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Equine-assisted therapy and its impact on cortisol levels of children and horses: a pilot study and meta-analysis

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Childhood trauma, abuse or neglect impacts the function and structure of the brain of affected children. Attunement with other beings as well as an enriched environment can contribute to normal brain development. The enriched environment of a barn and attunement with an animal may contribute to reductions in stress for traumatised children. A pilot study, using a multiple base line, single case design included four children with post-traumatic stress syndrome (aged eight to ten years) and four therapy riding horses. This study hypothesised that cortisol would correlate between each child–horse pair, using a 12-day intervention that included six consecutive days of riding and grooming. A meta-analysis was completed of correlation levels of four child–horse pairs. The weighted mean cross-correlation, controlling for autocorrelation, was 0.23, $Z = 3.03$, approximate 95% confidence interval $0.23 \pm (1.96 \times 0.076)$ or 0.08 to 0.38. The data suggest a need for further research.

Keywords: animal-assisted therapy; biobehavioural human–animal interaction; social work intervention

Introduction

Recent research confirms the importance that enriched environments play in the neurobiological development of human and non-human animals (Affi, Asmundson, Taylor, & Jang, 2010; Barry, Kochanska, & Philibert, 2008; Knafo & Plomin, 2006; Pragg, Kempermann, & Gage, 2000). Enriched environments are surroundings that are complex, facilitate learning and are socially stimulating; not reliant on a single factor but the combination and interaction of several factors that stimulate growth and change. Bio-ecological theory refers to this as ‘proximal processes’; the reciprocal, evolving interaction between the individual and their environment that contributes to their increasingly sophisticated and ongoing development (Bronfenbrenner & Evans, 2000). Social work’s ‘person-in-environment’ theory also recognises the importance of ‘goodness of fit’ between the individuals and their environment as a contributor to optimum health (Saleebey, 1992).

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One of the most significant contributions to neurological development in the individual's environment is the affiliation and attunement they have with other beings (Carter, 1998; Francis & Meaney, 1999; LeDoux, 1996; Panksepp, 1998; Perry, 2002, 2006; Van der Kolk, 2003). It follows that interventions pairing environmental enrichment with affiliative or social relationships may have the potential to enhance change and promote resiliency in children affected by stress or trauma. Human–animal interaction (HAI) strategies like animal-assisted therapies combine enriched environments and affiliative relationships that utilise touch, proximity and responsiveness. These interventions are non-invasive and they may mimic other significant relationships in children's lives.

This article presents the results of a meta-analysis of four child–horse interactions that look at the use of therapeutic riding as an intervention, measuring the emotional response of both children and horses to each other in six days of therapeutic riding and six days of story-telling and picture drawing. The use of single subject design provides clarity, an opportunity to view the interaction being studied in detail and collect pilot data.

Affiliation, attunement and attachment: brain development and emotional regulation

Social relationships span various degrees of intimacy, from affiliation to attunement and attachment. Affiliation is simply the act of being close to or responsive with other beings throughout the life cycle (Carter, Lederhendler, & Kirkpatrick, 1999; Feldman, Weller, Zagoory-Sharon, & Levine, 2007; Porges, 2003). It requires social engagement that often involves safe touch and proximity seeking behaviour (Ahnert, 2003). Affiliation with others can result in attunement. Attunement relies on responsive affiliation; a consequence of ongoing understanding and reciprocal interaction with another, and can lead to attachment (Baylis, 2006; Feldman et al., 2007; Leaper, 2000; Schore, 2003; Siegel, 2001). Glaser (2000) describes attachment as '... proximity-seeking behavior by a dependent organism (infant or child) when he or she experiences discomfort of any sort ...' (p. 102). Parental relationships are often one's first experience with affiliation, attunement and attachment, one of a myriad of complex factors (genetics, personality, other environmental influences such as trauma or stress) that can influence emotional regulation and cognitive development (Calkins, Smith, Gill, & Johnson, 1998; Eisenberg, Smith, Sadovsky, & Spinrad, 2004; Kramer, 1993; LeDoux, 1996; Liu, Diorio, Tannenbaum, Caldji, Francis, Freedman, Sharma, Pearson, Plotsky & Meaney, 1997; Panksepp, 2003; Perry, 2002, 2006; Tamaroff et al., 1986; Van der Kolk, 2003; Woltering & Lewis, 2009).

Children who experience stress and trauma, especially when it is in the context of family may experience difficulties with neurodevelopment related to self-regulation as a result of disrupted affiliation, attunement and attachment processes. The question is can interaction with others, particularly non-human beings, modulate emotional regulation processes and stress reactions that have been established and specifically can it modulate cortisol levels in children who have experienced trauma? It is important to explore what is known about how human animal interaction (HAI) might establish a safe relationship that includes safe touch and proximity. Finally what if any impact does the interaction have on a therapeutic animal? A review of the animal and human research related to affiliative relationships, neurodevelopment and the experience of stress is warranted.

