary Medicine, Columbia, Missouri*
[4]*Institute for Conservation Medicine, Saint Louis Zoo, Saint Louis, Missouri*

Association of Zoos and Aquariums (AZA) institutions provide a variety of benefits to visitors. However, one area that has received little study is the direct human health benefits from zoo and aquarium visits. With the increase in stress related non-infectious diseases in industrialized countries, understanding the extent of these benefits is important. We studied the effects on visitor stress of an experience at a touch tank exhibit featuring stingrays, sharks, and horseshoe crabs. Stress was measured by physiological and psychological parameters. Heart rate was recorded before, during, and after interacting with the animals, and mood was assessed before and after the experience using a psychological instrument. Multilevel models of heart rate show a quadratic trend, with heart rate elevated ($b = -3.01$, $t = 26.4$, $P < 0.001$) and less variable ($b = 3.60$, $t = 15.9$, $P < 0.001$) while touching the animals compared to before or after. Wilcoxon signed-rank tests on mood data suggest that most visitors felt happier ($V = 174.5$, $P < 0.001$), more energized ($V = 743.5$, $P < 0.001$), and less tense ($V = 5618$, $P < 0.001$) after the experience. This suggests that interacting with animals led to a physiological response during interactions reminiscent of a theme park experience along with a decrease in mental stress. The effects of confounding variables such as crowd size are also discussed. Further studies should be conducted to help deepen our understanding of the health benefits of experiences at AZA institutions. Zoo Biol. XX:XX–XX, 2015.

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INTRODUCTION

Urbanization worldwide is leading to an increase in the prevalence of stress related non-infectious diseases, including depression [Harpham, 1994; Chan et al., 2012]. Western medicine may not be able to adequately address these escalating 21st century health issues [Maller et al., 2006]. Associated with urbanization is the growing recognition that isolation from nature may be contributing to some of these health problems (e.g., nature deficit disorder), perhaps because of a discord created by living in spaces so unlike those which humans experienced during much of their evolutionary history [Wilson, 1984; Louv, 2008; Grinde and Patil, 2009]. Including ecological solutions with Western medicine may help relieve these discords and supplement the existing healthcare system [Maller et al., 2006]. The relationship between nature and health has been explored in a variety of contexts, including varying levels of contact with nature [Frumkin, 2001; Maller et al., 2006; Grinde and Patil, 2009; Joye and van den Berg, 2011], human-animal

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*Correspondence to: Sharon L. Deem, Institute for Conservation Medicine, Saint Louis Zoo, Saint Louis, Missouri.
E-mail: deem@stlzoo.org

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interactions [Hosey and Melfi, 2014], and keeping companion animals [O'Haire, 2010].

At the same time that the value of nature is being increasingly appreciated for human health, the public has been inundated with media coverage of emerging infectious diseases (EIDs). Many of the EIDs in the news today are classified as zoonotic (e.g., animal to human) [Jones et al., 2008]. Highlighting these EIDs without further explaining the reasons for the increase in zoonotic pathogens in humans (e.g., habitat modification, live animal trade, increased bushmeat use) may give the public the idea that nature is only a source of the problem [Friend, 2006; Louv, 2008; Deem, 2011].

The One Health initiative strives to expand transdisciplinary collaborations that improve health care for humans, animals, and the environment and to better communicate the interconnectedness of health for all three [Kahn et al., 2012; Gibbs, 2014; Deem, 2015]. Association of Zoos and Aquariums (AZA) institutions are increasingly taking a leadership role in the One Health initiative as staff conduct research at the interface of human, animal, and environmental health, with many of these studies focused on understanding diseases and mitigating their negative impacts for wildlife conservation [Deem and Dennis, 2012; Deem, 2015]. AZA institutions provide a variety of benefits to their visitors (e.g., entertainment, education), but debate continues about the extent of these benefits [Rabb and Saunders, 2005; Falk et al., 2007; Dick and Gusset, 2010; Marino et al., 2010; Conde et al., 2011; Cohen, 2013]. Showing that a visit to a zoo or aquarium has the potential for direct human health benefits is important in a One Health context and would further strengthen public perception of AZA zoos and aquariums. Furthermore, the opportunity to communicate the benefits of nature to visitors could encourage positive attitudes toward wildlife and increase public support for biodiversity conservation. However, little attention has been paid to this possible public health role. One study demonstrated slight improvements in blood pressure and self-perceived quality of life as a result of a zoo visit [Sakagami and Ohta, 2010]. Myers et al. [2004] studied emotional reactions to viewing animals in a zoo and concluded that the experience led to an "optimal form of arousal - alertness, engagement, and relaxation."

In this study, we explored the potential for AZA institutions to be part of a holistic approach to public health problems. Touch tanks are a common feature of many zoos and aquariums, and they provide a unique opportunity for guests to come in direct contact with animals. We studied the effects of an interactive experience at a touch tank exhibit featuring stingrays, sharks, and horseshoe crabs on visitor stress levels. Our own observations support the idea that these experiences elicit a strong emotional response [Niedbalski, unpublished data], and other research shows that they offer opportunities for families to engage in learning and exploration [Rowe and Kisiel, 2012]. We measured stress using heart rate variability (HRV) as a physiological parameter and mood as a psychological parameter. Our experimental hypothesis was that an opportunity to interact with stingrays at a touch tank exhibit would lead to a significant reduction in stress, represented by improved HRV and a more positive mood.

