Review

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Measuring Horse-Human Emotional Contagion: A Systematic Review of Methods and Outcomes

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Simple Summary: Understanding how emotions are shared between horses and humans is important for improving animal welfare and enhancing human-animal interactions. This study reviews different methods used to measure emotional contagion—the process where emotions transfer from one individual to another—between horses and people. Researchers have used various techniques, including observing horse behavior, measuring heart rate, and analyzing stress-related hormones to understand how horses respond to human emotions. The findings suggest that horses are highly sensitive to human emotional states and can react accordingly, which has implications for training, sports, and therapy. However, there are challenges in creating standardized methods to measure these emotional exchanges accurately. The study highlights the need for combining behavioral observations with physiological measurements to better assess horse emotions and their interactions with humans. This research is valuable for improving horse care, refining training techniques, and advancing equine-assisted therapy, ultimately benefiting both horses and humans.

Abstract: The study explores the phenomenon of emotional contagion between horses and humans, an area of growing interest in equine research due to its implications for welfare, training, and therapy. By conducting a systematic review of existing literature, the research identifies and evaluates methodologies used to measure emotional transfer in horse-human interactions. The review includes behavioral assessments such as body language, facial expressions, and vocalizations, alongside physiological indicators like heart rate, heart rate variability, and cortisol levels. Findings indicate that body language is the most frequently utilized behavioral measure, while heart rate and heart rate variability dominate physiological assessments. The review highlights the advantages of combining behavioral and physiological approaches to provide a comprehensive understanding of emotional states in horses. However, inconsistencies in methodological approaches and a lack of standardized evaluation frameworks pose challenges to advancing research in this field. The study concludes that interdisciplinary collaboration and the integration of emerging technologies, such as artificial intelligence and wearable devices, are crucial for enhancing the accuracy and reliability of emotional contagion assessments in equine science. These findings provide valuable insights that can inform evidence-based practices aimed at improving horse welfare and optimizing human-horse interactions.

Keywords: horse-human interaction; emotional contagion; equine behavior; physiological indicators; behavioral assessments; heart rate variability; animal-human bond

1. Introduction

Emotions in animals are intricate and multifaceted phenomena that play a vital role in their survival, social interactions, and overall well-being. These adaptive mechanisms have evolved over millennia to enable animals to respond appropriately to environmental challenges and opportunities, such as avoiding threats, pursuing rewards, and fostering social cohesion [1–3]. In horses, emotions are expressed through a range of measurable physiological and behavioral responses, making them a focal point for understanding equine welfare and their interactions with humans [4,5].

The scientific study of emotions in horses gained momentum in the late 20th century, coinciding with advancements in behavioral science, cognitive research, and physiological monitoring technologies [4,6,7]. These developments have not only enhanced our understanding of equine emotional states but have also underscored the significance of emotional contagion in horse-human relationships. Emotional contagion, defined as the transfer of emotional states between individuals, is a fundamental mechanism underpinning social communication and cohesion in many species, including horses [8].

Horses, as highly social animals, possess a sophisticated emotional repertoire that facilitates interactions within their species and with humans. They are acutely sensitive to environmental cues and the emotional states of conspecifics, as well as those of their human handlers. This sensitivity enables horses to respond to subtle emotional signals, fostering effective communication and coordination within social groups [9,10]. Research has shown that horses can detect human emotional cues, such as facial expressions and vocal tones, and adapt their behavior accordingly [11,12]. For instance, horses have been observed to differentiate between positive and negative human emotional expressions, responding more favorably to calm and relaxed individuals than to nervous or agitated ones [13].

Understanding the physiological and behavioral manifestations of emotions in horses is critical for advancing equine welfare. Physiological responses, such as changes in heart rate variability (HRV), cortisol levels, and eye temperature, provide objective measures of emotional states. HRV, in particular, has emerged as a valuable indicator of autonomic nervous system balance, reflecting the interplay between the sympathetic and parasympathetic branches [14]. High HRV is associated with relaxation and positive emotional states, while low HRV often indicates stress or emotional arousal [15]. Similarly, cortisol, a hormone commonly linked to stress, serves as a key biomarker for assessing emotional responses in horses. Cortisol levels can be measured using non-invasive methods such as saliva analysis, which minimizes stress during sample collection [16].

Behavioral indicators are equally important for evaluating equine emotions. Ethograms, which catalog specific behaviors associated with emotional states, have become a standard tool in this field. Behavioral responses such as ear and tail positions, vocalizations, and locomotion patterns provide visible clues to a horse's emotional state [9,17]. Advanced methodologies, including the Equine Grimace Scale (EGS) and the Equine Facial Action Coding System (EquiFACS), have further refined the ability to assess pain-related and emotional expressions through facial cues [12,18].