Animal research

Meaney and colleagues appear to have established a connection between early experience of stressors in mother–pup rodent interactions and long-term implications for hippocampal synaptic development and function (Liu et al., 1997). The hippocampus is important to memory as well as spatial thinking, or mapping (using the mind's eye) and plays an important role in cognitive processes and learning. Other studies indicate that variations in maternal care in infancy appear to regulate the development of stress reactivity (Caldji, Diorio, & Meaney, 2000). Enhanced sensitivity is known as kindling and it plays a role in the neuroplasticity of the brain in that it enhances sensitivity to later forms of enrichment (Glaser, 2000; Kramer, 1993). Bredy and colleagues found a partial reversal in cognitive function through the use of environmental enrichment, specifically maternal care (Bredy, Humpartzoomian, Cain, & Meaney, 2003). Maternal care appears to affect hippocampal glucocorticoid receptors and hypothalamic-pituitary-adrenal (HPA) responses to stress, and adversity in early life. It appears developing brains can be impacted by both trauma and/or neglect (which can cause kindling) as well as enriched environments (which can contribute to resilience).

The notion that environmental enrichment and nurturing practices in rats can contribute to partial reversal of the effects of stress/trauma is encouraging for human health. Healthy development in mammals is based on consistency in caregiver relationships that are responsive, and nurturing contributes to resilience in the face of adversity.

Human research

Bowlby (1958) and Ainsworth (1964, 1970, 1989) defined the role attachment plays in healthy developmental processes in children. Research across social science disciplines (nursing, social work, psychology) has shown that influences on early social affiliation, attunement and attachment are predictors of risk and resilience (Anderson & Seita, 2006; Antonucci, Akiyama, & Takahashi, 2004; Leichman et al., 2003; Thompson et al., 2003; Trevarthen, O'Connor, Hennighausen, & Lyons-Ruth, 2003). Combs-Orme (in press) has recently identified the importance epigenetics plays in social work's understanding of the impact of the environment on individual change, citing research that supports the passing on of some of these changes for generations. Affiliative interactions in humans contribute to neural processes of cognition utilising those same conduits of emotion, touch and proximity that we see in non-human animals (Feldman et al., 2007; Lewis, 1995, 2005a, 2005b, 2007; Putnam, 2007; Schore, 2003; Thompson, Lewis & Calkins, 2008; Todd & Lewis, 2008). Passive (neglect) or active (abuse) experiences during key stages of growth could be disruptive to attachment relationships and impact neuro pathways in the developing brain (Curtis & Cicchetti, 2003; Putnam, 2005). It is expressed as delays in growth, language, poor impulse control (emotional regulation), hyper vigilance and a lack of social ability in children. Research data show that the introduction of environmental enrichment at key junctures in development may counter the effects of stress and impact self-regulation (Lupien, McEwen, Gunnar, & Heim, 2009).

Pleasant touch plays an important role in environmental enrichment. It activates the seeking, pleasure and reward centre circuits of the brain, provoking emotion. This also activates the orbital frontal cortex (OFC) and the anterior cingulate cortex (ACC); parts of the cerebral cortex that play a role in cognition such as decision making, higher order cognitive processes and executive function (Critchley et al., 2003; in Luu & Posner,

2003; Phillips, 2003). Emotion and responsiveness provoke the release of neuropeptides such as oxytocin and vasopressin which results in feelings of security or warmth and contributing to stability in the development of the brain (Lewis & Stieben, 2004; Panksepp, 1998; Uvnas-Moberg, 1997). Emotion is important to the overall development of cognition and emotional development and regulation are processes related to the function of the ACC and the PFC (Lewis 1995, 2005a; Woltering & Lewis, 2011). Responsive and nurturing touch in infancy assists children as they age in their non-verbal ability to monitor future interactions and filter how external information is interpreted in the development of social bonding behaviour (Hofner, 1985; in Tortora, 2006, 2010). Body experiences resulting from touch and proximity to others become significant for trauma recovery in children who have not had the 'neurological safety' (Tortora, 2010, 39) required to maintain optimum cognitive and neurobiological development. Replicating these body experiences in therapeutic interaction is the rationale for programmes such as Theraplay (Jernberg & Booth, 1999) and Best Start Programs, where intensive interaction with others is utilised to provide an enriched environment and to stimulate early childhood development.

This is where animal-assisted therapy may be useful by providing stimulation, touch and proximity in ways that may stimulate seeking behaviour or responsiveness in the child. Seigel's work (2001) iterates that these kinds of body experiences might provide a context within which new synapses in the brain can develop. Social bonding behaviour relies on successful development of attachment relationships with caregivers and attachment appears to play a role in mitigating fear or anxiety (Carter, 2003). Some research challenges the notion that attachment to a primary caregiver alone is required to mitigate stress and perhaps attunement or sensitivity from caregivers and others is just as significant (Gunnar, 2003). The role these affiliative relationships have on brain development is important to understanding how to replicate these interactions in therapeutic encounters.

