People and Animals: The International Journal of Research and Practice

Volume 2 | Issue 1 Article 2

2019

Effects of Short-Term Human-Horse Interactions on Human Heart Rate Variability: A Multiple Single Case Study

Saan Ecker
University of New England, Australia, saane@westnet.com.au

Amy Lykins
University of New England, Australia, alykins@une.edu.au

People and Animals: The International Journal of Research and Practice

Volume 2 | Issue 1 | ISSN: 2575-9078 (2019)

Effects of Short-Term Human-Horse Interactions on Human Heart Rate Variability: A Multiple Single Case Study

Saan Ecker[1] and Amy Lykins[1]

Keywords: equine-assisted psychotherapy, heart rate variability, human-animal interactions, single case design, stress-moderating, stress arousal

Abstract: Influences from human-horse interactions form the basis of the emerging field of equine-assisted psychotherapy (EAP). However, the psychophysiological effects of horses on humans in the EAP context have been underinvestigated. This multiple single case design study examined the effects of short-term human-horse interactions on human heart rate variability (HRV). Nine adults with limited prior experience with horses participated in time-limited in vivo exposures to five different free-roaming horses in a yard. Results were mixed with HRV improving from a preexposure baseline in 40% and deteriorating in 23% of the 43 ten-minute horse-human interactions. In the remaining horse-human interactions, HRV was unchanged from baseline. Aggregated results showed an overall improvement in HRV across experimental phases despite considerable intrasubject and intersubject variability. These preliminary results suggest that interaction with the horses, as well as having a neutral effect, may have had either a stress-moderating effect or a stress-arousal effect on participants. This study validates findings from other studies that show a stress-moderating effect of animals in the therapeutic context and also supports findings showing human stress arousal when near horses. Findings indicate that stress arousal is an important variable that requires consideration in the EAP context. This study provides an early insight into the influences of human-horse interactions on the human autonomic nervous system, providing a foundation for further studies.

(1) University of New England, Australia

IAHAIO International Association of Human-Animal Interaction Organizations

Introduction

Equine-assisted psychotherapy (EAP) is an experiential application wherein the therapist facilitates an in vivo experience involving horses. EAP programs generally involve the achievement of specified tasks, usually activities that are ground-based (i.e., nonriding), with horses as an adjunct to therapy processes (Donaghy, 2006; Hallberg, 2008; Trotter, 2012). While increasing in popularity (Dorotik-Nana, 2011), EAP is at risk of being labeled a pseudopsychological intervention operating on a limited understanding of its own underlying principles.

The human-horse relationship, the basis of EAP, is poorly understood (Hausberger, Roche, Henry, & Visser, 2008; Payne, DeAraugo, Bennett, & McGreevy, 2016). EAP effectiveness studies typically assess changes based on participation in an 8–10 session EAP program. Self-report data indicate that EAP programs have improved measures associated with depression (Ewing, MacDonald, Taylor, & Bowers, 2007), coping with domestic violence (Froeschle, 2009) and sexual abuse (Porter-Wenzlaff, 2007), autism (Memishevikj & Hodzhikj, 2010), schizophrenia (Corring, Lundberg, & Rudnick, 2013), grief (Symington, 2012), and childhood emotional disorders (Trotter, Chandler, Goodwin-Bond, & Casey, 2008).

Physiological Effects of Human-Animal Interactions

Human-animal interactions (HAI) studies have attempted to quantify the effect of animals on humans (Serpell, 2011). Interaction with animals has been associated with improving short-term health benefits lasting for minutes or seconds (Wells, 2009). Improvement in human physiological parameters associated with reducing stress including cortisol, heart rate, blood pressure, and improvements in cardiovascular functioning have been reported from interactions with dogs (Allen, Blascovich, & Mendes, 2002; Beetz, Uvnäs-Moberg, Julius, & Kotrschal, 2012; Cole, Gawlinski, Steers, & Kotlerman, 2007; El-Alayli, Lystad, Webb, Hollingsworth, & Ciolli, 2006; Lorenz, 1954; Polheber & Matchock, 2014; Somervill, Kruglikova, Robertson, Hanson, & MacLin, 2008). Spending time with a friendly dog (E. Friedmann, 2000; Odendaal, 2000) and having a dog present during stressful tasks (Barker, Knisely, McCain, Schubert, & Pandurangi, 2010; Polheber & Matchock, 2014) were associated with reduced stress indicators for human participants.

Validity Issues in HAI Research

HAI research has suffered from a range of research design issues. A meta-analysis by Nimer and Lundahl (2007) found positive effects associated with animal-assisted therapy across categories including stress-related physiological outcomes, emotional well-being, and behavioral problems. However, as the majority of these studies did not include no-treatment control conditions, it is difficult to discern the contribution of the HAIs to reported effects (Crossman, 2017).

Another meta-analysis of HAI research by Marino (2012) also identified positive effects of HAIs; however, this study highlights construct validity issues associated with research designs that fail to separate the effect of the animal from other effects. In addition to the presence of horses, there are many aspects to an EAP program that may provide benefit including therapeutic alliance with the therapist/facilitator, nature connectedness, group affiliations, and exercise. Simply visiting a farm has been shown to improve well-being (Berget, Ekeberg, & Braastad, 2011). Thus far, EAP effectiveness studies generally have not controlled variables to assess the degree to which effects are attributable to the horse (Marino, 2012).

Isolating and understanding the specific contribution of the horse to therapeutic outcomes is a critical issue for the validity of EAP (Marino, 2012). Questions regarding the stress-moderating effects of animals on humans include how much the therapy animal (versus the therapist/handler) contributes to the stress response and to what degree previous past history, culture/beliefs, and trait anxiety might influence results (Barker et al., 2010).

In a more recent meta-analysis of HAI research, Crossman (2017) found that HAI effects were not adequately separated from other aspects that may influence these outcomes. Another methodological issue is generalization across animals based on results using one or two animals in the design, with recommendations that more than two animals should be used in research on HAI effects (Crossman, 2017).

HAI research findings have also been criticized for problems with demand characteristics associated with self-report (Serpell, 2011). The use of involuntary physiological indicators in combination with self-report, behavioral, and qualitative data has been recommended in evaluating human responses to animal contact to provide more objective, empirical evidence (Baragli, Vitale, Banti, & Sighieri, 2014; Melson, 2011; Serpell, 2011). Measuring physiological parameters in both humans and animals can also provide insight into the underlying mechanisms of HAIs (Serpell, 2011).

Heart Rate Variability

As one of the less invasive physiological measures, heart rate variability (HRV) presents a useful measure in assessing the impact of animal contact on humans (Baragli et al., 2014; Serpell, 2011). HRV measures the variation of the interbeat interval between heartbeats and provides information on autonomic nervous system (ANS) regulation, specifically the balance between the activating sympathetic nervous system (SNS) activity and the deactivating parasympathetic nervous system (PNS) activity (Berntson et al., 1997). HRV measures can be used in examining the interaction between the sympathetic and parasympathetic autonomic nervous system, which acts to respectively speed up and slow down heart rate (Karmakar, Khandoker, Voss, & Palaniswami, 2011). Deteriorating HRV indicates increased sympathetic tone associated with "fight and flight" responses as well as cardiac diseases and hypertension (Karmakar et al., 2011). Improved HRV indicates an increase of parasympathetic activity associated with the "rest and digest" response, including relaxation and inhibition of high energy functions (Berntson et al., 1997; Kleiger, Miller, Bigger, & Moss, 1987).

HRV is correlated with cardiovascular health and mortality indicators (Berntson et al., 1997) and has been used as an indicator of emotional state (Berntson et al., 1997; Bertsch, Hagemann, Naumann, Schächinger, & Schulz, 2012; Grossmann, Sahdra, & Ciarrochi, 2016; Sandercock, Bromley, & Brodie, 2005), mindfulness (Burg, Wolf, & Michalak, 2012; Henry & Crowley, 2015; Prazak et al., 2012), and emotional regulation (Segerstrom & Nes, 2007). HRV has the potential to be a noninvasive physiological measurement of stress levels (Taelman, Vandeput, Spaepen, & Van Huffel, 2009) and has been used for measuring stress responses as a result of therapeutic interventions (Bertsch et al., 2012). A meta-analysis of studies using HRV as a measure supports that HRV is impacted by stress and is appropriate for the objective assessment of psychological health and stress (Kim, Cheon, Bai, Lee, & Koo, 2018).

