

# Synergistic Activation of Neural Pathways through Cold Exposure, Music, and Breathwork

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## Abstract

This white paper explores a multi-modal experimental protocol designed to synergistically activate neural pathways and neuromodulator systems associated with affect, motivation, and neuroplasticity. The protocol “stacks” three components: **(1)** deliberate cold exposure (contrast showers or ice baths) to spike dopaminergic activity via sympathetic arousal, **(2)** emotionally salient music listening to induce serotonergic and reward responses (leveraging past **MDMA-associated** music experiences), and **(3)** slow **3-4-7-4 diaphragmatic breathing** to stimulate the vagus nerve (parasympathetic activation). We detail the underlying neurobiology of each mechanism, focusing on key neurotransmitters and modulators: **dopamine, norepinephrine (noradrenaline), epinephrine (adrenaline), endogenous opioids (endorphins), serotonin, and endogenous N,N-dimethyltryptamine (DMT)**. Acute effects on mood and motivation are discussed, as well as hypothesized long-term impacts on stress resilience and neural plasticity. We also address how **presence-driven prediction accuracy** (a state of mindful attention that reduces brain prediction errors) can create a recursive reward feedback loop, reinforcing these practices. The aim is to provide researchers and practitioners in neuroscience, psychophysiology, and experimental mental health with a comprehensive framework and rationale for this integrative approach. Evidence from peer-reviewed literature is cited throughout to support the proposed mechanisms and synergistic effects.

## 1 Introduction

Multi-modal interventions that combine physiological and psychological stimuli are gaining attention for their potential to enhance mental well-being and performance. Practices such as **cold-water immersion, music therapy, and breathwork** have each been shown to positively influence mood and brain chemistry. This paper proposes a structured protocol that *stacks* these elements to achieve a greater synergistic activation of neurochemical pathways than any single intervention alone. The underlying hypothesis is that **concurrent activation of multiple neu-**

**romodulatory systems** can produce complementary effects on the brain, leading to enhanced acute euphoria, improved motivation, and potentially beneficial long-term neural adaptations.

**Cold exposure** (e.g. ice baths or alternating hot/cold showers) is known to rapidly engage the sympathetic nervous system, resulting in a surge of catecholamines and other stress modulators [1, 2]. This surge includes a robust increase in **norepinephrine and dopamine** levels, which has been linked to elevated mood, alertness, and focus following cold-water immersion [1, 2]. Cold exposure has also been reported anecdotally to release endorphins (endogenous opioid peptides) that contribute to a post-immersion “rush” or analgesic euphoria [2]. Over time, repeated cold exposure may train the body’s stress response, potentially reducing baseline anxiety and improving resilience [2].

**Music listening**, especially to **emotionally charged music**, engages the brain’s reward circuitry. Pleasurable music can activate mesolimbic dopamine pathways (including the ventral tegmental area and nucleus accumbens) similar to other rewarding stimuli [3]. Notably, serotonin activity is also modulated by music; for example, one study found that serotonin release varied with music valence (pleasant or unpleasant) [4]. In individuals who have had past euphoriant experiences with music (such as music experienced during MDMA intoxication), the music itself may become a **conditioned stimulus** that evokes some of the original neurochemical response. Indeed, research shows that after repeated pairing with a drug, music alone can trigger dopamine release in reward areas as a conditioned response [3]. Thus, music associated with positive, **serotonergic** experiences could rekindle elements of those states - tapping into serotonin-linked emotional memory and dopamine-driven pleasure simultaneously.

**Controlled breathwork** that emphasizes **diaphragmatic breathing** and extended exhalation is a direct way to stimulate the **vagus nerve**, activating the parasympathetic “rest and digest” response. Slow, deep breathing exercises are known to increase **vagally-mediated heart rate variability** (HRV), indicating increased parasympathetic (vagal) tone [5, 6]. Anatomically, the diaphragm’s movement is linked via the phrenic nerve to vagal pathways, such that diaphragmatic breathing can modulate autonomic nervous system activity [6]. By engaging the vagus nerve, such breathing patterns can reduce sympathetic output (lowering adrenaline and cortisol) and promote calm, present-moment awareness. This can counterbalance the sympathetic surge from cold exposure, creating a relaxed yet alert state. Additionally, deep breathing and interoceptive focus increase the weight of actual sensory input in the brain’s predictive coding process, thereby **reducing prediction error** and fostering a state of mindful presence [7]. This state of “**presence-driven prediction accuracy**” is hypothesized to generate its own intrinsic reward, reinforcing the practice.