Neurobiology and trauma

The Diagnostic and Statistical Manual of Mental Disorders, fourth edition, Text Revision (DSM-IV-TR; American Psychiatric Association [APA], 2000) defines trauma as 'direct personal experience of an event that involves actual or threatened death or serious injury, or other threats to one's physical integrity' (Criterion A1, 463). Attachment can create resilience in the face of current and future stress and trauma, but there are events that can impact the trajectory of neurodevelopment in children (Glaser, 2000; Zeki, 2007; Schore, 2003).

A host of literature recognise that most children who experience traumatic symptoms do so as a result of maltreatment (abuse, neglect) and this can coincide with disrupted attachment with primary caregivers (Aisenberg & Mennen, 2000; Breslau, Wilcox, Storr, Lucia, & Anthony, 2004; Cicchetti & Lynch, 1993; Curtis & Cicchetti, 2003; Glaser, 2000; Graham-Berman, DeVoe, Mattis, Lynch, & Thomas, 2006; Henry, Sloan, & Black-Pond, 2007; Kramer, 1993; Perry, 2006; Van der Kolk, 2003). Stress is particularly offensive to developing brain systems, causing long-term changes to the HPA circuit and developmental stages of growth impairing the brain's ability to self-organise effectively and interfering with self-regulatory brain processes (Bredy et al., 2003; Glaser, 2000; Kramer, 1993; Lewis, 2005a; Nelson, 2000; Perry, 2006; Putnam, 2005). This implies a complex synaptic relationship between environment, cognition and physical response to trauma (Meaney, 2001). Both Nelson (2000) and

Putnam (2005) underpin the importance of the hypothalamus in the role it plays in translation of stress into brain responses. Lewis and Todd (2007) assert that the study of post traumatic stress disorder (PTSD) provides some insight into how these ‘vertical’ developmental processes can be compromised and highlight the role this plays in self-regulation. The plasticity of the cortical area (ACC and PFC) would make the age at which children experience maltreatment essential to their eventual capacity to self-regulate. The ACC is an important hub for self-regulations (and therefore, resilience), and better self-regulation can down-regulate cortisol secretion in the face of stressors. Benarroch (2012) describes this process as part of a ‘central autonomic network’ or a multilayered integrated process of ‘moment-to-moment control of visceral function, homeostasis and adaptation to internal and external challenges (p. 9).

The role of cortisol

One of the by-products of interrupted attachment is feelings of insecurity and the development of hyper arousal (fear system) which affects the function of the HPA axis, resulting in a flood of chemicals in the brain. In particular, children will experience cortisol (stress hormone) levels that are indicative of a stress response. Normal cortisol levels in children peak in the morning and drop gradually through the day (Gunnar, Morison, Chisholm & Schuder, (2001); Larson, White, Cochran, Donzella, & Gunnar, 1998; Price, Close, & Fielding, 1983; White, Gunnar, Larson, Donzella, & Barr, 2000). Researchers have determined that different kinds of stress or trauma, in addition to the consequential anxiety and/or depression can result in disrupted patterns of cortisol production (Dozier et al., 2006; Ramsay & Lewis, 2003; Willoughby, Vandergrift, Blair, & Granger, 2007; Yehuda, 2006). For example children who have experienced separation from a primary attachment figure will have different patterns of cortisol levels over a 24 hour period than children who have experienced maltreatment or sexual abuse (Cicchetti & Rogosch, 2001). Repeated exposure to trauma impacts basal (minimum level to maintain normal functioning) cortisol levels (Bevans, Cerbone, & Overstreet, 2008; Elbert, Heim, & Rockstroh, 2001). Disrupted basal and diurnal (expected highs and lows over 24 hours) cortisol rhythms may impact other self-regulating systems in the brain that controls emotion for example (Dozier et al., 2006; Fisher, Gunnar, Dozier, Bruce, & Pears, 2006; Schuengel, Oosterman, & Sterkenburg, 2009).

Overall the literature appears to support that buffering of stress levels may have a positive effect on neurobiological and physiological stress responses in development. Developing therapeutic interactions that can buffer these responses in traumatized children is challenging. Therapeutic human animal interactions may be useful in this regard.

Therapeutic HAIs

One of the burgeoning areas of interest in social work is HAI, specifically animal-assisted therapy. A meta-analysis that reviewed the efficacy of HAI interventions noted some promising results; however, it cautions that there is a need for further rigorous study (Nimer & Lundahl, 2007). These kinds of interventions, the concerns they seek to address and the short- and long-term outcomes are difficult to measure (McCardle, McCune, Griffin, Esposito, & Freund, 2010). Some social work literature is far more critical of HAI claiming it is based on pseudoscience and emphasising

the importance of an ‘evidence based’ approach in the use or endorsement of any intervention (Gambrill, 2001, 2003; Gilgun, 2005; Marino & Lilienfeld, 2007; Saleebey, 1997; Thyer & Pignotti, 2010; Wakefield, 1995). Thyer and Pignotti (2010) discuss some of the claims specifically being made about equine-assisted therapies, in particular psychotherapies without the support of rigorous high quality research, the lack of capacity to build on prior knowledge and an over reliance on anecdotal evidence. Rigorous research is a key to having HAI recognised as efficacious and it requires succinct and measured approaches. Understanding the neurobiology of interaction with others as aspects of environmental enrichment lends itself to an understanding of how HAI might be useful as a social work strategy.

