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A Clinical Perspective on Neurofeedback Integrated With Acceptance and Commitment Therapy (ACT)

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Abstract

The integration of neurofeedback (NF) with acceptance and commitment therapy (ACT) describes a multimodal intervention that provides access, noninvasively, to real-time information and feedback of client-relevant biological behavior set within an evidence-based psychotherapeutic behavioral context. It is advanced that the integration of therapies considers the range of contextual and learning factors that influence NF, which are supported by advancements in contextual behavioral theory and practice. This paper frames NF as a repeated experiential exercise that supports psychological flexibility processes relevant to acceptance, defusion, self-as-context, and contact with the present moment, while engaging values-based committed action. This clinical perspective offers that NF can be flexibly integrated and blended within an evidence-based psychotherapeutic context and applied as a transdiagnostic, process-based intervention that may provide a broad scope for meaningful change.

Keywords: ACT; psychotherapy; neurofeedback; neuromodulation; multimodal

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Introduction

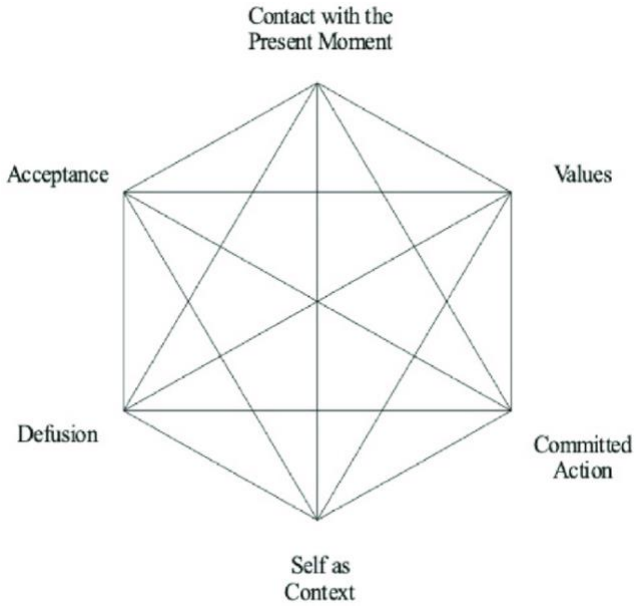
Flexibility is viewed from various perspectives widely across the study of the human mind, brain, and behavior. This includes but is likely not limited to psychological, behavioral, social, cognitive, cortical, neural, and network flexibility—each referring to adaptive change in changing contexts. Humans modulate behavior, that is, exert a modifying influence through environmental and language interactions from self and with others. However, behavior can also be influenced by other means, such as chemically, electrically, and electromagnetically. The aim of the present perspective is to consider the multimodal integration of a specific psychotherapeutic orientation, acceptance and commitment therapy (ACT), with technology that also provides a means for neuromodulation (i.e., neurofeedback [NF]), to offer a context for cultivating flexible change in a personalized, meaningful direction.

ACT has been described as part of the third wave of cognitive behavioral therapy (CBT), increasingly acknowledged as a process-based therapy (PBT; Hayes & Hofman, 2021). The foundation of ACT is firmly grounded in the scientific philosophy of functional contextualism and behavioral psychology, as well as developed alongside as a clinical application of an extended modern behavioral analytic theory of human cognition and language, relational frame theory (RFT; Hayes et al., 2012). ACT has accumulated an impressive evidence base with over 1,000 published randomized control trials to date (Hayes & King, 2024). There is demonstrated efficacy across a wide range of clinical presentations and settings, including but not limited to depression (Bai et al., 2020), anxiety disorders (Haller et al., 2021), chronic pain (Ma et al., 2023), obsessive compulsive disorders (Soondrum et al., 2022), substance use disorders (li et al., 2019), psychosis (Tonarelli et al., 2016), and insomnia (Salari et al., 2020), although the evidence base extends well beyond DSM diagnosable presentations (Hayes & King, 2024).

In a meta-analysis of meta-analyses across a broad range of mental health conditions, Gloster et al. (2020) showed small to medium effect sizes in favor of ACT over both active and inactive controls.

ACT is a flexible process-based model that takes a skills-based experiential approach to promoting health and growth through fostering psychological flexibility, that is, the ability to contact the present moment more fully as a conscious human being without defense and based on what the situation affords—to change or persist in behavior to serve valued ends (Hayes & Strosahl, 2004). The functional contextual approach of ACT directs focus on function over form of behavior, where function is defined in relation to context, then considered in terms of workability (Harris, 2019). Building skills in psychological flexibility are developed through six core interrelated processes of acceptance, defusion, present-moment awareness, self-as-context, values, and committed action (see Figure 1). The ACT model of psychopathology therefore conceptualizes that the inverse processes of psychological inflexibility are central to the development and maintenance of psychological suffering (Luoma et al., 2007).

Figure 1. *The ACT Hexaflex.*



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NF is a form of biological feedback that provides individuals with real-time information about their brain activity, most commonly measured via electroencephalography (EEG). This feedback is typically delivered through visual or auditory cues and reflects specific desired brain events, such as the presence of a targeted brain frequency at a predetermined power threshold (i.e., frequency band NF) or a slow shift in cortical excitation or inhibition (e.g., slow cortical potential [SCP]). NF is grounded in principles of learning theory, particularly classical and operant conditioning, wherein the reinforcement of desired brain states increases the likelihood of their recurrence (Sherlin et al., 2011). However, it is widely acknowledged that NF outcomes are influenced by multiple factors beyond simple conditioning. As Strehl (2014) notes, “the equipment is a tool within this interaction, NF is a method of behavior therapy” (p. 6), underscoring the importance of the therapeutic context. NF has demonstrated clinical efficacy across a range of populations, with the strongest empirical support in attention-deficit/hyperactivity disorder (ADHD; Van Doren et al., 2019). Additional evidence supports its use in conditions such as epilepsy (Tan et al., 2009), insomnia (Lambert-Beaudet et al., 2021), posttraumatic stress (Askovic et al., 2023), anxiety (Russo et al., 2022), depression (Fernández-Álvarez et al., 2022), chronic pain (Patel et al., 2020), and performance enhancement in nonclinical populations (Brito et al., 2022).

