

Neurophysiological and Emotional Effects of Equine-Assisted Activities

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Curriculum Vitae

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Neurophysiological and Emotional Effects of Equine-Assisted Activities

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Introduction



Chronic **stress** causes adverse psychological and physiological effects
(Faucher et al., 2023).



Pharmacological treatments may have side effects.
→ Growing need for **alternative approaches**



Animal-assisted interventions (AAIs) have emerged as a **complementary approach** for promoting psychological well-being.

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Introduction



- Highly sensitive to environmental and human signals
- Responsive to behavioral and emotional cues
- Capable of affiliative bonding

Suitable for providing feedback on human states

(Hama et al., 1996; Merckies et al., 2014; Smith et al., 2016; Smith et al., 2018; Trösch et al., 2019)

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Introduction

Importance of integrating psychological and neurophysiological measures

- Psychological benefits of AAls are consistently reported (Pendry et al., 2018; Wood et al., 2018).
- However, psychological improvements do not always correspond with physiological changes (Ein et al., 2018; Huber et al., 2024).
- Studies integrating psychological and neurophysiological measures remain limited.



Psychological states



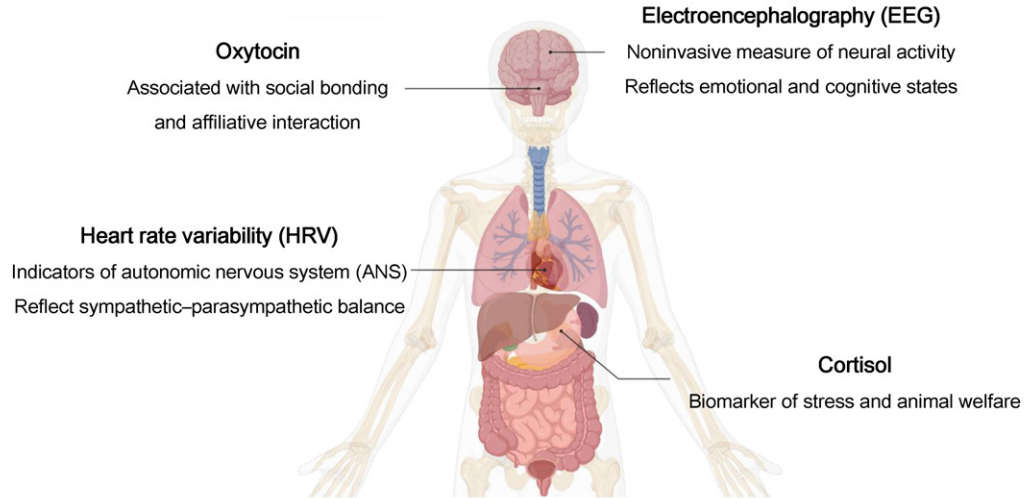
Neurophysiological states

A multimodal approach integrating self-reported psychological states with neurophysiological indicators may better capture the effects of AAls.

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Introduction

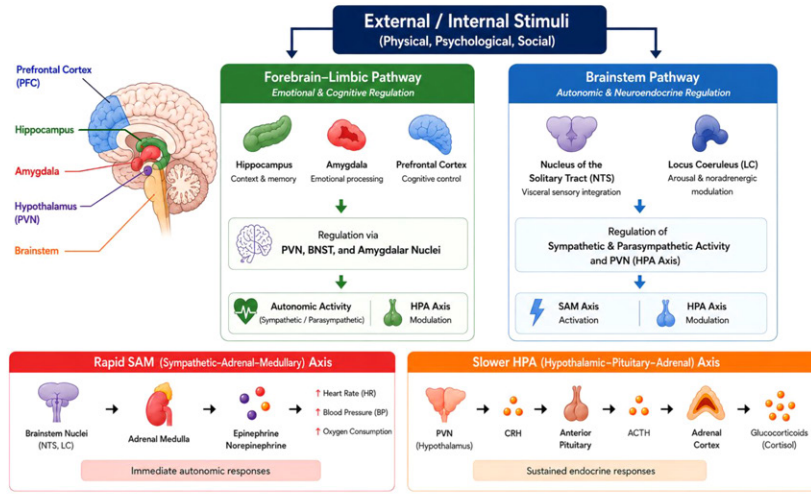
Neurophysiological markers in AAls



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Introduction

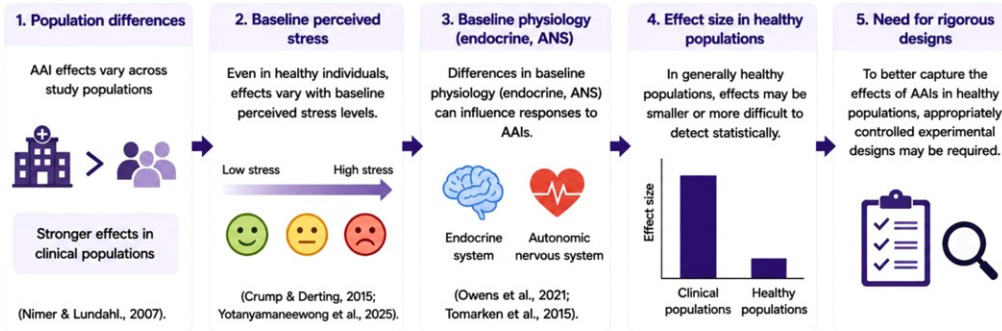
Neurophysiological mechanisms of stress response



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Introduction

Variability in AAI effects across populations and conditions



Welfare of participating animals

- Monitoring **physiological responses** is essential in AAIs to determine whether these interventions compromise **animal welfare**.
- Salivary biomarkers** are widely used to assess endocrine responses in animals during HAIs (Kapteijn et al., 2025).