Human–animal interaction research suggests that these relationships can be therapeutic for humans in ways that are similar to traditional therapeutic approaches to healing (Frewin & Gardiner, 2005; Friedmann, Katcher, Lynch, & Thomas, 1980; Jorgenson, 1997; Katcher, 1980; Katcher, Friedmann, Beck, & Lynch, 1983; Lagoni, Butler, & Hetts, 1994; McCardle et al., 2010; Yorke, Adams, & Coady, 2008). The psycho-physiological evidence indicates that companion animals impact humans by lowering blood pressure, quieting the autonomic nervous system, calming cardiovascular activity, provoking responses in oxytocin and vasopressin as well as cortisol and promoting physiological relaxation (Friedmann, Katcher, Thomas, Lynch, & Messent, 1983; Odendaal, 1999, 2000; Shiloh, Sorek, & Terkel, 2003; Uvnas-Moberg, 2009; Virues-Ortega & Bruela-Casal, 2006; Wilson, 1991).

Research with companion animals is also beginning to demonstrate that human–animal relationships share some aspects of attachment to human-to-human relationships as described in Bowlby’s (1958, 1988) attachment theory (Crawford, Worsham, & Swinehart, 2006; Prato-Previde, Custance, Spiezio, & Sabatini, 2003; Taggart, unpublished). Clinical research indicates that animals respond similarly to children when exposed to the Ainsworth’s Strange Situation Test (Ainsworth, 1970). Animals mobilise the attention of children, calm agitated behaviour and ameliorate emotional crises (Boat, 2006; Hart, 2000; Katcher & Wilkins, 1997; Strand, 2004).

The use of horses for therapeutic purposes (hippotherapy) has received increasing attention in a variety of healthcare disciplines (Bass, Duchowny, & Llabre, 2009; Bizub, Joy, & Davidson, 2003; Engel, 1997; Haylock & Cantril, 2006; Kaiser, Spence, Lavergne, & Vanden Bosch, 2006; Strauss, 1991). Horses are more recently being used in mental health therapeutically and researchers have studied the effectiveness as interventions for people with psychological and mental health problems with some results that have indicated it is effective and others concluding it is not (Christian, 2005; Ewing, MacDonald, Taylor, & Bowers, 2007; Karol, 2007). Research that investigates therapeutic riding has explored effectiveness increasing children’s self-esteem and self-confidence (Cawley, Cawley, & Retter, 1994; Davis, 2009; Shultz, Remick-Barlow, & Robbins, 2007; Taylor, 2001), reducing acting-out behaviour in adolescents (Ewing et al., 2007; Trotter, 2006) and anger in boys (Kaiser et al., 2006), providing an alternative for trauma recovery for a rider (Yorke, 2003; Yorke et al., 2008) and serving as a conduit for other therapies (Brooks, 2006; Taylor, 2001; Trotter, 2006; Tyler, 1994). Equine–human interaction research has indicated that children with autism improve social functioning (Bass et al., 2009) and self-regulation (Gabriels et al., 2012). Overall, there is an absence of rigorous biobehavioural research to support the efficacy of this kind of intervention for improved health in either human or animal participants.

The case for HAI as a biobehavioural intervention

Animal research has clearly demonstrated the relationships between the structures of the brain and experience, including the effects of nurturing on developmental neurobiology (Bredy et al., 2003). Current research confirms that many neural processes in brain development across species are the same, albeit that human cortical activity is more complex and many aspects of development are, as a consequence, still unknown (Panksepp, 1998). The research related to the impact of affinity, attunement, attachment, specifically related to touch, proximity, safety and trust makes a good case for a similar effect resulting from interspecies interaction (Bredy et al., 2003; Carter, 1998; Fleming, O'Day, & Kraemer, 1999; Liu et al., 1997; Noriuchi, Kikuchi, & Sino, 2008). Some specific research in HAI indicates that it can modulate stress levels (cortisol) and impact neuropeptides (oxytocin and vasopressin) in ways that might be useful therapeutically (Gabriels et al., 2012; Uvnas-Moberg, 2009; Viau, Arseneault-LaPierre, Fecteau, Champagne, Walker & Lupien, 2010). Finally, research also supports the process of self-organisation of the brain as a mechanism for creating resilience and it promotes the idea that adaptation is ongoing. The extent to which neurobiological development is enhanced by a supportive and enriched environment, and what periods of child development afford an opportunity for intervention is becoming clearer (Lewis & Todd, 2007; Putnam, 2005; Van der Kolk, 2003).