Neurofeedback-Integrated ACT: The Case for NF as an Experiential Exercise

It is offered that NF occurs on at least two different levels, that is, at the biophysiological level of brain-wave conditioning and an experiential level. While the integration of ACT and NF highlights the latter, there are several important factors that are argued to contribute to the worthy integration of these therapies. Foremost, behavior learning theory is foundational to both NF and ACT, and it is forwarded that the theoretical foundations of ACT, such as RFT, may assist in further appreciating some of the multifactorial mechanisms of change observed in NF. Secondly, it is argued that psychological flexibility processes may blend synergistically with NF practice rather than simply providing additive effects of pairing different modalities, as much as to frame the act of NF as a repeated experiential exercise when delivered within an ACT context and stance. At the level of experience, NF corresponds to flexibly allocating and sustaining attention to real-time brain behavior in the present moment with openness of experience in the service of moving in the direction of valued action. Finally, given that ACT is a transdiagnostic, process-based model, the combination of therapies may provide greater scope for the clinician and individual in terms of meaningful

change with use of psychological, behavioral and physiological processes simultaneously.

Considering the Multifactorial Mechanisms of Change

Despite the established clinical efficacy of NF, the literature continues to suffer from considerable methodological heterogeneity, small sample sizes, a lack of standardization in NF protocols and practice across clinicians, and a mixed evidence base despite decades of inquiry. NF opponents raise issues of inadequately controlled studies with lack of clarity in the mediators of change, often attributing the reported benefit arising from both nonspecific general and NF-related nonspecific treatment effects, such as technique and therapy expectations, the therapeutic interaction with the clinician, and effects of repeatedly sitting still and focusing with reinforcement, not otherwise directly resultant from specific brain wave reinforcement (Thibault & Raz, 2017). Although there are now controlled and adequately powered studies indicating nonsuperiority of active compared to sham NF, despite the clear clinical effectiveness of the highly active sham conditions (Arnold et al., 2021; Schönenberg et al., 2017), the validity of controlled studies that do not adhere to foundational operant conditioning learning principles (e.g., very high or automatic reward thresholding) has been questioned (Pigott et al., 2021).

For example, there is evidence from a recent well-powered (i.e., 144 children with ADHD), double-blind placebo-controlled randomized NF study from Arnold et al. (2021), including 25-month follow up (Arnold et al., 2023), which shows the clear, sustained clinical benefits of such stated nonspecific effects. In this study, both groups received counseling on sleep and nutrition, while the control group condition used prerecorded EEG signals to determine rewards while retaining live electromyography (EMG) biofeedback. It was found that both the active control and NF groups resulted in significant and sustained reduction in ADHD symptoms, indicating a majority psychotherapeutic/behavioral effect. For context, the highly active control group showed large and sustained clinically meaningful effect sizes for reduction in ADHD symptoms (e.g., Cohen's $d > 1$). While not statistically significant, there was a trend suggesting that more of the control group required medication compared to the active NF group at follow-up, alluding to the long-term and relevant benefits of the active, brainwave conditioning effect.

In studies where the attentional training component is controlled by comparing active NF to cognitive training, findings have shown superiority of the NF group in reducing ADHD symptoms in children (Gevensleben et al., 2009; Steiner et al., 2014), although this effect is not consistently demonstrated (Minder et al., 2018). As with Arnold et al. (2021), Steiner et al. (2014) also found that the active NF group did not require changes in medication, whereas the control groups saw increases in medication dose at 6-month follow-up. Consider that repeatedly training awareness to reinforcement that is importantly linked with changing biological function, whether measurable or perceived, may broadly train one's sensitivity to available contingencies, as opposed to direct attention training without biological feedback.

In addition to the literature attempting to compare active to sham NF, it is important to address trials showing nonsuperiority of NF over standard cognitive and behavioral type therapies (Abbasi et al., 2018; Kwan et al., 2022; Moreno-García et al., 2019; Schönenberg et al., 2017) when considering the value of a combinatorial, integrative approach rather than direct comparison. There has been one quasi-experimental trial comparing NF (i.e., 30 half-hour alpha reward sessions, three sessions per week), ACT (i.e., a dozen 1-hr weekly sessions), and a nonactive control group in women with anxiety disorders in Iran (Soleymani et al., 2020). The findings demonstrated significant reduction in anxiety at postintervention and follow-up for both the NF and ACT groups, albeit with significantly higher reduction of anxiety in the ACT group. Future studies may however explore whether the integration of NF within ACT augments and/or extends outcomes for particular clinical contexts.

Given NF is resource-intensive and hard to access, it is seldom used as a fine-line intervention and is typically considered after other therapies or medications have had limited success (Tsuji-Lyons & White, 2023). For example, as an adjunct therapy to trauma counseling where previous counseling had poor response, Askovic et al., (2020) followed 13 individuals with chronic PTSD at a tertiary trauma in clinic in Sydney Australia who underwent personalized NF, compared to a waitlist control group continuing only trauma counseling. Results of this preliminary retrospective study found that the adjunct NF group showed significantly reduced symptoms of trauma, anxiety, and depression, such that 12 of the 13 individuals were below PTSD diagnostic threshold at posttherapy. In individuals with medication refractory epilepsy, SCP NF has been integrated within a wider behavior therapy framework to increase context sensitivity to seizure-

related antecedents and reinforcing contingencies, resulting in significant reduction in severity of seizures relative to a pretraining phase (Kotchoubey et al., 1996). While not specifically ACT, these examples highlight the value of integrative psychotherapy with NF in a treatment-resistant population. Alternatively, the integration of mindfulness and acceptance skills via ACT with biofeedback technology, such as heart rate variability (HRV) training, has been well articulated clinically (Ehrenreich, 2024; Khazan, 2015), and it was recently further discussed in a chapter by Dr. Richard Gevirtz in *Integrating Psychotherapy and Psychophysiology* (Gevirtz, 2024). The latter application describes an example of psychotherapy integrated with biofeedback; however, it is appreciated that there is no existent literature on the integration of ACT with EEG-based biofeedback.