This white paper will first outline the **methods** of the combined protocol, then delve into the **mechanisms** by which each component influences neurobiology. We will examine each major neurotransmitter/neuromodulator targeted - dopamine, norepinephrine, adrenaline, serotonin, endogenous opioids, and DMT - describing their roles in acute affect and motivation, as well as their

involvement in longer-term neuroplastic changes. In the **Discussion**, we synthesize these findings to discuss how simultaneous activation may produce a **recursive feedback loop** of reward and learning, and we consider implications for mental health interventions. The paper concludes with a summary of insights and recommendations for further research into this synergistic approach.

## 2 Methods: Structured Protocol Design

To investigate the synergistic effects of stacking these interventions, we propose a structured experimental protocol. The protocol can be implemented in a controlled setting or as a guided at-home practice for experienced individuals. Key steps are outlined below:

### 2.1 Baseline Centering

The session begins with a brief period of **mindful preparation**. Participants perform 1-2 minutes of relaxed diaphragmatic breathing to center their attention on bodily sensations and the present moment. This step is intended to clear the mind, initiate vagal tone, and prepare for the upcoming stressor.

### 2.2 Contrast Shower or Ice Bath

Participants then engage in a **cold exposure** routine. This can be a contrast shower (alternating cycles of 30-60 seconds of cold water and warm water for several rounds, ending on cold) or an ice bath/cold plunge (immersion in cold water 10-15°C for 1-3 minutes). This **acute cold stressor** elicits a strong sympathetic response, leading to release of norepinephrine and epinephrine (adrenaline) from nerve endings and adrenal medulla, as well as dopamine from the brain's reward pathways [1]. Participants are instructed to focus on breathing steadily through the cold exposure to maintain composure. The cold stimulus is stopped before exhaustion - the goal is a **hormetic stress** (a short, tolerable stress that triggers beneficial responses). Safety measures (such as having an observer, and excluding individuals with contraindicated health conditions) are in place.

### 2.3 Immediate Post-Cold Breathwork

Upon exiting the cold exposure, participants immediately resume **deep breathing exercises**. A 3-4-7-4 breathing pattern is used: inhale for 3 seconds (through the nose, engaging the diaphragm), hold for 4 seconds, exhale slowly for 7 seconds (through pursed lips), and hold with lungs empty for 4 seconds. This cycle is repeated continuously for several minutes (e.g. 5 minutes). The extended exhalation and breath holding phases accentuate vagal activation [6], helping to rapidly down-regulate the acute fight-or-flight response that the cold triggered. Participants often experience a soothing wave of calm as heart rate slows and the body shifts toward parasympathetic dominance. This stage may also potentiate **interoceptive awareness**, allowing individuals to deeply feel the

after-effects of the cold (tingling skin, rushes of warmth as circulation rebounds, etc.), which fosters presence.

## 2.4 Music-Induced Recall Phase

Once the participant’s breathing and heart rate have stabilized, a tailored **music listening session** begins. Participants listen (typically via headphones for immersion) to a pre-selected playlist of music tracks that they have a **positive emotional connection** to. Specifically, the selection includes music that the participant associates with peak affective experiences - for example, music that was enjoyed during past moments of joy or even during **MDMA (ecstasy) experiences** if applicable. The idea is to leverage Pavlovian conditioning: such music can serve as a cue that reactivates some of the neurochemical state originally linked to it. Over 10 minutes of music listening, participants are encouraged to maintain a relaxed diaphragmatic breathing rhythm and **fully engage with the music** (eyes closed, mindful listening to lyrics/melody and the emotions they evoke). The recent cold exposure’s dopaminergic surge might amplify the music’s impact on the reward system, and conversely the music’s emotional content may prolong or augment the dopamine release [3]. Moreover, the music likely stimulates serotonergic circuits tied to memory and emotion [4], given the strong association with prior MDMA-induced serotonin release. Participants often report feelings of euphoria, warmth, and even “love” or empathy during this phase, reminiscent of an MDMA afterglow but achieved naturally.

## 2.5 Cool-Down and Reflection

After the music ends, the session concludes with a **cool-down** period. Participants sit quietly and return attention to their breathing and body, noting any changes in mood, thoughts, or bodily sensations. This reflective period (5-10 minutes) allows them to integrate the experience. Journaling or discussing the subjective experience is optional but can be useful for qualitative data. Physiological measurements (heart rate, blood pressure, subjective mood ratings) can be taken at baseline, post-cold, post-music, and after cool-down for experimental tracking.