MATERIALS AND METHODS

Experimental Measures

Heart rate variability measures the length of time between successive heart beats. Variation in heart rate occurs through changes in the balance between the sympathetic and parasympathetic nervous systems, which act to decrease and increase the time between beats, respectively, [Allen et al., 2007; Thayer et al., 2012]. Heart rate variability has been used to study a variety of psychophysiological phenomena [see references in Allen et al., 2007]. Many of these studies involve long-term cardiac and mental health, but HRV can also be used as a measure of short-term changes in stress. Such a stress response is characterized by a shift in the balance between the sympathetic and parasympathetic nervous systems, with the sympathetic nervous system taking more control and causing reduced HRV [Berntson and Cacioppo, 2007].

For assessment of a psychological parameter, the University of Wales Institute of Science and Technology Mood Adjective Checklist (UMACL) provided a measure of three dimensions of mood: hedonic tone (HT; ranging from happy to sad), energetic arousal (EA; ranging from energized to tired), and tense arousal (TA; ranging from tense to relaxed). Matthews et al. [1990] describe the statistical properties of the UMACL scales and show that these mood dimensions are sensitive to a variety of stressors. Specifically, they found evidence for a general stress response corresponding with decreased HT and EA, along with increased TA [Matthews et al., 1990].

Experimental Procedure

Stingrays at Caribbean Cove is an immersion exhibit at the Saint Louis Zoo that gives visitors the opportunity to directly interact with animals. The 17,000 gallon touch pool includes cownose (*Rhinoptera bonasus*) and southern (*Dasyatis americana*) stingrays, white-spotted bamboo sharks (*Chiloscyllium plagiosum*), brownbanded bamboo sharks (*Chiloscyllium punctatum*), bonnethead sharks (*Sphyrna tiburo*), and horseshoe crabs (*Limulus polyphemus*). Visitors gather along the sides of the pool and touch the animals as they swim by. Because stingrays appear in the largest numbers, and because the sharks and horseshoe crabs do not approach the edge of the pool as often, most interactions are between visitors and stingrays. Education staff members are available throughout the exhibit, demonstrating proper touch technique and answering questions as needed. We have previously documented that visitors usually come in family groups, that the majority

of people (97% of adults and 83% of children) touch the animals, and that the typical visit lasts about 20 min [Niedbalski, unpublished data].

Participants were selected from those waiting in line at Stingrays at Caribbean Cove between May and July 2014. Each study session began as a researcher stationed at the exhibit entrance approached every third adult, explained the basic study protocol, and invited his or her participation. Only those aged 18 and older who did not have a pacemaker or implanted defibrillator were allowed to take part. If the individual agreed, he or she was taken to an area sectioned off alongside the touch pool. All persons in the participant's group were also offered the opportunity to enter the study area. A researcher then provided the participant with a consent form explaining the purpose of the research. After giving informed consent, each participant completed a qualification form and the pre-touch UMACL. The qualification form (Table 1) included questions related to whether the participant had visited Stingrays at Caribbean Cove before, if he or she had a special interest in stingrays, and the participant's age. It also provided space for the researcher to note the crowd level in the exhibit (e.g., light = less than 25 visitors; moderate = between 25 and 50 visitors; or heavy = more than 50 visitors).

The version of the UMACL (Table 2) used in this study included 24 adjectives, with eight corresponding to each of the three dimensions. Within each set of eight, four adjectives represented the positive end of each dimension and four the negative end. Participants recorded how each adjective described their current mood using a four-point scale (1 = Definitely not, 2 = Slightly not, 3 = Slightly, 4 = Definitely).

The Polar RS800CX training computer with chest band and attached Polar WearLink W.I.N.D. transmitter were used to measure HRV [Polar Electro, Kempele, Finland]. The device is non-invasive, and data are transmitted from the visitor-worn transmitter clipped to a chest band to a wristband receiver worn by study staff in proximity to the visitors.

TABLE 1. Items on the pre-touch questionnaire answered by participants in the Saint Louis Zoo Stingrays at Caribbean Cove during the human health study

Item	
1.	Is today your first visit to Stingrays at Caribbean Cove?[a]
2.	If no, how many times have you visited in the past?[a]
3.	Did you have any special interest in or knowledge of stingrays before today?[a]
4.	If yes, please explain.[a]
5.	Please provide your age.[a]
6.	Day of week.[b]
7.	Crowd level (light, moderate, or heavy).[b]

[a]Completed by participant.
[b]Completed by study staff.