Neurofeedback and Relational Frame Theory (RFT)

Considering the complex means by which humans learn through language and cognition may help to appreciate the translation and transfer of repeated NF practice into meaningful changes in daily life. Further exploration through ACTs theoretical grounding, RFT, may help to elucidate some of the nonspecific psychotherapeutic effects that emerge from NF. As expressed in RFT, humans have the remarkable capacity to relate anything to anything else based on nonarbitrary properties of stimuli as well as arbitrarily defined relations (Torneke, 2010). Learning in humans is vast and complicated, extending beyond contingency-based learning through classical and operant conditioning; that is, humans hold the ability to learn through deriving relations without any direct learning experience through arbitrarily applicable relational responding. Although this capacity provides undeniable advantages to reflect, plan, organize, communicate, and anticipate consequences, rigid patterns of verbal rules dominating awareness can act to narrow behavior and limit sensitivity to available contingencies leading to psychological suffering (Villatte et al., 2015). Through derived relational responding, the psychological functions of stimuli and events can transform stimulus functions through relational frames based on contextual cues (Torneke, 2010). NF-related nonspecific effects leading to meaningful change beyond the therapy room may describe an individual's changing relationship with their context through a transformation of stimulus functions; context in NF considers the interaction with the therapist as well as the technology, feedback, and setting combined with their unique learning history and changing private experiences.

For instance, and even in "sham" NF conditions, experiential exercises based on repeated attentional training in the presence of a trained mental health behavior clinician can facilitate derived relational responding and transformation of stimulus functions. Consider the primary argued NF mechanism of operant conditioning of target brain waves, such as the occurrence of a brain event at a predetermined threshold (e.g., sensorimotor rhythm [SMR]) followed by positive reinforcement (e.g., presence or movement of desired visual and/or auditory stimulus), thereby increasing likelihood of such brain event reoccurring. There is also an arbitrary applied relational frame of coordination between the presence of the feedback with provided language (i.e., SMR = feedback = "relaxed attention"). In addition, there are many other likely recurring psychological events present or accessed during the exercise, including thoughts, feelings, sensations, and memories, including but certainly not limited to boredom, tiredness, alertness, busyness, anxiety, excitement, engagement, and so on. If such repeated psychological events such as boredom, tiredness, "I can't do this," or "I want to do something else" can be noticed and present without changing or shifting task, and they are related to the experience of "relaxed attention" and task engagement, this may in turn assist in a transformation of stimulus functions from aversive to appetitive in relevant contexts. When boredom then shows up during work-related tasks, it functions as less aversive now related to "relaxed attention" and has been experienced without task disengagement, thereby widening a previously narrow behavioral repertoire (e.g., boredom as an aversive resulting in experiential avoidance and task disengagement).

Indeed sham-controlled NF conditions represent a highly active intervention that demonstrates meaningful psychotherapeutic effects, such that derived relational responding may occur without feedback of any "real" live EEG activity through repeated experiential practice, exposure, and language, with acknowledgment that the individual receiving sham feedback is successfully blinded and therefore likely believes the feedback reflects their own biological function. However, the inclusion of operant conditioning of relevant brain events within the exercise remains worthwhile (Pigott et al., 2021), especially when considering some of the potential differences in long-term effects (Arnold et al., 2021; Steiner et al., 2014) between defined NF learners and nonlearners (Kolken et al., 2023; Krepel et al.,

2022). It is forwarded that it is the combination of underlying operant conditioning principles of physiological function interacting with a complex interpersonal language and relational learning context, as applied to a specific individual's context that works to guide flexible and sustained self-regulation. In this context, the term self-regulation refers to the role of attention and awareness processes to modulate behavior that is consistent with one's needs, values, and interests (Brown & Ryan, 2003).

Neurofeedback in a Process-Based Clinical Context

As outlined above, the focus of the present perspective is at the experiential level, and it is not within the scope of this paper to discuss the range of brain behavior targets and NF protocols available. Considering this, the practice and experience that informs this view emerged through working within the confines of the standard, well-researched, protocols including single channel reinforcement of SMR, theta-beta ratio, alpha-reward, and SCP NF (Arns et al., 2014; Marzbani et al., 2016) with sessions exclusively clinician-facilitated in clinic or via telehealth. These protocols relate to well-described and measurable biological processes functioning within the arousal-based vigilance model (Arns & Sterman, 2019). The appropriate NF protocol is guided in the context of clinical history, current presentation, and formulation through the clinician's standard clinical intake, in addition to integration of formal assessment with standardized symptom questionnaires as well as preintervention quantitative EEG (qEEG). Most critically, the NF protocol is aligned with the individual's primary concerns for seeking intervention (e.g., attention difficulties, affective dysregulation, etc.) and related to their therapy goals with attention to measurable behavioral goals.

Moreover, the current paper provides a narrative integration informed by clinical experience; it is but one perspective on an integrative psychotherapy approach in neuromodulation and it is not a systematic review of the literature. Importantly, the current position is not that the combination of therapies will necessarily result in an augmentation of specific clinical outcomes over monotherapy approaches, as there is not empirical data to support this, rather that the integration has the potential to reach wider in its effects, extending beyond symptom reduction.

