

Psychophysiological Changes in Individuals With Repetitive Negative Thinking During Idleness And on Assigning A Cognitive Task: A Biofeedback-Based Comparative Study

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Abstract

Background: Repetitive negative thinking (RNT) is a transdiagnostic cognitive process implicated in anxiety, depressive, and adjustment disorders, and is linked to autonomic dysregulation and reduced heart rate variability. Whether a brief, task-based biofeedback session can shift these physiological and subjective indices away from a ruminative, idle state has not been well studied in Indian outpatient populations.

Objectives: To assess and compare psychophysiological parameters and subjective distress/relaxation percentages during a period of idleness versus a period of task-based biofeedback in individuals with high RNT, and to examine consistency of these effects across age, gender, and diagnostic subgroups.

Methods: In this cross-sectional comparative study, 80 participants aged 18–58 years with adjustment disorder, anxiety disorder, depression, or obsessive thoughts, and a Penn State Worry Questionnaire score ≥ 20 , underwent 10 minutes of baseline biofeedback monitoring during idleness followed by a structured cognitive task (auditory-discrimination and sustained-attention exercises) under continued biofeedback monitoring. Heart rate (HR), respiratory rate (RR), galvanic skin response (GSR), peripheral temperature, and biofeedback-derived relaxation and distress percentages were recorded before and after the task using the RMS Relax 701 Advanced Bio-Feedback System. The Wilcoxon signed-rank test compared paired values; $p < 0.05$ was considered significant.

Results: Median HR fell from 86 (80.5–91.5) to 75 (72–82) bpm ($p < 0.001$). Relaxation percentage rose from 77% (72–82) to 90% (86–93) ($p < 0.001$), while distress fell from 22% (19.3–27.5) to 10% (7–14) ($p < 0.001$). RR, GSR, and temperature did not change significantly. Effects were preserved across age strata (≤ 30 vs > 30 years), gender, and diagnostic subgroups (generalized anxiety disorder [GAD] and depression).

Conclusions: A single, brief session combining a structured cognitive task with real-time biofeedback produced a rapid, reproducible reduction in heart rate and subjective distress and an increase in relaxation among individuals with high RNT, independent of age, gender, or diagnosis. This low-cost, scalable approach merits further evaluation as an adjunctive, transdiagnostic intervention in resource-constrained mental health settings.

Keywords: Repetitive negative thinking; biofeedback; transdiagnostic; heart rate variability; rumination; anxiety; depression; India

Introduction

Depression and anxiety disorders are among the leading causes of disability worldwide, imposing a substantial and rising burden on global public health and economies.^(1,2) Categorical nosologies such as the DSM-5 and ICD-11 classify these as discrete entities—major depressive disorder, generalized anxiety disorder (GAD), obsessive-compulsive disorder—yet a growing body of clinical research favours a transdiagnostic framework in which shared cognitive and physiological processes drive the marked comorbidity and chronicity observed across these conditions.⁽¹⁾

Repetitive negative thinking (RNT) sits at the centre of this transdiagnostic model. RNT denotes a maladaptive, perseverative style of thinking about negative content that is difficult to disengage from, and subsumes disorder-specific constructs such as rumination (dwelling on past failure, characteristic of depression) and worry (anticipatory anxiety about the future, characteristic of GAD).^(1,3) Although rumination and worry differ in temporal orientation, both consume attentional resources

and prolong emotional distress through a shared pathogenic mechanism. Importantly, RNT is not merely a symptom marker: it prospectively predicts the onset of depressive and anxiety disorders, mediates the link between stress exposure and psychopathology, and independently predicts suicidal ideation beyond overall symptom severity.(1) Targeting RNT therefore represents a high-yield strategy that could, in principle, benefit patients across several diagnostic categories simultaneously.

The Indian context lends particular urgency to this line of enquiry. The National Mental Health Survey (2015–16) estimated that nearly 15% of Indian adults require active intervention for a mental health condition,(2,4) and community-based studies from rural and semi-urban India report depression and anxiety prevalences as high as 15% and 10.6% respectively.(5) Among school-going adolescents, rates of depression and anxiety have been reported at 25.9% and 13.7%.(6) Despite this burden, the treatment gap in India frequently exceeds 80%, driven by stigma, workforce shortages, and limited access to specialist care.(2) Interventions that are brief, low-cost, and mechanistically transparent—qualities that make them acceptable even to patients who are ambivalent about conventional psychotherapy or medication—are therefore urgently needed.

