15 (2026) 50–56

Contents lists available at ScienceDirect

Deep Brain Stimulation

journal homepage: www.journals.elsevier.com/deep-brain-stimulation

Beyond motor improvement: The potential role of Mindfulness across the Deep Brain Stimulation pathway in Parkinson's Disease

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ARTICLE INFO

Keywords:
Parkinson's disease
Deep brain stimulation
Mindfulness
Psychological adjustment
Expectations
Quality of life

ABSTRACT

Deep brain stimulation (DBS) provides substantial and durable relief of levodopa-responsive motor symptoms and motor complications in people with advanced Parkinson's disease (PD), yet motor improvement does not invariably translate into satisfactory psychological, social, and quality-of-life outcomes. Anxiety, depression, apathy, cognitive vulnerability, unrealistic expectations, altered illness roles, and concerns about identity or authenticity may persist or emerge during the DBS pathway. Mindfulness-based interventions (MBIs), including mindfulness-based stress reduction and mindfulness-based cognitive therapy, have been investigated as adjunctive treatments in PD, whereas acceptance and commitment therapy (ACT) provides a related framework focused on psychological flexibility and values-guided action. This narrative review integrates the literature on MBIs in PD with evidence concerning cognition, expectations, placebo/nocebo responses, psychosocial adjustment, and identity after DBS. Small trials and meta-analyses suggest that MBIs are feasible and may improve anxiety, depressive symptoms, mindfulness skills, and some aspects of quality of life, while evidence for motor, cognitive, apathy, sleep, and caregiver outcomes remains inconsistent or preliminary. Direct trials of mindfulness in patients with PD undergoing DBS are essentially lacking. We propose that mindfulness is unlikely to enhance the neurostimulatory effect itself but may target modifiable mediators between motor capacity and lived outcome: stress reactivity, attentional control, symptom appraisal, expectation rigidity, experiential avoidance, and dyadic adjustment. A phase-specific framework is outlined for preoperative preparation, early postoperative programming, and long-term adaptation. Dedicated co-designed feasibility studies and adequately controlled trials are required before mindfulness can be recommended as a routine component of DBS care.

1. Introduction

Deep brain stimulation (DBS) is an established treatment for selected people with advanced Parkinson's disease (PD), particularly when levodopa-responsive motor symptoms and motor complications are no longer adequately controlled by medication [1]. Contemporary DBS is increasingly personalized, and adaptive systems can modulate stimulation according to patient-specific neural signals and fluctuating clinical states [2,3]. Beyond focal target effects, DBS can influence distributed neural networks relevant to cognitive, affective, and behavioral functions. Preliminary resting-state fMRI evidence in 10 patients suggests that STN-DBS can modulate limbic network dynamics [4], providing a