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Introduction

Objectives of this study

- To investigate emotional, endocrine, neural, and autonomic responses in humans under experimentally induced stress during EAls
- To assess endocrine responses in horses during EAls

✓ Hypotheses

- 1 Short-term EAls are hypothesized to improve psychological and neurophysiological outcomes in normal individuals under experimentally induced stress.
- 2 Participation in EAls is hypothesized not to adversely affect the welfare of participating horses.

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Materials and Methods

Participants

- 18 students (9 males, 9 females; 22.22 [2.691] years)

Ethical approvals

- 6 horses (1 stallion, 5 mares; 15.83 [2.317] years)
- Two Thoroughbreds, two Haflingers, and two Quarter Horses



Ethical approvals

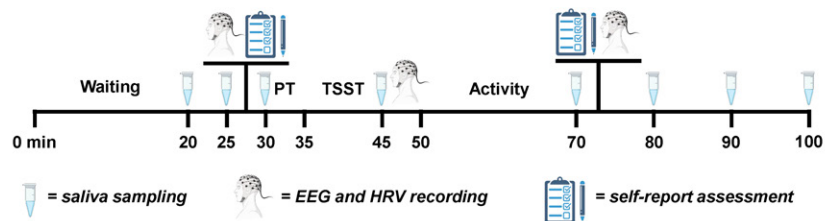
- Institutional Review Board (Kyungpook National University): 2025-0225
- Animal Experimentation Ethics Committee (Kyungpook National University): 2025-0389

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Materials and Methods

Experimental procedures

- Participants completed four distinct activities, at intervals of at least one week, in a randomized cross-over design.



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Materials and Methods

Trier Social Stress Task (TSST)

- Standardized protocol for inducing psychosocial stress (Birkett, 2011; Kudielka et al., 2004)
- Performed before each activity session
- 10 min task (5 min speech + 5 min mental arithmetic)
 - ✓ **Speech task:** continuous speaking (prompted if stopped early)
 - ✓ **Mental arithmetic:** serial subtraction (restart if incorrect)
- Stress induction components (Kirschbaum et al., 1993)
 - ✓ **Social-evaluative threat** (neutral evaluative panel, video recording)
 - ✓ **Uncontrollability** (continuous speaking, task restart)



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Materials and Methods

Meditation

- Included as a **relaxation** and comparison condition
- Participants sat comfortably with eyes closed and remained silent.
- Instructed to allow thoughts to arise naturally without control or suppression



Cognitive stress task

- Designed to elicit psychological stress using **social-evaluative threat** and **cognitive demands** (Dedovic et al., 2005; Dickerson & Kemeny, 2004).
- Participants were informed that performance would be scored and compared to normative data.
- Task included **English vocabulary (TOEFL-level)** and **mental arithmetic challenges**.
- Responses were given verbally within a limited time, with neutral feedback for errors or timeouts.



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Materials and Methods

Static activity (interaction-focused)

- ✓ Tactile interaction: grooming, rubbing, hugging
- ✓ Mane braiding and decorative activities
- ✓ Free interaction without supervision



Dynamic activity (task-based)

- ✓ Leading the horse through barrels
- ✓ Basic riding skills: halting, initiating movement, directional control
- ✓ Riding the horse through barrels



Ayala et al., 2021; Naber et al., 2025

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Materials and Methods

Self-report measures

- Pet Attitude Scale (PAS)
 - ✓ Measures participants' attitudes toward animals (Templer et al., 1981)
 - ✓ 18 items rated on a 7-point Likert scale
- Semantic Differential Method (SDM)
 - ✓ Assesses emotional states before and after each activity (Osgood, 1957)
 - ✓ 9 items rated on a 7-point Likert scale
 - ✓ Evaluates comfort, relaxation, enjoyment, and vitality

Materials and Methods

Pet Attitude Scale (PAS)

다음 질문에 대해 진로 느끼는 감정을 솔직하게 답변해 주십시오. 이 설문지는 익명으로 진행되며, 어떤 답변을 했는지 다른 사람은 절대 알 수 없습니다. 그러나 다른 사람들이 어떻게 답할지 신경 쓰지 마십시오. 얼마나 좋은 답변은 없으며, 중요한 것은 여러분의 진실한 생각을 표현하는 것입니다.

각 질문에 7가지 숫자 중 하나를 골라 표시해 주십시오.

1	2	3	4	5	6	7
매우 동의하지 않음	어느 정도 동의하지 않음	약간 동의하지 않음	잘 모르겠음	약간 동의함	어느 정도 동의함	매우 동의함

- 나는 반려동물이 용서를 받았게 하는 모습을 보는 것이 정말 좋다.
- 내 반려동물은 나에게 어떤 친구보다도 더 중요한 존재이다.
- 나는 내 집에 반려동물이 없기를 원한다.
- 반려동물들 키우는 것은 돈 낭비라고 생각한다.
- 반려동물은 내 삶에 행복을 더해준다 (또는 반려동물이 있다면 그럴 것이다).