The present paper also explores the integration of NF within an ACT framework transdiagnostically, and it is therefore not in reference to any specific clinical population. With that in consideration, much of the clinical experience that has informed this integration has come from those primarily seeking support for ADHD, along with the commonly occurring psychiatric and behavioral "comorbidities." There is an evidence base supporting the use of cognitive behavioral interventions to support the day-to-day impact on functioning from ADHD symptoms, including deficits in focused and sustained attention, inflexibility, behavioral problems, as well as related problems of depression, anxiety, psychological adjustment, and quality of life (Kretschmer et al., 2022). More specifically, mindfulness-based interventions have shown efficacy on improving core ADHD symptoms (Xue et al., 2019), and a scoping review by Munawar et al. (2021) suggested the use of ACT for ADHD is feasible, flexible, and promising; however, further well-controlled trials are required.

It is forwarded that multimodal interventions that are transdiagnostic and process-based, such as ACT and NF, may have additional utility in certain clinical contexts, such as ADHD and PTSD, where the majority are more likely than not to meet criteria for another diagnosable mental health disorder (Brady et al., 2000; Gnanavel et al., 2019). When supporting disorders of arousal-based dysfunction, there is the dual benefit of targeting psychological and behavioral processes while simultaneously supporting relevant biophysiological processes pertaining to sleep, arousal, and vigilance regulation within the same experiential exercise. Furthermore, there is often advantage in adapting mindfulness-based exercises in populations whose use of traditional mindfulness-meditation exercises may be particularly challenging to engage without modifications (e.g., as in ADHD; Janssen et al., 2020) or trigger aversive trauma responses (Lindahl et al., 2007).

Additionally, it is acknowledged that the existent body of intervention studies, including ACT, often shares limitations in the underrepresentation of certain demographic groups (Misra et al., 2023). As a result, it may work to limit the generalizability of such an integration of models which requires careful consideration when applied in diverse clinical populations. For example, much of the language used in this integration is in reference and drawn from work with adolescents and adults. It is necessary to adapt the language when working with children, for example, using the adapted Kidflex model (Black, 2022). Working effectively with children means working with their parents, with

consideration taken to teaching flexibility processes for parents to model at home and applying effective behavioral therapy techniques.

In this capacity, the integrated therapeutic work can function within a PBT model, that is, an overarching integration of evidence-based therapies that carefully considers selected mediators of change for the individual, organized across dimensions of function according to evolutionary adaptive processes of variation, selection, and retention in context across biophysiological and sociocultural levels (Hayes & Hofman, 2021). In NF practice when operating in the arousal model, attentional and affective dimensions can be targeted at the biophysiological level while simultaneously and synergistically addressing relevant psychological and behavior change processes through language-based and psychosocial interactions that are personalized and targeted to the individual. As a clinical example, consider an individual seeking intervention who presents with chronic difficulties with allocating and sustaining attention to tasks, loss of contact with the present moment, experiential avoidance of fatigue, boredom, and anxiety resulting in task disengagement and procrastination, alongside evidence of a vigilance impairment at brain level in the form of hypoarousal and elevated midline slow-wave theta activity. A process-oriented therapy may consider a repeated exercise of present moment awareness, with openness of experience and a flexible sense of self, while simultaneously guiding brain states towards mental alertness with acknowledgement of lowered arousal through operant conditioning, in the service of health, a sense of vitality, productivity, and efficiency.

Practically, NF practice delivered as an experiential exercise in clinical practice operates within standard approximate hour-long sessions, and the exercise duration typically lasts around 20–30 min, taking place usually at least on a twice weekly basis to facilitate learning. Therefore, in practice, there is still time spent before and after feedback to practice psychotherapy (Fisher et al., 2016; Tsuji-Lyons & White, 2023), such as ACT (please see the numerous available transdiagnostic treatment manuals for more information which has informed the current view, such as Harris, 2019; Luoma et al., 2007; Polk et al., 2016; Twohig et al., 2020; Villatte et al., 2015). The next section will consider the integration of each psychological flexibility process within NF practice. See Table 1 for an example protocol for ACT-based NF completed on an approximate twice weekly basis over approximately 20–30 sessions.

Table 1

Example Transdiagnostic Protocol for NF-Integrated ACT

Week	Session	Approximate Therapy Outline for ACT-Based NF Sessions *Each session comprises 20–30 min experiential NF practice and 20–30 min talk therapy*
1–2	0–4	Psychoeducation on biophysiological processes relevant to qEEG-guided NF protocol (e.g., arousal regulation, SMR, cortical flexibility, etc.). Permission to offer a different perspective by collaboratively exploring use of the ACT matrix (Polk et al., 2016). This perspective can set up useful noticing language to revisit throughout therapy, such as toward and away moves, senses, and mental experiencing. It also provides a clear platform to identify internal barriers and unworkable actions, and reveal motivations and values along with targets for behavioral change. Revisiting this perspective when introducing psychological flexibility processes can be useful. Orienting to the feedback mindfully, ***contacting the present moment.*** Flexible attention training through the NF experiential exercise is practiced in every session of NF-integrated ACT. ***Committed action*** for healthy sleep-wake behavior. Revisited regularly throughout intervention and often related to the biophysiological target processes (e.g., SMR, SCP, etc.).