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https://doi.org/10.1016/j.jdbs.2026.11.001
Received 19 September 2026; Received in revised form 28 October 2026; Accepted 1 November 2026
Available online 3 November 2026
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neurobiological context for variability in non-motor outcomes without implying direct neural convergence with mindfulness. Nevertheless, the success of DBS cannot be reduced to motor improvement [5–7]. Long-term observational and neuropsychological literature shows that patients may continue to experience cognitive, psychiatric, axial, autonomic, and psychosocial difficulties despite meaningful motor benefit [8–11]. This discrepancy between objective motor improvement and subjective recovery is clinically important. Expectations influence satisfaction and perceived outcome, and experimental manipulation of expectations can modify motor and cognitive performance even when stimulation parameters are unchanged [12,13]. Some patients describe DBS as restoring their authentic self, whereas others report alienation, personality change, or uncertainty about whether stimulation-related states are genuinely their own [14–16]. These challenges were recognized early, when patients were described as distressed "in a repaired body," experiencing marital, occupational, and self-image difficulties despite successful motor outcomes [17]. This phenomenon was interpreted as postoperative psychosocial maladjustment rather than surgical failure [18]. Together, these findings suggest a persistent gap between improved motor capacity and the ability to integrate these gains into a psychologically sustainable life. Moreover, STN-DBS-related outcomes do not depend solely on the well-being of people with PD but also on the well-being of individuals surrounding them [19]. Mindfulness-based interventions (MBIs) may be relevant to this gap. Mindfulness is commonly described as intentional, present-moment, non-judgmental awareness. Structured approaches include mindfulness-based stress reduction (MBSR), mindfulness-based cognitive therapy (MBCT), and PD-adapted protocols [20]. Acceptance and commitment therapy (ACT) is not synonymous with mindfulness but incorporates mindfulness-related processes within a broader model of acceptance, cognitive defusion, values clarification, and committed action [21,22]. Evidence in chronic illness and advanced progressive disease suggests feasibility and possible benefits for distress and psychological flexibility, although study quality and disease-specific evidence remain limited [21,23]. This narrative review integrates the literature on mindfulness in PD with studies of cognition, expectations, long-term outcome, and identity in DBS. Its purpose is not to claim an established treatment effect in the PD-DBS population, for which direct evidence is essentially absent, but to define plausible clinical targets, limits of inference, and a research agenda for phase-specific integration of MBIs across the DBS pathway.

The central rationale is therefore a translational hypothesis: DBS may improve motor capacity, whereas an adapted psychological intervention might help some patients respond to distress, uncertainty, residual symptoms, and changed roles in ways that support participation. This is not evidence that mindfulness improves stimulation efficacy, and it does not imply that all patients need or would benefit from an MBI.

2. Narrative approach and conceptual boundaries

This review draws on clinical trials, pilot and qualitative studies, study protocols, systematic reviews, meta-analyses, mechanistic viewpoints, and neuroethical analyses. Because no robust trial is dedicated to mindfulness in patients with PD treated with DBS, conclusions are separated into: (i) findings directly supported in general PD cohorts; (ii) established or recurrent challenges in DBS cohorts; and (iii) hypothesis-generating links between these two bodies of evidence. MBIs, meditation, MBCT, MBSR, and ACT were not treated as interchangeable. MBSR emphasizes mindfulness practice and stress regulation; MBCT combines mindfulness training with elements of cognitive therapy; PD-specific programs adapt duration, movement practices, and educational content; ACT emphasizes psychological flexibility and values-consistent behavior. This distinction matters because different interventions may act through different components and pooling them can obscure both efficacy and mechanism.

3. Clinical rationale and potential targets in Parkinson's disease

3.1. Stress-related distress and emotional symptoms

People with PD are particularly vulnerable to stress. Anxiety and depression are common, stressful situations can worsen tremor, freezing, and perceived motor disability, and motor symptoms can in turn amplify anticipatory anxiety and social avoidance [24]. A mechanistic viewpoint proposed that acute and chronic stress may engage limbic, autonomic, and corticostriatal systems that are already vulnerable in PD, while emphasizing that evidence for acceleration of human disease progression remains unproven [24]. MBIs are therefore better conceptualized as self-management interventions for stress-related symptom amplification and distress than as disease-modifying treatments [21,23]. The clinical literature broadly supports this positioning. Early systematic reviews found only a few small studies and concluded that evidence was limited and inconclusive despite promising signals [25,26]. Later meta-analyses reported improvement in psychological outcomes but differed regarding motor and quality-of-life effects. Lin et al. found benefits for motor scores and cognition across eight randomized trials, whereas Yi et al. found significant effects on depression, anxiety, mindfulness, and quality of life but not motor symptoms [20,27]. These differences reflect small samples, heterogeneous interventions, variable comparators, and inconsistent outcome definitions.