A useful theoretical anchor for RNT is the Neurovisceral Integration Model, which links prefrontal-cortical regulatory function to autonomic cardiac control.(8) Heart rate variability (HRV)—the beat-to-beat variation in the R–R interval—is the most widely used peripheral index of this link: higher resting HRV reflects stronger vagal (parasympathetic) tone and more flexible autonomic regulation, whereas low HRV is associated with poor top-down inhibition of amygdala reactivity.(9,10) This creates a self-sustaining loop in which RNT lowers vagal tone, and reduced vagal tone in turn impairs the very prefrontal control needed to disengage from negative thoughts.(10)

A complementary, cognitive account of RNT is the Resource Allocation Hypothesis, which holds that RNT competes for limited working-memory capacity.(11) During idleness—a state of low cognitive demand—the brain's default mode network (DMN), associated with self-referential and ruminative processing, becomes relatively more active.(12) Conversely, engaging a demanding external task recruits task-positive networks and consumes the very working-memory resources that would otherwise sustain RNT, in effect “crowding out” negative thought content.(12) Experimental work on distraction-based strategies supports this mechanism: focused distraction reduces distress associated with intrusive thoughts more effectively than suppression, even without necessarily reducing the frequency of the intrusions themselves.(35)

Biofeedback offers a natural means of operationalising both mechanisms within a single, brief clinical encounter. By measuring physiological signals—heart rate, skin conductance, respiration, peripheral temperature—and displaying them to the patient in real time, biofeedback enables a form of “bottom-up” self-regulation: voluntary modulation of breathing and heart rate stimulates vagal afferents, which in turn can enhance prefrontal–amygdala connectivity and, by extension, the capacity to inhibit negative thought content.(10,13) Unlike purely “top-down” cognitive therapies, biofeedback provides an immediate, tangible demonstration to the patient that their physiological and emotional state is modifiable.

Despite robust theoretical grounding for both mechanisms, few studies have directly compared physiological and subjective indices of distress during a period of unstructured idleness against a period of structured, task-based biofeedback within the same individuals, and fewer still have done so in Indian clinical populations characterised by high transdiagnostic RNT. Establishing whether a brief cognitive task delivered under biofeedback monitoring can measurably shift heart rate, relaxation, and distress compared with idling has direct implications for “activity scheduling” and distraction-based prescriptions that are inexpensive to deliver at scale. The present study was therefore undertaken to assess and compare psychophysiological parameters during idleness and during task-based biofeedback among individuals with RNT, and to determine whether any observed differences were statistically significant and consistent across demographic and diagnostic subgroups.

Objectives

Primary objectives:

1. To assess the percentage of distress and relaxation using a biofeedback technique in individuals with repetitive negative thinking during idleness and on assignment of a cognitive task.
2. To compare and interpret differences in percentage distress and relaxation between the idleness and cognitive-task conditions.

Secondary objective:

1. To determine the prevalence of repetitive negative thinking among patients with anxiety disorder, depressive disorder, and adjustment disorder.

Materials and Methods

Study design and setting. This was a cross-sectional comparative study conducted in the Department of Psychiatry, Adichunchanagiri Hospital and Research Centre, B.G. Nagara, Mandya district, Karnataka, over a period of 18 months, after approval from the Institute Ethics Committee (approval no. AIMS/IEC/045/2024) and written informed consent from all participants.

Participants. Individuals aged 18–60 years of either sex presenting with symptoms of adjustment disorder, anxiety disorder, depression, or obsessive thoughts, and scoring ≥ 20 on the Penn State Worry Questionnaire (PSWQ), were enrolled. Patients with acute general medical conditions, acutely symptomatic psychiatric illness, or active suicidal ideation were excluded.