The study of horse-human emotional contagion has also benefited from technological advancements. Wearable devices for monitoring HRV and other physiological parameters have enabled researchers to collect data in real-time, reducing the potential for observer-induced bias [19]. These technologies, originally developed for human applications, have been adapted to equine research, offering unprecedented precision in measuring stress and emotional states during various activities, including training and therapy sessions. Emerging tools such as machine learning algorithms and neural networks are now being employed to analyze complex datasets, paving the way for automated emotion recognition in horses [20].

One of the most intriguing aspects of equine emotional research is the bidirectional nature of horse-human interactions. Studies have demonstrated that emotional states can be transferred not only from humans to horses but also from horses to humans, highlighting the dynamic interplay within this dyad [21]. For example, synchronicity in HRV between horses and their handlers during in-hand tasks underscores the depth of emotional connection and mutual influence in these

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relationships [22]. This finding has profound implications for equine-assisted therapies, where the emotional alignment between horse and human is often a cornerstone of therapeutic success.

Despite these advancements, several challenges remain in the study of horse-human emotional contagion. One significant hurdle is the lack of a standardized framework for interpreting physiological and behavioral data across different contexts. While HRV and cortisol levels are widely used as indicators of stress and emotional arousal, their interpretation can vary depending on factors such as the horse's baseline physiological state, environmental conditions, and individual temperament [4,23]. Similarly, behavioral assessments often rely on subjective observations, which may introduce variability in data collection and analysis [9].

The integration of behavioral, physiological, and technological approaches offers a promising pathway for overcoming these challenges. By combining ethological observations with advanced physiological monitoring and computational analytics, researchers can achieve a more holistic understanding of equine emotions. For instance, combining HRV analysis with thermal imaging and behavioral ethograms can provide a comprehensive view of how horses respond to specific stimuli, enhancing the reliability and validity of emotional assessments [14,23].

Moreover, interdisciplinary collaboration between fields such as veterinary science, cognitive psychology, and artificial intelligence is essential for advancing the study of equine emotions. Recent developments in wearable technology and machine learning have the potential to revolutionize this field by enabling continuous, non-invasive monitoring of emotional states in both horses and humans [24]. These innovations not only enhance research capabilities but also have practical applications in equine training, welfare, and therapeutic interventions.

The study of horse-human emotional contagion is an evolving field that bridges multiple disciplines, offering valuable insights into the emotional lives of horses and their interactions with humans. By systematically reviewing the methods and outcomes of this research, this paper aims to contribute to a deeper understanding of how emotions are expressed, shared, and influenced within the horse-human dyad. Such insights have profound implications for improving equine welfare, optimizing training practices, and advancing the therapeutic use of horses, emphasizing the need for a nuanced and interdisciplinary approach to studying these remarkable animals. This review aims to summarize the prevalence of different methods used to assess horse – human emotional contagion.

2. Materials and Methods

The objective of this study was to conduct a systematic review of the methodologies currently employed to evaluate emotional contagion between humans and horses. Emotional transfer between humans and horses plays a pivotal role in shaping their interactions, influencing behavior, welfare, and performance. This review aims to identify areas of consensus and highlight existing gaps in the evidence base regarding methods for assessing emotional contagion in horse-human interactions.

A systematic literature search was conducted using Google Scholar, Web of Science/Clarivate, Scopus, PubMed, and ScienceDirect. Keywords and search terms included "horse-human interaction," "horse emotional contagion," and "emotional transfer in horses." All articles from 1988 until 2023 that met the inclusion citeria were reviewed. .

2.1. Inclusion Criteria

Studies hypothesizing and investigating horse-human interactions with a focus on emotional arousal in horses.

Studies that provided clear methodologies for measuring horses' emotional states.

Peer-reviewed original research articles published in English

All the articles included are presented in Appendix A.

2.2. Exclusion Criteria

Studies that did not measure emotional arousal in horses.

Studies that did not examine horse-human interactions.

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2.3. Data Collection

The literature search, conducted between March 2023 and January 2024, identified articles relevant to horse-human emotional interactions and methodologies for assessing emotional contagion. References were managed using Zotero, an open-source reference management tool.

Titles, abstracts, methods, and conclusions of identified articles were screened. Publications were retained if they focused on horse-human relationships and met the inclusion criteria. Studies failing to address horse emotional arousal or horse-human interactions were excluded (Figure 1).

