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Review Article

From Circuit Descriptions to a Testable Mechanism Space in PTSD: A Minimal, Identifiability-Aware Computational Framework for Heterogeneous Threat Inference

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Post-traumatic stress disorder (PTSD) is often described in terms of frontolimbic circuit alterations and stress-system dysregulation. Yet the central translational problem remains mechanistic: patients with similar symptom severity can differ in why fear persists, why safety fails under stress, and why relapse follows context shifts. Here we synthesize convergent evidence across fear circuitry, endocrine and noradrenergic gain control, memory systems, and context-dependent learning, and we propose a minimal computational framework designed to be (i) hypothesis-generating rather than confirmatory and (ii) constrained by identifiability limits in realistic multimodal human datasets. The framework separates fast threat-expression dynamics from slower latent-context inference and learning and compresses heterogeneity into four composite dimensions: *Control* (stress-fragile regulation), *Context* (imprecise or biased context inference), *Gain* (arousal-amplified expression), and *Recovery* (feedback and return-to-baseline). We emphasize that "attractor" language is used only as an inference-level coarse-graining, not as a claim that human PTSD circuitry has proven multistability. We then derive discriminative, falsifiable predictions and provide a translational mapping that distinguishes plausible causal levers from state-dependent modulators and correlational markers. The goal is not a PTSD biomarker but an adjudicable mechanism space: a disciplined way to ask which process is dominant in a given person, under which conditions, and with what decision-relevant consequences.

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1. Introduction

PTSD affects a substantial minority of trauma-exposed individuals and is characterized by intrusive re-experiencing, avoidance, negative alterations in cognition and mood, and hyperarousal [1][2]. Contemporary neurobiological accounts consistently implicate distributed systems spanning amygdala-centered threat processing, medial prefrontal regulation, hippocampal context encoding, and stress physiology [3][4]. Yet two translational gaps persist.

First, circuit descriptions often specify *where* differences are observed but less often specify *how* multi-timescale interactions generate hallmark clinical phenomena: (i) dissociation between explicit safety knowledge and persistent defensive responding, (ii) relapse under stress despite "knowing better," and (iii) context-dependent return of fear after extinction [5][6]. Second, PTSD is heterogeneous: similar symptom totals can emerge from different dominant mechanisms, and the same individual may shift mechanisms across contexts and internal states.

This paper proposes a minimal computational–clinical synthesis aimed at producing discriminative predictions rather than comprehensive biophysical realism. The framework is deliberately low-dimensional, but it is also *identifiability-aware*: we explicitly address the risk that richly parameterized models become empirically underdetermined (degenerate) in realistic multimodal human datasets, limiting interpretation [7][8].

1.1. Scope and Theoretical Objectives

The present framework serves as a theory-driven synthesis and a minimal phenomenological formalism. It is intended to translate circuit-level concepts into testable predictions rather than providing a comprehensive biophysical reconstruction of PTSD.

2. Empirical Substrate: What Is Stable, What Is Heterogeneous

2.1. Fear Circuitry as a Distributed Control Problem (Not a Lesion Model)

Across species, fear learning and extinction can be modeled as the acquisition of threat value plus context-dependent inhibitory learning, rather than erasure [5] [6]. Human PTSD studies implicate distributed abnormalities across the amygdala, medial prefrontal regions (including vmPFC/ACC), hippocampus, and their interactions, but effect sizes and directions are moderated by trauma type, comorbidity, medication, and measurement choice [3], [4]. The appropriate inference is therefore process-level: PTSD is plausibly a disorder of threat inference and its regulation, not a unitary circuit defect.