With regard to interactions with animals, HRV has been used to provide evidence of benefits from human-dog interactions, including improved autonomic regulation among pet owners compared to non–pet owners (E. Friedmann, Thomas, Stein, & Kleiger, 2003) and from walking with a dog vs. walking without a dog (Motooka, Koike, Yokoyama, & Kennedy, 2006). As a measure that provides finer detail on physiological responses than heart rate (HR) and is equally noninvasive, HRV is considered an appropriate measure for investigating the effects of horse-human contact (Baldwin, Rector, & Alden, 2018; Beetz, Kotrschal, Uvnäs-Moberg, & Julius, 2012; Sankey, Richard-Yrisb, Leroya, Henrya, & Hausberger, 2010).

Associations between contact with horses and human HR and HRV have been reported in equitation-related studies (Hausberger et al., 2008; Merkies et al., 2014; Sankey et al., 2010; von Lewinskia et al., 2013), although this relationship is complex. In the EAP context, HRV showed greater improvement in teenagers during an EAP session than during a play therapy session (Beetz, Kotrschal, et al., 2012), as well as in children with neurological disorders after sitting on a horse (Cabiddu et al., 2016). Baldwin et al. (2018) explored the effects on HRV of older adults of a therapist-led gratitude intervention with a horse. HRV improved significantly during the horse-human interaction, and the authors hypothesize that this improvement is related to increased awareness of bodily sensations and emotions during EAP (Baldwin et al., 2018).

The Current Study

The objective of our study was to examine the influence of short-term exposure to a horse, without a therapist/facilitator or structured exercises, on human ANS regulation. This study sought to isolate and measure the direct physiological effect associated with simply the presence of horses rather than assess the effectiveness of an EAP intervention. Our design aimed to address the failure in other research to isolate the effects of the animals from the effects of the handlers (Crossman, 2017).

A quasi-experimental, multiple single case design (SCD) with intrasubject replication was chosen for this study. As one of the first studies seeking empirical evidence of the specific influence of the horse in the EAP context, a single case approach was indicated and appropriate, as SCDs are recommended for exploring poorly understood phenomena (Hensen & Barlow, 1976). A multielement SCD suitable for time-limited repeated manipulations with slight variations (Wolery, Gast, & Ledford, 2014) was chosen. In multielement designs, conditions are randomly presented, usually with an initial baseline condition, with the design suitable for considering elements of an intervention (Wolery et al., 2014)—in this case, the presence of a horse. Multielement designs are also used for assessing differences in similar treatments, such as comparison of the same treatment delivered by different therapists (Hensen & Barlow, 1976) or in this case, the comparison of experiences with different horses. We hypothesized that short-term interactions with horses would lead to overall improved HRV values of the individual participants relative to baseline.

Research Questions

1. Is there a physiological effect of human-horse interactions on humans?
2. What is the effect of the presence of a horse on human HRV?
3. Can the presence of a horse have a significant stress-moderating effect on human participants?

Method

Participants

Nine adult participants (7 women and 2 men; age range 20 to 56 years, M_{age} = 39.00 years, SD = 9.56) were recruited from the general population through the online Canberra Community Development network. Participants registered their interest and answered health and safety screening questions presented in an online survey hosted by Qualtrics. Exclusion criteria included major concern associated with being near horses. People with high levels of concern about being near horses were excluded from the study as high levels of stress around horses could potentially introduce error into the experiment and also may introduce safety issues. Also, participants with a heart condition or over 70 years of age were excluded, as HRV recordings are less reliable under these conditions (Sinnreich, Kark, Friedlander, Sapoznikov, & Luria, 1998). Participants who were very experienced with horses were also excluded to reduce potential bias from previous horse interactions. The sample size of nine individuals is consistent with sample sizes of 8–12 used in other SCD studies examining the effects of therapeutic interventions on HRV (Kurita et al., 2006; Mantovani et al., 2016; Nishith et al., 2003). Participant details as determined through the online screening questionnaire are shown in Table 1.

Horses

Based on recommendations of at least three intrasubject replications of single case experiments (Lane & Gast, 2014), five different horses were used with each participant. The horses used were current EAP horses that regularly interact with strangers and therefore were accustomed to a variety of responses

Table 1 *Participant Demographics and Characteristics from Screening Questionnaire*

Participant	Gender	Age	Horse Experience	Level of Concern about Being Near Horses
1	Female	33	Some	Minor
2	Female	44	Limited	No concern
3	Male	31	Limited	Minor
4	Female	56	Limited	Minor
5	Female	20	Limited	Moderate
6	Female	36	Limited	No concern
7	Female	32	No experience	No concern
8	Female	50	No experience	Minor
9	Male	49	No experience	No concern

NB: Level of concern about being near horses was used as an exclusion criterion in participant recruitment and is not a result from the experiment.

Table 2 *Horse Characteristics*

Horse ID	Age (years)	Gender	Height (hands high)	Breed	Years as an EAP Horse
1	6	Stallion	14.2	Arabian	4
2	8	Gelding	10.3	Palouse pony	3
3	20	Mare	14.3	Arabian	3
4	10	Mare	15.1	Arabian	2
5	9	Gelding	11	Shetland pony	1

from humans. These horses were in excellent health and run in a herd of 11 horses over a 100-acre range. They are handled using natural horsemanship methods. Each interaction with a different horse was considered as a different variation in the multielement design. Details on horse characteristics are shown in Table 2.

Measures and Materials

Heart Rate Variability. Heart rate variability, in the form of interbeat intervals (IBI), was measured using a portable, digital telemetry system (Polar® V800, Polar Electro Oy, Kempele, Finland). IBIs are recorded via a transmitter strapped to the participant's chest and a recording device attached to the participant's wrist. The transmitter is able to detect ventricular depolarization at a sampling rate of 500 Hz (Gamelin, Berthoin, & Bosquet, 2006). An earlier version of this model has been validated against ECG monitoring equipment for supine and sitting positions (Gamelin et al., 2006).

Choices of HRV measures used in this study were based on recommendations by the Task Force of the European Society of Cardiology and the Northern American Society of Pacing Electrophysiology (1996). HRV variables analyzed were: (1) the square root of the mean of the sum of the squares of differences between adjacent normal-to-normal (N–N) intervals (RMSSD), for which increases represent increases in parasympathetic activity, and (2) the Low Frequency/High Frequency (LF/HF) ratio, for which decreases represent a shift toward more parasympathetic activity relative to sympathetic activity (Berntson et al., 1997; Stein & Kleiger, 1999; Task Force of the European Society of Cardiology and the Northern American Society of Pacing Electrophysiology, 1996). As a widely accepted indicator of parasympathetic to sympathetic balance (Berntson et al., 1997), the LF/HF ratio was selected as the primary indicator of interest in providing insight into the range of responses elicited during exposure to a horse. LF/HF has been used to assess changes due to therapeutic interventions (Burg et al., 2012; Kurita et al., 2006; Mantovani et al., 2016; Nishith et al., 2003) as well as the impact of mental stressors (Hjortskov et al., 2004; Taelman et al., 2009). Heart rate (HR) measures, also devised by the Kubios program, were included in the analysis because they are commonly understood by readers. Reliability of HRV measures used were assessed in a manner consistent with recommendations by Gamelin et al. (2006) using the Polar 810, an earlier version of the Polar V800, on a healthy population during rest and normal breathing for 10 minutes for RMSSD (.86), LF/HF (.56), and HR (.80).