Table 1

Example Transdiagnostic Protocol for NF-Integrated ACT

Week	Session	Approximate Therapy Outline for ACT-Based NF Sessions *Each session comprises 20–30 min experiential NF practice and 20–30 min talk therapy*
3	5–6	Creative hopelessness, undermining the control agenda through metaphor and other experiential exercises. Introduce experiential ***acceptance*** as an alternative to control. Facilitate open, nonjudgemental awareness of feedback. Practice gentle acknowledgement, accommodation, allowance, and appreciation of what is present and what is not under voluntary control (e.g., brain state compared to volitionally continuing to remain seated and engaged with the task).
4	7–8	Explore the process of ***defusion*** through metaphor and experiential exercises. Practice defusion techniques on private experiences showing up during NF exercises by noticing, naming, and expanding awareness. Physicalizing exercises, dropping anchor, placing thoughts on flowing feedback (e.g., puzzle pieces, moving bar), and metaphors using "waves" (e.g., wave surfing, boat on the water, etc.) can be particularly valuable to consider practicing during NF. Invite the client to practice defusion skills in daily life through behavioral commitments.
5	9–10	The ***self-as-context*** process is embedded within NF by attending to perspective-taking on one's brain activity. Invite the client to notice from what perspective are they able to notice the feedback and highlight the constancy of the self-as-context perspective with changing experience and brain function (e.g., NF as the self-as-context metaphor). Further explore any fusion with self-as-content through memories, roles, labels, and evaluations, and ask questions to take perspective across time, person, and place. Formally review progress at the 10th session. Clinical interview, formal questionnaires of relevant symptoms and processes.
6	11–12	Following the review and decision to continue with therapy, revisit and formally explore ***values*** as an intrinsic source of ongoing motivation that can be accessed in and outside of sessions to augment sources of reinforcement. Link values with relevant valued life domains where qualities of behavior (e.g., being open, aware, curious, loving, etc. at school, work, or home) can be engaged in within sessions and during NF practice, and then transferred to ***committed actions*** in daily life.
7–10	13–20	Review out of session practice, set and track behavioral commitments, flexibly revisit and address psychological flexibility processes as required. Work to integrate and transfer NF mindfulness skills into daily life. At the end of the 20th session, complete another formal review with questionnaires and any relevant behavioral or physiological measures (e.g., sleep-wake actigraphy watch).
11+	21–30	Depending on the client's progress and presentation, consider discontinuing therapy or continuing sessions to facilitate consolidation of therapy gains.

Note. The above protocol illustrates one example of a therapy protocol integrating ACT with NF. In practice, the order of processes addressed in therapy varies depending on the case conceptualization, functional assessment, and context, flexibly as needed. Please see the numerous available transdiagnostic treatment manuals for more information which has informed the current view, such as Harris, 2019; Luoma et al., 2007; Polk et al., 2016; Twohig et al., 2020; Villatte et al., 2015.

Psychological Flexibility Processes and Neurofeedback

Acceptance

Experiential acceptance refers to the open receiving of one's inner experience as it is, without attempts to remove or control it, with the inverse corresponding to experiential avoidance (Luoma et al., 2007). In practice, acceptance is often introduced as an action of willingness; that is, willingness reflects an active behavior to contact unpleasant or painful experience; to acknowledge, allow, accommodate, and appreciate inner experience; and to do so in the service of acting in accordance with one's values (Harris, 2019). The process of experiential acceptance is not readily appreciated within the aims of NF, a practice that is seemingly an attempt to control and influence brain activity in a targeted direction as an active attempt to change, reduce, or increase brain behavior through consequences. This aim is quickly met with "but how do I make my brain do what we are asking it to do?!"—at times along with frustration, disappointment, and self-judgement. Further, it can inadvertently send the message of a dysfunctional brain that needs to be fixed or normalized. Consider, however, that despite targeting specific brain events over repeated sessions, such as in frequency band training, pre–post testing of brain function in the direction of training is not always reliably found in specific neurophysiological measures at group level (Arns et al., 2012), and it is often not even evaluated in NF studies (Wigton & Krigbaum, 2015). This is not at all to say that brain changes are not occurring throughout NF, rather that brain activity and behavior are complex and dynamic, and aiming to simplify such complexity can be reductive met with inconsistency or unreliability in measurement on an individual basis.

To illustrate complexity in brain changes following NF, in a study of alpha reward NF for tinnitus, Vanneste et al. (2018) showed that there were distal functional connectivity changes as a result of decreasing cross-frequency coupling between beta and gamma synchrony with alpha activity, resulting in significant reduction in tinnitus-related distress. The authors discussed a possible means by which the coupling of slow and fast frequencies may influence changes in brain network communication, lending evidence to support complex interactional brain changes not otherwise noted in the targeted training frequency (e.g., alpha activity). There are other NF studies showing changes in event-related potentials (ERPs) at group level following NF (Kropotov et al., 2005; Strehl et al., 2011). Nevertheless, identification of client-relevant biological processes through a personalized qEEG-informed approach can inform standard NF protocols, as in ADHD, and enhance the multimodal treatment efficacy and likelihood of response (Pimenta et al., 2021). Although defining "learners" in NF is not necessarily straightforward (Strehl, 2014; Strehl et al., 2017), it remains essential that NF practice strictly adheres to the learning theory that it is founded on if any direct brain conditioning effects are to take place (Pigott et al., 2021; Sherlin et al., 2011). Given the recognized multifactorial mechanisms of change and complexity involved, meaningful change can still occur in the absence of demonstrated neurophysiological learning effects when evaluating therapy effectiveness on an individual basis.

Accordingly at the level of experience, the proposed perspective of ACT-integrated NF departs from the approach of normalizing brain waves to reduce the severity of symptoms. Alternatively, consider the functional contextual approach of removing any evaluative notions of good/bad of normal/abnormal brain behavior. Rather, it is inherent to the human condition to experience a full range of emotion. Similarly, it is inherent to display the full range of brain frequencies albeit with differences in measurable power within and across individuals depending on context. When there is observation of brain behavior through feedback, one notices oscillations and this up/down, ebb/flow, excitation/inhibition is the case for everyone. Within the framework of functional contextualism, the function of brain activity is interpreted within the individual's context and the aim of NF is to increase awareness and condition activity that is related to more workable behavior for the client.