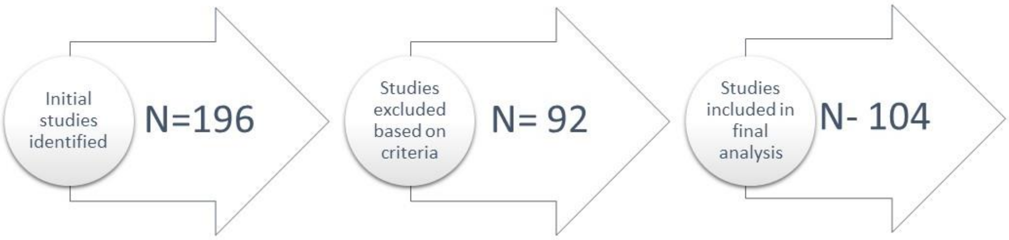

Figure 1. Phases of the study.

2.4. Data Extraction and Analysis

Included studies were systematically analyzed to extract data on methods used to assess horses' emotional states during interactions with humans. Extracted data included the study title, authorship, publication date, behavioral and physiological measures, and key findings as reported by the authors. Data were organized into extraction tables to facilitate comparison and synthesis of methodological approaches.

3. Results

3.1. Prevalence of Studies Measuring Emotions on Horses Solely or Horses and Humans Concomitently

In this review we introduced a number of 104 studies that met the inclusion criteria. From the studies included 68 focused only on horses (66.02%) whereas 35 (33.98%) examined both horses and humans.

Out of the 35 studies that examined both horses and humans, the distribution of measured parameters is presented in Table 1.

Table 1. The distribution of measured parameters in 35 studies that examined both horses and humans during interaction.

Measurement Type	Percentage (%)	Description
Heart Rate (HR) and HRV	28.57%	Studies focused on physiological parameters such as heart rate and heart rate variability, indicating a strong interest in physiological synchronization or autonomic responses of both species.
Body Language	14.29%	Studies analyzed human and horse body posture, gestures, and movement, emphasizing non-verbal communication and behavioral patterns.
Facial Expressions	20.00%	Studies explored facial recognition, human emotion perception, and horse responses to human expressions, shedding light on interspecies emotional recognition.
Other Constants	8.57%	Studies measured additional parameters such as cortisol levels, EEG, and other stress-related biomarkers, indicating a smaller but relevant focus on neurophysiological and hormonal responses.

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3.1. Behavioral Responses in Horses

Behavioral responses were predominantly measured through body language (73.1% of studies). Other behavioral measures included facial cues (13.5%) and vocalizations (3.8%). Notably, body language emerged as the most frequently analyzed indicator, given its observable nature and relevance in interpreting emotional states (Table 2).

The low percentage of studies involving facial cues and vocalizations could reflect the challenges in reliably interpreting these indicators in horses. Facial cues require fine-tuned observational methods, and vocalizations are less common and context-specific in equine behavior.

Table 2. Frequency and percentage distribution of behavioral indicators observed in horse-human interaction studies. The table presents data on facial cues, body language, and vocalizations across a sample of 104 observations. The results highlight the prevalence of these behavioral responses and their significance in assessing emotional states in horses.

		Facial Cues			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	90	86.5	86.5	86.5
	Yes	14	13.5	13.5	100.0
	Total	104	100.0	100.0	
		Body Language			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	28	26.9	26.9	26.9
	Yes	76	73.1	73.1	100.0
	Total	104	100.0	100.0	
		Vocalization			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	100	96.2	96.2	96.2
	Yes	4	3.8	3.8	100.0
	Total	104	100.0	100.0	

3.2. Physiological Responses in Horses

Physiological responses were primarily measured using heart rate (49%) and heart rate variability (30.8%). Cortisol levels were assessed in about 15% of studies, with variations in the type of cortisol measured (salivary, blood, or fecal). Less common physiological indicators included EEG (1%) and respiration (1.9%) (Table 3).

Heart rate and HRV, being non-invasive and relatively easy to monitor, were the preferred physiological measures. The infrequent use of EEG and respiration might be attributed to the technical complexity and potential stress induced by these methods during measurement.

Table 3. Frequency and percentage distribution of physiological indicators used to assess emotional states in horse-human interaction studies. The table presents data on heart rate, heart rate variability (HRV), cortisol levels (including blood, salivary, and fecal cortisol), EEG, and respiration across a sample of 104 observations. The findings illustrate the prevalence of each physiological measure and their role in evaluating stress and emotional responses in horses.