Self-Report and Qualitative Data. At baseline and immediately after each horse interaction, participants completed the Toronto Mindfulness Scale (TMS) (Lau et al., 2006) and were invited to write about their experience with the horse. The results of this part of the experiment will be reported in a separate paper.

Behavioral Data. A stationary video camera (Panasonic Model HC-VX550M) recorded the human and horse behavioral responses. This documentation was also important to assist in identifying artifacts in the HRV data. Video recordings were assessed to check participant adherence to experimental conditions (e.g., no touching of the horses, remain seated) and to assess whether there were times of close proximity of the horse to the human. Video data were assessed for approach of the horse to close proximity (within 1.5 meters) of the human, and length of the period spent standing still (less than or greater than 1 minute).

Experimental Procedure

Data collection proceeded after approval was granted from the University of New England Human Research Ethics Committees (Approval number HE16-063) and the University of New England Animal Research Ethics Committee (Approval number AEC16-016). Participants provided informed consent prior to the screening portion of the study, which was completed via an online questionnaire. They also completed a written informed consent form in person prior to the experimental procedure. The experimental procedure involved HRV monitoring at preexposure baseline and during five horse exposure conditions described as Human-Horse Interactions (HHI), shown in Figure 1.

The experience assessed during this experiment was that associated with the human-horse interaction (HHI). Intentionally, this is not defined as anything other than a horse and a human sharing a confined space. HHIs were defined as simply the presence of both human and horse in a yard together. The design involved a seated person and a free-roaming horse and as such interactions were not guaranteed, in keeping with the "liberty" approach often employed in EAP (Hallberg, 2008). Lack of physical interaction does not preclude two-way interaction, as horses regularly communicate with each other and with humans at distance (Proops & McComb, 2012).

Instructions on the procedure, including safety information, were provided and the HRV monitoring device was fitted and checked prior to the first exposure. Because HRV measures are more reliable with less participant movement (Berntson et al., 1997), both the preexposure baseline (without horse) and experimental condition (with horse) involved the participant sitting in the center of a 12 m x 10 m yard on a rotating stool, as per the motionless person design by Merkies et al. (2014). There was only one

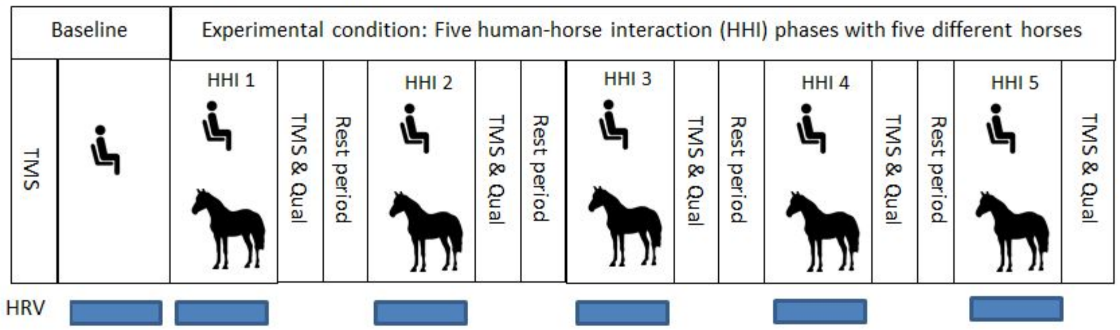


Figure 1. Schematic of the experimental procedure. At baseline the participant completes the Toronto Mindfulness Scale (TMS) and then sits in the yard without a horse for ten minutes. During the experiment, the participant sits in the yard with an unrestrained horse for ten minutes. The horse is removed and the participant leaves the yard and completes the TMS and the qualitative component (Qual). This is repeated five times with five different horses in randomised sequence. Phases were interspersed with a 10 minute rest. Periods of heart rate variability recording (HRV) are shown as shaded blocks.

Figure 1. Details of experimental procedure

preexposure baseline HRV taken, as HRV values have strong stability over short time periods, good reproducibility during same-day recordings, and baseline and placebo intervention HRV measures have been found to be almost identical (Young & Leicht, 2011). Von Borell et al. (2007) note that short-term measures of HRV return rapidly to baseline after changes introduced from a range of short-term interventions.

As brief human-animal interactions of 2–12 minutes have proven sufficient to determine physiological changes in human-animal interactions (Cole et al., 2007), the experimental phases lasted 10 minutes. Participants were instructed to “do nothing while sitting with the horse” and not to touch the horse or stand (unless necessary for safety). They were allowed to swivel around on the chair and talk to the horse. The HRV device and the video camera were synchronized to start at the same time. Horse presentation was randomized to control for any effects of individual horses on interparticipant results. Each interaction procedure, including testing and delay (rest) period, took between 20 and 30 minutes, requiring a total of 2–3 hours per participant. As HRV monitoring has large demands on battery life of the device, measurement was during baseline and experimental phases only. Interaction between the participant and research team was limited to reduce social desirability bias. Observation for safety issues, of which there were none, was from a concealed window to reduce participant reactive effect (Kazdin, 1982). The procedure was implemented according to a protocol checklist for each participant.

Data Analysis

Data were entered into Kubios 2.2 HRV Software (Biomedical Signal Analysis Group, 2016) for analysis. The tachogram for each 10-minute period was analyzed separately for each participant. The Kubios program provides automatic artifact correction, though the first and last 30 seconds of each recording were deleted to exclude artefacts associated with interference by the horse handler or the researcher. The custom filter was used, the artifact correction was set at medium, and nonstationary trend components were corrected using the “smoothness priors” detrending as recommended by Biomedical Signal Analysis Group (2016). Visual inspection of corrected data was also undertaken; no significant artifacts were observed. RMSSD, LF/HF, and HR were derived as a mean for each phase using algorithms in Kubios. Data were assessed for normal distribution and outliers. As analysis of SCD studies is not dependent on normal distributions (Hensen & Barlow, 1976), the purpose of this was checking for data inaccuracies.

In SCD studies, visual analysis of change through different conditions is the most common approach

(Smith, 2012) and enables intrasubject variability to be examined by the reader (Morgan & Morgan, 2009). Individual HRV results were graphed for all 6 experimental phases and assessed for decelerating, accelerating, or cyclic trends. Stability and variability within trend lines were assessed, with high variability within trend lines considered to be unacceptable for interpreting trends (Gast, 2014). HRV results for each unique exposure were assessed for significant change compared to preexposure baseline (which was assumed to be stable, as discussed earlier).

Averages of all individual experimental phases for each participant (e.g., mean over 50 minutes) were also compared to the preexposure baseline to determine the overall effect of all HHIs on the individual. This allowed for determination of how the participant performed on average across conditions (Morgan & Morgan, 2009). Percentage change between baseline and HHI phase mean was also determined for each individual as a measure indicating relative change from baseline.

Interparticipant data analysis involved comparison of all participants' baseline measures with all participants' HHI measures, enabling assessment of overall trends in group data and identification of generality across participants (Morgan & Morgan, 2009). Averages for all participants by phase sequence were also compared to baseline to assess generality in responses by phase.

Reliable Change Index. A statistical approach commonly used to define meaningful change in psychotherapy single-cases research, the Reliable Change Index (RCI) was used to detect meaningful change in HRV scores between experimental conditions. The RCI differentiates change due to an intervention from change due to measurement unreliability (Evans, Margison, & Barkham, 1998; Jacobson & Truax, 1991) and is essentially a treatment effect measure. The index indicates statistically significant reliable change between initial (baseline) scores and intervention (human-horse interaction) scores, taking into account results due to measurement discrepancy (Evans et al., 1998).

The formula used to determine the RCI is a function of the initial standard deviation of the measure, and the test-retest reliability of the measure is detailed in Jacobson and Truax (1991). The index is established based on $p < .05$, meaning that change would occur by measurement error over the retest interval in less than 5% of observations made on the same person (Jacobson & Truax, 1991). In this study, RCIs were determined for each HRV measure and were used to detect significant changes from baseline. Because there is large variability and a lack of agreement on norms for HRV measures, comparison between individuals is problematic (Sandercock et al., 2005). Hence, RCIs for HRV measures were determined using the standard deviation from each single case observation across baseline and five experimental phases.