Context has always been vital to the interpretation of electrical brain activity. If the behavior of the brain (i.e., EEG activity) in a particular context is not serving the individual and is misaligned with the individual's needs and goals at the time (e.g., the presence of slow-wave theta or alpha activity during times of task engagement and mental alertness), it can lead to challenges for the individual (Strehl, 2014). When brain activity is not flexibly in line with the changing context, this may be viewed as a form of cortical inflexibility. Acceptance through NF may be reflected in a simple statement such as acknowledging that "this is my brain as it is working in this moment." Although the person is not in direct voluntary control of their electrical brain activity at any specific moment, they can notice and respond to it in the service of living a valued life. The use of

mindful language to frame the context of the experiential practice can promote the acceptance process, such as “allowing,” “guiding,” “permitting,” and “letting be” what is noticed (Khazan, 2015).

Defusion

Cognitive fusion refers to entanglement with symbolic relations that dominate awareness which, while adaptive in many contexts, can work to limit context sensitivity and result in psychological rigidity and inflexibility. Fusion is often described as being “hooked” or buying into the content of thoughts as literal truths (Harris, 2019). Cognitive defusion is thereby the process of disentangling from and changing the relationship with thoughts to observe them as they are—symbolic relations in the mind—from a distance (Luoma et al., 2007). The act of taking internal experiences, such as arousal and attention, then correlating such processes with more complex behaviors, cognitions, and affect involved in topographic symptoms, derived from measurable brain activity, and relating it to concrete, nonsymbolic fluctuations, can facilitate defusion. Put simply, NF is an opportunity to witness painful or challenging experiences as squiggly lines, moving bars, and beeps—distilling something into a partial representation of its electrophysiological correlate. Moreover, the inner world does not stop showing up when someone attends to and notices their brain activity in real time; that is, language and cognition do not cease during NF. The verbal human is endlessly languaging, weighing in on what is in the here and now with evaluations, judgements, rules, reasons, self-statements, and narrations. During ACT-integrated NF we practice noticing, naming, and making room for cognitions that show up and dominate awareness, and we gently redirect attention to the here-now senses experience of the feedback.

SCP NF is a form of brain feedback involving learned cortical self-regulation of slow brain potentials. The target and experience in SCP are somewhat different to traditional frequent band training. SCP feedback is focused on slow electrical shifts in brain activity reflecting underlying cortical activation and inhibition. Activation refers to increased excitation of the underlying cortex whereas inhibition represents a decrease in neuronal firing related to inhibition (Mayer et al., 2012). The context of SCP feedback often evokes thoughts of confusion and self-judgement, although these are certainly not unique to SCP. Thoughts such as “I don’t get it,” “I suck at this,” “my brain is broken,” “my brain isn’t listening to me,” or “I don’t have any control,” all commonly show up and do so especially in the early learning phase of therapy. It was initially thought that cognitive strategies employed during NF may facilitate learning; however, the literature and clinical experience suggest otherwise (Kober et al., 2013; Strehl, 2014). Strategies may be helpful for some people, some of the time; however, consistent use of the same strategy will often prove ineffective across changing context. Adopting the same strategies without sensitivity to context in a rigid and inflexible way conforms with the control agenda, and they will not infrequently be met with seemingly random signals, moving in unpredictable directions and giving rise to the above-mentioned experiences of frustration, confusion, and a perceived lack of control. A common clinical observation of flexibility in training cortical excitation and inhibition over the course of sessions tends to emerge alongside an open and flexible stance, with expanded awareness of noticing inner and perceptual experiences. In other words, the cortically flexible client often appears open, aware, and engaged. There is acknowledgement when their signal moves in some desired direction, and there is open acceptance and curiosity when noticing departures.

There are numerous exercises and metaphors to help facilitate defusion which often starts with experimenting with and modeling language which encourages and facilitates observation and effective tracking of experience. For example, “dropping anchor” is a powerful technology which can be helpful to introduce early into psychotherapy combined NF sessions (Harris, 2019). The ACE formula for dropping anchor-related exercises of Acknowledge (i.e., acknowledge your inner world), Connect (i.e., connect with your body), and Engage (i.e., engage in what you’re doing), as described by Harris (2021), can be nicely adapted within and during NF sessions as a defusion tool amidst distraction and disengagement. Importantly, the intention is not to introduce cognitive-emotional content and mental activity during NF that may then interfere with the conditioning process but rather to build tools in effectively responding to the content that inevitably shows up.

Self-as-Context

The process of noticing oneself as the container of one’s experiences, from above and distinct from the experience itself, contacts the process of self-as-context or is sometimes referred to as flexible perspective taking (Harris, 2019). Alternatively, when self is viewed from the perspective of one’s experiences, informed by the collection of thoughts, beliefs, narratives, roles, and memories, typically in

the form of "I am" statements, it is referred to as the conceptualized self. If attachment to a rigid and inflexible conceptualized self results in unworkable behavior, learning to shift perspectives to contact self-as-context can foster a more psychologically flexible perspective that transcends the verbal mind. From clinical experience, a common client description of changes noticed from NF follows an individual stating that they have increased awareness of their attention and arousal from a hierarchical relation to self (i.e., "I notice my attention more").

NF facilitates an opportunity to view the brain from a different perspective. It is an experiential exercise that invites the person to engage with the noticing or observing an aspect of experience contained within self in a physical and concrete way. The self-as-context process considers deictic relations across person ("I-you"), place ("here-there") and time ("now-then") to view anyone and anything from a perspective of I-here-now (Torneke, 2010). Therefore, during NF one notices that they can notice their brain as it is working in real time. It offers the perspective of I-here-now can notice my brain working there, now. For some entering therapy with long histories of prior intervention, they may have developed an unhelpful frame and relationship with their brain and self, sometimes embedded in the mechanistic and medicalized model of psychiatry that can provide some sense of naming and distancing from pathology, however replaced with fusion to the conceptualized self (e.g., my ADHD/depressed brain is bad, useless, or broken, etc.). NF may facilitate a transformation of function in the way an individual relates to self by providing a platform to observe one's brain function from a different perspective (e.g., "I-here-now notice my ADHD brain working over there"). Of interest, Hawkins (2014) postulated that physiological self-regulation through biofeedback may reflect an illusion of self-control and that improvements in health and behavior are understood as a function of an improved sense of coherence through an RFT perspective.