TABLE 2. Items on the pre- and post-touch UMACL used during the human health study

Item	HT[a,d]	EA[b,d]	TA[c,d]
Happy	+		
Dissatisfied	−		
Energetic		+	
Relaxed			−
Alert		+	
Nervous			+
Passive		−	
Cheerful	+		
Tense			+
Jittery			+
Sluggish		−	
Sorry	−		
Composed			−
Depressed	−		
Restful			−
Vigorous		+	
Anxious			+
Satisfied	+		
Unenterprising		−	
Sad	−		
Calm			−
Active		+	
Contented	+		
Tired		−	

The same version of the UMACL instument was used in pre- and post-touch. Participants marked how each adjective reflected his or her current mood using a four-point scale (1 = Definitely not, 2 = Slightly not, 3 = Slightly, 4 = Definitely).
[a]HT- Hedonic tone.
[b]EA- Energetic arousal.
[c]TA - Tense arousal.
[d]"+" indicates that the adjective contributed to the positive end of the mood dimension; "−" indicates that the adjective contributed to the negative end of the mood dimension.

Data Collection

After completing the forms, each participant was provided a study T-shirt to ensure a consistent level of contact between the HRV monitor and the heart while interacting with the animals. In seven cases, the correct size of the study T-shirt was not available, and the participant was allowed to wear his or her own shirt. A researcher then fitted the participant with the Polar chest band, synced the transmitter to the receiver, and monitored the signal. Participants were asked to sit for 2 min to collect baseline pre-touch heart rate data, after which they were invited to interact with the stingrays. Prior to the touch period, participants were asked to refrain from feeding the stingrays during the study, as this only occurs at certain times throughout the day and, thus, is not necessarily part of a typical visit to the exhibit. A researcher demonstrated proper touch technique before allowing the participant to interact with the animals; however, the experience was not directed in any way. Participants may have differed in their level of contact with the animals, but our intention was only to give

all participants the same opportunity to interact. After 10 min of touch time, the participants rested in the study area for an additional 2 min for collection of post-touch heart rate data. Participants then completed a post-touch UMACL and a follow-up questionnaire about their visit to the Zoo. The questionnaire (Table 3) included questions about the total size of the group with whom the participant was visiting the Zoo, the number of children under age 14 in the group, and the gender of the participant. Participants were also asked to describe how touching the stingrays made them feel. Upon completion of the forms, participants kept their study T-shirt and were given a $15 gift certificate for use in the Zoo. Each step in the data collection process was timed by a researcher. These data were analyzed to verify that all participants had similar opportunities to interact with the animals and that there were no periods of rest other than those we allotted at the beginning and end of the touch period.

This study was approved by the University of Missouri Health Sciences Institutional Review Board (IRB) (#1208610) and all researchers on the study team completed the Collaborative Institutional Training Initiative (CITI) IRB training. The study was deemed expedited with written consent. All participants completed the informed consent process before initiating any study-related activities.

Statistical Analysis

HRV data processing

HRV data were measured as the time between successive R waves within heart beats (RR intervals) by the Polar RS800CX training computer. The findings were first inspected for extreme or missing readings indicative of apparent equipment failure. Participants judged to have unacceptably high amounts of extreme or missing data were excluded from further analysis. For the remaining participants, short regions of apparent equipment failure were deleted.

Data for each participant were divided into five approximately equal time periods for analysis representing: (1) the 2 min pre-touch rest period; (2) the first 2 min of the 10 min touch period; (3) the middle 2 min of the touch period; (4) the last 2 min of the touch period; and (5) the 2 min post-touch rest period. Measurement periods of 2 min in duration are standard in studies of short-term HRV [Task Force, 1996]. A small number of participants chose not to touch for the entire 10 min; if their total touch time was not greater than 6 min, only data from the first and last 2 min of touch were used.

Further processing was accomplished using ARTiiFACT version 2.09 [Kaufmann et al., 2011]. First, additional errors were found using ARTiiFACT's automated detection module. This makes use of the distribution of successive RR interval differences to create unique threshold criteria for distinguishing real and spurious measurements for each individual. These artifacts were detected and corrected using cubic spline interpolation. Summary statistics were generated for each participant within each time period using ARTiiFACT's default settings.

UMACL mood dimension data processing

Subscores for each mood dimension were obtained by summing the responses to each adjective given by each participant in the pre- and post-touch UMACL. Responses for adjectives negatively related to each dimension were reversed. In the few cases where participants skipped an adjective on one of the scales, missing scores were imputed using the participant's average response of the other adjectives on the positive or negative end within that dimension.

Statistical analysis

The Wilcoxon signed-rank test was used to test for differences among HRV and UMACL variables between time points. Deviations from normality in some outcome variables necessitated the use of a nonparametric test. More detailed models were used to investigate the effects of covariates on these outcomes. Because measurements were nested within individuals, we used multilevel models to account for the structure of the data. We constructed separate models for each of the three dimensions measured by the UMACL, as well as the two statistics derived from the HRV data: mean heart rate (HR) and the root mean square of successive RR interval differences (RMSSD), also called cycle variability or RR variability. Mean HR provides an overall description of the heart's reaction to the experience. RMSSD is a time domain statistic that provides a measure of the influence of the parasympathetic nervous system on the heart [Allen et al., 2007; Task Force, 1996]. Strong influence from the parasympathetic nervous system is associated with high RMSSD [Schwerdtfeger and Friedrich-Mai, 2009].