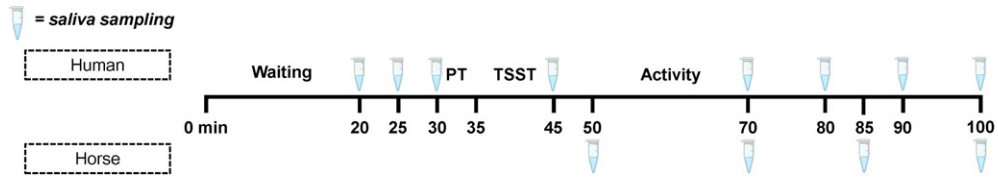
Semantic Differential Method (SDM)

FI post PC

	1	2	3	4	5	6	7
불편하다.	----- ----- ----- ----- ----- -----						편안하다.
압박감을 느낀다.	----- ----- ----- ----- ----- -----						여유롭다.
초조하다.	----- ----- ----- ----- ----- -----						안정적이다.
불안하다.	----- ----- ----- ----- ----- -----						침착하다.
충분하다.	----- ----- ----- ----- ----- -----						차분하다.
걱정스럽다.	----- ----- ----- ----- ----- -----						평온하다.
우울하다.	----- ----- ----- ----- ----- -----						즐겁다.
무기력하다.	----- ----- ----- ----- ----- -----						활기차다.
비관적이다.	----- ----- ----- ----- ----- -----						낙관적이다.

Materials and Methods

Saliva sample collection



- For animals, samples were collected in triplicate per activity.



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Materials and Methods

Hormonal analysis

Baseline: mean of three saliva samples collected -10, -5, and 0 min before TSST (Pérez-Edgar et al., 2008)



Oxytocin ELISA
 ADI-900-153A (Enzo)
 Sensitivity: 15.6 pg/mL



Cortisol ELISA
 1-3002 (Salimetrics)
 Sensitivity: 0.007 µg/dL

Species	Intra-CV(%)	Inter-CV(%)
Human	2.673	6.508
Horse	3.596	8.509

Species	Intra-CV(%)	Inter-CV(%)
Human	4.482	10.570
Horse	7.994	19.371

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Materials and Methods

ECG (Electrocardiography)

- Recording for 3 min using QEEG-64Fx system (Laxtha, Republic of Korea)



- Electrodes placed on both wrists.
- R-peak detection: R (R studio, USA) / HRV analysis: Kubios HRV Scientific Lite (v 4.1.1, Finland)
- Spectral bands: extremely low frequency (0–0.04 Hz), low frequency (LF; 0.04–0.15 Hz), high frequency (HF; 0.15–0.40 Hz)
- HRV metrics (Shaffer & Ginsberg, 2017; Song et al., 2026)
 - ✓ SDNN (the standard deviation of normal-to-normal intervals)
 - ✓ RMSSD (root mean square of successive RR interval differences)
 - ✓ LF/HF ratio

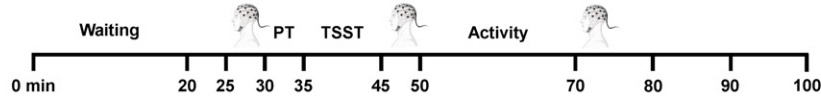


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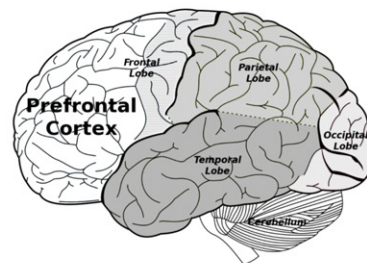
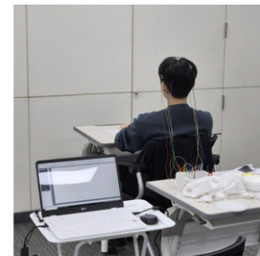
Materials and Methods

EEG (Electroencephalography)

- Recording for 3 min using QEEG-64Fx system and Telescan (Laxtha, Republic of Korea)



- Electrodes placed over prefrontal (Fp), frontal (F), temporal (T), and parietal (P) regions.
 - ✓ International 10-20 system (Song et al., 2026)
- Power spectral analysis of four bands
 - ✓ Delta (0.5-4 Hz), Alpha (8-13 Hz), Low-beta (13-19 Hz), High-beta (20-30 Hz)
 - ✓ Relative power calculated as band power / total power (0.5-50 Hz)



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Materials and Methods

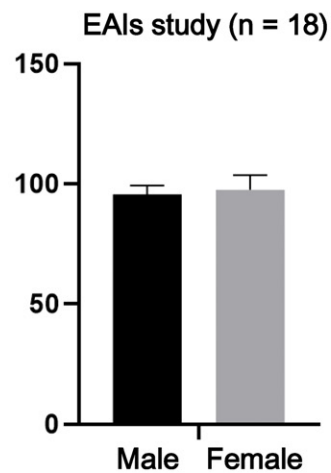
Statistical analysis

- G*power (v 3.1.9.7, Germany), SPSS (v 29.0.2.0, USA), SAS (v 9.4, USA)
 - ✓ G*Power: sample size estimation for repeated-measures design
 - ✓ **Independent t-test**: comparison of PAS scores between sexes
 - ✓ Principal factor analysis: identification of SDM subscales
 - ✓ **Linear mixed-effects model (SAS PROC MIXED)**: analysis of emotional, endocrine, neural, and autonomic responses with fixed effects of sex, activity, and time
 - ✓ Model-based contrasts: targeted pairwise comparisons between time points and activities
 - ✓ Akaike information criterion/ Bayesian information criterion: selection of covariance structure

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Results and Discussion

Pet Attitude Scale scores



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Results and Discussion

Emotional state scores during EAls (n = 18)

- Values: mean (SE)
- A, B: across time (within activity, $p < 0.05$)
- a, b, c: across activities (within time, $p < 0.05$)

	Time point	Meditation	Cognitive stress task	Static activity	Dynamic activity
Emotional stability	Pre	4.77 (0.259)	4.79 (0.259) ^A	4.59 (0.259) ^A	4.98 (0.259)
	Post	5.04 (0.259) ^a	3.88 (0.259) ^{B, b}	5.62 (0.259) ^{B, c}	5.48 (0.259) ^{ac}
Vitality	Pre	4.74 (0.241)	4.72 (0.241) ^A	4.39 (0.241) ^A	4.78 (0.241) ^A
	Post	4.72 (0.241) ^a	4.13 (0.241) ^{B, b}	5.61 (0.241) ^{B, c}	5.91 (0.241) ^{B, c}

- Previous studies have reported improvements in stress and emotional states following EAls (Chakales et al., 2020; Pasiuk et al., 2023).
- These effects may be associated with increased [endorphin release](#) (Brown et al., 2020).