3.2. Attention, metacognition, and symptom awareness: preliminary evidence

Mindfulness training repeatedly requires attention to present experience, recognition of distraction, and deliberate return of attention. In non-PD samples, receptive attention and decentering were found to mediate the relationships among trait anxiety, attentional control, and cognitive failures, whereas receptive attention did not, suggesting that facets of dispositional mindfulness may relate differently to everyday cognitive functioning [28]. This framework is relevant to PD, in which anxiety, executive inefficiency, and fluctuating symptoms can compete for limited attentional resources. A PD-specific protocol, IPSUM, was designed to improve self-awareness of motor symptoms through mindfulness [29]. Results of the subsequent randomized pilot are summarized in Section 4.3 [30]. The negative primary result is important: mindfulness should not be assumed to increase objective symptom insight, and heightened body attention could theoretically become hypervigilance in anxious individuals.

3.3. Motivation, apathy, and goal-directed activity

Apathy is multidimensional and may involve emotional, cognitive, and goal-directed components [31–33]. A realist review identified exercise and mindfulness as the principal non-pharmacological approaches studied for apathy in PD but emphasized that mindfulness evidence was sparse and most applicable to patients without major cognitive impairment and with adequate support [32]. In a group pilot involving patients and caregivers, greater attendance and home practice were associated with increased mindfulness and reductions in apathy and anxiety, but these associations do not establish causality [34]. ACT may be conceptually useful here because acceptance is paired with values-guided action rather than passivity. A protocol testing ACT for fear of falling and physical activity illustrates how psychological flexibility could be linked to objective behavior and wearable outcomes, although efficacy results were not yet available [35].

4. Clinical evidence for mindfulness-based interventions in PD

4.1. Depression, anxiety, and distress

The most recurrent positive findings have concerned emotional outcomes, although estimates remain imprecise and the evidence is limited by small samples, heterogeneous interventions, and variable study designs. A modified MBCT pilot randomized 36 participants and found a significant reduction in depressive symptoms relative to waitlist, while group-level anxiety and quality-of-life effects were not significant; reliable-change analyses nevertheless suggested that some participants improved and that deterioration was more frequent in controls [36]. An eight-week adapted program in 14 patients reported post-intervention reductions in anxiety, depression, and global distress, alongside exploratory cognitive and motor changes [37]. A mixed-method waitlist-controlled lifestyle program found no significant change in the PDQ-39 summary index but reported a small improvement in activities of daily living at six months and qualitative benefits in coping [38]. Qualitative work helps explain how such changes may occur. Participants in an MBCT course described changing coping patterns, consolidation of existing coping skills, group support in the context of loss and stigma, and tensions between the bodily experience of PD and meditation practice [39]. These data caution against reducing mindfulness to symptom reduction: patients may value a changed relationship to symptoms, loss, and uncertainty even when disease-specific scales change little.

4.2. Feasibility, delivery, and caregiver involvement

Feasibility is supported across in-person and remote formats. The M-Park project combined a national survey with a 30-patient feasibility study. Most surveyed patients favored integration of mindfulness into care, although many had limited understanding of what it involved; 25 of 30 trial participants completed the program, with no mindfulness-related adverse events reported and improvements in anxiety, depression, and quality of life in an uncontrolled analysis [40]. Online MBCT was also feasible in a small mixed sample of patients and caregivers, with high completion and reductions in anxiety and depressive symptoms together with increases in mindfulness facets [41]. Caregiver inclusion is clinically attractive because PD-related disability and neuropsychiatric symptoms are embedded in a dyadic system. In the Cash et al. pilot, both patients and caregivers showed increased mindfulness, while patient-specific exploratory gains were seen in attention, flexibility, and self-reported symptoms [34]. However, caregiver samples were too small to support firm conclusions. Qualitative evidence in advanced PD suggests that caregiver overprotection and discrepant perceptions of regained capacity may contribute to relational friction after functional improvement and may require explicit renegotiation of autonomy [19]. Future programs should distinguish shared sessions aimed at communication from patient- or caregiver-specific therapeutic needs.