We chose variables for the models based on their expected relevance to the outcome measures. All models included the following predictors: experience (0 = first visit to the exhibit, 1 = repeat visit), interest (0 = no special interest in stingrays, 1 = special interest), age, crowd level (0 = light crowd, 1 = moderate crowd, 2 = heavy crowd), total party size, number of children in party, and gender (0 = male, 1 = female). For models of heart rate and RMSSD, period was

TABLE 3. Items on the post-touch questionnaire answered by participants in the Saint Louis Zoo Stingrays at Caribbean Cove during the human health study

Item	
1.	How did you feel after this experience touching the stingrays?
2.	Including yourself, how many people are in your party today?
3.	How many children under the age of 14 are in your party today?
4.	What is your gender?

coded 0 = pre-touch rest, 1 = start of touch, 2 = middle of touch, 3 = end of touch, 4 = post-touch rest; these models also included a parameter for the period code squared to test for a quadratic effect of time. For models of each mood dimension, period was coded 0 = pre-touch, 1 = post-touch. Data derived from the open-ended question on the follow-up questionnaire were examined for common themes, and codes were assigned for analysis. These data enabled us to describe the participants' perception of interacting with the stingrays, and models of the mood dimensions included relevant codes. For hedonic tone, this included generally positive responses (0 = no mention, 1 = weak positive response, 2 = strong positive response) and responses mentioning feeling proud (0 = no mention, 1 = proud). For energetic arousal, this included responses mentioning feeling energized (0 = no mention, 1 = energized) or relaxed (0 = no mention, 1 = relaxed). For tense arousal, this included responses mentioning no longer feeling scared (0 = no mention, 1 = not scared), feeling relaxed (0 = no mention, 1 = relaxed), or still feeling anxious (0 = no mention, 1 = anxious). During the study, we also noted whether stingray feeding by other visitors was going on at the time and if the heart rate monitor equipment temporarily failed during the study and needed to be readjusted.

Statistical analysis was conducted using R 3.1.1 [R Core Team, 2014], and multilevel models were built using the package "nlme" [Pinheiro et al., 2014].

RESULTS

Sample

In total, 165 participants took part in the study. Twenty-six individuals were excluded due to missing data or poor quality HRV data, leaving data from 139 participants for the final analysis. The sample was 72% female, similar to typical attendance figures [Niedbalski, unpublished data], and the average age was slightly over 35 years (range: 18–68). There was a nearly equal mix of first time and repeat visitors to Stingrays at Caribbean Cove, with 55% of participants having never visited the exhibit before. Average party size was 4.2 individuals, including 1.8 children under the age of 14.

HRV

Trends in average HR and RMSSD over the course of the experience are shown in Figure 1. Average HR increased sharply from the pre-touch rest to the first 2 min of the touch period. It was more stable over the course of the touch period, increasing slightly from an average of 93 beats per minute in the first 2 min to a high of 96 beats per minute in the last 2 min. In the post-touch rest period, heart rate fell but did not return to the pre-touch baseline. Conversely, RMSSD was highest during the pre-touch period. It fell during touch, reaching its lowest point during the middle 2 min, after which it started to increase but did not return to the pre-touch baseline.

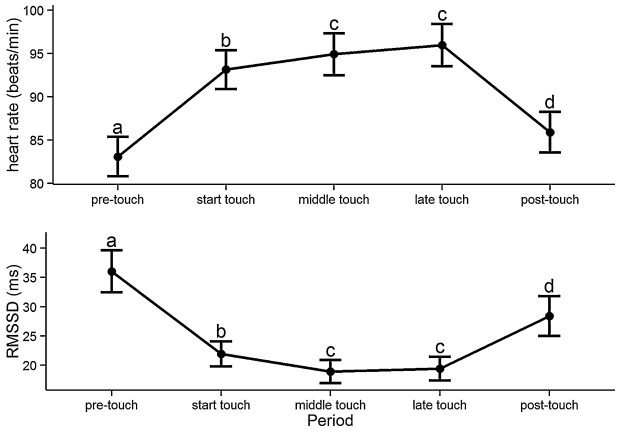

Fig. 1. Changes in heart rate variability (HRV) statistics over the course of an experience interacting with stingrays at a touch tank exhibit. Average values for each statistic at each time point are plotted. Error bars show 95% confidence intervals. Letters indicate significantly different groups based on the Wilcoxon signed-rank test.

To further investigate the changes in HRV and how particular characteristics of each participant impacted his or her experience, we constructed separate multilevel models for HR and RMSSD (Table 4). Modeling the effect of time period revealed a significant quadratic trend in the data for both variables (HR: $b = -3.0$, $t = 26.4$, $P < 0.001$; RMSSD: $b = 3.6$, $t = 15.9$, $P < 0.001$) (Fig. 1). In the case of HR, two additional factors were found to be significant. Heart rate increased with crowd level ($b = 3.7$, $t = 2.7$, $P < 0.01$) (Fig. 3a), whereas the number of children in the group had the opposite effect ($b = -2.6$, $t = -2.1$, $P < 0.05$).