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Results and Discussion

Salivary concentrations of cortisol (nmol/L) during EAls (n = 18)

Time point	Meditation	Cognitive stress task	Static activity	Dynamic activity
Baseline	4.23 (0.552) ^{AB}	4.59 (0.569) ^A	3.88 (0.531) ^{AB}	3.49 (0.559) ^{ABC}
Post-TSST	4.86 (0.622) ^{AB, ab}	5.95 (0.639) ^{BC, a}	4.63 (0.600) ^{A, ab}	4.33 (0.634) ^{AB, b}
Post-activity (0 min)	4.61 (0.545) ^{A, a}	6.00 (0.557) ^{B, b}	3.96 (0.529) ^{A, a}	4.05 (0.557) ^{B, a}
+10 min	4.56 (0.555) ^{AC, ab}	5.51 (0.570) ^{AB, a}	3.56 (0.538) ^{A, b}	4.02 (0.567) ^{B, b}
+20 min	3.87 (0.459) ^{B, a}	4.90 (0.473) ^{AC, b}	3.02 (0.450) ^{B, a}	3.32 (0.471) ^{AC, a}
+30 min	3.85 (0.462) ^{BC, a}	4.86 (0.473) ^{AB, b}	2.84 (0.452) ^{B, c}	3.13 (0.473) ^{C, ac}

Cortisol

Indicator of stress response

- Values: mean (SE)
- A, B, C: across time (within activity, $p < 0.05$)
- a, b, c: across activities (within time, $p < 0.05$)

AAIs may facilitate [post-stress cortisol recovery](#) in humans.

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Results and Discussion

Salivary concentrations of oxytocin (pg/mL) during EAls (n = 18)

Time point	Meditation	Cognitive stress task	Static activity	Dynamic activity
Baseline	78.25 (11.482) ^{AB, ab}	84.31 (11.482) ^a	84.68 (11.482) ^a	56.82 (11.482) ^{A, b}
Post-TSSST	96.05 (12.122) ^{AB}	86.16 (11.621)	77.90 (11.873)	70.51 (12.124) ^{AB}
Post-activity (0 min)	72.18 (10.827) ^A	82.27 (10.827)	86.62 (11.212)	76.70 (11.038) ^{AB}
+10 min	97.06 (9.637) ^B	79.62 (9.646)	91.63 (9.460)	86.09 (9.282) ^B
+20 min	73.88 (10.856) ^{AB}	81.91 (10.856)	82.37 (10.856)	67.18 (10.966) ^{AB}
+30 min	72.63 (11.083) ^A	82.31 (10.763)	79.16 (10.859)	71.88 (11.092) ^{AB}

Oxytocin

Associated with social interaction and bonding

- Values: mean (SE)
- A, B: across time (within activity, $p < 0.05$)
- a, b: across activities (within time, $p < 0.05$)

Dynamic activity may have induced increases in oxytocin through interaction.

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Results and Discussion

HRV parameters during EAls (n = 18)

Parameter	Time point	Meditation	Cognitive stress task	Static activity	Dynamic activity
SDNN	Pre	63.05 (5.680)	56.49 (5.533)	57.16 (5.569)	55.99 (5.751)
	TSSST	56.30 (5.799)	53.90 (5.639)	60.35 (5.681)	57.17 (5.877)
	Post	59.52 (5.665)	55.32 (5.519)	54.20 (5.555)	51.89 (5.735)
RMSSD	Pre	68.77 (6.516) ^A	57.88 (6.519)	59.08 (6.598)	56.35 (6.700)
	TSSST	57.77 (6.407) ^B	55.10 (6.410)	63.19 (6.484)	63.56 (6.582)
	Post	66.63 (5.766) ^{AB, a}	55.70 (5.769) ^b	61.40 (5.810) ^{ab}	54.16 (5.883) ^b
LF/HF ratio	Pre	1.14 (0.192)	1.21 (0.211)	0.88 (0.199) ^{AB}	1.19 (0.198)
	TSSST	1.11 (0.176)	1.15 (0.185)	1.28 (0.186) ^A	1.16 (0.178)
	Post	0.86 (0.170) ^a	1.27 (0.175) ^{ab}	0.84 (0.180) ^{B, a}	1.33 (0.183) ^b

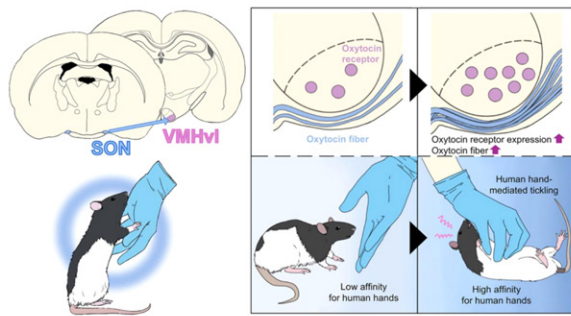
- SDNN: overall HRV (Chand et al., 2024; Wu et al., 2026).
- RMSSD: parasympathetic activity (Song et al., 2026).
- LF/HF ratio: sympathovagal balance (Shaffer & Ginsberg, 2017).