Heart Rate					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	53	51.0	51.0	51.0
	Yes	51	49.0	49.0	100.0
	Total	104	100.0	100.0	
Heart Rate Variance (HRV)					
		Frequency	Percent	Valid Percent	Cumulative Percent

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Valid	No	72	69.2	69.2	69.2
	Yes	32	30.8	30.8	100.0
	Total	104	100.0	100.0	

Cortisol

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	89	85.6	85.6	85.6
	Blood Cortisol	6	5.8	5.8	91.3
	Salivary Cortisol	8	7.7	7.7	99.0
	Fecal Cortisol	1	1.0	1.0	100.0
	Total	104	100.0	100.0	

EEG

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	103	99.0	99.0	99.0
	Yes	1	1.0	1.0	100.0
	Total	104	100.0	100.0	

Respiration

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	102	98.1	98.1	98.1
	Yes	2	1.9	1.9	100.0
	Total	104	100.0	100.0	

3.3. Comparison and Overlap in Measures (Horses)

A significant number of studies (approximately 76.5%) that measured heart rate also assessed body language. This suggests that combining behavioral and physiological responses enhances the reliability of emotional assessments.

Of all the studies examining body language, more than half of them also examine the heart rate of its subjects (n=39), while about 29% examine HRV as well (n=22). Vocalization (n=2) and facial ques (n=2) are involved in a lower number of the studies. Similarly, EEG (n=1) and respiration are (n=2) also less mentioned. Cortisol has a high count of mentions (Table 4).

Table 4. Frequency and percentage distribution of various physiological and behavioral indicators observed in horse-human interaction studies. The table presents data on vocalization, heart rate, heart rate variability (HRV), cortisol levels (including blood, salivary, and fecal cortisol), EEG, and respiration, highlighting their occurrence across a sample size of 76 observations. The results indicate the prevalence of each measure and its relative importance in assessing emotional states in horses.

Vocalization

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	72	94.7	94.7	94.7
	Yes	4	5.3	5.3	100.0
	Total	76	100.0	100.0	

Heart Rate

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	37	48.7	48.7	48.7
	Yes	39	51.3	51.3	100.0
	Total	76	100.0	100.0	

Heart Rate Variance (HRV)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	54	71.1	71.1	71.1
	Yes	22	28.9	28.9	100.0

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	Total	76	100.0	100.0	

Cortisol					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	65	85.5	85.5	85.5
	Blood Cortisol	4	5.3	5.3	90.8
	Salivary Cortisol	6	7.9	7.9	98.7
	Fecal Cortisol	1	1.3	1.3	100.0
	Total	76	100.0	100.0	

EEG					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	75	98.7	98.7	98.7
	Yes	1	1.3	1.3	100.0
	Total	76	100.0	100.0	

Respiration					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	74	97.4	97.4	97.4
	Yes	2	2.6	2.6	100.0
	Total	76	100.0	100.0	

All the studies that examine vocalization also examine body language (n=4). Half of them also examine heart rate (n=2) (Table 5)

Table 5. Frequency and percentage distribution of body language and heart rate observations in horse-human interaction studies. The table presents data on the occurrence of these behavioral and physiological indicators across a sample of 4 observations, highlighting their equal distribution in assessing emotional states in horses.

Body Language.					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	4	100.0	100.0	100.0

Heart Rate					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	2	50.0	50.0	50.0
	Yes	2	50.0	50.0	100.0
	Total	4	100.0	100.0	

77% of studies measuring heart rate, also involve the analysis of body language (n=39). While 53% analyze HRV as well (n=27) (Table 6)

Table 6. Frequency and percentage distribution of behavioral and physiological indicators observed in horse-human interaction studies. The table presents data on facial cues, body language, vocalization, heart rate variability (HRV), cortisol levels (including blood, salivary, and fecal cortisol), and respiration across a sample of 51 observations. The results highlight the prevalence of these indicators in assessing emotional states in horses, emphasizing the importance of combining behavioral and physiological measures for comprehensive evaluations.