RMSSD was significantly affected by age ($b = -0.37$, $t = -3.8$, $P < 0.001$), with younger people having more variable heart rates. Higher RMSSD was also associated with more children in the visitor's group ($b = 3.02$, $t = 2.4$, $P < 0.05$). Neither measure of HRV was associated with gender, overall group size, self-reported interest in stingrays, or whether the participant was a first time or repeat visitor to Caribbean Cove. Stingray feeding by other visitors and readjusting the heart rate monitor also were not associated with changes in HRV.

UMACL Mood Dimensions

Pre-touch hedonic tone scores indicate that participants entered the study quite happy (mean pre-touch score = 30.2 out of a maximum 32); nonetheless, testing showed a significant increase after the experience (Wilcoxon signed-rank test: $V = 174.5$, $P < 0.001$) (Fig. 2). Similarly, comparing pre- and post-touch energetic arousal and tense arousal scores indicate that participants felt more energized ($V = 743.5$, $P < 0.001$) and less tense ($V = 5618$, $P < 0.001$) after the interaction (Fig. 2).

TABLE 4. Results of multilevel models relating heart rate variability (HRV) variables to predictors of participants in the human health study

	Heart rate (beats/min)		
Parameter	Estimate (SE)	t	P
Intercept	84.31 (4.78)	17.730	<0.001
Period	12.90 (0.48)	27.134	<0.001
Period^2	−3.01 (0.11)	−26.420	<0.001
Age	−0.15 (0.10)	−1.567	0.120
Gender	1.29 (2.42)	0.535	0.593
Crowd	3.73 (1.39)	2.688	0.008
Party size	0.74 (0.78)	0.959	0.339
No. children	−2.62 (1.25)	−2.099	0.038
Experience	−0.58 (2.17)	−0.268	0.789
Interest	2.01 (2.58)	0.781	0.436
	RMSSD (ms)		
Intercept	49.73 (4.82)	10.322	<0.001
Period	−16.18 (0.94)	−17.150	<0.001
Period^2	3.60 (0.23)	15.912	<0.001
Age	−0.37 (0.10)	−3.777	<0.001
Gender	1.27 (2.43)	0.521	0.603
Crowd	−2.00 (1.40)	−1.429	0.155
Party size	−1.28 (0.78)	−1.644	0.103
No. children	3.02 (1.25)	2.406	0.018
Experience	1.91 (2.18)	0.874	0.384
Interested	−1.60 (2.59)	−0.616	0.539

We used multilevel models to explore the effects of additional variables on changes in mood scores (Table 5). For HT, there was a significant increase in scores between the pre- and post-touch periods ($b = 2.2$, $t = 6.4$, $P < 0.001$). We discovered significant effects of gender ($b = 1.3$, $t = 3.8$, $P < 0.001$) and crowd level ($b = 0.6$, $t = 3.2$, $P < 0.01$) (Fig. 3b), as well as the interaction of these two variables with time period (period x gender: $b = -0.7$, $t = -2.3$, $P < 0.05$; period x crowd: $b = -0.5$, $t = -2.7$, $P < 0.01$).

Energetic arousal also showed a significant increase between time periods ($b = 3.6$, $t = 8.9$, $P < 0.001$). In addition, crowd level and the interaction of crowd and period were significant (crowd: $b = 1.2$, $t = 3.3$, $P = 0.001$; period x crowd: $b = -1.3$, $t = -4.5$, $P < 0.001$) (Fig. 3b). A significant difference in EA was also found among participants who mentioned feeling relaxed in their post-touch questionnaire ($b = -1.3$, $t = -2.1$, $P < 0.05$).

Tense arousal decreased after touching the stingrays ($b = -2.4$, $t = -6.6$, $P < 0.001$). As with the other mood dimensions, crowd size had a significant impact on TA as well ($b = -0.9$, $t = -2.4$, $P < 0.05$) (Fig. 3b). Tense arousal declined with increasing crowd level, and participants in heavy crowd conditions had lower TA both pre- and post-touch. There was a significant association between TA and having a strong interest in stingrays as recorded in the pre-touch qualification ($b = -1.6$, $t = -2.3$, $P < 0.05$), with interested participants having lower TA throughout the experience. There was also a substantial interaction between period and if the participant mentioned still feeling anxious on the post-touch questionnaire ($b = 7.9$, $t = 5.8$, $P < 0.001$) (Fig. 4).