Static activity may reduce stress-related autonomic arousal.

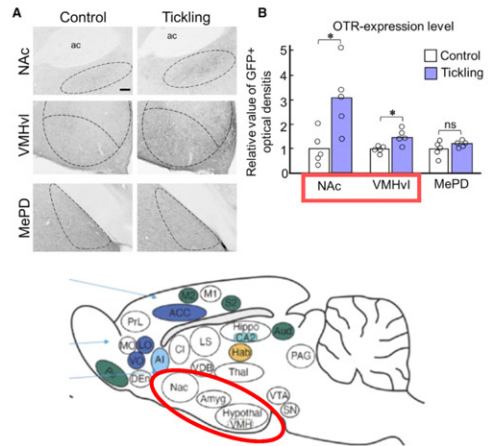
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Results and Discussion

Tactile interaction activates the oxytocin system

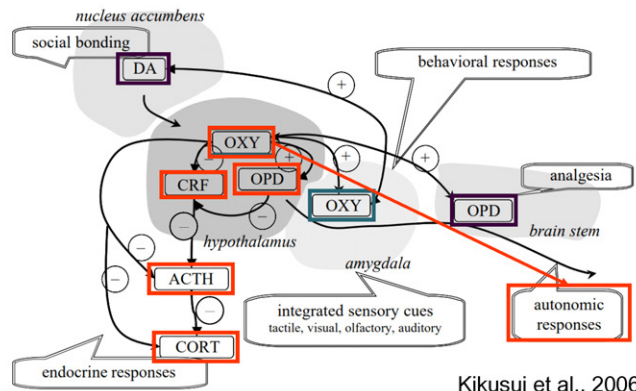
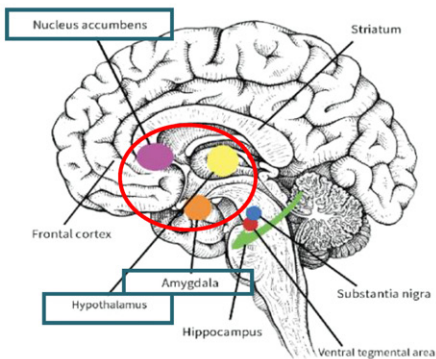


Hayashi et al., 2025



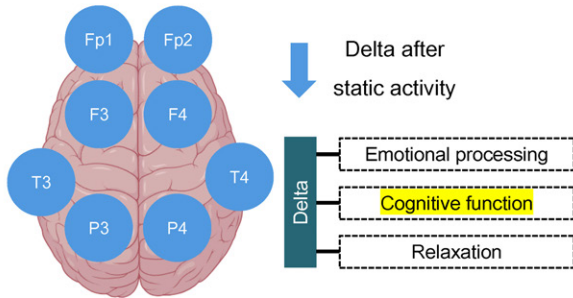
Results and Discussion

Social buffering mechanisms



Kikusui et al., 2006

Relative delta power during EAIs (n = 18)

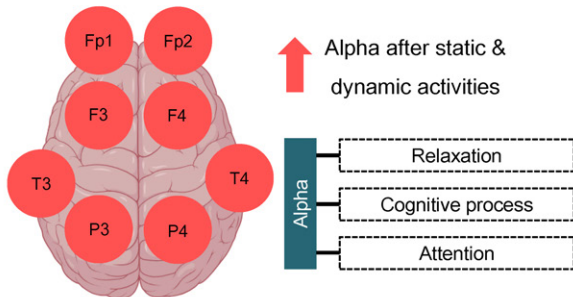


- Decreased delta power is associated with increased cognitive processing (Knyazev, 2012).
- Suggests enhanced cognitive engagement during horse interaction