2.2. Context Processing and the Implicit–Explicit Memory Dissociation

A key clinical puzzle is the coexistence of explicit safety knowledge with persistent physiological reactivity. This is naturally framed as a dissociation between (i) **explicit/episodic** memory (hippocampal-dependent contextualized recall and narrative integration) and (ii) **implicit/perceptual** memory systems

that support priming, habit-like cue reactivity, and non-conscious stimulus-response associations. In PTSD, multiple paradigms support enhanced perceptual priming for trauma-related material alongside disturbances in explicit memory and dissociation severity [9][10]. A psychobiological perspective is that strong implicit emotional learning can coexist with insufficient explicit trauma encoding, sustaining intrusive re-experiencing and generalized defensive responding even when declarative recall is fragmented [11].

Structural work (e.g., smaller hippocampal volume in meta-analytic and consortium studies) is informative but not determinative: it can constrain plausible mechanisms without proving causality [12][13]. For the present framework, the mechanistic role is operational: hippocampal/context processes constrain *context inference precision* and the integration of safety learning across situations, which directly predicts renewal-like relapse after a context shift.

2.3. Stress and Arousal Reshape Expression and Learning: LC–NE and HPA-Axis Heterogeneity

Arousal changes do not merely "add symptoms"; they can alter how threat signals are amplified, how control is deployed, and how context is inferred. The locus coeruleus–noradrenaline (LC–NE) system is a canonical gain-control architecture that modulates signal-to-noise and behavioral policy under uncertainty [14]. Stress also impairs prefrontal function via well-characterized pathways, producing state-dependent reductions in cognitive control and top-down regulation [15].

HPA Axis: Why Findings Look Inconsistent.

HPA-axis findings in PTSD are frequently described as "inconsistent," but much of that inconsistency is predictable once one separates:

1. **Basal cortisol phenotypes** (e.g., diurnal levels, awakening response, hair cortisol),
2. **Acute reactivity** (responses to laboratory stressors, trauma cues, or pharmacological challenge),
3. **Feedback sensitivity** (e.g., dexamethasone suppression dynamics),
4. **Moderators** (time since trauma, developmental timing, comorbid depression, sex, medication, trauma-exposed controls).

Meta-analytic work emphasizes heterogeneity rather than a single cortisol phenotype [16]. Both **hypocortisolemia** and **hypercortisolemia** have been reported across subgroups, and basal levels need not align with acute stress responses within the same individual. Longitudinal and treatment-focused syntheses further suggest that HPA markers can shift with symptom change and intervention, reinforcing that they are better treated as *state-dependent modulators and feedback features* than as diagnostic signatures [17], [18], [19]. The implication for mechanism modeling is not "cortisol causes PTSD" but: endocrine gain and feedback shape the *conditions under which control fails and learning generalizes*.

2.4. Genetic and epigenetic susceptibility: FKBP5 and beyond

PTSD risk is partially heritable, with twin-based estimates often in the range of roughly one-third, while common-variant effects are distributed (polygenic) and

moderated by trauma exposure [20][21]. Candidate-gene work has been historically underpowered; large GWAS now identify multiple loci of modest effect and highlight immune, neuronal, and stress-response pathways, reinforcing polygenicity and ancestry/sex moderation [22].

What FKBP5 is.

FKBP5 (FK506 binding protein 5) encodes a co-chaperone that regulates glucocorticoid receptor (GR) sensitivity and trafficking; in simplified terms, higher FKBP5 expression can reduce GR efficiency, altering negative feedback and stress-hormone dynamics. FKBP5 is one of the most replicated examples of a **gene** × **environment** signal in stress-related psychopathology: childhood adversity can interact with FKBP5 variants to predict later PTSD symptoms [23]. Mechanistically, allele-specific epigenetic changes (DNA demethylation at GR-responsive elements) have been shown to mediate this interaction, linking early stress to durable GR-system calibration shifts [24].

Is FKBP5 the only mechanism?

No. It is a *paradigmatic* example of how genetic liability, developmental timing, and epigenetic regulation can converge on stress systems, but the genetic architecture of PTSD is broader and includes multiple loci and pathways with small effects [22], [21]. Therefore, the appropriate modeling stance is to treat FKBP5-related biology as one *instance* of stress-feedback heterogeneity that can modulate Gain/Recovery, not as a universal cause.