Results

Response Rate and Data Accuracy

Each of the nine participants interacted with five different horses, resulting in a total of 45 human-horse interactions. HRV data was not available for the last two interactions of Participant 7 due to data download error. Otherwise, HRV data were successfully collected and retrieved. All interactions were video recorded, totaling nine hours of recording. Results were within previously published ranges for short-term recordings of HRV for healthy adults, which are LF/HF (.29–11.6) and RMSSD (19–75) (Nunan, Sandercock, & Brodie, 2010; Voss, Schroeder, Heitmann, Peters, & Perz, 2015). Aggregated means, standard deviations, and ranges of results are shown in Table 3.

Behavioral Responses—Human and Horse

The horse-human interaction was defined as a 10-minute period during which the horse and the human were both in the yard with the human seated and the horse at liberty (i.e., untethered and free to move around the yard at will). No expectations of interaction were discussed with the participant.

Table 3 *HRV Measures for Baseline and During Human-Horse Interactions, Aggregated for All Participants (N = 9)*

	Baseline				Human-Horse Interactions			
Variable	M	SD	Minimum	Maximum	M	SD	Minimum	Maximum
HRV								
LF/HF power (ms^2)	2.80	2.37	0.65	8.25	1.91	0.77	0.95	3.27
Mean HR (beats/min)	73.98	9.95	57.70	86.78	72.11	9.03	58.76	85.41
RMSSD (ms)	35.35	16.76	14.86	68.51	35.12	11.30	21.70	58.22

Note: LF/HF ratio: ratio of low frequency to high frequency; HR: heart rate; RMSSD: root mean square of successive differences of RR intervals.

Human participants followed instructions for the experimental conditions (no touching the horse and remain seated) except for two occasions, when participants stood briefly and then resumed sitting. The experience was assessed using a stopwatch to time the interaction and video recordings. For the purpose of this paper, the video recordings were used to assess only the proximity of the horse to the human. In 30 of the 45 interactions, horses approached and spent some time at a standstill within 1.5 meters of the participant.

Heart Rate Variability—LF/HF. Individual HRV LF/HF results in response to the experimental phases and the significance of these results, based on Reliable Change Indexes determined for each measure, are shown in Figure 2. Decreases indicate improvement.

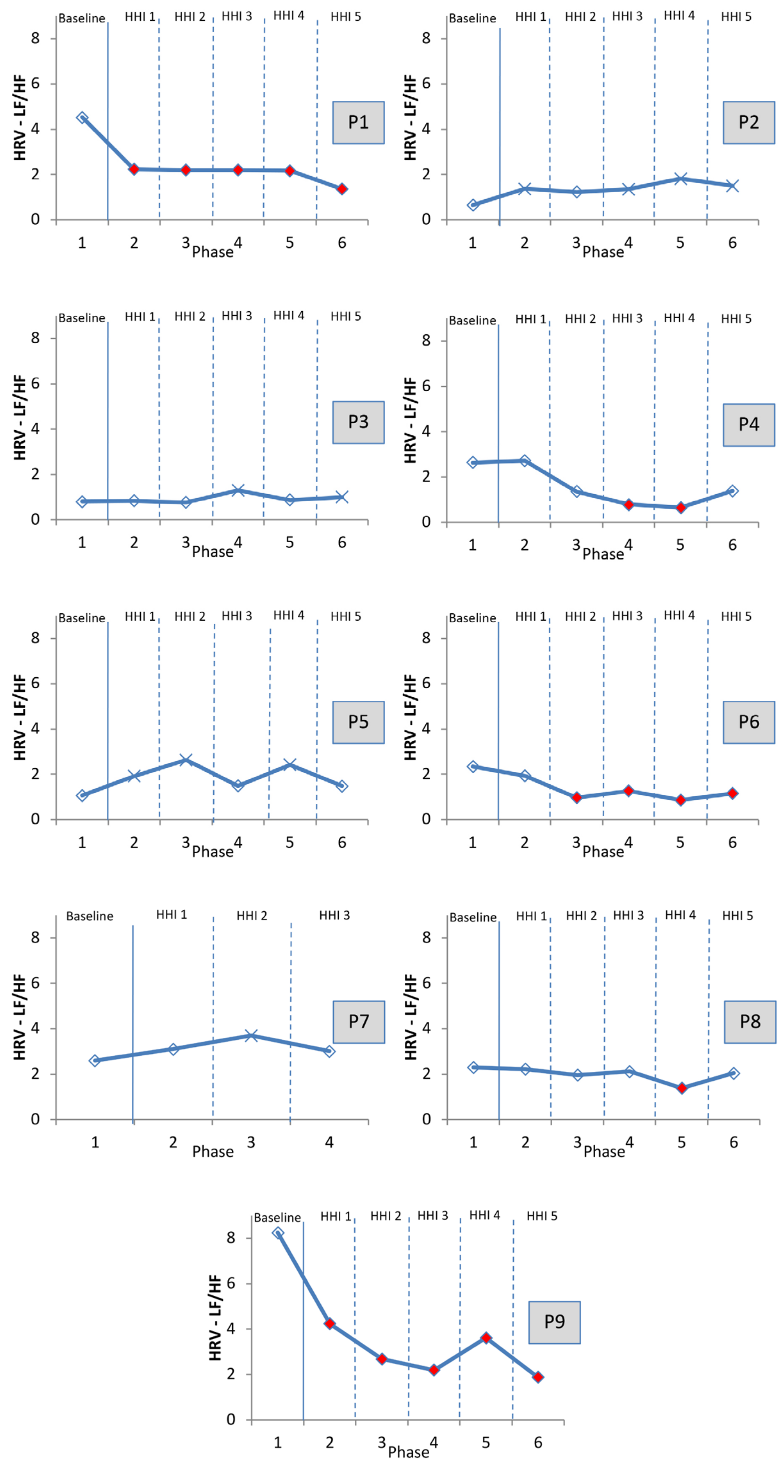
Statistically significant improvement in LF/HF compared to preexposure baseline was observed in at least one HHI phase for five of the participants. Four participants showed deterioration in LF/HF in one or more HHI phases. Significant improvement from baseline in the hypothesized direction was observed in 17 of 43 interactions (40%) and deterioration was observed in 10 (23%), with the remaining measuring below the threshold of the Reliable Change Index devised for each participant. Figure 3 shows LF/HF aggregated for all participants for each phase. There was a decreasing trend across HHI phases indicating overall improvement over the duration of the experiment.

Relative Change. Table 3 shows percentage change based on comparison of baseline to the mean across all HHIs for each participant. Five participants showed an overall improvement in LF/HF, with statistically significant improvements for three of those participants (Table 4). Four participants deteriorated in LF/HF, with one participant showing significant deterioration. When HRV results were aggregated by horse, it appears that the sequence of the interactions, for which horses were presented randomly for each participant, was a greater influence on HRV than the individual horses themselves.

Discussion

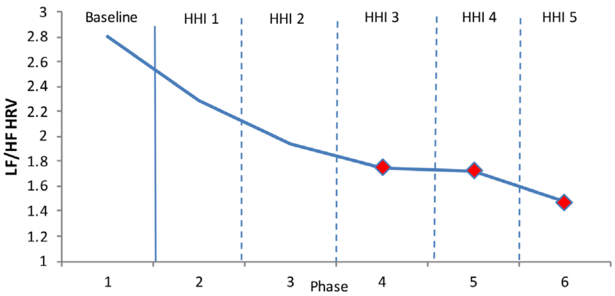
With regard to research question 1, "Is there a physiological effect of HAIs on humans?", exposure to horses was associated with a measurable physiological change from baseline in 27 of the 43 exposures (63%). Concerning research question 2, regarding the nature of this effect, results were mixed. In some cases, HAIs were associated with an improvement in HRV, indicating a more relaxed state than baseline. In others, a deterioration in HRV was observed, indicating more stress arousal than baseline. In some cases, no change in HRV was observed at all.