Site	Time point	Meditation	Cognitive stress task	Static activity	Dynamic activity
Fp1	Pre	0.64 (0.054) ^Δ	0.62 (0.054)	0.64 (0.054) ^Δ	0.66 (0.054)
	TSST	0.60 (0.049) ^Δ	0.63 (0.049)	0.65 (0.049) ^Δ	0.62 (0.049)
	Post	0.53 (0.045) ^{Δ, a}	0.57 (0.045) ^{Δ, b}	0.53 (0.045) ^{Δ, a}	0.61 (0.045) ^{Δ, b}
Fp2	Pre	0.66 (0.051) ^Δ	0.62 (0.051)	0.65 (0.051) ^Δ	0.62 (0.051)
	TSST	0.60 (0.049) ^Δ	0.63 (0.049)	0.65 (0.049) ^Δ	0.61 (0.049)
	Post	0.50 (0.045) ^{Δ, a}	0.57 (0.045) ^{Δ, b}	0.51 (0.045) ^{Δ, a}	0.60 (0.045) ^{Δ, b}
F3	Pre	0.49 (0.045) ^Δ	0.48 (0.045) ^Δ	0.50 (0.045) ^Δ	0.46 (0.045)
	TSST	0.47 (0.040) ^Δ	0.46 (0.040) ^Δ	0.43 (0.040) ^Δ	0.43 (0.040)
	Post	0.38 (0.035) ^{Δ, b}	0.39 (0.035) ^{Δ, b}	0.38 (0.035) ^{Δ, b}	0.40 (0.035)
F4	Pre	0.47 (0.046) ^Δ	0.46 (0.046) ^Δ	0.49 (0.046) ^Δ	0.43 (0.046)
	TSST	0.42 (0.042) ^Δ	0.44 (0.042) ^Δ	0.39 (0.042) ^Δ	0.41 (0.042)
	Post	0.36 (0.036) ^{Δ, b}	0.38 (0.036) ^{Δ, b}	0.36 (0.036) ^{Δ, b}	0.39 (0.036)
T3	Pre	0.47 (0.041) ^Δ	0.49 (0.041) ^Δ	0.49 (0.041) ^Δ	0.46 (0.041)
	TSST	0.42 (0.040) ^{Δ, b}	0.43 (0.040) ^Δ	0.40 (0.040) ^{Δ, b}	0.42 (0.040)
	Post	0.37 (0.035) ^{Δ, b}	0.36 (0.035) ^{Δ, b}	0.36 (0.035) ^{Δ, b}	0.41 (0.035)
T4	Pre	0.48 (0.047) ^Δ	0.52 (0.047) ^Δ	0.52 (0.047) ^Δ	0.43 (0.047)
	TSST	0.42 (0.046) ^{Δ, b}	0.44 (0.046) ^{Δ, b}	0.39 (0.046) ^{Δ, b}	0.43 (0.046)
	Post	0.35 (0.040) ^{Δ, b}	0.37 (0.040) ^{Δ, b}	0.36 (0.040) ^{Δ, b}	0.43 (0.040)
P3	Pre	0.34 (0.042) ^Δ	0.37 (0.042) ^{Δ, a}	0.40 (0.042) ^Δ	0.36 (0.042) ^Δ
	TSST	0.30 (0.035) ^{Δ, b}	0.34 (0.035) ^Δ	0.29 (0.035) ^{Δ, b}	0.31 (0.035) ^{Δ, b}
	Post	0.25 (0.031) ^{Δ, a, b}	0.25 (0.031) ^{Δ, a, b}	0.26 (0.031) ^{Δ, a, b}	0.32 (0.031) ^{Δ, a, b, Δ}
P4	Pre	0.36 (0.042)	0.39 (0.042) ^Δ	0.41 (0.042) ^Δ	0.34 (0.042)
	TSST	0.31 (0.038)	0.35 (0.042) ^Δ	0.30 (0.038) ^{Δ, b}	0.32 (0.038)
	Post	0.28 (0.032)	0.27 (0.032) ^{Δ, b}	0.27 (0.032) ^{Δ, b}	0.29 (0.032)

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Relative alpha power during EAIs (n = 18)



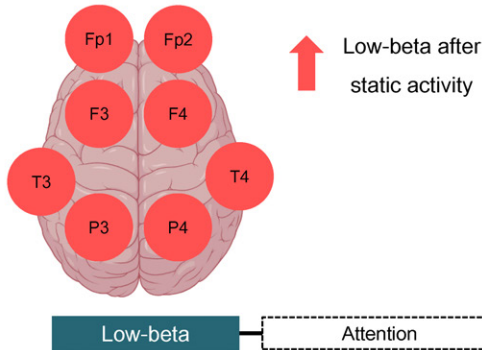
Increased alpha power indicates enhanced attentional engagement and emotional stability.

Klimesch et al., 2007; Knyazev, 2007;
Pascucci et al., 2025; Song et al., 2026

Site	Time point	Meditation	Cognitive stress task	Static activity	Dynamic activity
Fp1	Pre	0.17 (0.032) ^Δ	0.20 (0.033)	0.16 (0.032) ^Δ	0.16 (0.032)
	TSST	0.19 (0.029) ^Δ	0.19 (0.029)	0.16 (0.029) ^Δ	0.17 (0.029)
	Post	0.24 (0.029) ^{Δ, b}	0.20 (0.029)	0.22 (0.029) ^{Δ, b}	0.20 (0.029)
Fp2	Pre	0.16 (0.033) ^Δ	0.21 (0.033)	0.17 (0.033) ^Δ	0.19 (0.033)
	TSST	0.20 (0.031) ^Δ	0.19 (0.031)	0.16 (0.031) ^Δ	0.18 (0.031)
	Post	0.26 (0.029) ^{Δ, a, b}	0.21 (0.029) ^{Δ, b}	0.22 (0.029) ^{Δ, a, b}	0.21 (0.029) ^{Δ, b}
F3	Pre	0.24 (0.031) ^Δ	0.27 (0.031)	0.24 (0.031) ^Δ	0.26 (0.031) ^Δ
	TSST	0.27 (0.029) ^Δ	0.28 (0.029)	0.26 (0.029) ^{Δ, b}	0.28 (0.029) ^{Δ, b}
	Post	0.31 (0.028) ^{Δ, b}	0.29 (0.028)	0.30 (0.028) ^{Δ, b}	0.31 (0.028) ^{Δ, b}
F4	Pre	0.26 (0.032) ^Δ	0.28 (0.032)	0.24 (0.032) ^Δ	0.28 (0.032) ^{Δ, b}
	TSST	0.29 (0.029) ^Δ	0.28 (0.030)	0.28 (0.029) ^{Δ, b}	0.28 (0.029) ^{Δ, b}
	Post	0.33 (0.028) ^{Δ, b}	0.30 (0.028)	0.31 (0.028) ^{Δ, b}	0.32 (0.028) ^{Δ, b}
T3	Pre	0.21 (0.024) ^Δ	0.22 (0.025)	0.21 (0.024) ^Δ	0.22 (0.024)
	TSST	0.23 (0.024) ^Δ	0.23 (0.024)	0.22 (0.024) ^{Δ, b}	0.23 (0.024)
	Post	0.28 (0.024) ^{Δ, b}	0.25 (0.024)	0.26 (0.024) ^{Δ, b}	0.26 (0.024)
T4	Pre	0.19 (0.026) ^Δ	0.18 (0.027) ^Δ	0.17 (0.026) ^Δ	0.21 (0.026)
	TSST	0.23 (0.025) ^Δ	0.20 (0.026) ^{Δ, b}	0.22 (0.025) ^{Δ, b}	0.21 (0.025)
	Post	0.27 (0.025) ^{Δ, b}	0.23 (0.025) ^{Δ, b}	0.25 (0.025) ^{Δ, b}	0.23 (0.025)
P3	Pre	0.36 (0.033) ^Δ	0.35 (0.033)	0.33 (0.033) ^Δ	0.34 (0.033) ^Δ
	TSST	0.39 (0.029) ^{Δ, b}	0.37 (0.030)	0.38 (0.029) ^{Δ, b}	0.37 (0.029) ^{Δ, b}
	Post	0.43 (0.029) ^{Δ, b}	0.38 (0.029)	0.42 (0.029) ^{Δ, b}	0.40 (0.029) ^{Δ, b}
P4	Pre	0.35 (0.036) ^Δ	0.34 (0.036)	0.33 (0.036) ^Δ	0.38 (0.036) ^{Δ, b}
	TSST	0.38 (0.034) ^{Δ, b}	0.37 (0.034)	0.38 (0.034) ^{Δ, b}	0.38 (0.034) ^Δ
	Post	0.42 (0.033) ^{Δ, b}	0.40 (0.033)	0.41 (0.033) ^{Δ, b}	0.43 (0.033) ^{Δ, b}