Enriched and challenging environments impact aspects of development in infants and young animals as well; exposure to stimulating contexts appears to be prophylactic (Johnson, 2000; Nelson, 2000). Children might naturally seek affiliative relationships that are rewarding in this way. Phillips (2003) talks about the role of oxytocin and vasopressin in the brain systems focused on liking, and dopamine in the brain system focused on wanting, and their inevitable connection to pleasure. Seeking behaviour would be indicative of the need humans and animals have for tactile interaction with each other that appears to be related to pleasure (Phillips, 2003). It follows that this relationship has the strong potential to contribute to positive neurological development as a consequence. This opens the door to the use of interspecies interaction as a mechanism to promote healthy neurobiological development through the use of touch, proximity and the evocation of emotion, such as pleasure and reward seeking behaviours, at particular times in the developmental processes. Woltering & Lewis (2009) discuss emotional regulation as integrated mechanisms of emotional control, indicating that strategies to intervene that are 'emotionally engaging and contextually realistic' (166) could be useful for children, targeting the part of the brain, the anterior cingulate cortex (ACC) as an example that mediates regulatory style. Benarroch's (2012) discussion of a central autonomic network and its role in self-regulation and consequently down-regulation of cortisol secretion could play a role in some synchrony between human and animal.

Conversely it is important to be cautious about the research that provides neurobiological support for the impact of the interspecies interaction premise as it is sparse. Lupien and colleagues have participated in one study that measures the relationship between enriched environments in children and proficiency in education (Lupien, King, Meaney, & McEwen, 2000; Lupien, King, Meaney & McEwen, 2001). This study is important because it attempts to apply a body of literature amassed in animal science to humans. It is apparent however that research focusing directly on interspecies interaction and the neurobiological impact for both human and animal is lacking.

The studies discussed in this article were designed to measure stress responses in four children identified as traumatised and the horses they interact with in a therapeutic riding programme, over 12 days, which includes six days of riding. These are unique studies in that they measure cortisol rates in both children and horses and it looks for synchronicity in child–horse pairs. The meta-analysis discussed here is part of a broader study that includes individual analysis of eight single system designs. This article discusses the meta-analysis performed on the cross-correlations of the cortisol levels in the four child–horse interactions in that study. The purpose of this meta-analysis is to gauge the overall effect size of in-tandem fluctuations of cortisol in the four child–horse pairs.

Hypotheses and variables

Dependent variables were cortisol levels. Independent variables for children were drawing pictures, writing stories, grooming and being groomed and riding and being ridden. Independent variables for horses were resting and being groomed and ridden. Heart rates are not reported in this article.

It was hypothesised that HAI generates positive affiliation, attunement and/or attachment, all of which may have a modulating (response to kindling) or prophylactic effect (resilience) on the traumatised child. The hypothesis posed in this study was:

- (1) After ongoing interaction between traumatised children and therapeutic riding horses, both the children's and the horses' heart and cortisol levels will fluctuate in tandem.

Methodology

Participants

Children who were eight to ten years of age, not using medication, meeting the criteria for PTSD using the Child Post Traumatic Stress Disorder Symptom Scale or CPSS (Foa, Johnson, Feeny, & Treadwell, 2001) and not violent were recruited for the study. They were recruited through child welfare agencies in the same geographical region as the farm, through a women's shelter, paediatric psychiatrist and family counselling service as well as the waiting list for the farm where the study took place. A total of seven children were screened, two did not meet the criteria, one child dropped out at the last minute. Screening included contacting child welfare organisations, asking them to broker contact with parents of children who might meet the criteria, getting consents signed to get access to the families and making contact. This included a presentation to the agencies, organising interview times at the agencies and screening children there, preliminary discussion with parents to describe the study and meetings with the clinical supervisors in the agencies to discuss criteria for participation.

Horses were chosen from the available mounts at the therapeutic riding facility and matched to children by coaches certified through the Canadian Therapeutic Riding Association (CanTRA) according to size and personality. The study included eight single subject designs, and four child–horse pairs.