Sample size. The sample size was calculated using the standard formula for comparison of means, $N = (Z\alpha/2 + Z\beta)^2 \cdot SD^2/d^2$, with $Z\alpha/2 = 1.96$ ($\alpha = 0.05$), $Z\beta = 0.84$, and an absolute error (d) of 10%, yielding a minimum requirement of 80 participants at 95% confidence.

Procedure. After sociodemographic data collection, participants underwent 10 minutes of continuous biofeedback monitoring during a period of idleness with no assigned task and no relaxation instruction. Immediately thereafter, without interruption of monitoring, participants were administered a structured cognitive task comprising instrumental-sound identification and sustained-attention exercises. Distress and relaxation percentages, along with HR, RR, GSR, and peripheral temperature, were recorded continuously and compared between the idleness phase and the post-task phase.

Assessment tools, available in both English and Kannada, included:

- The Perseverative Thinking Questionnaire (PTQ), a 15-item, 5-point Likert-scaled measure of repetitive, intrusive, and difficult-to-disengage-from thinking (score range 0–60; higher scores indicate greater RNT).
- The Ruminative Responses Scale of the Response Styles Questionnaire (22 items, 1–4 scale) to assess depressive rumination.
- The Penn State Worry Questionnaire (16 items) to assess worry severity.
- The RMS Relax 701 Advanced Bio-Feedback System, a multimodal device recording pulse rate, skin temperature, respiration, and galvanic skin response in real time, with visual (colour bar graph) and audio feedback, and computed relaxation/distress percentages.

Statistical analysis. Data were entered in Microsoft Excel and analysed using SPSS v22 and Epi Info. Categorical variables were summarised as frequencies and percentages, and continuous variables as mean (SD) or median (interquartile range, IQR) as appropriate after testing for normality. Paired values obtained during idleness and during the task-based biofeedback condition were compared using the Wilcoxon signed-rank test (with paired t-test used where data were normally distributed). Subgroup analyses were performed by age (≤ 30 vs > 30 years), gender, and diagnosis (GAD vs depression). A two-tailed p -value < 0.05 was considered statistically significant.

Results

Sample characteristics. Eighty participants were enrolled, with a mean (SD) age of 33.5 (9.7) years (range 18–58) and a mean (SD) illness duration of 11.8 (27.3) months (median 7.5, IQR 4–12). Fifty-three-point-eight percent were aged > 30 years, and 55.0% were men. Educational attainment was heterogeneous: 37.5% undergraduate, 30.0% high-school educated, 15.0% primary-school educated, 11.3% illiterate, and 6.3% graduate. Most participants were employed (60.0%), followed by unemployed (28.7%) and unskilled workers (10.0%). Just over half resided in rural areas (52.5%), 45.0% in semi-urban areas, and 2.5% in urban areas. Most were married (63.7%), and nearly half belonged to the middle socioeconomic class (46.3%).

The most common diagnosis was GAD (47.5%), followed by adjustment disorder (23.8%), depression (15.0%), panic disorder (8.8%), illness anxiety disorder (2.5%), acute stress reaction (1.3%), and obsessive-compulsive disorder (1.3%). A positive personal psychiatric history was uncommon (1.3%); 15.0% reported a positive family history, 8.8% had medical comorbidities, and 20.0% reported substance use.

Baseline RNT and related scores. Total PTQ (negative thinking) scores ranged from 26–47 (mean [SD] 38.9 [4.1]); total worry (PSWQ) scores ranged from 32–61 (mean [SD] 47.0 [4.7]); and total rumination scores ranged from 34–53 (mean [SD] 43.2 [4.0]), confirming a sample with uniformly elevated RNT irrespective of categorical diagnosis.

Primary comparison: idleness versus task-based biofeedback. Compared with the idleness phase, task-based biofeedback was associated with a significant reduction in median HR, from 86 (80.5–91.5) to 75 (72–82) bpm ($p<0.001$). Relaxation percentage increased significantly, from 77% (72–82) to 90% (86–93) ($p<0.001$), while distress percentage decreased significantly, from 22% (19.3–27.5) to 10% (7–14) ($p<0.001$). No statistically significant differences were observed for RR [20.0 (17.0–22.0) vs 18.0 (16.0–24.0); $p=0.921$], GSR [500.0 (472.5–510.0) vs 494.0 (486.5–506.0); $p=0.222$], or peripheral temperature [73.7 (71.0–75.0) vs 72.0 (69.0–77.0); $p=0.227$].