2.5. Sex differences: PACAP/PAC1 and female vulnerability as a testable moderator

The PACAP/PAC1 receptor system refers to signaling by **pituitary adenylate cyclase-activating polypeptide (PACAP)** acting on the **PAC1 receptor** (ADCYAP1R1). Human studies report sex-specific associations linking PACAP levels and PAC1 receptor variation to PTSD diagnosis/symptoms and fear physiology in heavily traumatized cohorts, with stronger signals in females [25] [26]. This has been proposed to reflect sex-dependent regulation (including hormonally relevant regulatory elements), yielding a plausible pathway for female vulnerability that is best framed as a *moderator hypothesis*: PACAP/PAC1 biology may shift gain and stress responsivity for some women under certain developmental and trauma contexts, rather than serving as a universal explanation.

3. A minimal multi-timescale framework

3.1. Why "minimal" is a methodological commitment

As a core design principle, when parameters are not identifiable in practice, the framework prioritizes identifiable predictions and composite dimensions over precise parameter recovery. Mechanistic ambition must be balanced against identifiability. Complex dynamical models frequently exhibit "sloppiness," where many parameter combinations yield similar outputs, limiting the interpretability of fitted parameters without strong experimental constraints [7]. We therefore construct a minimal model that (i) yields discriminative predictions, (ii) can be

linked to tasks and perturbations, and (iii) can be reduced to composite dimensions even when micro-parameters cannot be uniquely recovered.

3.2. Layer A (fast): threat expression with stress-fragile control

Let x_t denote a coarse threat-expression state and u_t a coarse regulatory-control state at behavioral timescales (seconds–minutes). We model their interaction phenomenologically:

$$x_{t+1} = x_t + f(x_t; \theta_x) - c_t u_t + g_t + \epsilon_t, \tag{1}$$
$$u_{t+1} = u_t + h(u_t; \theta_u) - d_t x_t + \eta_t. \tag{2}$$

Here g_t is a state-dependent **gain** term (LC–NE / autonomic / endocrine influences), c_t is effective control availability (which can fall under stress), and d_t is interference (bidirectional disruption of control by a high threat state). This is not a claim about specific synapses; it is a compact representation of an empirically testable idea: the same learned safety can fail to express when gain is high or control is fragile.

3.3. Layer B (slow): latent context inference and learning

Let K_t denote latent context and $o_{1:t}$ observed cues/outcomes. Context inference is Bayesian:

$$P(K_t \mid o_{1:t}) \propto P(o_t \mid K_t; \mathrm{ctxPrec}) P(K_t \mid K_{t-1}), \tag{3}$$

where ctxPrec denotes context-inference precision (kept as a mnemonic Latin label). Threat value learning is context-sensitive (any standard RL variant suffices at this abstraction):

$$V_{t+1} = V_t + \mathrm{lr}(K_t)\,(r_t - V_t). \tag{4}$$

Fear expression is a function of learned threat value plus current state:

$$\mathrm{FearExpr}_t = \Phi\,(V_t, x_t, g_t). \tag{5}$$

Low ctxPrec and/or biased priors over context can yield overgeneralization and renewal-like relapse after context shifts [5][6]. The implicit–explicit dissociation maps naturally here: impaired hippocampal-dependent context integration reduces effective ctxPrec for episodic/contextual safety while leaving implicit cue reactivity intact.

3.4. Composite mechanism space (four dimensions)

To avoid overparameterization, we compress heterogeneity into four composite dimensions that can be operationalized even when micro-parameters are not identifiable:

- **Control (CTRL):** stress-fragile regulation (effective c_t falls as arousal rises; interference d_t rises).
- **Context (CTX):** low precision or biased priors in context inference (low ctxPrec and/or biased $P(K)$).
- **Gain (GAIN):** arousal-amplified expression (high g_t; LC–NE / autonomic / endocrine state).
- **Recovery (REC):** return-to-baseline dynamics (feedback and damping in stress physiology and autonomic recovery).