Study design

Single subject design was chosen at this stage to establish dosage (frequency, length of interaction) and observe the subtle effects of HAI that might be missed in a larger group

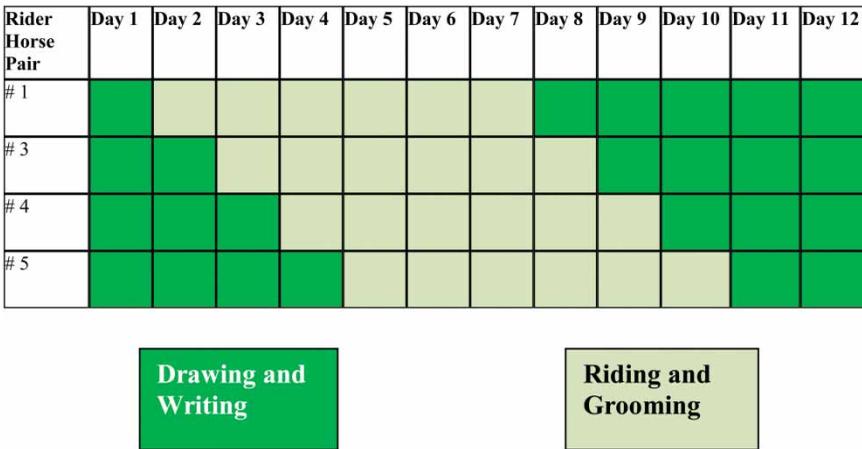


Figure 1. Multiple baseline single case design.

design. An ABCBA single case design, with multiple baseline elements, was used in the study. The phases of this single case design are as follows (Figures 1 and 2). The first baseline (A) phase involved the collection of three samples of cortisol a day, one day a week, for three weeks. The day of the week (Tuesday, when the principal investigator was available) the samples were collected was specifically chosen so the horses and children could be tested on the same day. Baseline samples for children were taken in the child’s home by her or his guardian, with one measure taken in the morning upon awakening, one in the middle of the day, after school, and one late in the evening, before bed. Horse baseline samples were collected at the same times, in their stalls at the farm, allowing 30 minutes without food. The STAIC-Trait Inventory

Multiple baseline	<ul style="list-style-type: none"> • Each child/horse pair added daily to riding program • Alternates Phases B/C & C/B for 6 days
Phase A	<ul style="list-style-type: none"> • Baseline collection of cortisol • Child at home, horse in barn • Prior to intervention (Phases B & C) and follow up
Phase B	<ul style="list-style-type: none"> • Child at the farm • Drawing a picture • Writing a story • Before or after intervention (Phase C) • Not in contact with the horse
Phase C	<ul style="list-style-type: none"> • Child at farm in barn • Horse in barn • Grooming (15 minutes) • Riding (30 minutes) • Grooming (15 minutes)

Figure 2. Phases of the study, three weeks, one day a week for baseline and follow up, 12 days for the intervention, six days for drawing pictures and writing stories, six days for riding and grooming.

was administered in this phase, prior to the beginning of the B phase (Spielberger, 1973; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 2008). In the B phase, children came to the farm, the location for the therapeutic riding programme, for one hour a day to draw a picture and write a story. The STAIC-State was administered before and after each drawing and writing session by the same team member (the principal investigator and social work student). During this phase the children's heart rate was monitored while they were drawing and writing, and their cortisol levels were measured every 20–30 minutes.

The C phase was the intervention. It involved the children coming to the farm for an hour. During this hour, participants groomed a horse for approximately 15 minutes, rode the horse for approximately 30 minutes and then groomed the horse for another 15 minutes. Cortisol was collected during this phase every 20–30 minutes, and the children's heart rates were continuously monitored. When children were riding the horses, they were video-taped for five minutes at the beginning and five minutes at the end of each riding session with the child.

The second B phase had the child come to the farm for one hour per day for drawing and writing. Cortisol levels and heart rates were collected as described above for the first B phase. The concluding A phase of the study was identical to the first A phase.

Salivary cortisol assay analysis

Saliva samples were thawed to a maximum of 4–8°C over eight hours before they were tested. Saliva samples were analysed using ELISA assay kits by Dia Metra according to the protocol described in the kit. Each kit provides 96 sample readings on a micro plate, including seven standards. Samples were systematically divided across baseline, study and follow-up samples, for both children and horses, and distributed across the 26 plates. Each sample was tested twice for accuracy. Missing samples were left blank. Samples were processed according to the Dia Metra kit instructions. Standards were calculated and charted for each plate. Raw data were converted to actual cortisol amounts using a four-parameter logistical equation in the KC junior software in the micro plate reader, as indicated in the Dia Metra Elisa kit instructions. Duplicate samples were averaged after completion of the conversion. Cortisol sample results were then charted according to baseline, study and follow-up results for each child and horse.

Reference values, accuracy, specificity and sensitivity

The immunoassay ELISA kit provides preliminary guidelines for cortisol values of 3–10 nanogram per millilitre (ng/ml) in the morning and 0.6–2.5 ng/ml in the evening. Intra- and inter-assay variations are 7% and 9.3%, respectively. Specificity of the cross-reaction of the antibody calculated at 50% with an average of $\pm 6.3\%$. Sensitivity indicates that the lowest detectable concentrations of cortisol that can be distinguished from the zero standard are 0.05 ng/ml at the 95% confidence limit.