Table 1. Comparison of physiological and subjective parameters during idleness and task-based biofeedback (N = 80)

Variable	Idleness, median (IQR)	Task-based biofeedback, median (IQR)	p-value
Heart rate (bpm)	86.0 (80.5–91.5)	75.0 (72.0–82.0)	<0.001
Respiratory rate (/min)	20.0 (17.0–22.0)	18.0 (16.0–24.0)	0.921
Galvanic skin response	500.0 (472.5–510.0)	494.0 (486.5–506.0)	0.222
Peripheral temperature (°F)	73.7 (71.0–75.0)	72.0 (69.0–77.0)	0.227
Relaxation (%)	77.0 (72.0–82.0)	90.0 (86.0–93.0)	<0.001
Distress (%)	22.0 (19.3–27.5)	10.0 (7.0–14.0)	<0.001

Subgroup analyses. The pattern of a significant fall in HR and distress and a significant rise in relaxation, with no significant change in RR, GSR, or temperature, was reproduced consistently across all pre-specified subgroups.

By age, participants ≤ 30 years showed HR reduction from 84 (77–92) to 74 (72–77) bpm and those >30 years from 86 (80–90) to 75 (72–84) bpm (both $p<0.001$); relaxation and distress changes were similarly significant in both strata ($p<0.001$ for each).

By gender, men showed HR reduction from 86 (82–92) to 75 (72–80) bpm and women from 86 (80–90) to 74.5 (72–84) bpm (both $p<0.001$), with concordant improvements in relaxation and distress ($p<0.001$ for each). A modest but statistically significant fall in temperature was noted among men only [74 [72–76] vs 71.1 [68.8–76]; $p=0.026$], not replicated in women.

By diagnosis, participants with GAD showed HR reduction from 82.5 (72–86.8) to 74 (72–76) bpm, and those with depression from 86 (82.5–92) to 79 (72–86) bpm (both $p<0.001$); relaxation and distress again changed significantly in both groups ($p<0.001$ for each), with no significant change in RR, GSR, or temperature in either subgroup.

Table 2. Subgroup comparison of heart rate, relaxation, and distress during idleness versus task-based biofeedback

Subgroup	HR idleness	HR task-BF	Relax. idleness (%)	Relax. task-BF (%)	Distress idleness (%)	Distress task-BF (%)
Age ≤ 30 y	84 (77–92)	74 (72–77)	77 (72–82)	90 (83.5–91)	23 (19.5–28)	10 (9–16.5)
Age >30 y	86 (80–90)	75 (72–84)	78 (72–82)	90 (86–94)	22 (19–26)	10 (6–14)

Su bg ro up	HR idlen ess	HR task -BF	Relax . idlen ess (%)	Relax. task- BF (%)	Distr ess idlen ess (%)	Distress task-BF (%)
M en	86 (82– 92)	75 (72– 80)	76.5 (72– 81.8)	90 (86.3– 93)	22 (19– 28)	10 (7–13.8)
W o m en	86 (80– 90)	74.5 (72– 84)	77.8 (74.3 –82)	90 (85.3– 94)	22 (20– 26)	10 (6–14.8)
GA D	82.5 (72– 86.8)	74 (72– 76)	76 (72– 78)	90 (87– 95)	23 (20– 26.5)	10 (5–13)
De pr es sio n	86 (82.5 –92)	79 (72– 86)	78.5 (73– 83.5)	92 (75.5– 77)*	23 (20– 31.8)	8 (5.3– 24.5)

All values are median (IQR); $p < 0.001$ for HR, relaxation, and distress within each subgroup. HR in beats per minute. *IQR as reported in original dataset.