Contact With the Present Moment

In behavioral terms, attention training is the process of learning how to voluntarily broaden or narrow stimulus control (Villatte et al., 2015). Allocating and sustaining purposeful attention to the real-time brain activity feedback provided in the here-now can provide a particularly rich experience through the lens of ACT. The experience of noticing brain activity involves directing attention purposively towards visual and/or auditory representations—attending carefully to moving details on a monitor and/or changes in sound (e.g., pitch, volume, speech, etc.). The stance is open, curious, and nonjudgmental. While there is a focus on acknowledgement of reward in the presence of target features (e.g., hearing a beep or seeing something happen on the screen is a wanted and desired action), performance is secondary to the act of observation. Attention invariably fluctuates during NF from a senses experience, noticing bodily sensations and arising internal experiences of thoughts, feelings, images, and memories. When attention wanders, the individual is asked to notice and acknowledge it, then gently return their attention and integrate their internal experience with the feedback provided in the present moment. It is not only feedback of brain activity that facilitates present moment awareness but also orientation to slight changes in movement and muscle activity through EMG and EOG (electrooculography) biofeedback that provides valuable real-time information on the body. Indeed, active control groups that provide EMG biofeedback in NF studies still show significant sustained clinical outcomes (Arnold et al., 2021; Schönenberg et al., 2017; Strehl et al., 2017).

The following script was adapted from the Music Mindfulness and Defusion exercise (Stoddard & Afari, 2014). This exercise facilitates both purposeful attention to the feedback and observing the complexity of any internal experiences that shows up during the feedback. This script allows the individual to notice the distinction between their senses and mental experience during NF and can complement integrating perspective work with the ACT matrix (Polk et al., 2016). It can be adapted to frame the context for a NF round, typically lasting around 5 min, followed by debriefing on the client's experience.

Before we start the next round of feedback, I invite you to experiment with observing the place where you can witness your experience gently and without judgment. I'd like you to pay particular attention to visual elements on the screen, holding and noticing the details that you see related to movement, color, shape, and content (e.g., notice the bars moving up and down; really attend to when the bar fills above or below the threshold line; hold attention on the car as it moves; focus on empty space within the puzzle, etc.). In your own time, flexibly move your attention around the screen to another feature and hold your focus there, again noticing movement, color, and content with open curiosity. You may move your attention to the sounds that you hear, noticing any changes in pitch or frequency. You may move your

attention from what you see and hear and take notice of sensations in the body, such as breath, pulse, temperature, tension, pressure, and other physical sensations. Continue to flexibly move your attention around to focus on what you see, hear, feel, and touch, with an open stance.

As you acknowledge the feedback of your brain activity, I want you to pay attention to your unique experience of noticing your brain as it is working. As you continue to attend, consider this: the experience of you noticing your brain activity may provoke sensations, thoughts, emotions, experiences, evaluations, and judgments. This is just what our minds naturally do—this is our mental programming, and it is happening all the time. Notice any thoughts, emotions, evaluations, or judgments you are having about the feedback. Become aware of how you are currently relating to the experience.

[Once the round has ended] Now gently bring your awareness to the present moment by taking a moment to look around the room and attend to any other sounds present. Notice the sensation of pressure in your body where it contacts the chair and the floor. In your mind's eye, picture yourself in the room.

EEG and Mindfulness

Mindfulness is captured through psychological flexibility processes of present moment awareness with an open, accepting, nonjudgmental, and flexible sense of self (Luoma et al., 2007). There is a body of research that has explored the role of brain activity, including EEG effects, of mindfulness practice as well as NF and mindfulness that is of relevance to this discussion (e.g., Treves et al., 2024). EEG studies across healthy and clinical populations have revealed increased synchronized alpha and theta power associated with mindfulness meditation practices, relative to an eyes-closed resting state (Lomas et al., 2015). Increased synchrony in the gamma EEG frequency band has also been found as enhanced in a small group of long-term meditators during meditation, in addition to increases in theta and alpha activity (Lutz et al., 2004). Moreover, NF protocols rewarding alpha power have shown benefits in mindfulness-related outcomes (Navarro Gil et al., 2018), and combining mindfulness with alpha reward NF has demonstrated augmented benefits to psychological and emotional outcomes as compared to mindfulness with sham NF (Lee et al., 2024).

As a flexible process-based therapy, ACT can be practiced in a myriad of ways, involving the use of direct and indirect mindfulness-based practices, as well as experiential exercises and metaphors contacting specific processes, or by combining and organizing processes in different and creative ways. Thus, while mindfulness practices play a central role in ACT, specific processes are contacted through nonmeditative style experiential exercises and depending on the integration, it may not require or recruit sensitive, specific, or readily measurable brain-wave correlates (e.g., alpha, theta, or gamma activity) in such a changing context. The distinction between this line of research and the current perspective is that, in the former NF, technology is primarily used as a tool to augment the specific mindful-meditation practice, as opposed to delivering NF within a wider ACT-based psychotherapeutic context that flexibly integrates mindful and acceptance processes.