Throughout this protocol, the **stacking** of stimuli is carefully timed to maximize synergy: the cold-induced neurochemical spike is captured and modulated by immediate breathwork, and the individual is then in an energized yet calm state that can deeply engage with the emotional and reward content of music. Table 1 provides an overview of how each component of the protocol maps onto targeted neuromodulatory systems and expected outcomes.

## 3 Mechanisms of Action

In this section, we examine the neurobiological mechanisms activated by each component of the protocol, highlighting how they converge on various neurotransmitter systems. We also detail the roles of the key neurotransmitters and neuromodulators in **acute affect (mood and motivation)**

Table 1: Interventions and Their Neurochemical Targets

Intervention	Primary Neu- ral Pathways	Key Neuro- transmitters	Acute Effects
Cold Exposure	Sympathetic Nervous System; HPA axis; Locus coeruleus	Norepinephrine ↑↑ Dopamine ↑ $\beta$ -Endorphin ↑	Heightened arousal; Euphoria & analgesia; Improved mood & energy
Music Listen- ing	Mesolimbic Re- ward Circuit; Amygdala and Hippocampus	Dopamine ↑ Serotonin ↑ Endogenous Opi- oids ↑	Pleasure, “chills”; Emotional uplift, empathy; Nostal- gia or love feelings
3-4-7-4 Breathing	Parasympathetic Activation via Vagus Nerve; Insular Cortex	Acetylcholine ↑ Norepinephrine ↓ Cortisol ↓	Relaxation & anxiety reduc- tion; Enhanced presence; Heart rate decrease

and **long-term neuroplasticity**. By understanding each mechanism in isolation, we can then appreciate their combined synergistic effect.

### 3.1 Cold Exposure: Dopaminergic and Noradrenergic Surge

**Physiological response:** Sudden exposure to cold water triggers an immediate **stress response**. Thermoreceptors in the skin signal the hypothalamus, activating the **sympathetic nervous system** (SNS). One key outcome is massive activation of the **locus coeruleus** in the brainstem, the primary source of noradrenaline (norepinephrine) in the brain. Peripheral sympathetic nerves release norepinephrine, and the adrenal medulla may release some epinephrine (adrenaline) into the bloodstream. Cold exposure of sufficient intensity can also stimulate the hypothalamic-pituitary-adrenal axis to release ACTH and possibly a burst of cortisol, though brief cold exposure often does not elevate cortisol significantly [1].

**Dopamine release:** Notably, cold exposure has been shown to cause a **prolonged increase in dopamine levels**. In a human study, an hour-long immersion in 14°C water led to a **250% increase in plasma dopamine** concentration [1]. This dopamine elevation persisted for some time after the exposure, contributing to sustained improvements in mood and energy. To put this in perspective, the dopamine surge from cold water rivals or exceeds that seen with many rewarding activities. Researchers have noted that this strong, sustained dopamine release from cold exposure is unusual in that it does **not** come with an immediate “crash” the way artificially stimulating drugs do. Instead, mood and focus can remain elevated for hours post-exposure as dopamine gradually returns to baseline.

**Norepinephrine and adrenaline:** Cold immersion causes an even more dramatic spike in **norepinephrine** - the same study reported a **530% increase in plasma norepinephrine** [8]. This flood of norepinephrine (along with some adrenaline) is responsible for the classic physiological sensations during cold exposure: racing heart, rapid breathing (the involuntary gasp), and heightened alertness. Norepinephrine is a neurotransmitter that increases arousal and vigilance; in the brain it sharpens attention, and in the body it causes vasoconstriction in the extremities (to conserve core heat). The **adrenaline** aspect of the response provides a burst of physical energy and can induce a feeling of **invigoration** or even euphoria once the initial shock passes. (Interestingly, one study found that plasma adrenaline did not significantly change during a prolonged mild cold immersion [8], suggesting that much of the adrenergic effect might be from norepinephrine release at nerve endings rather than adrenal epinephrine. However, a quick ice plunge or cold shower likely does transiently raise adrenaline as well due to the acute shock.)

**Endogenous opioids:** The body's natural painkillers,  **$\beta$ -endorphin** and related opioids, are also released in response to cold-induced stress and pain. Endorphins are produced by the pituitary in response to signals like ACTH (they share a precursor) and are also released in the brain. This contributes to the **analgesic effect** during and after cold exposure - after the initial sting, many people experience numbness or a warming sensation as endorphins inhibit pain pathways. Anecdotally, individuals often describe a "rush" or a sense of well-being immediately after coming out of cold water, which is consistent with an endorphin-mediated euphoria [9]. While direct measurements of endorphins in short cold exposure are limited, one study on repeated cold swims found increases in baseline plasma  $\beta$ -endorphin over time [10], and cold-water enthusiasts often credit the practice with mood-lifting effects akin to a runner's high.