The hypothesized improvement in HRV measures from interactions with horses was only partially supported, as results were mixed. In vivo horse exposures improved LF/HF measures (40%) more



◆ Significant change as compared to preexposure baseline in the hypothesized direction
◇ Baseline or no significant change from baseline
X Significant change as compared to preexposure baseline opposite to the hypothesized direction

Figure 2. LF/HF HRV for Participants 1–9



Note: Low Frequency / High Frequency HRV results averaged by experimental phases for all partcipants ($N = 9$). Statistically significant change in hypothesized direction indicated by solid marker on trend line ($p < .05$). There was no significant change in the direction opposite to hypothesized change in aggregated results.

Figure 3. LF/HF HRV for All Participants

Table 4 *Percentage Change and Significance Comparing Individual Baseline and Means of HHI Phases for HRV (N = 9)*

Direction of Change Indicating Improvement	Percentage Change – Baseline to HHIs		
	LF/HF	RMSSD	HR
	Decrease	Increase	
Participant ID			
1	–55% *	–7%	5%
2	123% (*)	–6%	2%
3	18%	9%	–1%
4	–48%	97% *	–1%
5	87%	–15%	0%
6	–47% *	22% *	–7%
7	26%	–15% (*)	6%
8	–15%	23%	–10%
9	–65% *	–22% (*)	–13%
Avg. change	10%	12%	–3%

Note: HR: heart rate; RMSSD: root mean square of successive differences of RR intervals; LF/HF: ratio of low frequency to high frequency power. *Denotes statistically significant improvement as compared to preexposure baseline, (*) denotes statistically significant deterioration as compared to preexposure baseline. Where no notation used, denotes no statistically reliable change as compared to preexposure baseline. Statistical reliability not calculated for Avg. change. Statistical significance notations are in reference to the significance of difference between the average of exposure scores and baseline scores, not the percentage change.

than were unchanged (36%) or deteriorated (23%). Hence regarding research question 3, concerning whether human-horse interactions can have significant stress-moderating effects, results show that the presence of a horse can be associated with a stress-moderating effect on human participants.

These findings provide some support to the few previous studies providing empirical links between horse contact and physiological indicators of relaxation. Pendry, Smith, and Roeter (2014) found improvements in adolescents' cortisol measurements associated with attending an EAP program compared to waitlist, and Baldwin et al. (2018) observed improvements in parasympathetic response in older adults following an EAP intervention. An important difference is that the current study provides evidence that the presence of a horse alone can contribute to a stress-moderating effect in isolation from the influence of the therapist/handler and other aspects of EAP. The study also captured unique evidence of stress-arousal from HHIs, which may have been moderated in other studies by the presence of the therapist/handler.

Support for the hypothesis of improved HRV from HAIs was provided by three of the nine participants who showed significant overall improvement on LF/HF. In contrast, one participant significantly deteriorated overall on LF/HF. Viewed as aggregated results for all participants, LF/HF showed improving trends across the condition phases, suggesting a cumulative positive effect of the HHIs. This also implies that group averages may fail to recognize the increased stress arousal in some individuals. While the hypothesis cannot be fully supported from this study, failure to replicate among all participants should not detract from the intra- and interparticipant replications that did support the hypothesis (Hensen & Barlow, 1976). That this influence was inconsistent across cases suggests that more investigation is needed into the variables that may be at work in HHIs.

While the findings preclude conclusions of generality, they have the potential to reveal individual nuances. A potentially important insight arising from this study is that none of the individuals who showed a significant improvement in LF/HF during any phase also showed a significant deterioration in any phase. The converse was also true (i.e., none of the participants who showed significant deterioration showed significant improvement in any phase).

Given that there was deterioration of HRV in some HHIs and for one participant overall, investigation into factors that may have caused this is required. Deteriorations in HRV have been associated with state or trait anxiety, worry, and emotional arousal (Dishman et al., 2000; Friedman, 2007; Jönsson, 2007). A variable emerging from the present study as a potential influence in HHIs is apprehension around horses. Initial apprehension may negatively influence the outcomes of human-animal interactions (Merkies et al., 2014; von Borstel, Euent, Graf, König, & Gauly, 2011), although having initial apprehension about the horse may not preclude the potential for improvement in the EAP context (Earles, Vernon, & Yetz, 2015).

Limitations and Future Studies

The multimodal SCD approach was effective in providing in-depth information on the influence of the HHI condition. This study addressed construct validity threats in previous research by isolating the specific effect of the horse from social facilitation or other therapeutic influences associated with the EAP context (Crossman, 2017). However, other factors associated with the design—including enjoying nature, sitting quietly, and general environmental enrichment—may have shared influence with the presence of a horse. These aspects are in keeping with most EAP programs and provide ecological validity, rather than confounds to be controlled. Additionally, it would be difficult to control these factors in a naturalistic setting. This study also addressed the problem of generalization across animals (Crossman, 2017) by using five horses of different sizes, breeds, and sexes.

While the use of HRV as a physiological indicator has been widespread and the software used in this study allows for sophisticated correction of errors, there are several caveats to the interpretation of HRV results, as discussed in detail by Berntson et al. (1997). In terms of improving the current SCD approach, assessing the reliability of baseline HRV recordings would improve confidence in results. Replications used in SCD studies are associated with serial dependency (Gast, 2014) and as such, improvements and deteriorations may have occurred at a similar rate without the horse. A design improvement would be to address maturation effects through a crossover design where participants are allocated either to a horse or nonhorse condition. Further interpretation of behavioral data based on interobserver agreement would also provide greater insight and may lead to further refinement in understanding horse-human interactions.

Progression of the current study to a systematic replication attempt is worthwhile, noting that the present study has met the minimally acceptable standard for systematic replication of three successful intersubject replications (Gast, 2014). Further SCD testing of our hypotheses would ideally follow the 5-3-20 recommendation for validating SCD study findings, where the study is replicated at least five times by three different research teams with at least 20 participants (Gast, 2014).

A limitation of multiple single case studies is that they do not have the statistical power of a larger sample study. Studies using comparison groups and large sample numbers, which would enable the use of inferential statistics, are also required in investigating the underlying mechanisms of HHIs (Selby & Smith-Osborne, 2013). A larger sample study with a control group using a similar multimodel approach is recommended for future investigations. Future study designs are needed that lead to better understanding of individual responses to horses.

Summary for Practitioners

EAP is a growing field with a limited evidence base; however, it can be attractive to clients that might not willingly attend evidence-based therapeutic interventions. This study contributes provisional evidence for the beneficial inclusion of horses in the therapy context, demonstrating a stress-moderating effect associated with simple physical proximity to horses, while noting complexities in the results. There was high individual variability in HRV response to HHIs. There were improvements, deteriorations, and neutral effects shown by participants but no individual participant had both improvement and deterioration. This trend of either improvement or deterioration in HRV suggests that where there is an effect of HHIs, it may be relatively consistent and stable for each individual participant. These findings highlight the importance of differentiating between client responses and having a client-focused approach rather than a one size fits all approach to EAP.

Taken as an aggregated group, there was a cumulative significant improvement in HRV among study participants across HHIs, due to quite large consecutive improvements in HRV for some individuals. Taken in the field context, this may imply that some participants will gain a cumulative effect of being in the presence of horses. As well as an indicator of improved health, improved HRV has been associated with adaptive emotional responding (Grossmann et al., 2016) and emotion regulation (Burg et al., 2012). As such the results from this study may be interpreted to imply that HHIs could contribute to increased emotional regulation. Relaxation and emotional regulation are a fundamental part of psychotherapy and have a robust effect on hyperarousal and anxiety problems (Tolin, 2016). Time spent with a horse at liberty without undertaking specific tasks may help to relax and calm otherwise anxious clients more than in the same context without a horse. Emotional regulation is also associated with attentional deployment, cognitive change, and response modulation (Gross, 1998). As such, calm states experienced during HHIs may provide the opportunity for clients to improve attention and decision-making in the therapy context.