Facial Cues					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	47	92.2	92.2	92.2
	Yes	4	7.8	7.8	100.0
	Total	51	100.0	100.0	

Body Language					

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		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	12	23.5	23.5	23.5
	Yes	39	76.5	76.5	100.0
	Total	51	100.0	100.0	
Vocalization					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	49	96.1	96.1	96.1
	Yes	2	3.9	3.9	100.0
	Total	51	100.0	100.0	
Heart Rate Variance (HRV)					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	24	47.1	47.1	47.1
	Yes	27	52.9	52.9	100.0
	Total	51	100.0	100.0	
Cortisol					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	42	82.4	82.4	82.4
	Blood Cortisol	3	5.9	5.9	88.2
	Salivary Cortisol	5	9.8	9.8	98.0
	Fecal Cortisol	1	2.0	2.0	100.0
	Total	51	100.0	100.0	
Respiration					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	49	96.1	96.1	96.1
	Yes	2	3.9	3.9	100.0
	Total	51	100.0	100.0	

A large majority of studies examining HRV (n=32) also examine heart rate as well (n=27). While, body language is also examined in 69% of the studies examining HRV (n=22) (Table 7).

Table 7. Frequency and percentage distribution of behavioral and physiological indicators in horse-human interaction studies. The table presents data on facial cues, body language, heart rate, and cortisol levels (including blood, salivary, and fecal cortisol) across a sample of 32 observations. The findings highlight the prevalence of these indicators, demonstrating their role in assessing emotional states and stress responses in horses.

Facial Cues					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	29	90.6	90.6	90.6
	Yes	3	9.4	9.4	100.0
	Total	32	100.0	100.0	
Body Language					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	10	31.3	31.3	31.3
	Yes	22	68.8	68.8	100.0
	Total	32	100.0	100.0	
Heart Rate					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	5	15.6	15.6	15.6
	Yes	27	84.4	84.4	100.0

	Total	32	100.0	100.0	

Cortisol					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	26	81.3	81.3	81.3
	Blood Cortisol	2	6.3	6.3	87.5
	Salivary Cortisol	3	9.4	9.4	96.9
	Fecal Cortisol	1	3.1	3.1	100.0
	Total	32	100.0	100.0	

All studies looking at fecal cortisol also analyze the body language and EEG of its subjects (n=1). Further, 4 studies involving blood cortisol also involve body language, while tree involve heart rate. In the case of salivary cortisol, 6 involve body language and 5 involve heart rate. 3 studies measuring Heart Rate Variance also measure Blood Cortisol, while another 3 measure salivary cortisol (Table 8, Table 9).

Table 8. Frequency and percentage distribution of cortisol levels in relation to behavioral indicators in horse-human interaction studies. The table presents data on the presence of facial cues, body language, and vocalization in horses, categorized by cortisol type (blood, salivary, and fecal). The results provide insights into the relationship between these behavioral responses and physiological stress markers, highlighting variations in cortisol levels across different observed behaviors.

		Cortisol							
		No		Blood Cortisol		Salivary Cortisol		Fecal Cortisol	
		Count	Column N %	Count	Column N %	Count	Column N %	Count	Column N %
Facial Cues	No	75	84.3%	6	100.0%	8	100.0%	1	100.0%
	Yes	14	15.7%	0	0.0%	0	0.0%	0	0.0%
Body Language	No	24	27.0%	2	33.3%	2	25.0%	0	0.0%
	Yes	65	73.0%	4	66.7%	6	75.0%	1	100.0%
Vocalization	No	85	95.5%	6	100.0%	8	100.0%	1	100.0%
	Yes	4	4.5%	0	0.0%	0	0.0%	0	0.0%

Table 9. Frequency and percentage distribution of cortisol levels in relation to physiological indicators in horse-human interaction studies. The table presents data on heart rate, heart rate variability (HRV), EEG, and respiration, categorized by different cortisol types (blood, salivary, and fecal). The findings provide insights into the relationship between physiological responses and cortisol levels, offering valuable information on stress assessment in horses. .

		Cortisol							
		No		Blood Cortisol		Salivary Cortisol		Fecal Cortisol	
		Count	Column N %	Count	Column N %	Count	Column N %	Count	Column N %
Heart Rate	No	47	52.8%	3	50.0%	3	37.5%	0	0.0%
	Yes	42	47.2%	3	50.0%	5	62.5%	1	100.0%
Heart Rate Variance (HRV)	No	63	70.8%	4	66.7%	5	62.5%	0	0.0%
	Yes	26	29.2%	2	33.3%	3	37.5%	1	100.0%
EEG	No	88	98.9%	6	100.0%	8	100.0%	1	100.0%
	Yes	1	1.1%	0	0.0%	0	0.0%	0	0.0%
Respiration	No	87	97.8%	6	100.0%	8	100.0%	1	100.0%

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Yes	2	2.2%	0	0.0%	0	0.0%	0	0.0%

The only study measuring EEG also measures body language (Table 10).