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Relative low-beta power during EAls (n = 18)

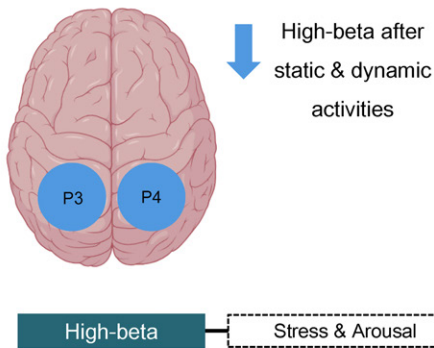


- Increased low-beta power indicates enhanced attentional engagement (Habelt, 2026).

Site	Time point	Meditation	Cognitive stress task	Static activity	Dynamic activity
Fp1	Pre	0.03 (0.004) ^a	0.03 (0.004)	0.03 (0.004) ^a	0.02 (0.004)
	TSST	0.03 (0.003) ^a	0.027 (0.003)	0.03 (0.003) ^a	0.03 (0.003)
	Post	0.04 (0.003) ^{h,a}	0.03 (0.003) ^h	0.04 (0.003) ^{h,a}	0.03 (0.003) ^h
Fp2	Pre	0.03 (0.004) ^a	0.03 (0.004)	0.03 (0.004) ^a	0.03 (0.004)
	TSST	0.03 (0.003) ^a	0.03 (0.003)	0.03 (0.003) ^a	0.03 (0.003)
	Post	0.04 (0.003) ^{h,a}	0.03 (0.003) ^h	0.03 (0.003) ^{h,a}	0.03 (0.003) ^h
F3	Pre	0.05 (0.004)	0.04 (0.004) ^a	0.04 (0.004) ^a	0.04 (0.004)
	TSST	0.05 (0.004)	0.04 (0.004) ^a	0.05 (0.004) ^h	0.05 (0.004)
	Post	0.05 (0.003)	0.05 (0.003) ^h	0.05 (0.003) ^h	0.05 (0.003)
F4	Pre	0.04 (0.004)	0.04 (0.004)	0.04 (0.005) ^a	0.04 (0.004)
	TSST	0.05 (0.004)	0.05 (0.004)	0.05 (0.004) ^h	0.05 (0.004)
	Post	0.05 (0.003)	0.05 (0.003)	0.05 (0.003) ^h	0.05 (0.003)
T3	Pre	0.06 (0.005)	0.05 (0.006) ^a	0.05 (0.006) ^a	0.06 (0.005)
	TSST	0.07 (0.005)	0.06 (0.005) ^h	0.07 (0.005) ^h	0.06 (0.005)
	Post	0.07 (0.004)	0.07 (0.004) ^h	0.07 (0.004) ^h	0.06 (0.004)
T4	Pre	0.06 (0.007)	0.05 (0.007) ^a	0.06 (0.007) ^a	0.07 (0.007)
	TSST	0.07 (0.008)	0.07 (0.008) ^h	0.07 (0.008) ^h	0.07 (0.008)
	Post	0.07 (0.007)	0.07 (0.007) ^h	0.07 (0.007) ^h	0.06 (0.007)
P3	Pre	0.06 (0.006)	0.06 (0.006) ^a	0.05 (0.006) ^a	0.06 (0.006)
	TSST	0.07 (0.006)	0.06 (0.006) ^a	0.07 (0.006) ^h	0.07 (0.006)
	Post	0.07 (0.005)	0.08 (0.005) ^h	0.07 (0.005) ^h	0.06 (0.005)
P4	Pre	0.06 (0.005)	0.05 (0.005) ^a	0.05 (0.006) ^a	0.06 (0.005)
	TSST	0.06 (0.005)	0.06 (0.005) ^a	0.06 (0.005) ^h	0.06 (0.005)
	Post	0.06 (0.005) ^h	0.07 (0.005) ^{h,a}	0.06 (0.005) ^h	0.06 (0.005) ^h

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Relative high-beta power during EAls (n = 18)



- Decreased high-beta power suggests reduced stress.