The EA therapist needs to consider the possibility that interaction with a horse may induce a stress arousal response. Horses are large, intimidating animals, particularly for those who are not familiar with them and also for clients with previous frightening interactions with horses. HHIs will be influenced by expectations of certain behaviors, both positive and negative, with nervousness of a human associated with a perception of a problematic horse, rather than based on the actual behavior of the horse (Munsters, Visser, & van den Broek, 2012; Visser et al., 2008). Increased stress is not necessarily negative and in a safe environment can lead to more focused attention and improved confidence and skills, as people overcome the cause of stress (Joels, Pu, Wiegart, Oitzl, & Krugers, 2006) or develop distress tolerance for troubling thoughts.

An important role of the therapist is to identify and help clients identify their appraisal of the HHI(s) and provide appropriate information, support, and context. This includes helping participants to understand the horse's behavior, such as explaining the difference between relaxation, hypervigilance, play, and dominance in horses. Therapists need to help participants to communicate more effectively with the horse(s) so that they can confidently deal with horses, set boundaries, and keep themselves safe. The process of identifying and managing perceived threats has application to life problems, and overcoming stress experienced around safe horses can be used as a metaphor for other issues in the client's life. Clients may come to see that feelings of apprehension (around safe horses) may be related to their own thoughts rather than the externalities, thereby enhancing cognitive restructuring opportunities.

An important finding of this study is that HRV effects were in the context of voluntary interactions using horses that were emotionally and physically healthy and socialized with humans. The interactive influence of a free-roaming horse on a human is underresearched and has generally been assessed only under certain conditions, such as positive reinforcement or stressful or novel circumstances. Von Borstel et al. (2011) hypothesize that horses at liberty can express their emotions freely and can choose how and when they approach humans (which is not the case with led or ridden horses), potentially allowing for greater willingness to connect with humans. That horses spent time beside the seated participants in 70% of the interactions shows that voluntary horse-human co-being (Maurstad, Davis, & Cowles, 2013) can occur without the use of reinforcements to shape horse behavior. This voluntary co-being is worthy of exploration in the EAP context.

Practitioners need to increase their awareness of the variable effects of HHIs on clients and utilize appropriate assessment tools that measure effects on clients. Sessions can then be structured taking stress responses into consideration within the context of validated therapeutic approaches. Widespread documentation and publication on the effects of HHIs is important in continuing to critically evaluate the evidence for EAP.

Acknowledgments

The authors acknowledge the University of New England D. R. Grey Research Foundation and the Jean M Oxley Bursary for funding of monitoring devices and study participant travel reimbursement. Thanks are extended to Joanne Byrnes, senior therapist at Peakgrove, for support, advice, and experiment logistics oversight. Thanks also go to Terri-Anne Goodreid and Caitlen Goodreid, whose assistance was vital during the experiment. We also acknowledge the time and willingness of our study participants and the five horses involved in this study. The encouragement of Ann Alden, Barbara Rector, and Ann Baldwin, pioneers in this field, is also respectfully acknowledged.

References

Allen, K., Blascovich, J., & Mendes, W. B. (2002). Cardiovascular reactivity and the presence of pets, friends, and spouses: The truth about cats and dogs. *Psychosomatic Medicine, 64*(5), 727–739.

Baldwin, A. L., Rector, B. K., & Alden, A. C. (2018). Effects of a form of equine-facilitated learning on heart rate variability, immune function, and self-esteem in older adults. *People and Animals: The International Journal of Research and Practice, 1*(1), 5.

Baragli, P., Vitale, V., Banti, L., & Sighieri, C. (2014). Effect of aging on behavioural and physiological responses to a stressful stimulus in horses (*Equus caballus*). *Behaviour, 151*, 1513–1533. https://doi.org/10.1163/1568539X-00003197

Barker, S. B., Knisely, J. S., McCain, N. L., Schubert, C. M., & Pandurangi, A. K. (2010). Exploratory study of stress-buffering response patterns from interaction with a therapy dog. *Anthrozoos, 23*(1), 79–91.

Beetz, A., Kotrschal, K., Uvnäs-Moberg, K., & Julius, H. (2012). *Basic neurobiological and psychological mechanisms underlying therapeutic effects of equine assisted activities.* HHRF Grant 2011—Public Report. Retrieved from http://www.horsesandhumans.org/HHRF_grant_final_report_public_version_June_2012_Basic_Neurobiological_Psychological.pdf

Beetz, A., Uvnäs-Moberg, K., Julius, H., & Kotrschal, K. (2012). Psychosocial and psychophysiological effects of human-animal interactions: The possible role of oxytocin. *Frontiers in Psychology, 3*(234). https://doi.org/10.3389/fpsyg.2012.00234

Berget, B., Ekeberg, O., & Braastad, B. O. (Producer). (2011, May 5, 2013). Animal-assisted therapy with farm animals for persons with psychiatric disorders: Effects on self-efficacy, coping ability and quality of life, a randomized controlled trial. [Open Access article]. Retrieved from http://creativecommons.org/licenses/by/2.0

Berntson, G. G., Thomas Bigger, J., Eckberg, D. L., Grossman, P., Kaufmann, P. G., Malik, M., . . . Van Der Molen, M. W. (1997). Heart rate variability: Origins, methods, and interpretive caveats. *Psychophysiology, 34*(6), 623–648. https://doi.org/10.1111/j.1469-8986.1997.tb02140.x

Bertsch, K., Hagemann, D., Naumann, E., Schächinger, H., & Schulz, A. (2012). Stability of heart rate variability indices reflecting parasympathetic activity. *Psychophysiology, 49*(5), 672–682. http://dx.doi.org/10.1111/j.1469-8986.2011.01341.x

Biomedical Signal Analysis Group. (2016). Kubios 2.2 HRV Software, Kuopio, Finland: Department of Applied Physics, University of Kuopio. Retrieved from https://dl.dropboxusercontent.com/u/62457657/KubiosHRV_2.2_installer.exe

Burg, J. M., Wolf, O. T., & Michalak, J. (2012). Mindfulness as self-regulated attention associations with heart rate variability. *Swiss Journal of Psychology, 71*(3), 135–139.

Cabiddu, R., Borghi-Silva, A., Trimer, R., Trimer, V., Ricci, P., Italiano Monteiro, C., . . . Carvalho, E. (2016). Hippotherapy acute impact on heart rate variability non-linear dynamics in neurological disorders. *Physiol Behav, 159*, 88–94. https://doi.org/10.1016/j.physbeh.2016.03.012

Cole, K. M., Gawlinski, A., Steers, N., & Kotlerman, J. (2007). Animal-assisted therapy in patients hospitalized with heart failure. *American Journal of Critical Care, 16*, 575+.

Corring, D., Lundberg, E., & Rudnick, A. (2013). Therapeutic horseback riding for ACT patients with schizophrenia. *Community Mental Health Journal, 49*(12), 121–126.

Crossman, M. K. (2017). Effects of interactions with animals on human psychological distress. *Journal of Clinical Psychology, 73*(7), 761–784. https://doi.org/10.1002/jclp.22410

Dishman, R., Nakamura, Y., Garcia, M., Thompson, R., Dunn, A., & Blair, S. (2000). Heart rate variability, trait anxiety, and perceived stress among physically fit men and women. *International Journal of Psychophysiology, 37*(2), 121–133.

Donaghy, G. (2006). Equine assisted therapy. *Mental Health Nursing, 26*(4), 5.

Dorotik-Nana, C. (2011). Equine therapy certifications: Which is best? *Psych Central*. Retrieved from http://blogs.psychcentral.com/equine-therapy/2011/03/equine-therapy-certifications-which-is-best/

Earles, J. L., Vernon, L. L., & Yetz, J. P. (2015). Equine-assisted therapy for anxiety and posttraumatic stress symptoms. *Journal of Traumatic Stress, 28*(2), 149–152. https://doi.org/10.1002/jts.21990

El-Alayli, A., Lystad, A. L., Webb, S. R., Hollingsworth, S. L., & Ciolli, J. L. (2006). Reigning cats and dogs: A pet-enhancement bias and its link to pet attachment, pet-self similarity, self-enhancement, and well-being. *Basic and Applied Social Psychology, 28*, 131–143.