These are axes of variation, not diagnostic categories.

4. Identifiability and degeneracy: constraints, not footnotes

Even if a model is identifiable in principle, real datasets can render parameters practically non-identifiable due to noise, sparse sampling, and correlated measurements [8]. In sloppy regimes, the recommended stance is to focus on predictions stable across broad parameter ranges [7]. We therefore propose three design strategies:

1. **Composite inference:** infer CTRL/CTX/GAIN/REC rather than a high-dimensional parameter vector.
2. **Orthogonal perturbations:** pair learning tasks with state manipulations (stress induction, sleep restriction, adrenergic challenge) to separate Gain from Context and Control.
3. **Hierarchical repeated measures:** fit within-person, across-state variation and between-person differences jointly, improving practical identifiability via repetition [27].

Interpretation rule: if two mechanistic stories fit the same data, the correct conclusion is not "both are true," but "the study did not adjudicate them."

5. Translational mapping without biomarker determinism

A frequent failure mode is to map markers directly to interventions as if markers were causal levers. We instead distinguish:

- **Causal leverage:** changing this process is hypothesized to change outcomes.
- **State modulation:** changing this process changes expression/engagement conditions, not necessarily learned threat itself.
- **Correlational marker:** informative about prognosis/subgrouping but not necessarily a lever.

Axis	Operational signature	Primary role	Treatment implication (hypothesis)
CTRL	Safety learned in-session but fails under stress; control metrics degrade under challenge; strong state-dependence	Leverage / Modulation	Stress-inoculation; pacing and scaffolding of exposure; reduce interference; executive-control support
CTX	Poor context discrimination; renewal after context shift; explicit safety knowledge does not generalize	Leverage	Contextualized and multi-context exposure; discrimination training; context variability to prevent renewal
GAIN	Hyperarousal/startle; sleep disruption; autonomic amplification predicts expression conditional on threat value	Modulation	Stabilize arousal to enable learning; symptom-targeted adjuncts; improve engagement/tolerability
REC	Slow return to baseline after stressors; prolonged physiological recovery predicts volatility/relapse	Leverage / Modulation	Target recovery: sleep/circadian support, autonomic recovery training, stress-feedback stabilization

Table 1. Mechanism-space mapping: levers vs. modulators vs. markers, with required abbreviation definitions.

Abbreviation glossary:

w_{PA}^{inhib} *= P→A inhibition weight (prefrontal inhibitory influence on amygdala threat expression);*
w_{PA}^{sup} *= P→A suppression/gating weight (state-dependent top-down suppression during stress);*
g_{LC} *= LC–NE gain parameter proxy (arousal-related amplification of threat expression);*
HRV = heart-rate variability;
y_E *= exposure/engagement index (e.g., within-session extinction expression or approach behavior);*
a_{ext} *= extinction learning strength index;* a_{thre} *= threat learning/acquisition index;*
h *= latent hazard/volatility estimate (context-change expectation);*
EMA = ecological momentary assessment.

6. Discriminative predictions (what would falsify the story)

We present predictions in an adjudication-friendly form: *mechanism ⇒ manipulation ⇒ measurable consequence*.

1. **CTRL-dominant:** acute stress induction disproportionately degrades control signatures, predicting relapse despite intact in-session extinction.
2. **CTX-dominant:** context shift produces renewal-like relapse even when arousal is controlled; discrimination training preferentially reduces relapse probability.

3. **GAIN-dominant:** arousal markers (startle/pupil/autonomic indices) predict fear expression conditional on equivalent learned threat value; arousal stabilization increases tolerability/adherence.
4. **REC-dominant:** slow physiological recovery predicts symptom volatility and relapse over time beyond baseline severity.

Failure of any prediction should be informative: it refines which axis dominates in which subgroup and whether the coarse-graining is adequate.

