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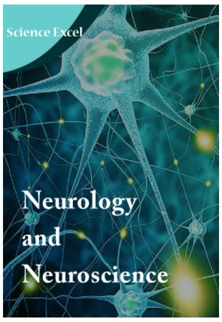

Scroll, Stress, Repeat: The Neuroscience of Trauma in a Digital World

Zoe Wyatt

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*Correspondence
Dr Zoe Wyatt
Neurocon Conference 2025

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Introduction – Scroll, Stress, Repeat

In contemporary society, digital platforms have become primary mediators of sensory and emotional experience [1]. The human stress response - evolved to react to immediate, tangible threats - is now increasingly activated by algorithmically curated streams of information [2]. Recommendation systems, optimised for sustained engagement, have been shown to selectively amplify emotionally salient material, including content that elicits fear, outrage, or distress [3]. This shaping of the user's information environment alters not only attentional priorities but also perceived threat probability and the brain's capacity for emotional regulation [4].

In this context, "digital trauma" can be understood as a spectrum of neurobiological and psychological responses to repeated, high-intensity exposure to distressing material in online environments [5]. These responses range from heightened emotional distress and hypervigilance to trauma-like symptom clusters. For example, *Intrusive imagery* refers to unwanted, distressing mental images that spontaneously enter a person's mind, often resembling flashbacks [6]. *Emotional blunting* refers to a reduced capacity to feel or express emotions, resulting in a sense of emotional numbness or detachment [7]. *Avoidance* involves consciously or unconsciously steering clear of reminders - whether situations, topics, or content - that trigger distress [6]. While such patterns may not always meet the diagnostic criteria for *post-traumatic stress disorder (PTSD)* - a condition characterised by persistent re-experiencing of a traumatic event, avoidance of reminders, negative changes in mood and thinking, and heightened arousal - they share overlapping neural mechanisms [6]. A common feature is the repeated activation of the brain's threat detection and regulation systems in ways that mirror the processes observed in vicarious or secondary trauma, particularly when exposure is frequent, unpredictable, and unresolved [5].

The result is a novel form of psychosocial stressor: a digitally mediated, recurrent, and often unpredictable presentation of distressing material [8]. Unlike direct traumatic events, such exposures may occur at high frequency with minimal recovery intervals, increasing the likelihood of alterations in neural systems implicated in threat detection, salience attribution, and autobiographical memory [9]. Of particular relevance are the Default Mode Network (DMN), which integrates self-referential processing and memory consolidation; the anterior cingulate cortex (ACC), which mediates conflict monitoring and affect regulation; and predictive coding mechanisms, which generate and update threat-related expectations [10,11]. Alterations in these systems can fundamentally reshape how the brain encodes, anticipates, and recovers from perceived threats [10].

Evidence from trauma and stress neurobiology suggests that repeated activation of these circuits - especially without contextual resolution - can foster maladaptive patterns such as hypervigilance (persistent, heightened scanning for danger) and dysregulation of the hypothalamic–pituitary–adrenal (HPA) axis, the body's central stress-response system [9]. In digital environments, these processes may be intensified by the density, novelty, and visual-emotional intensity of curated content streams [12,13]. Over time, the brain may interpret the online environment as a constant low-level threat landscape, keeping stress circuits in a sustained state of readiness even in the absence of direct personal danger [11,12].

This article integrates recent findings in neuroscience to: (1) examine how algorithm-driven content delivery influences trauma reactivity at a neural level; (2) investigate the specific brain systems affected by prolonged exposure to emotionally intense digital material; and (3) explore how trauma-informed principles could guide the design of digital environments that promote psychological safety and resilience. By combining neurobiological, computational, and psychosocial perspectives, the aim is to extend existing models of trauma to include the unique challenges posed by the contemporary digital ecosystem.

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The Algorithm as a Silent Sculptor of Emotion

Digital platforms increasingly function as emotional intermediaries - not simply reflecting the user's world, but actively shaping perception and emotional tone [1]. Through algorithmic curation, individuals are routinely exposed to highly salient, emotionally provocative content, often presented in rapid, unpredictable succession [13]. These content streams are optimised not for emotional neutrality, but for engagement - a metric frequently correlated with outrage, fear, and distress [15,16]. Unlike traditional media, which has long been recognised as capable of producing vicarious trauma such as the extensive broadcast coverage of 9/11 - its structure generally offered buffered, temporally constrained programming, with clearer boundaries around exposure [16]. In contrast, contemporary digital environments provide minimal reprieve and limited contextual framing. Features such as infinite scroll, autoplay, push notifications, and real-time "breaking" updates ensure that emotionally charged material can surface at any moment, disrupting attentional stability and preventing the nervous system from returning to baseline [17].