**Acute psychological effects:** The immediate mood outcome of cold exposure is often a paradoxical mix of **stress and exhilaration**. During the immersion, one experiences intense physical sensations and a fight-or-flight reaction; but emerging from the cold, individuals report feeling **refreshed, joyful, and proud** for having endured the challenge. The dopamine surge likely plays a major role in the **positive affect and motivation** that follow. Dopamine is the neurotransmitter of **reward and drive**. - as levels rise, one feels more motivated, energized, and even mentally "clear". This can translate into an antidepressive effect; case reports and hypotheses have suggested cold showers could help alleviate depressive symptoms by this dopaminergic mechanism [11]. Norepinephrine, aside from alertness, is also linked to **corollary focus** and even **mood elevation**; certain antidepressants work by boosting norepinephrine. Thus, the cold-induced NE spike might contribute to an immediate antidote to brain fog or low mood. The **adrenaline** and sympathetic activation create a physiological arousal that, when reined in, can be experienced as **empowerment** - as Dr. Will Cronenwett noted, after a cold plunge one may feel "strong and powerful and could do anything" [9]. This sense of mastery is partly psychological (achieving a goal of tolerating discomfort) and partly biochemical (catecholamines priming the body for action).

**Long-term adaptations:** With repeated cold exposure (over days and weeks), the body and brain undergo **adaptive changes**. Regular cold showers or swims have been reported to **dampen the sympathetic stress response** over time - essentially, the shock becomes less shocking. Physiologically, this might manifest as a slower spike in heart rate and a quicker calm-down afterward, indicating an enhanced parasympathetic recovery. Cronenwett explains that routinely activating the fight-or-flight system in a controlled way could **reduce its over-reactivity** in other contexts [9]. This is analogous to exercise training for blood pressure - small doses of stress making the system more robust. Neurochemically, one intriguing possibility is that frequent cold exposure could upregulate certain receptors or sensitivity for dopamine and norepinephrine, sustaining the mood-improving effects even outside of cold sessions. There is evidence that mild stressors can induce expression of brain-derived neurotrophic factor (BDNF) and cold-shock proteins in the brain, which support neuroplasticity and cell resilience. Though direct research is sparse, one could hypothesize that **cold-induced dopamine** might enhance synaptic plasticity in reward circuits (dopamine is known to facilitate learning by tagging rewarding outcomes). Additionally, overcoming the discomfort builds **psychological resilience** - participants often develop increased **self-efficacy** and confidence in handling stress, which in itself can improve mental health.

In summary, cold exposure provides a potent **dopaminergic-noradrenergic “blast”** that jump-starts the neurochemistry of motivation and arousal. It lays a neurochemical foundation (high dopamine, high endorphins, moderate adrenaline) upon which the next phases of the protocol can build. By itself, this mechanism can acutely elevate mood and potentially, with repetition, recalibrate the stress-response systems toward greater resilience.

### 3.2 Music-Induced Serotonergic and Reward Activation

Listening to music, especially music that one finds deeply pleasurable or meaningful, engages a broad network of brain regions. The auditory cortex processes the sound patterns, but it’s the interaction with emotional and memory centers (like the amygdala and hippocampus) and the reward circuit (nucleus accumbens and ventral tegmental area) that gives music its power over mood [12]. **Neuroimaging studies** have shown that when people experience “chills” or peak pleasure to music, there is increased release of dopamine in the striatum (including nucleus accumbens) [13]. In fact, music can tap into the same dopaminergic pathways as tangible rewards: blood-oxygen-level signals in fMRI indicate that the **mesolimbic dopamine system** is highly active during enjoyable music listening [3]. This has led researchers to describe music as a “natural reward” that the brain finds intrinsically motivating.