7. Practical roadmap: what datasets and analyses would make this real

We recommend a staged validation program:

1. **Stage 1:** Demonstrate that CTRL/CTX/GAIN/REC can be estimated with acceptable reliability from tasks plus repeated measures (not necessarily fMRI-first).
2. **Stage 2:** Show incremental predictive utility for outcomes (dropout, relapse, remission) beyond symptom totals.
3. **Stage 3:** Embed mechanism estimates into adaptive trials where augmentation is assigned by dominant axis.

Open resources can accelerate this program, including evidence-synthesis repositories and curated fear-learning databases [28][29].

8. Limitations

This is a minimal phenomenological framework. It omits important contributors (inflammation, social threat, sleep-memory microstructure, dissociation subtypes beyond the present coarse mapping) and collapses multiple interacting mechanisms into composite axes. The payoff is adjudicability: clear predictions, explicit uncertainty, and a roadmap for falsification without biomarker determinism.

9. Conclusion

PTSD is best approached as a heterogeneous disturbance of threat inference and its regulation across contexts and states, constrained by arousal gain control, endocrine feedback, and memory-system dissociations. The contribution here is not a new circuit diagram but a disciplined mechanism space that (i) distinguishes evidence from hypothesis, (ii) respects identifiability limits, and (iii) yields discriminative predictions and translational designs. If the framework fails, it should fail informatively: by telling us which coarse-grainings were wrong, in which subgroups, and under which perturbations.

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No potential competing interests to declare.

Ethics

Not applicable. This article is a theoretical synthesis and does not contain any studies with human or animal participants performed by the author.

Data Availability

Data sharing is not applicable to this conceptual synthesis as no datasets were generated during the current study.

Author Contributions

R.M.A.F. is the sole author. The author conceived the framework, performed the literature synthesis, developed the theoretical model, and wrote the manuscript.

References

1. ^*Kessler RC, Sonnega A, Bromet E, Hughes M, Nelson CB (1995). "Posttraumatic Stress Disorder in the National Comorbidity Survey." Arch Gen Psychiatry. **52**(12):1048 1060. doi:10.1001/archpsyc.1995.03950240066012.*
2. ^*Koenen KC, Ratanatharathorn A, Ng L, McLaughlin KA, Bromet EJ, Stein DJ, Karam EG, Meron Ruscio A, Benjet C, Scott K, Atwoli L, Petukhova M, Lim CCW, Aguilar-Gaxiola S, Al-Hamzawi A, Alonso J, Bunting B, Ciutan M, de Girolamo G, Degenhardt L, Gureje O, Haro JM, Huang Y, Kawakami N, Lee S, Navarro-Mateu F, Pennell B-E, Piazza M, Sampson N, ten Have M, Torres Y, Viana MC, Williams D, Xavier M, Kessler RC (2017). "Posttraumatic Stress Disorder in the World Mental Health Surveys." Psychol Med. **47**(13):22602274. doi:10.1017/S0033291717000708.*
3. a, b*Pitman RK, Rasmusson AM, Koenen KC, Shin LM, Orr SP, Gilbertson MW, Milad MR, Liberzon I (2012). "Biological Studies of Post-Traumatic Stress Disorder." Nat Rev Neurosci. **13**(11):769787. doi:10.1038/nrn3339.*
4. a, b*Shin LM, Liberzon I (2010). "The Neurocircuitry of Fear, Stress, and Anxiety Disorders." Neuropsychopharmacology. **35**(1):169191. doi:10.1038/npp.2009.83.*
5. a, b, c*Milad MR, Quirk GJ (2012). "Fear Extinction as a Model for Translational Neuroscience: Ten Years of Progress." Annu Rev Psychol. **63**:129151. doi:10.1146/annurev.psych.121208.131631.*
6. a, b, c*Bouton ME (2004). "Context and Behavioral Processes in Extinction." Learn Mem. **11**(5):485494. doi:10.1101/lm.78804.*
7. a, b, c*Gutenkunst RN, Waterfall JJ, Casey FP, Brown KS, Myers CR, Sethna JP (2007). "Universally Sloppy Parameter Sensitivities in Systems Biology Models." PLoS Comput Biol. **3**(10):e189. doi:10.1371/journal.pcbi.0030189.*
8. a, b*Chis O-T, Banga JR, Balsa-Canto E (2011). "Structural Identifiability of Systems Biology Models: A Critical Comparison of Methods." PLoS One. **6**(11):e27755. doi:10.1371/journal.pone.0027755.*
9. ^*Lyttle N, Dorahy MJ, Hanna D, Huntjens RJC (2010). "Conceptual and Perceptual Priming and Dissociation in Chronic Posttraumatic Stress Disorder." J Abnorm Psychol. **119**(4):777790. doi:10.1037/a0020894.*
10. ^*Brewin CR (2014). "Episodic Memory, Perceptual Memory, and Their Interaction: Foundations for a Theory of Posttraumatic Stress Disorder." Psychol Bull. **140**(1):6997. doi:10.1037/a0033722.*
11. ^*Wessa M, Flor H (2002). "Posttraumatic Stress Disorder and Trauma Memory: A Psychobiological Perspective." Z Psychosom Med Psychother [Journal of Psychosomatic Medicine and Psychotherapy]. **48**(1):2844. doi:10.13109/zptm.2002.48.1.28.*