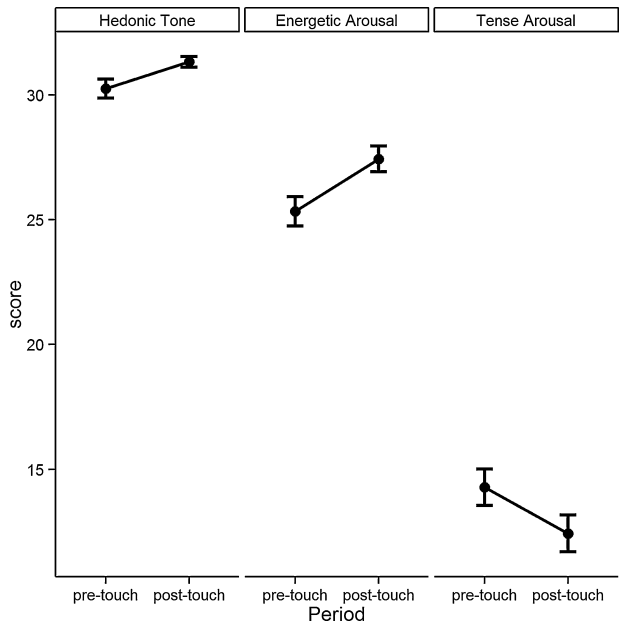

Fig. 2. Changes in UMACL mood dimension scores after an experience interacting with stingrays at a touch tank exhibit. Points are average scores. Error bars represent 95% confidence intervals. Pre- and post-touch scores are significantly different for all three mood dimensions (Wilcoxon signed-rank test).

DISCUSSION

The goal of this study was to determine whether interacting with stingrays, sharks, and horseshoe crabs at a touch tank exhibit would have a measurable impact on stress. We hypothesized that visitors would have higher HRV and improved mood as a result of the touch experience. The results partially support this hypothesis. During touch, we observed a significant reduction in HRV, as demonstrated by increased mean HR and decreased RMSSD. Although HRV improved during the post-touch rest, levels were still slightly but significantly different from their pre-touch baselines. In addition, mood scores before and after touch showed that visitors tended to feel happier, more energized, and less tense after the interaction. The findings on mood were, thus, supportive of our hypothesis whereas the physiological outcomes were not. Taken together, the physiological and psychological parameters reveal a more complex picture of the participants' reactions to touching the stingrays than either measure by itself. On the one hand, the HRV results are consistent with a short-term decrease in parasympathetic nervous system activity [Berntson and Cacioppo, 2007]. However, such a short-term stress response is not necessarily detrimental; it is when stress persists over a long period of time that health suffers [Hjortskov et al., 2004]. Pringle et al. [1989] and Kuschyk et al. [2007] observed substantial increases in heart rate among people during roller coaster

TABLE 5. Results of multilevel models relating UMACL mood dimension scores to predictors of participants in the human health study

	Hedonic tone		
Parameter	Estimate (SE)	*t*	*P*
Intercept	28.22 (0.68)	41.45	<0.001
Period	2.16 (0.34)	6.43	<0.001
Age	0.01 (0.01)	0.80	0.424
Gender	1.32 (0.34)	3.84	<0.001
Crowd	0.64 (0.20)	3.21	<0.010
Party size	0.10 (0.10)	1.05	0.296
No. children	−0.23 (0.16)	−1.49	0.139
Experience	0.81 (0.50)	1.63	0.105
Interest	−0.15 (0.33)	−0.46	0.644
Positive	−0.05 (0.18)	−0.28	0.781
Proud	−0.26 (0.51)	−0.52	0.606
Period × Crowd	−0.48 (0.18)	−2.69	<0.010
Period × Gender	−0.72 (0.31)	−2.34	0.021
	Energetic arousal		
Intercept	23.43 (1.17)	20.01	<0.001
Period	3.64 (0.41)	8.90	<0.001
Age	0.01 (0.02)	0.58	0.563
Gender	0.91 (0.57)	1.60	0.112
Crowd	1.20 (0.36)	3.32	0.001
Party size	0.10 (0.18)	0.57	0.569
No. children	−0.41 (0.29)	−1.39	0.166
Experience	−0.05 (0.51)	−0.10	0.922
Interest	−0.57 (0.60)	−0.96	0.340
Energized	0.47 (0.94)	0.51	0.614
Relaxed	−1.30 (0.63)	−2.07	0.041
Period × Crowd	−1.30 (0.29)	−4.49	<0.001
	Tense arousal		
Intercept	16.37 (1.34)	12.25	<0.001
Period	−2.43 (0.36)	−6.65	<0.001
Age	−0.04 (0.03)	−1.48	0.142
Gender	0.22 (0.66)	0.34	0.735
Crowd	−0.91 (0.38)	−2.40	0.018
Party size	0.05 (0.21)	0.24	0.808
No. children	0.07 (0.34)	0.20	0.843
Experience	0.61 (0.59)	1.02	0.309
Interest	−1.64 (0.71)	−2.31	0.022
Relaxed	−0.36 (0.73)	−0.50	0.619
Not scared	1.01 (1.20)	0.84	0.401
Anxious	−0.01 (1.34)	−0.01	0.994
Period × Anxious	7.93 (1.36)	5.82	<0.001

rides compared to before or after, but concluded that these changes posed no risk to long-term health. The resemblance of the HRV data presented here with that of the roller coaster riders suggests an underlying similarity between the two experiences. Since the vast majority of participants in this study wouldn't be expected to have regular encounters with the types of animals found in the touch tank, it seems reasonable that they would react as if they were in an exciting, unfamiliar, and potentially unpredictable experience, much like riding a roller coaster.