Discussion

In this cross-sectional comparative study of 80 individuals with elevated repetitive negative thinking, a single, brief session combining a structured cognitive task with real-time biofeedback produced a rapid and clinically appreciable shift toward a calmer psychophysiological state. Median heart rate fell from 86 to 75 beats per minute, subjective relaxation rose from 77% to 90%, and subjective distress fell from 22% to 10%, with all three changes highly significant ($p < 0.001$). These effects were preserved across age strata, gender, and the two largest diagnostic subgroups (GAD and depression), while respiratory rate, galvanic skin response, and peripheral temperature remained essentially unchanged.

Consistency with a transdiagnostic model of RNT. The elevated and narrowly distributed baseline PTQ, worry, and rumination scores across a diagnostically heterogeneous sample support the premise that RNT functions as a shared cognitive process cutting across DSM categories, rather than a feature specific to any single disorder.(1,3,14–16) That task-based biofeedback improved physiological and subjective indices comparably in both the GAD and depression subgroups reinforces the argument that interventions targeting RNT as a transdiagnostic process—rather than a categorical diagnosis—can plausibly deliver benefit across multiple disorders simultaneously, a position consistent with the broader process-based treatment literature.(1,3,20)

Convergence with the HRV-biofeedback literature. Although this study did not derive formal HRV indices, the magnitude of HR reduction alongside increased relaxation and decreased distress is consistent with enhanced vagally mediated cardiac control. Schumann and colleagues showed that a six-week smartphone-guided HRV-biofeedback protocol in depressed patients increased resting vagal HRV while reducing state rumination, perceived stress, anxiety, and depressive symptoms relative to a waitlist control; in the same study, experimentally induced rumination acutely raised heart rate and skin conductance, underscoring the physiologically activating nature of ruminative idling.(38) The present findings—reduced HR and distress specifically during the task-biofeedback condition—align closely with this mechanism. A meta-analysis of 14 randomised controlled trials ($N = 794$) by Pizzoli and colleagues reported a moderate pooled effect (Hedges' $g = 0.38$) of HRV-biofeedback on depressive symptoms,(40) and a five-week HRV-biofeedback trial by Jung and colleagues found that reductions in negative emotion were statistically mediated by increases in resting HRV.(39) Collectively, this literature and the present single-session findings point to a common mechanistic pathway in which biofeedback-guided physiological self-regulation promotes parasympathetic dominance, which in turn attenuates negative affect.

Role of cognitive task engagement. A distinguishing feature of the present protocol is the deliberate pairing of biofeedback with an active cognitive task rather than passive relaxation alone. This design draws on the Resource Allocation Hypothesis and on default-mode/task-positive network models of rumination: idle states favour DMN-driven self-referential processing, whereas an externally directed task recruits task-positive networks and consumes working-memory capacity that would otherwise sustain RNT.(11,12,21–24) The observed pre–post changes likely reflect the additive effects of vagal up-regulation through the biofeedback loop and attenuation of RNT through focused cognitive load. This is consistent with experimental work by Najmi and colleagues, who found that focused distraction reduced distress associated with intrusive thoughts more effectively than suppression in patients with obsessive-compulsive disorder,(35) and with Hilt and Pollak's finding that brief distraction reduced rumination and negative affect following a negative mood induction in youth.(28)

Selectivity of the physiological response. The absence of significant change in RR, GSR, and temperature may initially seem discordant with HRV-biofeedback studies reporting broader autonomic shifts,(38,43) but several explanations are plausible. First, the present intervention was a single, brief session, whereas protocols demonstrating respiratory and electrodermal change typically involve multiple weeks of paced-breathing training. Second, cardiac vagal modulation is known to respond more rapidly to cognitive and emotional manipulation than sweat-gland activity or peripheral vasoconstriction, which may follow distinct time courses linked more closely to discrete orienting or threat responses.(9,25) The present pattern—marked cardiac and subjective change without parallel electrodermal or thermoregulatory shift—is therefore compatible with a selective, rapid enhancement of parasympathetic cardiac control rather than a global sympathetic dampening.