12. ^ *Logue MW, van Rooij SJH, Dennis EL, Davis SL, O'Connor L, Wildman DE, Fallon N, van Erp TGM, Morey RA, Krystal JH, Hefner K, Resick PA, Marx CE, Calhoun PS, Beckham JC, Fairbank JA, Kimbrel NA, Dennis PA, Clouston S, Stein MB (2018). "S maller Hippocampal Volume in Posttraumatic Stress Disorder: A Multisite ENIGM A-PGC Study: Subcortical Volumetry Results From Posttraumatic Stress Disorder Consortia." Biol Psychiatry. **83**(3):244253. doi:10.1016/j.biopsych.2017.09.006.*
13. ^ *O'Doherty DCM, Chitty KM, Saddiqui S, Bennett MR, Lagopoulos J (2015). "A Sys tematic Review and Meta-Analysis of Magnetic Resonance Imaging Measureme nt of Structural Volumes in Posttraumatic Stress Disorder." Psychiatry Res Neuroi maging. **232**(1):133. doi:10.1016/j.pscychresns.2015.01.002.*
14. ^ *Aston-Jones G, Cohen JD (2005). "An Integrative Theory of Locus Coeruleus-Nor epinephrine Function: Adaptive Gain and Optimal Performance." Annu Rev Neur osci. **28**(1):403450. doi:10.1146/annurev.neuro.28.061604.135709.*
15. ^ *Arnsten AFT (2009). "Stress Signalling Pathways That Impair Prefrontal Cortex Structure and Function." Nat Rev Neurosci. **10**(6):410422. doi:10.1038/nrn2648.*
16. ^ *Morris MC, Compas BE, Garber J (2012). "Relations Among Posttraumatic Stress Disorder, Comorbid Major Depression, and HPA Function: A Systematic Review a nd Meta-Analysis." Clin Psychol Rev. **32**(4):301315. doi:10.1016/j.cpr.2012.02.002.*
17. ^ *Schumacher S, Niemeyer H, Engel S, Cwik JC, Knaevelsrud C (2018). "Psychother apeutic Treatment and HPA Axis Regulation in Posttraumatic Stress Disorder: A S ystematic Review and Meta-Analysis." Psychoneuroendocrinology. **98**:186201. do i:10.1016/j.psyneuen.2018.08.006.*
18. ^ *Yehuda R (2007). "HPA Alterations in PTSD." Encyclopedia of Stress. Elsevier In c. 359364. doi:10.1016/B978-012373947-6.00737-6.*
19. ^ *Kellner M, Yehuda R, Arlt J, Wiedemann K (2008). "Longitudinal Course of Saliv ary Cortisol in Post-Traumatic Stress Disorder." Acta Psychiatr Scand. **105**(2):1531 55. doi:10.1034/j.1600-0447.2002.01012.x.*
20. ^ *Stein MB, Chen C, Ursano RJ, et al. (2016). "Genome-Wide Association Studies of Posttraumatic Stress Disorder in 2 Cohorts of US Army Soldiers." JAMA Psychiatr y. **73**(7):695704. doi:10.1001/jamapsychiatry.2016.0350.*
21. a, b *Nievergelt CM, et al. (2019). "International Meta-Analysis of PTSD Genome-Wi de Association Studies Identifies Sex- and Ancestry-Specific Genetic Risk Loci." N at Commun. **10**(1):4558. doi:10.1038/s41467-019-12576-w.*
22. a, b *Stein MB, Levey DF, Cheng Z, Wendt FR, Harrington K, Pathak GA, Cho K, Qua den R, Radhakrishnan K, Girgenti MJ, Ho Y-LA, Posner D, Aslan M, Duman RS, Zh ao H, Department of Veterans Affairs Cooperative Studies Program no. 575B, VA Million Veteran Program, Polimanti R, Concato J, Gelernter J (2021). "Genome-Wi de Association Analyses of Post-Traumatic Stress Disorder and Its Symptom Subd omains in the Million Veteran Program." Nat Genet. **53**(2):174184. doi:10.1038/s415 88-020-00767-x.*
23. ^ *Binder EB, Bradley RG, Liu W, Epstein MP, Deveau TC, Mercer KB, Tang Y, Gillespi e CF, Heim CM, Nemeroff CB, Schwartz AC, Cubells JF, Ressler KJ (2008). "Associat ion of FKBP5 Polymorphisms and Childhood Abuse With Risk of Posttraumatic St ress Disorder Symptoms in Adults." JAMA. **299**(11):12911305. doi:10.1001/jama.29 9.11.1291.*
24. ^ *Klengel T, Mehta D, Anacker C, Rex-Haffner M, Pruessner JC, Pariante CM, Pace TWW, Mercer KB, Mayberg HS, Bradley B, Nemeroff CB, Holsboer F, Heim CM, Res sler KJ, Rein T, Binder EB (2013). "Allele-Specific FKBP5 DNA Demethylation Medi ates Gene-Childhood Trauma Interactions." Nat Neurosci. **16**(1):3341. doi:10.1038/ nn.3275.*