Meta-analysis

Meta-analyses provide a practical statistical approach to determining the impact of a specific intervention. Ideally they would provide a relevant accumulative sample size for studying the impact of interventions in similar quantitative studies. With single subject designs, sample sizes are intentionally not the focus – identifying small and

subtle effects of the intervention and, in this case, identifying what effects would be most useful to study in a group design, was the goal. Meta-analysis was a useful way to gauge the accumulative effect size of the cross-correlation in equine–human interaction in these studies. It also provides a baseline for future studies with this population using an identical methodology, for comparison.

Time series analysis

Time series analysis allows the researcher to analyse a collection of data points that occur in a sequence or series, over a specific period of time (Chatfield, 2004). Analysis of data can be used to describe the data by plotting it, explain the changes in the data from point to point, and the results may be useful to predict or control future interventions. Issues of autocorrelation and understanding of the relevance of moving averages can assist in explaining how patterns emerge and relate to other time series data. Autocorrelation is the correlation that may exist between repeated patterns of time series data (in this case data from both a child and a horse). These kinds of results may indicate a lag effect between the two data series although, in this case, data were not tested for lag time correlation. Moving averages meant that samples one through four were averaged, then two through five, three through six and so on were combined and averaged (see Figures 4–7).

Results

A meta-analytic technique was used to estimate the mean cross-correlation between child/horse cortisol levels during the riding phase. This meta-analytic technique has been described by Field (2001). This method is a random effects model for doing a meta-analysis of correlations (Hunter & Schmidt, 1990). It is designed to take into account sampling error associated with the numbers of observations for each child, as well as sampling error associated with the sample of four child/horse pairs. It is a more conservative approach than a fixed effects analysis method, which takes into account only the first of these levels of sampling variability. In addition, graphs of moving averages (four point) or ‘smoothing out’ of the data are used to compare both horse and child cortisol levels across the 12 days of the intervention (Figures 4–7).

A lag-zero cross-correlation was calculated for each child/horse pair. Then, following the method described by Field (2001), the weighted mean cross-correlation for the four child/horse pairs was calculated, along with the standard error of this sample mean cross-correlation.

Participant pairs	Pearson r (correlation)	(weighted mean)	Standard error	95% Confidence interval		Weighted overall mean	Z statistic
Child/horse pair 1	.278	5.84	.076	.08	.38	.2261905 or .23	3.03 ($p < .001$)
Child/horse pair 3	.447	9.39					
Child/horse pair 4	.146	3.07					
Child/horse pair 5	.041	.7					

Figure 3. Table of random effects model correcting for autocorrelation.

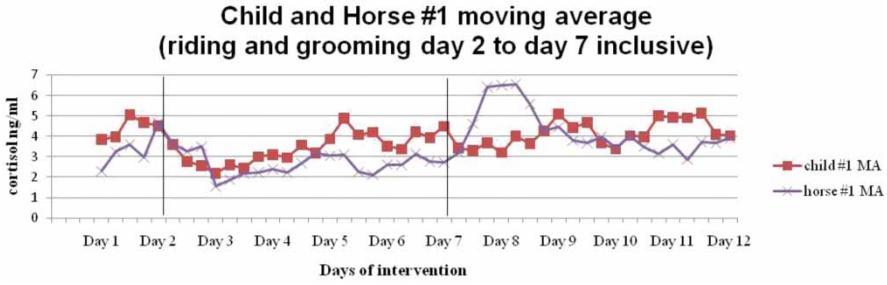


Figure 4. Cortisol pattern for both child and horse #1 across both phase B (drawing and writing) and phase C (riding and grooming).

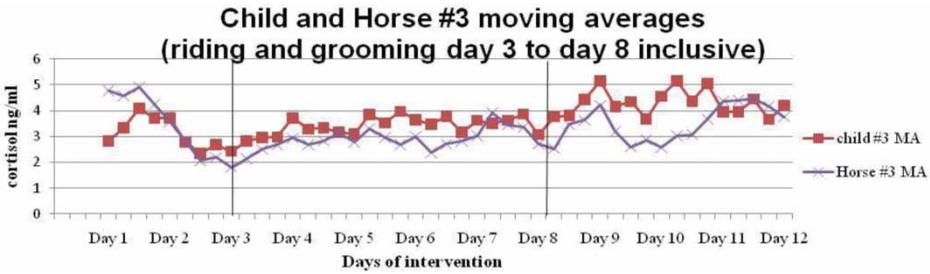


Figure 5. Cortisol pattern for both child and horse #3 across both phase B (drawing and writing) and phase C (riding and grooming). This child missed day 6.

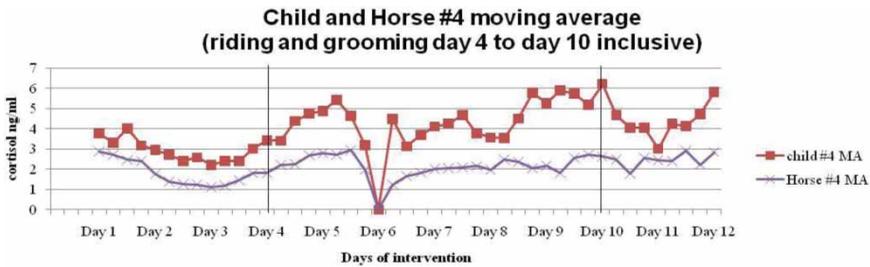


Figure 6. Cortisol pattern for both child and horse #4 across both phase B (drawing and writing) and phase C (riding and grooming). This child missed day 6.