Consistency across subgroups. The reproducibility of the core effect across age strata, gender, and diagnosis is a notable strength. That both younger and older participants, and both men and women, showed comparable reductions in HR and distress alongside increased relaxation suggests that the underlying mechanisms—vagal activation and task-positive network engagement—are broadly preserved across adulthood and across sex, echoing Jung and colleagues' observation that HRV-mediated emotional benefits of biofeedback generalise across genders.(39) Diagnostic subgroup analyses similarly showed comparable benefit in GAD and depression, in keeping with a wider literature documenting HRV-biofeedback benefit across both anxiety and depressive presentations, including case reports in GAD and randomised evidence in peripartum depression.(40–42)

Clinical implications. These findings support the incorporation of brief, task-based biofeedback modules into treatment pathways for patients with high RNT, whether presenting with GAD, depression, adjustment disorder, or related conditions. Given the scale of the treatment gap in low- and middle-income settings, such a low-intensity, mechanistically transparent intervention could plausibly be delivered in outpatient psychiatry clinics, primary care, or community mental health settings with modest equipment and training requirements. It may hold particular value as an initial engagement strategy for patients who are ambivalent about pharmacotherapy or structured psychotherapy, offering a concrete, experiential demonstration that physiological and emotional states are modifiable. The approach also complements existing evidence-based psychotherapies: rumination-focused cognitive behavioural therapy (RF-CBT), which shifts patients from abstract evaluative thinking toward concrete, present-focused processing, has demonstrated meaningful reductions in depressive symptoms and rumination.(31) Embedding brief task-based biofeedback sessions within RF-CBT or standard CBT could reinforce experiential learning about the link between attention, behaviour, and bodily arousal, potentially strengthening overall treatment effect.

Strengths and limitations. Strengths of this study include a clear mechanistic rationale grounded in established models of RNT and autonomic regulation, the use of objective psychophysiological measures alongside validated self-report instruments, and systematic subgroup analyses that demonstrated broad generalisability of the core finding. Several limitations warrant emphasis. The single-session, pre–post, uncontrolled design precludes causal inference regarding the durability of the observed effects and cannot disentangle the relative contribution of the cognitive task from that of the biofeedback loop itself; a design incorporating an active comparator (e.g., idleness alone continued for an equivalent duration, or biofeedback without a concurrent task) would be needed to isolate these components. The absence of a longer follow-up period means it remains unknown whether the observed physiological improvements translate into sustained reductions in RNT frequency or clinical symptom burden. Formal HRV metrics (e.g., root mean square of successive differences, high-frequency power) were not derived, limiting direct comparison with the broader HRV-biofeedback literature. Finally, as a single-centre study conducted in a semi-urban South Indian tertiary hospital, generalisability to other clinical and cultural settings should be established prospectively.

Future directions. Randomised controlled trials comparing task-based biofeedback against active and passive control conditions, incorporating formal HRV indices and extended follow-up, are needed to establish durability of effect and to disentangle the contributions of cognitive engagement versus physiological feedback. Combining psychophysiological recording with neuroimaging could allow direct testing of the hypothesised shift between default-mode and task-positive

network activity. Dose–response studies examining the number and duration of sessions required for sustained benefit, and identification of baseline moderators such as resting HRV, RNT severity, or working-memory capacity, would further refine patient selection for this intervention.

Conclusion

In this comparative study of 80 individuals with elevated repetitive negative thinking, a single brief session of task-based biofeedback produced a significant reduction in heart rate and subjective distress, together with a significant increase in relaxation, compared with an equivalent period of idleness. These effects were reproducible across age, gender, and diagnostic subgroups (GAD and depression), while respiratory rate, galvanic skin response, and peripheral temperature remained unchanged, suggesting a selective enhancement of parasympathetic cardiac regulation. By combining bottom-up autonomic regulation with top-down attentional engagement, task-based biofeedback represents a promising, low-cost, and mechanistically grounded intervention for transdiagnostic RNT that merits further evaluation—through randomised, controlled, and longer-term designs—as a scalable adjunct in resource-constrained mental health settings such as India.

Declarations

Ethics approval and consent to participate: The study was approved by the Institute Ethics Committee, Adichunchanagiri Hospital and Research Centre, B.G. Nagara, Mandya district (approval no. AIMS/IEC/045/2024). Written informed consent was obtained from all participants prior to enrolment.

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