This unpredictability is critical from a neurobiological perspective [1]. The brain's threat detection mechanisms, such as the amygdala and associated salience networks, are sensitive to both the nature and the timing of potential threats [2]. Inconsistent, intermittent exposure to high-arousal stimuli creates a reinforcement pattern for vigilance, training attention systems to remain on alert for the next possible emotional disruption [18]. Over time, this can extend into offline contexts, where the individual remains primed for danger even without immediate cues [19].

Emerging research suggests that repeated exposure to distressing content in digital environments can produce trauma-like symptoms, even in the absence of direct personal threat [20,21]. Users report experiencing sleep disturbances, emotional numbing, intrusive mental imagery, and heightened anxiety following prolonged interaction with crisis-oriented media streams [20]. The sense of helplessness often induced by consuming traumatic content without the ability to intervene - a hallmark of digital exposure - may further intensify these effects [16]. While such symptoms may not meet the formal threshold for PTSD, their cumulative impact on well-being and emotional functioning warrants serious consideration, especially given how frequently individuals encounter such content in daily digital routines [12].

Neural Systems Implicated in Trauma Reactivity

Trauma reactivity arises from the interplay of several interconnected neural systems, each contributing to how threat is detected, interpreted, and remembered [22]. These systems operate in sequence: initial threat detection by limbic and salience networks, regulatory modulation by cortical regions such as the ACC, integration of the experience within the DMN, and updating of future threat expectations through predictive coding mechanisms [23-25]. Repetition without adequate recovery or contextual resolution can progressively bias this cycle toward chronic vigilance and heightened reactivity [26].

The Default Mode Network (DMN) is a large-scale network engaged during self-referential thinking, autobiographical memory retrieval, and the simulation of possible future scenarios [11,23]. Alterations in DMN function are frequently observed in trauma-exposed populations, including heightened connectivity between nodes that reinforce intrusive recollection and rumination [10]. Such patterns can contribute to a persistent reactivation of threat-related memories, even in the absence of direct cues from the external environment [27]. For example, a person who has previously experienced a traumatic event may find that scrolling through news headlines about unrelated crises still triggers vivid sensory recall of their own trauma, as the DMN persistently links external information to self-referential threat memories [28].

The anterior cingulate cortex (ACC), situated within the medial frontal cortex, plays a critical role in conflict monitoring and the regulation of emotional responses [24]. In trauma contexts, reduced ACC activity has been linked to diminished top-down control over limbic structures such as the amygdala, resulting in heightened emotional reactivity and impaired capacity to modulate stress responses [26]. This dysregulation can perpetuate a state of heightened vigilance, particularly when individuals are repeatedly exposed to unpredictable or emotionally charged digital stimuli [29]. For instance, a sudden appearance of graphic footage while casually browsing social media can elicit a disproportionate physiological stress response, with the ACC unable to sufficiently temper the amygdala's activation before the next stimulus arrives [30].

Predictive coding offers a complementary perspective on trauma reactivity, emphasising the brain's reliance on prior experiences to anticipate sensory input [25]. Following trauma, the brain may update its predictive models to overestimate the probability of threat, leading to hypervigilance and rapid

Table 1. *Neural systems implicated in trauma reactivity and their potential modulation through algorithmically curated digital exposure*

Neural System	Core Function	Trauma-Related Changes	Relevance to Digital Exposure
Default Mode Network (DMN)	Self-referential thinking, autobiographical memory, simulating future scenarios	Increased connectivity in trauma-exposed individuals, reinforcing intrusive recollections and rumination	Algorithmically curated distressing content may trigger repeated self-referential recall of threat-related memories
Anterior Cingulate Cortex (ACC)	Conflict monitoring, regulation of emotional responses, top-down control of limbic activity	Reduced activity can lead to diminished control over emotional reactivity and stress responses	Repeated unpredictable exposure to emotionally charged digital stimuli may overwhelm regulatory capacity
Predictive Coding Circuits	Generating and updating expectations based on prior experience	Overestimation of threat likelihood, leading to hypervigilance and rapid threat attribution	Curated feeds may disproportionately present threat-related content, reinforcing maladaptive threat expectancies

threat attribution in ambiguous situations [31]. In digital environments, algorithmic curation can inadvertently reinforce these maladaptive priors by supplying a disproportionate amount of salient, fear-inducing content, thereby confirming the brain's expectation that danger is both frequent and imminent [2].

A concentrated example of this can be seen in the occupational experiences of digital content moderators, whose daily tasks require sustained exposure to violent, graphic, or otherwise disturbing material. Over time, this exposure - occurring without variation or positive counterbalancing stimuli - can recalibrate predictive models to anticipate danger as the default state [21,32]. The result is a profile of secondary traumatic stress characterised by intrusive imagery, hypervigilance, emotional blunting, and disrupted sleep [33]. This high-intensity occupational context illustrates the same predictive coding mechanisms that may operate more diffusely in the general population through curated digital feeds, albeit with less frequency but far greater reach.