Table 10. Frequency and percentage distribution of body language observations in horse-human interaction studies. The table presents data on the occurrence of body language as a behavioral indicator, with all observed instances indicating its consistent presence in the sample.

Body Language					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	1	100.0	100.0	100.0

The two studies that focus on respiration also involve body language and heart rate (Table 11).

Table 11. Frequency and percentage distribution of body language and heart rate observations in horse-human interaction studies. The table presents data showing that both body language and heart rate were consistently observed across all recorded instances, emphasizing their potential importance in assessing equine emotional states.

Body Language					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	2	100.0	100.0	100.0
Heart Rate					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	2	100.0	100.0	100.0

Correlations			
		Heart Rate	Heart Rate Variance (HRV)
Heart Rate	Pearson Correlation	1	.471**
	Sig. (2-tailed)		.000
	N	104	104
Heart Rate Variance (HRV)	Pearson Correlation	.471**	1
	Sig. (2-tailed)	.000	
	N	104	104
**. Correlation is significant at the 0.01 level (2-tailed).			

3.4. Correlations

A positive correlation was observed between heart rate and HRV ($r = 0.47$, $p < 0.001$), indicating that studies often measure these indicators together to understand autonomic nervous system responses. In contrast, a negative correlation was found between body language and facial cues ($r = -0.52$, $p < 0.001$), implying that studies focusing on one are less likely to focus on the other (Table 12).

Table 12. Correlation between facial cues and body language in horse-human interaction studies. The table presents Pearson correlation coefficients, significance values (2-tailed), and sample size (N=104). A significant negative correlation ($p < 0.01$) was observed, indicating an inverse relationship between facial cues and body language, suggesting that horses may rely on different expressive modalities depending on the context.

Correlations			
		Facial Cues	Body Language
Facial Cues	Pearson Correlation	1	-.523**
	Sig. (2-tailed)		.000
	N	104	104
Body Language	Pearson Correlation	-.523**	1

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	Sig. (2-tailed)	.000	
	N	104	104

**. Correlation is significant at the 0.01 level (2-tailed).

3.5. Other Methods

Other methods were less frequently used (Table 13).

Table 13. Frequency and percentage distribution of additional assessment methods used in horse-human interaction studies. The table presents various approaches, including questionnaires, salivary metabolites, blood hormones, artificial intelligence, and physiological indicators such as eye wrinkle analysis and infrared thermography. The distribution highlights the prevalence of these methods and their contribution to understanding equine emotional and physiological responses.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	73	70.2	70.2	70.2
	Questionnaires	11	10.6	10.6	80.8
	Other Salivary Metabolites	1	1.0	1.0	81.7
	Blood Hormones	4	3.8	3.8	85.6
	Artificial Intelligence	1	1.0	1.0	86.5
	Both in Humans and Horses	3	2.9	2.9	89.4
	Eye Wrinkle	1	1.0	1.0	90.4
	Infrared Thermography	4	3.8	3.8	94.2
	Odor	2	1.9	1.9	96.2
	Eye Blink	3	2.9	2.9	99.0
	Positive ER	1	1.0	1.0	100.0
	Total	104	100.0	100.0	

4. Discussion

The findings highlight the importance of a multi-faceted approach in evaluating horse emotions. While body language remains the cornerstone of behavioral analysis, physiological measures like heart rate and HRV add robustness to the interpretation of emotional states. The limited use of facial cues and vocalizations suggests that further research is needed to develop standardized protocols for these indicators.

Moreover, the low prevalence of studies using EEG and respiration underscores the need for innovative, non-invasive technologies that can provide deeper insights into equine neurophysiology without inducing stress. Future research could focus on integrating wearable technologies and AI-driven analysis for real-time monitoring of both behavioral and physiological responses.

Current methodologies however have several limitations of both physiological and behavioral indicators including observer bias in behavioral assessments or environmental and contextual factors affecting physiological markers, as for example hormonal fluctuation in mares throughout their cycle. Longitudinal studies might bring more light in assessing emotional contagion over time.

Out of the 35 studies that examined both horses and humans, the distribution of measured parameters suggests that while heart rate and HRV remain the predominant physiological measures, facial expressions and body language are also significant areas of study. However, hormonal and neurophysiological measurements are less commonly explored, presenting potential gaps for further research in horse-human interaction studies.