Looking at the UMACL mood data supports the notion that interacting with the animals was ultimately a positive experience. The analysis showed changes in participants' mood that are consistent with a reduction in stress [Matthews et al., 1990]. Our observations during the study and the responses of the participants when they were asked how touching the stingrays made them feel were further supportive of stress reduction. Eighty percent of individuals gave a positive response to this question on the post-touch questionnaire, whereas only 7% reported feeling nervous, anxious, or unsure. Thus, interacting with stingrays at a touch tank exhibit led to a short-term physiological stress response along with a more positive overall mood.

Models of both the HRV and mood data suggest that other variables were important as well. Mean heart rate was positively associated with crowd level, meaning that participants in heavier crowds tended to have slightly higher heart rates throughout the study than those in less crowded conditions. This is not surprising, as crowding is a known stressor [Baum et al., 1981], although it is interesting to note that this effect did not reach significance for RMSSD. Also expected was the significant decrease in RMSSD with increasing age [Zhang, 2007]. A more intriguing finding was that more children in the participant's group was associated with reduced mean heart rate and increased RMSSD. Research on zoo and aquarium audiences shows that adults often serve as facilitators for other party members [Falk et al., 2007], and because most children had very positive reactions to touching the animals, there could have been some stress relief from seeing the children enjoy the experience.

The three dimensions of mood were also significantly impacted by crowd level. For HT and EA, there was a significant interaction between time period and crowd level, with participants in heavier crowd conditions feeling slightly happier and more energized at the start of touch compared to those in less crowded conditions. However, the participants in smaller crowds showed greater gains in HT and EA post-touch, with participants in all crowd conditions showing very similar average HT and EA scores after the touch experience. It should be noted that the interaction effect for HT may be a ceiling effect. The maximum score on the HT dimension was 32, so those with very high HT scores at the start (i.e., those in heavy crowd conditions) could not show as much of an increase as the participants in light crowds. In the case of TA, participants in heavier crowds were less tense both before and after touching than people in lighter crowds.

A few variables showed significant effects on a single mood dimension. Gender showed a significant interaction effect with time period, as women were happier pre-touch than men, but men showed greater gains in HT than women. Much like crowding, however, this interaction could be a ceiling effect because the pre-touch HT scores of women were very close to the maximum value possible. Those who expressed an interest in stingrays on their pre-touch qualification form had lower TA scores both pre- and post-touch, perhaps suggesting a lower level of anxiety

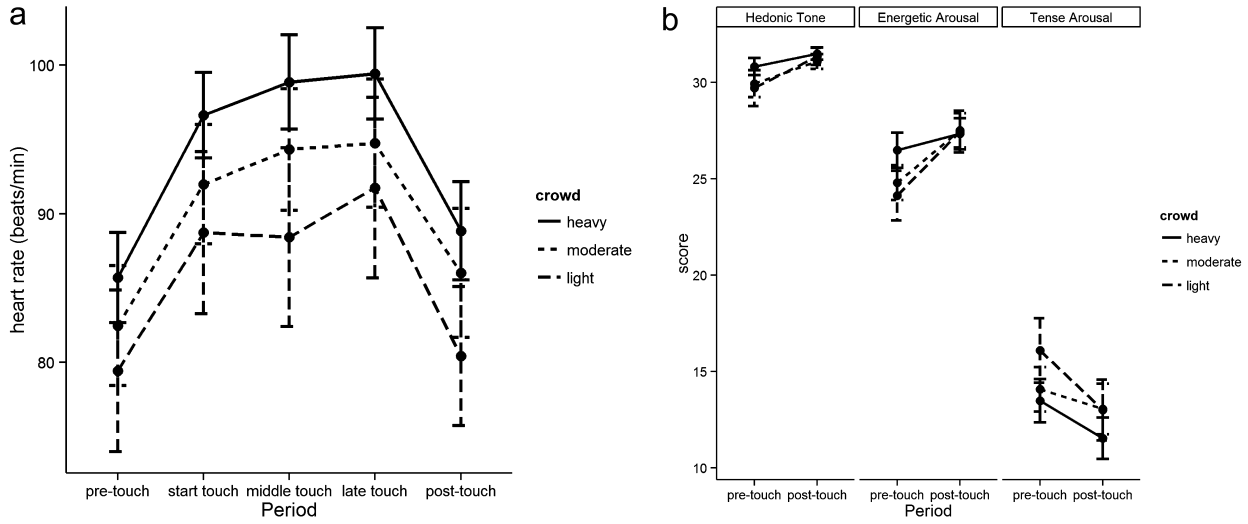

Fig. 3. (**a**) Changes in average heart rate by crowd level at a touch tank exhibit. Error bars show 95% confidence intervals. Multilevel models show that heart rate was significantly higher in larger crowds. (**b**) Changes in UMACL mood dimension scores by crowd level at a touch tank exhibit. Error bars show 95% confidence intervals. Multilevel models indicate significant main effects of crowd on hedonic tone (HT), energetic arousal (EA), and tense arousal (TA) and significant interactions with period for HT and EA.