4.3. Motor, cognitive, and biological outcomes

Motor findings remain uncertain. Dissanayaka et al. reported improvements in rigidity, gait, and postural-instability-related measures, and Lin et al. estimated a pooled improvement in UPDRS-III scores [20,37]. Conversely, Yi et al. found no significant pooled motor effect [27]. Lack of blinded assessment, variation in medication state, mixed inclusion of yoga or movement elements, and expectancy effects may contribute. MBIs should therefore not be presented as established treatment for motor symptoms in PD. Cognitive and imaging findings are similarly preliminary. Pickut et al. reported neurobehavioral effects after mindfulness training in a small cohort, while a companion randomized trial found increased gray-matter density in limbic regions; neither was designed to establish neuroprotection [42,43]. The IPSUM pilot suggested selective attentional and language effects without improvement in its primary awareness endpoint [30]. The MIND-PD protocol describes a 124-participant randomized trial of eight-week MBCT with 12-month follow-up and clinical, biochemical, and MRI outcomes; as a protocol, it cannot support efficacy claims [44]. The evidence reviewed across the preceding sections is summarized in Table 1.

5. Clinical challenges across the DBS pathway

5.1. Cognition, medication-related symptoms, and neuropsychiatric monitoring

DBS outcome is shaped by disease progression, target, surgical effects, stimulation, and medication changes. Systematic reviews generally conclude that global cognition is not markedly worsened in appropriately selected patients, while verbal fluency decline is the most reproducible domain-specific finding [9,10]. Bucur and Papagno also reported small long-term declines in memory and inhibition alongside mild improvement in anxiety and depression after STN-DBS [10]. Sisodia et al. concluded that postoperative cognitive decline did not clearly reduce motor efficacy and that DBS was broadly cognitively safe apart from moderate, possibly transient verbal-fluency effects [11]. These results support careful selection and monitoring rather than a generalized narrative of cognitive harm. Long-term clinical outcomes also extend beyond cognition. In a multicenter observational comparison, Scelzo et al. found similar dementia and mortality risk and lower rates of mild cognitive impairment, incontinence, nocturia, and falls in the

Table 1
Evidence domains and implications for a PD-DBS mindfulness framework.

Evidence domain	What is supported	What remains uncertain	Implication for PD-DBS
Depression/ anxiety	Small trials and meta-analyses show a generally favorable signal.	Magnitude, durability, active-control effects, and clinical significance.	Reasonable primary targets for feasibility trials.
Motor symptoms	Some pilots and one meta-analysis report improvement.	Conflicting pooled results; medication state, movement components, and expectancy confounding.	Do not use motor improvement as the principal rationale or primary endpoint.
Cognition/ awareness	Selective attentional and language signals; primary awareness outcome negative in IPSUM.	Prevention of cognitive decline and objective symptom-awareness effects.	Use targeted measures; avoid claims of neuroprotection.
Apathy/ activity	Preliminary associations and ACT-based rationale.	Efficacy and mechanisms in PD and after DBS.	Assess medication-related contributors before considering acceptance- and values-guided behavioral approaches.
Caregivers	Dyadic programs are feasible.	Independent caregiver efficacy and optimal shared versus separate content.	Include caregiver outcomes and role renegotiation.
Expectations/ identity	DBS outcomes are influenced by expectations; authenticity concerns are documented conceptually and clinically.	Whether mindfulness improves satisfaction, expectation calibration, or identity integration.	Central hypothesis-generating targets for PD-DBS trials.

surgical cohort, but more PD-related hospitalizations, largely procedure-related; they noted that the cognitive advantage may partly reflect preoperative selection [8]. Neuropsychiatric symptoms should be considered separately from cognitive outcomes, even though the two domains may interact clinically. For example, apathy after subthalamic DBS may reflect dopaminergic withdrawal following postoperative medication reduction rather than a direct stimulation effect; it therefore warrants medical assessment before psychological intervention [31,45]. Thus, psychosocial difficulty after DBS should not be attributed simplistically to neurostimulation; it may reflect residual symptoms, progressive disease, medication changes, expectations, or adaptation to changed capacity.