Cumulative Effects of Curated Exposure

While isolated encounters with distressing digital content may elicit short-lived emotional reactions, sustained engagement with algorithmically prioritised material can exert a far deeper influence on the brain's stress-regulation architecture [34]. The absence of predictable intervals between exposures denies neural systems the recovery time needed to return to baseline, fostering a prolonged state of physiological readiness [34]. Over time, this persistent activation can consolidate maladaptive patterns in the Default Mode Network (DMN), anterior cingulate cortex (ACC), and predictive coding circuits, gradually shifting the individual's default emotional state toward vigilance and reactivity [29,30].

In neurobiological terms, this represents a shift from an adaptive, event-based stress response to a chronic state in which stress circuits are continually primed [35]. Once established, such patterns are resistant to spontaneous reversal because the neural systems involved - particularly the DMN and predictive coding pathways - are designed to maintain stability in the face of perceived environmental demands [10,11]. The "digital adversity load" thus functions less like a single traumatic blow and more like a prolonged environmental conditioning process that slowly resets the nervous system's baseline.

Longitudinal research underscores the power of cumulative exposure in shaping mental health trajectories. In a large-scale study of over 8,000 early adolescents, [36] found that both adverse childhood experiences (ACEs) and bullying victimisation independently predicted elevated levels of internalising symptoms such as anxiety and depression, and externalising behaviours, including aggression and rule-breaking. These effects were dose-dependent: greater cumulative exposure was associated with progressively worse outcomes, even when the exposures were of different types [36]. The findings support the cumulative risk model, in which disparate stressors compound over time, placing sustained pressure on emotional regulation systems [36]. Importantly, the study also showed that these risks were not limited to those with the most severe or frequent exposures - even lower-intensity but repeated adversities had measurable effects on mental health, suggesting that ongoing, varied stressors may erode resilience incrementally [36].

The relevance of these findings to digital environments is underscored by disaster-media research. Following Hurricane Irma, [14] reported that youth with high exposure to disaster-related media exhibited significantly higher rates of post-traumatic stress symptoms, even when geographically distant from the storm and physically safe. Crucially, it was the intensity and frequency of media exposure - rather than direct physical threat - that emerged as the key predictor of psychological impact [14]. These results highlight how mediated experiences can activate the brain's threat-response systems in much the same way as direct exposure, especially when coverage is repetitive, emotionally charged, and visually graphic [14].

A striking illustration of algorithmically mediated emotional influence can be seen in the large-scale "emotional contagion" experiment conducted on Facebook [37]. In this study, researchers manipulated the news feeds of nearly 700,000 users over the course of one week, reducing the proportion of either positive or negative posts to examine downstream effects on users' own emotional expression [37]. The findings demonstrated that when exposure to positive content was reduced, users subsequently produced fewer positive posts themselves, and when exposure to negative content was reduced, users' own negative expression declined [37]. Importantly, these changes occurred without direct interpersonal interaction and outside of participants' conscious awareness, indicating that algorithmic curation alone was sufficient to shape collective emotional tone [37]. The controversy surrounding this experiment underscored the ethical stakes of large-scale digital manipulation, but it also provides empirical evidence of how subtle, repeated adjustments to online environments can recalibrate emotional states at scale [38]. This aligns closely with the cumulative stress models discussed above, suggesting that even relatively minor but repeated algorithmic shifts in affective content can meaningfully alter psychological outcomes over time.

Algorithmically curated feeds can impose what might be termed a digital adversity load - a sustained accumulation of minor but emotionally charged stressors delivered without predictable intervals or opportunities for resolution [39]. The micro-timing of delivery, combined with emotionally potent visual content, ensures that the nervous system is repeatedly brought to a state of alert before it has returned to baseline. For adolescents, whose neural systems for emotion regulation and threat appraisal are still under construction, this constant oscillation between neutral and threat-laden stimuli can recalibrate the brain's baseline toward heightened vigilance [40]. Over time, this adaptation risks hardening into enduring patterns of avoidance, hyperarousal, or emotional constriction - patterns that, once established, are resistant to spontaneous reversal and may require deliberate intervention to unwind [41].

Recognising the neurobiological costs of a sustained digital adversity load raises an urgent question: how can these environments be restructured to safeguard - rather than erode - neural resilience? The same algorithms that currently magnify emotional distress could, in theory, be recalibrated to foster recovery, provide emotional balance, and buffer against maladaptive threat responses. Moving from diagnosis to prevention requires integrating insights from trauma neuroscience, developmental psychology, and human–computer interaction.