around touching stingrays among these participants. Variables derived from the qualitative question on the post-touch questionnaire tended to reinforce the data from the UMACL. Of particular interest is the group of participants that mentioned feeling anxious, unsure, or nervous after touching. The pre-touch TA scores of these participants were very similar to those who did not mention these feelings on the questionnaire, but while most participants showed a decrease in TA scores after the experience, those who felt anxious afterward had much higher TA scores. Also interesting is that this effect did not appear in the other mood dimensions or in either measure of HRV.

Our findings support the notion that zoos and aquariums have a role to play in promoting human health through their work within the One Health framework. As places that serve the public by facilitating contact with biodiversity, zoos, and aquariums are in a unique position to develop this underexplored area of research. Additional studies should be conducted to understand how health is affected by different types of experiences in these institutions. Having this understanding will put the zoo and aquarium community in a better position to communicate the benefits of biodiversity to their visitors. Making a case for the importance of biodiversity will be critical for those hoping to protect it into the future.

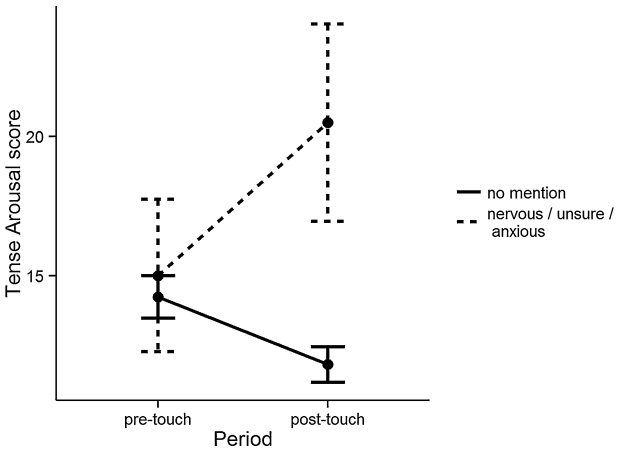

Fig. 4. Interaction between time period and score on the tense arousal (TA) dimension. Post-touch TA scores were significantly higher in participants who reported feeling nervous, unsure, or anxious afterward.

LIMITATIONS

Some limitations are worth exploring. Attempts to combine HRV and mood into a single analysis revealed no significant relationships between the two sets of variables (data not shown). In part, this task was complicated by the experimental design because measurements of both HRV and mood were not taken at each time point. However, it is not clear that changing the study design would have altered the findings. Matthews et al. [1990] found no significant correlation between a measure of HRV and hedonic tone or energetic arousal but a negative correlation between HRV and tense arousal. Aside from Matthews et al. [1990], there does not appear to be a theoretical basis relating changes in physiological variables like HRV with indicators of mood over short time periods.

Complications also arose with the HRV data. Changes in participant position, most often during the touch portion, led to occasional signal failure between the heart rate monitor and training computer, resulting in short periods of unusable data. This makes interpretation of the HRV data somewhat tenuous [Lippman et al., 1994; Berntson and Stowell, 1998]. However, our analysis was restricted to measures that are less

sensitive to problematic data compared with more complex approaches [Berntson et al., 1997]. An alternative measure of physiological stress (e.g., salivary cortisol) may be advisable in future studies.

The potential health benefits shown by this study should not be overstated. Just as the short-term increase in physical stress during the touch portion does not signal long-term problems, we cannot be certain that the improved moods and reduced mental stress with which most participants left the experience necessarily translate into improved overall health. It should also be noted that participants had chosen to visit the zoo and the touch tank exhibit before entering the study. Thus, strictly speaking, it may not be possible to infer that the same effects would apply to all people. However, nearly half of the sample had not visited the exhibit before, yet this was not a significant factor in models of any of the outcome variables. If novelty does not appear to affect the experience, perhaps zoo goers are generally predisposed to have more positive experiences with animals. Further studies should explore these and other issues related to the range of potential connections between health parameters and zoo or aquarium experiences, especially those including direct contact between visitors and animals. The place of AZA institutions within this larger context may best be summarized by Ackerman [2012], "though not a natural world by any means, more like a collection of living dioramas, a zoo exists in its own time zone, somewhere between the seasonal sense of animals and our madly ticking watch time. The relatively quiet, park like setting offers an oasis in the crowded, noisy, stressful, morally ambiguous world, where humans tend to congregate."

CONCLUSIONS

An experience at an exhibit allowing visitors to interact with stingrays, sharks, and horseshoe crabs was associated with a short-term increase in physiologic stress while touching the animals but a decrease in mental stress after leaving the exhibit. This supports the potential for experiences at AZA zoos and aquariums to be part of an overall effort to improve public well-being by reconnecting people with nature.

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