Values

Values are about knowing what truly matters to a person, with the "what" relating to the important qualities of behavior one strives to embed in their actions on an ongoing basis (Luoma et al., 2007). Values vary across life domains, such as those we hold close in relationships, work, education, leisure, spirituality, health, and so forth. For those who have not witnessed or experienced NF, the experience varies between people and also within individuals over the course of their therapy, session to session, and even moment to moment. It can be highly introspective, stimulating, engaging, and interoceptive. Alternatively, by nature it is extremely repetitive, simple, routine, and therefore boring! Moreover, the practice of watching one's brain activity can be abstract and difficult to relate to real-world processes and target behaviors of change. It is extremely common for people to experience thoughts such as "how is this supposed to help me?", "what has this got to do with my life and problems?", and certainly "what's the point?!" Although relevant biological processes are linked with client experiences, reinforcers are augmented by clearly identifying and returning to how the work serves the person and who or what it brings them closer to thereby providing underlying motivation and direction for meaningful behavior change.

Identification of therapy goals and values tends to take place from the clinical intake; however, it is then helpful to often engage in "valuing" behavior during sessions thereby fueling motivation for engagement in session and augmenting the learning process. It can be helpful to begin sessions by reviewing any noticing practice since the previous session, or a

choice-point, values bullseye, or ACT Matrix sort (Harris, 2019; Polk et al., 2016).

Committed Action

Committed action is an overt behavior change process, that is, to exert choice in one's behavior, establish goals, and make action plans to create meaningful change in one's life in the direction of their values despite the presence of obstacles. NF is a short-term and intensive intervention, often at a frequency of twice per week, aimed at building automatized skills for long-term sustained effects to help live a more effective life. There is the foremost commitment to attend sessions with regularity and consistency, which is especially essential in the initial phase of intervention; this is where committed action starts. Behavioral values-based goals are formed and reviewed during each session, as appropriate. There is a focus on evaluating changes and responses to identified behaviors as indicators of therapy response. As in the case of attentional and arousal-based struggles, there is goal setting and careful monitoring around whether the individual is demonstrating increased awareness and sensitivity to changing context and whether they are then able to respond more effectively to shifts in attentional focus, to flexibly redirect attention in a way that helps them live in line with what matters to them.

For a common example of committed action in NF, we can attend to the role of sleep-wake behavior. Sleep, arousal, and NF are inextricably linked (Arns, & Kenemans, 2014). Sleep function and quality are well known to influence electrical brain activity and behavior both in the short and long term. Brain behavior targets in NF will commonly have relations to sleep function (e.g., the network relation between SMR and sleep spindle circuitry; Hoedlmoser et al., 2008), and sleep quality has an established impact more broadly on the brain's ability to learn and consolidate new information and relations. Sleep-wake behavior and direct attention to sleep hygiene practices are strongly followed alongside NF and are commonplace amongst mental health support and psychotherapy more widely, commonly reflecting values within domains of health and a general sense of vitality. Sleep function more broadly is another critical transdiagnostic feature (Arns et al., 2021).

Recommended sleep hygiene practices are usually introduced into sessions as suggestions through psychoeducation to help facilitate valued living. With consideration to values and committed action, individuals are encouraged to practice and experiment with behaviors that may assist them with their sleep quality, wake feeling more refreshed, and set them up to respond effectively to what shows up that day. In other words, they make behavioral commitments to establishing consistent sleep-wake behavior and habits that are workable for them in their context. While there is considerable overlap between cognitive behavioral therapy for insomnia (CBT-i), a gold-standard intervention for insomnia (Muench et al., 2022) and ACT-i, the latter also has demonstrated effectiveness (Salari et al., 2020) and may be useful for those who do not respond to CBT-i (Shin et al., 2023).

Future Directions and Concluding Remarks

The proposed integration of ACT with NF introduces a notable potential caveat: the concurrent use of active cognitive and emotional processes during NF may interfere with the operant conditioning mechanisms that underlie effective learning. Specifically, there is a risk that cognitive loading could disrupt stimulus-reward contingencies, reduce the precision of reinforcement learning, or lead to unanticipated verbal associations. These potential concerns suggest that the timing and structure of the integration warrants careful consideration and flexibility in clinical practice with diligence to frame the experiential NF context, as to not weaken the operant neurophysiological conditioning. Further empirical research is needed to explore the impact of embedded versus sequential delivery of therapy modalities on NF efficacy and clinical outcomes.

To examine the clinical effectiveness of an integrated approach, future trials will need to consider treatment arms with active and sham NF both with combined ACT, as well as monotherapy NF and ACT to assist in elucidating augmentation of outcomes from a combined model and understanding any mechanisms of change. It is important to assess clinical outcomes over follow-up time points to capture more sensitive underlying changes with active NF conditions. Regardless, there is benefit in future NF literature including secondary measures related to psychological flexibility and mindfulness processes, for example, including but certainly not limited to the Acceptance and Action Questionnaire (AAQ-2; Bond et al., 2011) or the Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2008), which may assist in revealing empirically the capacity of NF to more broadly promote psychological flexibility processes. Finally, other more fine-grained experimental designs within individuals receiving NF over time may investigate the impact of combined ACT processes during NF through tracking of biological and idiographic

psychological or behavioral measurements taken over time.

Despite decades of research showing meaningful clinical benefits of providing real-time feedback of an individual's brain behavior through NF, there is continued uncertainty in the causal mechanisms, with claims that much of the clinical benefit is attributed to the nonspecific psychotherapeutic effects. Rather than discounting the clinical benefits of NF due to multifactorial mechanisms of change, recognizing the benefits of a noninvasive brain-based intervention while embracing the wider psychotherapeutic and behavioral context through a robust, evidenced-based, model of psychotherapy may provide an effective step forward. An NF-integrated ACT approach considers the whole individual addressing brain and behavior function simultaneously at biophysiological and psychosocial levels. The multimodal intervention can be implemented within a widely established individualized and process-based psychotherapeutic framework, and direct empirical investigation is invited.

Author Declaration

Steven Wickens and Trevor Brown are both employed by Neurocare Group (Melbourne, Australia) who offer psychological services and neuromodulation treatment and training services within their clinics. The authors otherwise declare that they have no conflict of interest or declarations.

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