Evans, C. E., Margison, F., & Barkham, M. (1998). The contribution of reliable and clinically significant change methods to evidence-based mental health. *Evidence-Based Mental Health, 1*, 70–72.

Ewing, C. A., MacDonald, P. M., Taylor, M., & Bowers, M. J. (2007). Equine-facilitated learning for youths with severe emotional disorders: A quantitative and qualitative study. *Child Youth Care Forum, 36*, 59–72.

Friedman, B. H. (2007). An autonomic flexibility–neurovisceral integration model of anxiety and cardiac Vagal tone. *Biological Psychology, 74*(2), 185–199. http://dx.doi.org/10.1016/j.biopsycho.2005.08.009

Friedmann, E. (2000). The animal-human bond: Health and wellness. In A. Fine (Ed.), *Handbook on animal-assisted therapy: Theoretical foundations and guidelines for practice* (pp. 1–58). California: Academic Press.

Friedmann, E., Thomas, S., Stein, P., & Kleiger, R. (2003). Relation between pet ownership and heart rate variability in patients with healed myocardial infarcts. *American Journal of Cardiology, 91*, 718–721.

Froeschle, J. (2009). Empowering abused women through equine assisted career therapy. *Journal of Creativity in Mental Health, 4*(2), 180–190. http://dx.doi.org/10.1080/15401380902945228

Gamelin, X. F., Berthoin, G. S., & Bosquet, L. (2006). Validity of the Polar S810 heart rate monitor to measure R–R intervals at rest. *Medicine & Science in Sports & Exercise, 38*(5), 887–893. https://doi.org/10.1249/01.mss.0000218135.79476.9c

Gast, D. L. (2014). Replication. In D. L. Gast & J. R. Ledford (Eds.), *Single case research methodology: Applications in special education and behavioural sciences* (2nd ed., pp. 105–123). New York, NY: Routledge.

Gross, J. J. (1998). The emerging field of emotion regulation: An integrative review. *Review of General Psychology, 2*(3), 271.

Grossmann, I., Sahdra, B. K., & Ciarrochi, J. (2016). A heart and a mind: Self-distancing facilitates the association between heart rate variability and wise reasoning. *Frontiers in Behavioral Neuroscience, 10*. https://doi.org/10.3389/fnbeh.2016.00068

Hallberg, L. (2008). *Walking the way of the horse—exploring the power of the horse-human relationship*. Bloomington, IN.

Hausberger, M., Roche, H., Henry, S., & Visser, E. K. (2008). A review of the human–horse relationship. *Applied Animal Behaviour Science, 109*(1), 1–24.

Henry, C. L., & Crowley, S. L. (2015). The psychological and physiological effects of using a therapy dog in mindfulness training. *Anthrozoos, 28*(3), 385–402. https://doi.org/10.1080/08927936.2015.1052272

Hensen, M., & Barlow, D. (1976). *Single case experimental designs: Strategies for studying behaviour change*. New York: Pergamon Press.

Hjortskov, N., Rissén, D., Blangsted, A. K., Fallentin, N., Lundberg, U., & Søgaard, K. (2004). The effect of mental stress on heart rate variability and blood pressure during computer work. *European Journal of Applied Physiology, 92*(1–2), 84–89.

Jacobson, N. S., & Truax, P. (1991). Clinical significance: A statistical approach to defining meaningful change in psychotherapy research. *Journal of Consulting and Clinical Psychology, 59*(1), 12–19.

Joels, M., Pu, A., Wiegart, O., Oitzl, M. S., & Krugers, H. (2006). Learning under stress: How does it work? *Trends in Cognitive Science, 10*, 152–158.

Jönsson, P. (2007). Respiratory sinus arrhythmia as a function of state anxiety in healthy individuals. *International Journal of Psycho-physiology, 63*(1), 48–54. https://doi.org/10.1016/j.ijpsycho.2006.08.002

Karmakar, C. K., Khandoker, A. H., Voss, A., & Palaniswami, M. (2011). Sensitivity of temporal heart rate variability in Poincaré plot to changes in parasympathetic nervous system activity. *BioMedical Engineering OnLine, 10*(17). http://doi.org/10.1186/1475-925X-10-17

Kazdin, A. E. (1982). *Single-case research designs: Methods for clinical and applied settings*. New York: Oxford University Press.

Kim, H.-G., Cheon, E.-J., Bai, D.-S., Lee, Y. H., & Koo, B.-H. (2018). Stress and heart rate variability: A meta-analysis and review of the literature. *Psychiatry Investigation, 15*(3), 235–245. https://doi.org/10.30773/pi.2017.08.17

Kleiger, R. E., Miller, J. P., Bigger, J. T., & Moss, A. J. (1987). Decreased heart rate variability and its association with increased mortality after acute myocardial infarction. *American Journal of Cardiology, 59*(4), 256–262. http://dx.doi.org/10.1016/0002-9149(87)90795-8

Kurita, A., Takase, B., Okada, K., Horiguchi, Y., Abe, S., Kusama, Y., & Atarasi, H. (2006). Effects of music therapy on heart rate variability in elderly patients with cerebral vascular disease and dementia. *Journal of Arrhythmia, 22*(3), 161–166.

Lane, J. D., & Gast, D. L. (2014). Visual analysis in single case experimental design studies: Brief review and guidelines. *Neuropsychological Rehabilitation, 24*(3), 445–463. https://doi.org/10.1080/09602011.2013.815636

Lau, M. A., Bishop, S. R., Segal, Z. V., Buis, T., Anderson, N. D., Carlson, L., . . . Devins, G. (2006). The Toronto Mindfulness Scale: Development and validation. *Journal of Clinical Psychology, 62*(12), 1445–1467. https://doi.org/10.1002/jclp.20326

Lorenz, K. (1954). *Man meets dog*. Methuen.

Mantovani, A., Fregonesi, C. E. P., Lorençoni, R. M. R., Savian, N. U., Palma, M., Salgado, A., . . . Parreira, R. (2016). Immediate effect of basic body awareness therapy on heart rate variability. *Complementary Therapies in Clinical Practice, 22*, 8–11.

Marino, L. (2012). Construct validity of animal-assisted therapy and activities: How important is the animal in AAT? *Anthrozoos, 25*(sup1), s139–s151. https://doi.org/10.2752/175303712X13353430377219

Maurstad, A., Davis, D., & Cowles, S. (2013). Co-being and intra-action in horse–human relationships: A multi-species ethnography of be(com)ing human and be(com)ing horse. *Social Anthropology, 21*(3), 322–335. https://doi.org/10.1111/1469-8676.12029

Melson, G. F. (2011). Principles for human-animal interaction research. In P. McCardle, S. McCune, J. A. Griffin, & V. Maholmes (Eds.), *How animals affect us: Examining the influences of human-animal interaction on child development and human health*. American Psychological Association.

Memishevikj, H., & Hodzhikj, S. (2010). The effects of equine assisted therapy in improving the psychosocial functioning of children with autism. *Journal of Special Education and Rehabilitation, 11*(3/4), 57–67.

Merkies, K., Sievers, A., Zakrajsek, E., MacGregor, H., Bergeron, R., & König von Borstel, U. (2014). Preliminary results suggest an influence of psychological and physiological stress in humans on horse heart rate and behavior. *Journal of Veterinary Behaviour, 9*, 242–247.

Morgan, D., & Morgan, R. (2009). *Single-case research method for the behavioural and health sciences*. Thousand Oaks, CA: Sage Publications.

Motooka, M., Koike, H., Yokoyama, T., & Kennedy, N. L. (2006). Effect of dog-walking on autonomic nervous activity in senior citizens. *Medical Journal of Australia, 184*(2), 60.