A network-level perspective may help explain why focal stimulation can have effects beyond motor circuitry. PD involves distributed motor, associative, and limbic systems, and STN stimulation can influence connected cortical and subcortical networks. In a small resting-state fMRI study of 10 patients, Eraifej et al. reported stimulation-related modulation of limbic network connectivity, including networks relevant to affective processing [4]. These findings are preliminary and do not imply a shared neural mechanism or direct synergy between DBS and mindfulness; rather, they provide a limited biological rationale for considering psychological and affective adaptation within DBS care.

5.2. Expectations and the motor-subjective outcome gap

Expectations are among the clearest modifiable determinants of subjective outcome. Mameli et al. reviewed studies showing that positive expectations can contribute to treatment response, whereas unrealistic expectations are associated with lower satisfaction, poorer psychosocial adjustment, and discrepancies between clinical improvement and perceived benefit [13]. Keitel et al. experimentally manipulated positive, negative, and neutral expectations in STN-DBS patients while holding stimulation parameters constant. Positive expectations enhanced proximal motor performance but, in motor placebo responders, were accompanied by a trend toward poorer verbal fluency, reproducing both the benefit and the cognitive cost of stimulation, a coupling attributed to implicit learning [12]. Mindfulness cannot remove expectations and should not be used to lower legitimate hopes or replace the team's established expectation-management and consent procedures. Its hypothesized added value is skills-based rather than informational: patients may practice noticing expectations as mental events, distinguishing valued goals from predictions about outcomes, tolerating uncertainty, and appraising change against personally meaningful functional goals. These processes would complement, not replace, guideline-based education and shared decision-making; this added value remains untested in PD-DBS. This application remains hypothetical and requires direct testing.

5.3. Identity, authenticity, and relational adjustment

DBS can challenge narratives of selfhood because stimulation may alter movement, mood, agency, and interpersonal roles rapidly. Kraemer described cases in which DBS either produced alienation or relieved the alienation previously imposed by PD [14]. Witt et al. argued that reports of becoming "another person" require conceptual and empirical analysis focused on individual identity and core attitudes, and that conventional clinical instruments may not adequately capture such change [16]. Pugh et al. proposed a diachronic, value-based account in which authenticity concerns the coherence of traits and values over time rather than a single momentary state [15]. These analyses do not establish that identity change is common, but they identify a clinically meaningful domain often missed by motor and psychiatric scales. Mindfulness and ACT may offer language for observing changing internal states without immediately equating them with a lost or restored "true self," while values work may help patients integrate new capacities into a longitudinal identity. Such interventions must avoid covert paternalism: clinicians should not define which stimulated or unstimulated self is authentic. Taken together, the available evidence supports a mindfulness-informed conceptual framework for DBS care. The contributing evidence domains and their clinical implications are summarized in Table 1.

6. A cautious, phase-specific framework for the DBS pathway

6.1. Preoperative phase

Before surgery, an adapted intervention could support informed preparation and realistic, individualized expectations. Candidate targets include anxiety, rigid expectations, avoidance of feared future states, and clarification of personally meaningful goals. Mindfulness practice may help patients distinguish direct experience from catastrophic prediction, while ACT-informed values work may translate broad hopes such as "getting my life back" into observable goals. Preoperative assessment should explicitly distinguish expectations of motor benefit from expectations of broader life or relational change, because unrealistic or poorly aligned expectations are associated with lower postoperative satisfaction and poorer perceived outcomes [13]. Flexibility in revising broader personal and relational expectations may also be relevant, as psychosocial maladjustment can occur despite successful motor improvement [17]. The multidisciplinary DBS team, including movement-disorder neurologists, neurosurgeons, neuropsychologists and/or psychologists, nursing, and programming staff as locally available, should retain responsibility for education about realistic motor, non-motor, medication, and programming outcomes; a mindfulness/ACT facilitator should support psychological skills rather than determine surgical candidacy or expected neurostimulatory benefit.