Designing for Neural Resilience: Strategies for Mitigating Digital Trauma Reactivity

Strategy 1: Algorithmic Buffering with Contextual Framing

A trauma-informed redesign of recommendation systems could combine two complementary interventions: emotional pacing and meaning-making [42]. Rather than clustering distressing content or delivering it without reprieve, algorithms could intersperse emotionally neutral or positively valenced material after high-arousal stimuli, drawing on evidence that restorative cues—such as natural imagery, prosocial narratives, or humour - facilitate recovery in the salience and default mode networks [43,44]. This approach mirrors established post-disaster media guidelines, which caution against repeated exposure to graphic coverage and recommend the inclusion of stabilising material, especially for youth and trauma-exposed individuals [45].

Equally important is the integration of contextual scaffolding. Research indicates that unframed, ambiguous stimuli trigger more intense amygdala-driven threat responses than those accompanied by clarifying information [35,39]. Embedding factual timelines, verified sources, or expert commentary can activate prefrontal appraisal circuits, reducing limbic overactivation and preventing the consolidation of fear-laden memory traces [46]. In practice, an algorithm could detect high-intensity content and follow it not only with restorative stimuli, but also with framing elements that enable users to situate events within an organised narrative [47]. By doing so, platforms could address two neurobiological vulnerabilities at once: limiting excessive DMN-driven rumination and recalibrating predictive coding away from overestimating the likelihood of future threat [35].

Strategy 2: User-Governed Exposure Controls

In parallel with systemic changes, platforms could offer users greater agency in determining their own exposure thresholds. Current filtering tools are often limited and reactive; a proactive model would allow individuals to set parameters for both the frequency and intensity of emotionally charged material [42]. Adjustable "intensity sliders" could alter the proportion of distressing content, while temporal buffers could ensure predictable intervals between high-arousal exposures [48,49].

From a neurobiological standpoint, predictable recovery intervals are essential for ACC-mediated regulation of amygdala activity and for parasympathetic reactivation of the HPA axis. Even modest reductions in exposure can stabilise affective functioning, limit intrusive memory formation, and help recalibrate predictive coding away from constant threat anticipation [50]. For adolescents and individuals with trauma histories, whose neural systems are either still maturing or more easily dysregulated, such controls could be particularly protective [40,44].

Strategy 3: User-Initiated Micro-Recovery Intervals

While platform-level redesigns could theoretically mitigate harm, the commercial architecture of social media makes such changes improbable in the short term [51]. Engagement - often fuelled by outrage, fear, and novelty - remains the primary currency of Facebook, TikTok, Instagram, and similar platforms [52]. Given this reality, individual users may need to implement their own protective measures [53].

One evidence-based approach is the deliberate creation of micro-recovery intervals - brief, intentional breaks inserted between exposure to emotionally intense content and continued scrolling [53,54]. These intervals could be as short as two minutes, during which the user engages in a regulating activity such as diaphragmatic breathing, visual grounding, or shifting focus to neutral or positive stimuli offline [52,54,55].

Research on stress habituation and autonomic regulation suggests that even short, self-initiated pauses can facilitate parasympathetic reactivation, allowing the hypothalamic–pituitary–adrenal (HPA) axis to begin returning to baseline before the next potential stressor [56, 57]. Over time, these pauses can reduce cumulative stress load, interrupt the reinforcement of maladaptive predictive models, and preserve emotional bandwidth [56]. While less seamless than structural reform, this self-directed strategy offers an immediately actionable buffer against the relentless pace of algorithmically driven content delivery [42] [57].

Strategies in Context: Between Idealism and Pragmatism

These strategies correspond directly to the neural vulnerabilities identified earlier: algorithmic buffering targets DMN rumination and predictive coding biases; exposure controls support ACC regulation and recovery intervals; and micro-recovery intervals assist HPA axis reset and parasympathetic activation. The first two require structural change that may conflict with platform profit models, while the third can be implemented by individuals immediately. A pragmatic approach is therefore dual: advocate for trauma-informed structural design while equipping individuals to manage their own exposure in the current digital climate.

Conclusion

The convergence of trauma neuroscience and digital media research reveals that the brain's threat systems are not bound by physical proximity to danger. Algorithmically curated environments can sustain states of vigilance, emotional dysregulation, and maladaptive memory formation through recurrent exposure to distressing content. These effects are particularly pronounced in developmental stages where neural circuits for emotion regulation remain malleable, but they extend across the population in ways that are often invisible yet cumulative.

Addressing this reality requires reframing digital environments as active agents in shaping mental health, rather than neutral conduits of information. Trauma-informed approaches - whether through design, user agency, or contextual framing - offer a framework for reducing harm, but meaningful implementation will depend on aligning technological capability with public health priorities. In the absence of systemic reform, awareness and self-regulation remain critical tools for resisting the erosion of neural resilience in an age where the next threat cue is always one swipe away.

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