Figure 7. Cortisol pattern for both child and horse #5 across both phase B (drawing and writing) and phase C (riding and grooming). This child missed day 6.

Cross-correlation and autocorrelation

Estimates of cross-correlations can be biased by autocorrelation in time series (Chatfield, 2004; Nugent, 2010). It has been recommended that time series data have autocorrelation removed prior to computing estimated cross-correlations, a process referred to as 'whitening' or 'pre-whitening' the time series (Chatfield, 2004). Briefly, this is done by first identifying autocorrelation patterns in the time series using the autocorrelation and partial autocorrelation functions. The whitened time series for a child's cortisol level can be thought of as the cortisol level with autocorrelation removed. The meta-analytic method described above is then applied to the cross-correlations estimated from the time series with autocorrelation removed. Figure 3 shows the results using this analytic methodology.

The weighted mean cross-correlation, controlling for autocorrelation, was 0.23, $Z = 3.03$, approximately 95% confidence interval $0.23 \pm (1.96 \times 0.076)$ or 0.08–0.38. These autocorrelation corrected results were also consistent with the research hypothesis (Figure 3).

Discussion

These small studies contribute to the current literature on equine-assisted interventions in that they demonstrate some correlation between the child–horse pairs. Overall the weighted mean (0.23) and the Z -statistic which calculates effect size (3.03, $p < 0.05$) indicated that there was a mild to moderate symmetry collectively between the child–horse pairs. This could be random, the result of the short period of time the pairs spent together, or a product of child–horse matching. In the co-relational data analysis, it was determined that only one child's time series of data (child number five) and one of the horses (horse number three) experienced autocorrelation.

One would expect to see no reaction in cortisol levels or a minimal reaction between children experiencing PTSD and the horses they ride for only six days which makes the results of this study compelling. Further investigation of the process rather than outcome of these child–horse interactions could shed some light on protocol for programming in therapeutic riding programmes specific to traumatised children. It may also rely on the history and experience of the horses, how stressful the barn and participating in the programme is, and what impact exercise of any kind has on lowering cortisol levels for humans and animals.

Implication of the study for current theory, limitations and future research recommendations

Such interventions may be especially useful for traumatised children who are neuro-physiologically dysregulated, providing an attunement with another being that soothes through touch, proximity and the development of trust. Marino and Lilienfeld (2007) in particular notes the fleeting nature of the measured impact HAI has in most studies. If, however, HAI can be used strategically at important junctures in neurobiological development, the short-term effect may garner long-term consequences.

Changes in neurobiology as a result of HAI suggest that further investigation is warranted. Research that has measured cortisol levels and plasma levels of neuropeptides and neuromodulators, specifically endorphins, oxytocin, prolactin, phenylethylamine and dopamine in dogs and humans interacting suggests that human–animal relationships can mitigate stress responses (Odendaal, 1999, 2000; Odendaal & Meintjes,

2003; Uvnas-Moberg, 2009). A recent study by Viau and colleagues (2010) found that cortisol awakening responses (CAR) in autistic children were impacted by the presence of a service dog.

There are some obvious limitations to this meta-analysis and the single case designs included in them. It is difficult to measure physiological changes in children and just as difficult to interpret the results (Carter, 2003). There was some interference from parents, the outcomes could have been affected by season, attitudes towards horses or the fact that interaction with horses was a new experience. There are similar cautions in the literature regarding measuring and interpreting cortisol levels in animals (McGreevy, 1995; Pell & McGreevy, 1999). Children who participated in the study were not chosen from a large sample randomly. The horses were not randomly chosen either and the matching of child to horse was not random.

Future research should focus on the process as well as the outcome of HAIs. Variations in age, severity of PTSD as well as dosage (length of time riding), child–horse matching and context (coach, volunteers) can all play a role in the impact of the interaction. Longitudinal studies that follow up on children involved in these programmes would provide some insight regarding the impact HAI may have on developmental neurobiology in traumatised children.

Conclusion

This is an exploratory investigation, the results of which suggest that a larger study looking at coordination of cortisol secretion patterns between a therapy horse and a rider with PTSD is warranted. A longer intervention and larger sample may lead to the discovery of a stronger effect. This study is useful because it focuses on the interaction between humans and animals, specifically on the synchronicity in the child–horse pairs. Understanding how species respond to each other neurobiologically may provide some insight into how animal-assisted therapy can be useful for children affected by trauma and has promise as an animal welfare measure as well.

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