Site	Time point	Meditation	Cognitive stress task	Static activity	Dynamic activity
Fp1	Pre	0.03 (0.005) ^h	0.03 (0.005)	0.03 (0.006)	0.03 (0.005)
	TSST	0.03 (0.005) ^a	0.03 (0.005)	0.03 (0.005)	0.03 (0.005)
	Post	0.04 (0.006) ^h	0.04 (0.006)	0.03 (0.006)	0.03 (0.006)
Fp2	Pre	0.03 (0.005)	0.03 (0.005)	0.03 (0.006)	0.03 (0.005)
	TSST	0.03 (0.005)	0.03 (0.005)	0.03 (0.005)	0.03 (0.005)
	Post	0.04 (0.006)	0.04 (0.006)	0.03 (0.006)	0.03 (0.006)
F3	Pre	0.04 (0.006)	0.04 (0.006) ^a	0.04 (0.006)	0.04 (0.006)
	TSST	0.04 (0.006)	0.05 (0.006) ^h	0.05 (0.006)	0.05 (0.006)
	Post	0.05 (0.006)	0.05 (0.006) ^h	0.04 (0.006)	0.04 (0.006)
F4	Pre	0.05 (0.006)	0.05 (0.006)	0.04 (0.007)	0.05 (0.006)
	TSST	0.05 (0.006)	0.05 (0.006)	0.05 (0.006)	0.06 (0.006)
	Post	0.05 (0.006)	0.05 (0.006)	0.04 (0.006)	0.05 (0.006)
T3	Pre	0.06 (0.007)	0.05 (0.007) ^a	0.05 (0.007)	0.05 (0.007)
	TSST	0.07 (0.007)	0.06 (0.007) ^h	0.06 (0.007)	0.06 (0.007)
	Post	0.06 (0.007) ^h	0.07 (0.007) ^{h,a}	0.05 (0.007) ^h	0.06 (0.007) ^h
T4	Pre	0.06 (0.009)	0.06 (0.010) ^a	0.05 (0.009) ^a	0.06 (0.009)
	TSST	0.07 (0.010)	0.07 (0.010) ^h	0.07 (0.010) ^h	0.06 (0.010)
	Post	0.07 (0.010) ^h	0.08 (0.010) ^{h,a}	0.06 (0.010) ^{h,b}	0.06 (0.010) ^h
P3	Pre	0.06 (0.007)	0.05 (0.007) ^a	0.05 (0.007) ^a	0.05 (0.007) ^h
	TSST	0.06 (0.007)	0.06 (0.007) ^a	0.06 (0.007) ^h	0.06 (0.007) ^a
	Post	0.06 (0.007) ^a	0.07 (0.007) ^{h,b}	0.05 (0.007) ^{h,a}	0.05 (0.007) ^{h,a}
P4	Pre	0.06 (0.007) ^h	0.05 (0.007)	0.05 (0.007) ^a	0.05 (0.007)
	TSST	0.06 (0.007) ^a	0.06 (0.007)	0.06 (0.007) ^h	0.06 (0.007)
	Post	0.05 (0.007) ^{h,a}	0.06 (0.007) ^a	0.05 (0.007) ^{h,b}	0.05 (0.007) ^h

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Results and Discussion

Cortisol concentrations (nmol/L) during EAIs (n = 6)

Time point	Resting activity	Static activity	Dynamic activity
Baseline	2.75 (0.443) ^A	2.55 (0.443)	2.73 (0.443)
Post-activity (0 min)	3.09 (0.443) ^A	2.94 (0.443)	2.76 (0.443)
+15 min	2.69 (0.443) ^A	2.80 (0.443)	2.46 (0.443)
+30 min	2.05 (0.443) ^B	2.46 (0.443)	2.39 (0.443)

Log-transformed oxytocin concentrations during EAIs (n = 6)

Time point	Resting activity	Static activity	Dynamic activity
Baseline	4.64 (0.348) ^a	4.31 (0.348) ^{A, ab}	4.17 (0.348) ^b
Post-activity (0 min)	4.66 (0.348)	4.67 (0.348) ^B	4.44 (0.348)
+15 min	4.61 (0.348)	4.61 (0.348) ^{AB}	4.45 (0.348)
+30 min	4.63 (0.348) ^a	4.82 (0.348) ^{B, a}	4.18 (0.348) ^b

Values represent natural log-transformed concentrations of oxytocin.

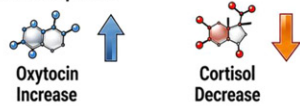
- Previous studies have reported increased oxytocin concentrations following **interaction-based activities** (Handlin et al., 2011; Lopez-Arjona et al., 2021; MacLean et al., 2017; Odendaal & Meintjes, 2003; Ogi et al., 2020).
- Notably, **physical contact** such as stroking has been identified as a **key factor** driving this effect (Handlin et al., 2023).
- Therefore, **tactile interaction-based** activities may induce **stronger oxytocin responses**.

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Conclusions

NEUROPHYSIOLOGICAL EFFECTS (HUMAN)

Hormonal Response



EEG Brainwave Changes



HRV Analysis



PSYCHOLOGICAL IMPACT (HUMAN)

Emotional Stability Increase



Vitality Boost



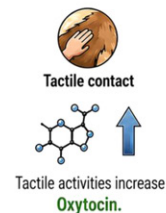
These effects may vary depending on activity type and animal species.

ANIMAL WELFARE & STRESS

STRESS LEVELS



Positive Physiological Response



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■ Thanks for your attention.