Munsters, C., Visser, E. K., & van den Broek, J. (2012). The influence of challenging objects and horse-rider matching on heart rate, heart rate variability and behavioural score in riding horses. *Veterinary Journal, 12*, 75–80.

Nimer, J., & Lundahl, B. (2007). Animal-assisted therapy: A meta-analysis. *Anthrozoos, 20*(3), 225–238. https://doi.org/10.2752/089279307X224773

Nishith, P., Duntley, S. P., Domitrovich, P. D., Uhles, M. L., Cook, B. J., & Stein, P. K. (2003). Effect of cognitive behavioral therapy on heart rate variability during REM sleep in female rape victims with PTSD. *Journal of Traumatic Stress, 16*(3), 247–250.

Nunan, D., Sandercock, G. R. H., & Brodie, D. A. (2010). A quantitative systematic review of normal values for short-term heart rate variability in healthy adults. *Pacing and Clinical Electrophysiology, 33*(11), 1407–1417. https://doi.org/10.1111/j.1540-8159.2010.02841.x

Odendaal, J. (2000). Animal-assisted therapy—magic or medicine? *J Psychosom Res, 49*(4), 275–280.

Payne, E., DeAraugo, J., Bennett, P., & McGreevy, P. (2016). Exploring the existence and potential underpinnings of dog–human and horse–human attachment bonds. *Behavioural Processes, 125*(114–121). http://dx.doi.org/10.1016/j.beproc.2015.1010.1004

Pendry, P., Smith, A. N., & Roeter, S. M. (2014). Randomised trial examines effects of equine facilitated learning on adolescents' basal cortisol levels. *Human-Animal Interaction Bulletin, 2*(1), 80–95.

Polheber, J. P., & Matchock, R. L. (2014). The presence of a dog attenuates cortisol and heart rate in the Trier Social Stress Test compared to human friends. *Journal of Behavioral Medicine, 37*, 860+.

Porter-Wenzlaff, L. (2007). Finding their voice: Developing emotional, cognitive, and behavioral congruence in female abuse survivors through equine facilitated therapy. *Explore, 35*(5), 529–534.

Prazak, M., Critelli, J., Martin, L., Miranda, V., Purdum, M., & Powers, C. (2012). Mindfulness and its role in physical and psychological health. *Applied Psychology: Health and Well-Being, 4*(1), 91–105. https://doi.org/10.1111/j.1758-0854.2011.01063.x

Proops, L., & McComb, K. (2012). Cross-modal individual recognition in domestic horses (*Equus caballus*) extends to familiar humans. *Proceedings of the Royal Society B: Biological Sciences, 279*, 3131–3138. https://doi.org/10.1098/rspb.2012.0626

Sandercock, G., Bromley, P., & Brodie, D. (2005). The reliability of short-term measurements of heart rate variability. *Int J Cardiol., 103*(3), 238–247.

Sankey, C., Richard-Yrisb, M., Leroya, M., Henrya, S., & Hausberger, M. (2010). Positive interactions lead to lasting positive memories in horses, *Equus caballus*. *Animal Behaviour, 79*(4).

Segerstrom, S. C., & Nes, L. S. (2007). Heart rate variability reflects self-regulatory strength, effort, and fatigue. *Psychological Science, 18*(3), 275–281.

Selby, A., & Smith-Osborne, A. (2013). A systematic review of effectiveness of complementary and adjunct therapies and interventions involving equines. *Health Psychology, 32*(4), 418–432.

Serpell, G. A. (2011). Animal assisted interventions in historical perspective. In A. H. Fine (Ed.), *Handbook on animal-assisted therapy*. Academic Press.

Sinnreich, R., Kark, J. D., Friedlander, Y., Sapoznikov, D., & Luria, M. H. (1998). Five minute recordings of heart rate variability for population studies: Repeatability and age-sex characteristics. *Heart, 80*(2), 156–162. http://dx.doi.org/10.1136/hrt.80.2.156

Smith, J. (2012). Single-case experimental designs: A systematic review of published research and current standards. *Psychological Methods, 17*(4). https://doi.org/10.1037/a0029312

Somervill, J. W., Kruglikova, Y. A., Robertson, R. L., Hanson, L. M., & MacLin, O. H. (2008). Physiological responses by college students to a dog and a cat: Implications for pet therapy. *North American Journal of Psychology, 10*, 519.

Stein, P. K., & Kleiger, R. E. (1999). Insights from the study of heart rate variability. *Annual Review of Medicine, 50*(249–261).

Symington, A. (2012). Grief and horses: Putting the pieces together. *Journal of Creativity in Mental Health, 7*(2), 165–174.

Taelman, J., Vandeput, S., Spaepen, A., & Van Huffel, S. (2009). Influence of mental stress on heart rate and heart rate variability. In J. Vander Sloten, P. Verdonck, M. Nyssen, & J. Haueisen (Eds.), *4th European Conference of the International Federation for Medical and Biological Engineering: ECIFMBE 2008 23–27 November 2008 Antwerp, Belgium* (pp. 1366–1369). Berlin, Heidelberg: Springer Berlin Heidelberg.

Task Force of the European Society of Cardiology and the Northern American Society of Pacing Electrophysiology. (1996). Heart rate variability—Standards of measurement. physiological interpretation and clinical use. *Circulation, 93*, 1043–1065.

Tolin, D. F. (2016). Modulating emotion. In D. F. Tolin (Ed.), *Doing CBT: A comphrehensive guide to working with behaviours, thoughts and emotions*. New York, NY: Guilford Press.

Trotter, K. S. (2012). *Harnessing the power of equine assisted counseling: Adding animal assisted therapy to your practice*. New York, NY: Routledge.

Trotter, K. S., Chandler, C. K., Goodwin-Bond, D., & Casey, J. (2008). A comparative study of the effficacy of group equine assisted counseling with at-risk children and adolescents. *Journal of Creativity in Mental Health Nursing, 3*(3), 254–284.

Visser, E. K., Van Reenen, C. G., Blokhuis, M. Z., Morgan, E., Hassmén, P., Rundgren, T. M., & Blokhuis, H. J. (2008). Does horse temperament influence horse-rider cooperation? *Journal of Applied Animal Welfare Science, 11*(3), 267–284. https://doi.org/10.1080/10888700802101254

von Borell, E., Langbein, J., Després, G., Hansen, S., Leterrier, C., Marchant-Forde, J., . . . Veissier, I. (2007). Heart rate variability as a measure of autonomic regulation of cardiac activity for assessing stress and welfare in farm animals—A review. *Physiology & Behavior, 92*(293–316).

von Borstel, K., Euent, S., Graf, P., König, S., & Gauly, M. (2011). Equine behaviour and heart rate in temperament tests with or without rider or handler. *Physiology & Behavior, 104*, 454–463.

von Lewinskia, M., Biaub, S., Erberc, R., Illec, N., Aurichd, J., Faureb, J.-M., . . . Aurichc, C. (2013). Cortisol release, heart rate and heart rate variability in the horse and its rider: Different responses to training and performance. *Veterinary Journal*, *187*(2), 229–232.

Voss, A., Schroeder, R., Heitmann, A., Peters, A., & Perz, S. (2015). Short-term heart rate variability—Influence of gender and age in healthy subjects. *PLoS ONE*, *10*(3), e0118308. https://doi.org/10.1371/journal.pone.0118308

Wells, D. L. (2009). The effects of animals on human health and well-being. *Journal of Social Issues*, *65*(3), 523–543. https://doi.org/10.1111/j.1540-4560.2009.01612.x

Wolery, M., Gast, D. L., & Ledford, J. R. (2014). Comparison designs. In D. L. Gast & J. R. Ledford (Eds.), *Single case research methodology: Applications in special education and behavioural sciences* (2nd ed., pp. 297–345). New York, NY: Routledge.

Young, F. L. S., & Leicht, A. S. (2011). Short-term stability of resting heart rate variability: Influence of position and gender. *Applied Physiology, Nutrition, and Metabolism*, *36*, 210–221.