The intraoperative period is not proposed as a separate mindfulness treatment phase in this framework. In centers using awake mapping or test stimulation, procedural anxiety and distress may be clinically relevant, but any mindfulness-based preparation should be delivered preoperatively and should not interfere with intraoperative neurological assessment, communication, or surgical workflow. Dedicated evidence in awake DBS is limited and does not currently support a distinct intraoperative intervention module.

6.2. Early postoperative programming

The early postoperative period involves repeated programming, including systematic monopolar review where applicable, medication adjustment, fluctuating benefit, and uncertainty about whether changes reflect stimulation, medication, transient microlesion ("stun") effects, context, or disease. Because transient postoperative benefit may occur independently of active stimulation, perceived improvement during this window should not be attributed to psychological practice without first considering this confounder. Brief practices emphasizing non-reactive observation and structured symptom reporting could potentially reduce catastrophic interpretation and improve communication. However, mindfulness must never substitute for prompt medical review of adverse effects, mood elevation, suicidality, cognitive change, new impulsivity or impulse-control symptoms, or possible hardware complications. New or unexplained neurological deterioration, wound or skin changes, pain over hardware, or abrupt loss of benefit should be treated as potential organic or device-related problems rather than reframed as difficulties in psychological adaptation.

The hypothesized value at this stage is limited to supporting coping with uncertainty and communicating observations clearly. No evidence currently establishes that mindfulness accelerates programming, improves stimulation response, or reduces the need for clinical contacts. Whether even this proposed supportive benefit occurs remains unknown and should therefore be evaluated initially in terms of acceptability and feasibility. Motor and non-motor fluctuations should be considered when planning and evaluating any intervention across this phase. OFF

periods, fatigue, anxiety, mood changes, and medication-state-dependent symptoms may affect willingness or ability to practise and may influence self-reported outcomes. Feasibility work should record session timing in relation to medication and stimulation state, document relevant fluctuations, and allow flexible practice duration and format.

6.3. Long-term adaptation

After motor settings stabilize, the principal target may be translation of capacity into participation. Some patients remain socially withdrawn, fearful of falling, apathetic, or uncertain about family roles despite better movement. Given that post-DBS apathy is frequently a dopamine-withdrawal phenomenon responsive to medical management (Section 5.1), values-guided psychological work for apathy should be offered only after dopaminergic and medication-related contributors have been assessed and addressed; treating a neurochemical symptom as purely motivational risks both clinical error and patient disengagement. Values-guided action, acceptance of residual symptoms, and graded re-engagement may be more relevant than further symptom-focused monitoring. Dyadic components could address caregiver over-protection, discrepant perceptions of change, and renegotiation of autonomy. The concepts discussed across the preceding sections are integrated into a proposed phase-specific intervention model (Table 2). Evidence from PD and advanced illness suggests feasibility of ACT-related approaches, and a randomized psychoeducation trial after subthalamic DBS reduced social maladjustment; still, no mindfulness- or ACT-based PD-DBS trial yet exists [21,23,35,46]. Operational feasibility is equally important. Standard mindfulness-based programs and PD-adapted protocols commonly involve structured multiweek interventions, which may impose additional demands on patients already undergoing an intensive DBS pathway [29,30,44]. Rather than automatically transferring these formats to PD-DBS, early studies should test brief, modular, hybrid, or remote approaches delivered by appropriately trained psychology/neuropsychology staff integrated with the DBS team, and should explicitly quantify patient and caregiver burden, adherence, completion, and dropout. “Values-guided action” means identifying activities and relationships that matter to the individual and planning realistic steps toward them within current motor, cognitive, and non-motor capacity; it does not mean accepting avoidable adverse effects or treating apathy as a purely psychological problem.