The process of emotion contagion between horses and humans is central to equine welfare, training, and therapy. The statistical interpretation of the studies indicates that only 33.98% of research includes both horse and human physiological and behavioral responses, highlighting a research gap in understanding the bidirectional influence of human emotions on horses. Studies demonstrate that human emotions such as stress, relaxation, and emotional states can influence a

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horse's physiological responses, supporting the concept of emotional co-regulation between the two species [25,26]. Horses appear to interpret human facial expressions and vocal tones, responding more positively to calm and happy expressions while showing stress-related responses to negative cues [27]. The way a human approaches and interacts with a horse significantly affects equine behavioral responses, suggesting that non-verbal cues play a vital role in establishing trust and communication [11,28,29]. Despite the importance of cortisol levels and EEG readings in assessing stress and arousal, only a small portion of studies have examined these markers in both horses and humans simultaneously.

5. Conclusions

The systematic review underscores the complexity of horse-human emotional contagion and the necessity for holistic assessment methods. Behavioral indicators, especially body language, dominate current research, but physiological responses offer critical, objective validation. Combining these approaches will be pivotal in advancing our understanding of equine emotions, improving training practices, and enhancing horse welfare.

Future studies should aim to bridge the gap between behavioral and physiological measures by exploring underutilized indicators like EEG and respiration. Additionally, efforts should be made to establish standardized guidelines for measuring and interpreting both types of responses, ultimately fostering a more empathetic and scientifically informed approach to horse care and management.

Given the bidirectional nature of emotional transfer, future research should focus on the development of standardized methodologies to quantify human-horse emotional interactions more accurately. Advances in wearable technology, AI-driven analysis, and interdisciplinary research will be key to deepening our understanding of how human emotions shape equine experiences and behaviors.

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Abbreviations

The following abbreviations are used in this manuscript:

HR	Heart rate
HRV	Heart rate variability
EEG	electroencephalogram

Appendix A

Appendix A.1 Comprehensive List of Referenced Studies

This appendix includes a detailed table of all the studies cited and analyzed in this review article. The table categorizes each study by its authorship, year of publication, and the specific behavioral or physiological parameters investigated. These parameters include aspects such as **facial cues, body language, vocalization, heart rate, heart rate variability (HRV), cortisol levels, EEG patterns, respiratory responses**, and other metrics.

The purpose of this appendix is to provide readers with a clear and accessible summary of the research base underpinning our findings. Each entry allows for a quick identification of the studies that explore specific response types or methodologies, aiding in transparency and facilitating further research by others in the field.

For studies where data on certain parameters are not provided, the corresponding cells are left blank. Special abbreviations (e.g., XB, XS, BH, Q, etc.) indicate additional relevant details, which are elaborated upon in the main text.

			BEHAVIORAL RESPONSES			PHYSIOLOGICAL RESPONSES					
No.	AUTHORS	YEAR	FACIAL CUES	BODY	VOCALIZATIO	HEART RATE	HRV	CORTISOL	EEG	RESPIRATION	OTHER
1	Anderson et.al. [30]	1999		X				XB			BH
2	Austin and Rogers [31]	2007		X							
3	Baba et.al. [11]	2019	X								
4	Baragli et al. [32]	2014		X		X	X				
5	Baragli et al. [33]	2009		X		X	X				
6	Baragli et al. [34]	2011		X		X					
7	Becker-Birck et al. [14]	2013				X	X	XB			
8	Birke et al [35]	2011		X							
9	Bornmann et al. [36]	2021		X							Q
10	Brandt [28]	2004		X							Q
11	Cavanaghn [37]	2017		X							
12	Chamove et.al. [38]	2002		X							
13	Chapman et.al. [39]	2020		X							Q
14	Christensen et al. [40]	2012		X		X	X	XF			
15	Christensen et.al. [41]	2005		X		X					
16	Contreras Aquilar et.al. [16]	2019		X				XS			SM
17	Corujo et.al. [24]	2021		X							
18	Cravana et.al. [42]	2021				X		XB			BH
19	Dalla Costa et.al. [43]	2017		X							
20	dIngeo et al. [44]	2019		X					X		
21	Drinkhouse et.al. [45]	2012				X					
22	Duclugosz et al. [46]	2020						XS			
23	Dyson et.al. [47]	2021		X							Q
24	Farmer et.al. [48]	2010	X								
25	Feighelstein et.al. [20]	2023	X								AI
26	Fejsakova et al. [49]	2013		X		X	X	XS			
27	Felici et al. [50]	2023		X			X				
28	Fureix et al. [51]	2012		X				XB			
29	Gerhke et.al. [52]	2011				X	X				
30	Gleerup et al. [53]	2015	X								