25. ^Ressler KJ, Mercer KB, Bradley B, Jovanovic T, Mahan A, Kerley K, Norrholm SD, Kilaru V, Smith AK, Myers AJ, Ramirez M, Engel A, Hammack SE, Toufexis D, Braas KM, Binder EB, May V (2011). "Post-Traumatic Stress Disorder is Associated With PACAP and the PAC1 Receptor." Nature. **470**(7335):492497. doi:10.1038/nature09856.
26. ^Dias BG, Ressler KJ (2012). "PACAP and the PAC1 Receptor in Post-Traumatic Stress Disorder." Neuropsychopharmacology. **38**(1):245. doi:10.1038/npp.2012.147.
27. ^Turner BM, Forstmann BU, Love BC, Palmeri TJ, Van Maanen L (2017). "Approaches to Analysis in Model-Based Cognitive Neuroscience." J Math Psychol. **76**(Pt B):6579. doi:10.1016/j.jmp.2016.01.001.
28. ^O'Neil ME, Harik JM, McDonagh MS, Cheney TP, Hsu FC, Cameron DC, Carlson KF, Norman SB, Hamblen JL (2020). "Development of the PTSD-Repository: A Publicly Available Repository of Randomized Controlled Trials for Posttraumatic Stress Disorder." J Trauma Stress. **33**(4):410419. doi:10.1002/jts.22520.
29. ^FearBase Consortium (n.d.). "FearBase: A Dynamically Growing Fear Conditioning Database." FearBase. https://fearbase.org.

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