7. Candidate mechanisms, safety, and patient selection

A multilevel model is preferable to claims of direct synergy between meditation and neurostimulation. Psychological mechanisms may include reduced rumination, worry, experiential avoidance, and reactivity; attentional mechanisms may include improved monitoring and decentering; behavioral mechanisms may include adherence, activity, and values-consistent goal pursuit; interpersonal mechanisms may include less reactive communication and better role negotiation. Neurobiological hypotheses involving stress regulation, limbic-prefrontal networks, salience processing, and autonomic function are plausible but remain unestablished in people undergoing DBS [24,42]. Patient selection and treatment goals should take account of the clinical context. STN and GPi stimulation should not be treated as interchangeable, as differences in postoperative dopaminergic medication reduction and potentially in cognitive, mood, and behavioral outcomes may influence the interpretation of postoperative difficulties [47]. In particular, apathy after STN-DBS may reflect dopaminergic medication reduction or dopamine-withdrawal phenomena, whereas new or worsening impulsivity, disinhibition, or hypomanic symptoms may be related to medication or stimulation effects [31,33,45]. These manifestations should therefore prompt appropriate medical, medication, and stimulation review before being framed primarily as psychological adjustment problems.

Mindfulness- or ACT-based goals should be individualized only after the DBS team has reviewed the stimulation target, medication changes, possible stimulation-related behavioral effects, and cognitive status. Potential candidates include patients with adequate cognitive capacity who experience mild-to-moderate anxiety, depressive symptoms, adjustment difficulties, avoidance, fear of falling, or caregiver strain. Particular caution or clinical stabilization may be required in the presence of dementia, active psychosis, mania, severe depression with suicidal risk, marked impulsivity, or difficulty engaging safely in practice. Interventions should be adapted to fatigue, dysarthria, hearing difficulties, motor fluctuations, postural instability, and cognitive load. Potential harms include frustration, increased symptom vigilance, emotional distress, and the mistaken belief that acceptance means tolerating remediable adverse effects.

Mindfulness and ACT should therefore be offered only as optional adjuncts for patients who want psychological support. They must not delay investigation of new symptoms, medication review, programming changes, or urgent neuropsychiatric assessment. The format and intensity of any intervention should be adapted to individual needs and capacity, with feasibility and patient burden assessed before a structured program is incorporated into routine DBS care.

8. Research agenda

An initial study should be a co-designed feasibility/proof-of-concept study focused on one prespecified phase of the DBS pathway, rather than a broad efficacy or biomarker programme. The phase and intervention format should be selected in collaboration with patients, caregivers, and the multidisciplinary DBS team. The early postoperative programming phase is a plausible candidate because uncertainty and symptom interpretation may be particularly salient, but its suitability should be confirmed during co-design. The intervention should be brief and modular, delivered by appropriately trained psychology or neuropsychology staff in coordination with the DBS team, and adapted to fatigue, motor fluctuations, medication state, cognitive capacity, and caregiver availability.

Primary outcomes should address feasibility and safety, including recruitment, retention, attendance, acceptability, participant burden, intervention fidelity, and adverse events. Only a small number of prespecified exploratory clinical outcomes, aligned with the selected intervention target, should be included, for example, anxiety or distress, or psychosocial adjustment and participation. If randomized, the study should use an active comparator, such as education or supportive

Table 2
Proposed phase-specific intervention model.