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31	Guidi et.al. [54]	2016					X				
32	Hama et.al. [55]	1996				X					x2
33	Hausberger and Muller [13]	2002		X							
34	Hintze et al. [56]	2016		X							
35	Hintze et al. [57]	2017	X								EW
36	Hockenhull and Creighton [58]	2013		X							Q
37	Hockenhull et.al. [21]	2015				X					
38	Hotzel et.al. [59]	2019		X							Q
39	Ijichi et.al. [60]	2023	X			X	X				IRT
40	Ijichi et.al. [61]	2018		X		X					IRT
41	Ille et al. [62]	2014				X	X				
42	J. W., C et.al. [63]	2008		X		X					
43	Janczarek et.al. [64]	2019		X		X		XS			
44	Janczarek et.al. [65]	2018		X		X	X				
45	Kaiser et.al. [66]	2006		X							
46	Keeling et.al. [67]	2009		X		X					x2
47	Kim and Yoon [68]	2022									BH
48	Konig et.al. [69]	2011		X		X	X				
49	Kosiara and Harrison [70]	2021		X		X				X	
50	Kowalik et al. [71]	2017				X	X				
51	Lanata et.al. [22]	2016					X				
52	Lanata et.al. [72]	2018					X				ODOUR
53	Lansade and Bouissou [10]	2008		X		X					
54	Lansade et.al. [27]	2018		X		X	X				BH
55	Lansade et.al. [73]	2020		X							
56	Lee et al. [5]	2021		X		X	X				
57	Leiner and Fendt [74]	2011		X	X	X					
58	Lie [75]	2017		X							
59	Lloyd et.al. [76]	2007		X							Q
60	Lundberg et.al. [29]	2020		X	X	X					
61	Lundblad [77]	2018	X			X					
62	Maros et.al. [78]	2008		X							
63	McBride et al. [79]	2022	X	X			X				EYE BLINK
64	McCann et.al. [80]	1988		X		X				X	
65	McGreevy et.al. [9]	2009		X							
66	Merkies et al. [81]	2022		X		X					
67	Merkies et.al. [82]	2014		X		X					x2
68	Merkies et.al. [83]	2019	X	X		X					EYE BLINK
69	Momozawa et.al. [84]	2005		X							Q
70	Mott et al. [85]	2020	X			X	X	X			EYE BLINK
71	Mullard et.al. [86]	2017	X								

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72	Nakamura et.al. [87]	2018	X						
73	Noble et.al. [88]	2013		X		X	X	XB	
74	Norton et al. [19]	2018		X		X	X		
75	Pereira et.al. [89]	2023				X			BH
76	Perez Manrique et al. [90]	2019		X		X	X		
77	Pierard et.al. [17]	2019		X					Q
78	Popescu et.al. [91]	2013		X					Q
79	Reid et al. [92]	2017		X		X	X		
80	Rietmann et al. [93]	2004		X		X	X		
81	Rorvang et.al. [94]	2015		X		X	X		
82	Sabiniewicz et.al. [95]	2020		X					ODOUR
83	Sankey et al. [96]	2010		X		X	X		
84	Sauer et.al. [97]	2019		X				XB	BH
85	Schmidt et al. [15]	2010		X		X	X	XS	
86	Schrimpf et.al. [26]	2020	X						
87	Schutz and Schmitz [98]	2021		X					
88	Scopa et.al. [99]	2020				X	X		
89	Seaman et.al. [100]	2002		X					
90	Siipola et.al. [101]	2019		X		X			
91	Smith et. al. [25]	2018		X					
92	Squibb et al. [102]	2018		X		X	X		IRT
93	Stomp et.al. [103]	2018		X	X				POSITIVE EM
94	Trosch et.al. [104]	2020		X		X			
95	Valera et.al. [23]	2012						XS	IRT
96	Visser et al. [105]	2008		X		X			
97	Visser et.al. [4]	2002		X		X	X		
98	von Borstel et al. [106]	2007		X		X			
99	von Lewinski et al. [107]	2013		X		X	X	XS	
100	Wathan et al. [12]	2015	X						
101	Wathan et al. [108]	2016		X					
102	Wilk and Janczarek [109]	2015		X		X	X		
103	Wolff et.al. [110]	1997		X	X				
104	Young et al. [111]	2012		X		X		XS	

XB – Blood Cortisol, XS – Salivary Cortisol, XF – Fecal (Faeces) Biomarkers, IRT – Infrared Thermography, BH – Blood Hormones, Q – Questionnaires, x2 – Studies Conducted in Both Humans and Horses, AI – Artificial Intelligence Applications, SM – Other Salivary Metabolites.

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