DBS phase	Candidate unmet need	Proposed mindfulness/ACT process	Candidate outcome
Preoperative	Anxiety, rigid or unrealistic expectations, unclear personal goals	Present-moment awareness, decentering, values clarification	Expectation congruence, decisional quality, anxiety
Early postoperative/ programming	Uncertainty, symptom hypervigilance, reactive interpretation of fluctuations	Non-reactive observation, structured reporting, distress tolerance	Programming-related distress, communication, satisfaction
Long-term	Residual symptoms, avoidance, reduced engagement, incomplete role recovery	Acceptance, committed action, graded re-engagement	Participation, goal attainment, quality of life
Dyadic	Caregiver burden, overprotection, discrepant perceptions of outcome	Mindful communication, shared values, role renegotiation	Caregiver burden, autonomy, relationship adjustment

contact. Medication and stimulation state should be documented at each session, and transient microlesion effects and programming changes should be considered when interpreting patient-reported outcomes.

Broader outcome batteries, wearable or ecological momentary measures, target-stratified comparisons, mediation analyses, and imaging or biomarker assessments should be deferred until feasibility and a preliminary clinical signal justify further investigation. Questions of identity and continuity discussed in narrative analyses [48] may be explored qualitatively during co-design, but should not be treated as established intervention targets or additional primary outcomes. The relevance of psychosocial adjustment following DBS is illustrated by work examining maladjustment after subthalamic stimulation [46]. Adaptive DBS illustrates personalization based on neural signals [2,3]; in this context, initial personalization should instead be guided by psychological needs, patient preferences, and individual capacity rather than an assumption that all patients require the same intervention. The MIND-PD study protocol provides an example of a structured trial designed to investigate mindfulness-based cognitive therapy in people with Parkinson's disease [44], although it does not establish efficacy specifically in the DBS population.

The present framework does not designate the intraoperative period as a separate mindfulness-treatment phase. Although awake mapping and test stimulation can be psychologically demanding, current evidence does not establish the value of a specific intraoperative mindfulness protocol. Any future exploration should therefore be limited to assessing whether skills introduced preoperatively might be used during awake procedures to manage distress, provided that they do not interfere with neurological assessment, communication with the surgical team, or procedural workflow. Such use would remain exploratory and would not constitute a dedicated intraoperative intervention module.

9. Conclusions

DBS can markedly improve motor function in PD, but successful neurostimulation does not automatically resolve anxiety, apathy, cognitive vulnerability, unrealistic expectations, relational change, or questions of identity. MBIs in general PD populations have generally been feasible in published studies and show the clearest, though still modest and heterogeneous, evidence for depression, anxiety, distress, mindfulness skills, and selected quality-of-life outcomes. Evidence for motor benefit, cognition, apathy, caregiver outcomes, and biological effects is preliminary or inconsistent. Direct evidence in PD-DBS populations is essentially absent.

Mindfulness should therefore be framed as a promising adjunct for the psychological translation of motor gain, not as an enhancer of stimulation efficacy or a substitute for medical and neuropsychiatric care. The strongest rationale concerns stress reactivity, expectation flexibility, values-guided activity, and dyadic adaptation across preoperative, early postoperative/programming, and long-term phases, with intervention goals adapted to cognitive status, DBS target, medication changes, and stimulation-related behavioral effects. Carefully adapted, co-designed, and actively controlled trials are needed before integration into routine DBS pathways.

CRediT authorship contribution statement

Giada Coluccio: Conceptualization, Literature review, Writing – original draft, Writing – review & editing. Francesca Sireci: Conceptualization, Supervision, Writing – original draft, Writing – review & editing. Francesco Cavallieri: Supervision, Writing – original draft, Writing – review & editing. Valentina Fioravanti, Giacomo Argenziano, Giacomo Portaro, Luca Codeluppi, Ottavia Iotti, Claudio Fusella, Amani A. Alrikabi, Giuseppe Biagini, Alberto Feletti, Fiorina Bartiromo, Corrado Iaccarino and Sara Montepietra: Writing – review & editing. All authors read and approved the final version of the manuscript.

Funding

This work was partially supported by the Italian Ministry of Health – Ricerca Corrente Annual Program 2026.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT (OpenAI) to support literature synthesis, manuscript structuring, drafting support, language refinement, and editorial formatting. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No new data were generated or analyzed in this narrative review.

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