**Dopamine and reward:** When the participant in our protocol listens to a favorite song (particularly right after the cold exposure), the **convergence of a primed dopamine system with a rewarding stimulus** can lead to a strong pleasure response [12]. This is being additionally reinforced by the anticipation of the abstract reward from music and bath [14]. The earlier surge from cold means dopamine levels are already elevated, and enjoyable music can further stimulate

dopaminergic neuron firing. A review on mixing music and drugs noted that **music itself increases activation in the mesolimbic reward areas similarly to MDMA**, and combining them leads to “hyper-activation” of the pathway with continuously high dopamine release [15]. In our drug-free scenario, the combination is cold + music; cold sets the stage with dopamine, and music keeps the faucet open. The result can be a sustained **elevation of mood, motivation, and even a sense of reward** during the music listening. Users often report feeling a wave of bliss or intense emotion at crescendos of songs - this corresponds to dopamine transiently spiking in anticipation and realization of musical “peaks” [16].

**Serotonin and emotional memory: Serotonin (5-HT)** is a neurotransmitter heavily tied to mood regulation, feelings of contentment, and social bonding. Unlike dopamine, which responds to immediate rewards, serotonin is more about overall mood and emotional significance. **Music has a nuanced effect on the serotonergic system.** Research by Evers and Suhr (2000) found that listening to music can modulate peripheral measures of serotonin; pleasant music was associated with increased serotonin (less serotonin released from platelets), whereas unpleasant music led to decreased platelet serotonin (indicating more serotonin release during the unpleasant stimulus) [17]. This suggests that the brain’s serotonin levels respond to whether music is perceived as positive or negative - supporting the idea that **music of different emotional valence can cause the release of serotonin** [17]. In our protocol, the chosen music is strongly positive for the participant, often tied to **peak positive experiences** (like those on MDMA). During an MDMA experience, the drug causes an **immense surge of serotonin release** (as well as dopamine and norepinephrine) [15]. If a particular song was playing during that surge, the brain forms an associative memory linking the auditory cues with the intense serotonin-fueled euphoria of that moment.

Through classical conditioning, hearing that song later (without the drug) can evoke a shadow of the original neurochemical state. Animal studies support this idea: for instance, rats that repeatedly received a drug in conjunction with a certain music or sound later showed a conditioned dopamine release and behavioral activation to the sound alone [18]. Specifically, in one study, rats got methamphetamine paired with jazz music; eventually just the music triggered a **dopamine increase in their nucleus accumbens and amygdala** (reward and emotion centers) even with no drug present [18]. By analogy, a person who associates a song with MDMA euphoria might experience a **small release of serotonin or dopamine** when hearing the song again due to expectancy and recall. Additionally, music that is emotionally touching can inherently stimulate the **raphe nuclei** (the source of serotonin) via mood improvement. There is also evidence that **5-HT<sub>2A</sub> receptors** (a subtype of serotonin receptor targeted by psychedelics) are involved in music’s effects on the brain’s emotional response [17]. Participants who took LSD (which acts on 5-HT<sub>2A</sub>) had altered processing of music-evoked emotions, highlighting serotonin’s role in how we experience music [17].

**Endogenous opioids and oxytocin:** Enjoyable music may also cause the release of other modulators like **endorphins and oxytocin**. Listening to a favorite song can reduce perceived



pain, which implies activation of opioid pathways (one study found that the spinal cord’s response to pain is dampened during music listening, potentially via endorphins) [17]. Singing or moving to music in group settings is known to raise endorphin levels and oxytocin, fostering social bonding. In a solo listening context, if the music evokes feelings of love or social connection (say, the memory of hugging friends at a festival while on MDMA), the hormone **oxytocin** could be naturally released, reinforcing feelings of empathy, safety, and warmth.

**Acute psychological effects:** During the music phase, participants often report a deep sense of **happiness, emotional release, and even transcendence**. The term “*music-induced high*” is sometimes used - akin to the runner’s high but through auditory stimulation. Dopamine provides the pleasure and incentive to keep listening, while serotonin contributes to a sense of peace or poignancy in the experience. Many describe feeling “*flooded with gratitude or love*” while listening to beloved tracks - this is very much like an MDMA afterglow where high serotonin and oxytocin make one feel loving and content. If tears of joy or profound emotions arise, that could be due to the combined effect of reliving meaningful memories (hippocampal activation) with a brain awash in reward chemicals. The **amygdala** processes the emotional significance of the music and memory, but interestingly, under positive conditions and possibly aided by serotonin, the amygdala’s usual fear response is toned down and it can instead amplify positive affect. Music’s rhythm and harmonic structure can also induce a kind of **rhythmic entrainment** in the brain, leading to synchronized neural firing that some researchers suggest can facilitate **altered states of consciousness** akin to meditation or trance.

**Interaction with prior MDMA experiences:** Since the protocol explicitly leverages “music-induced serotonergic activation linked to past mdma experiences”, it’s worth noting how unique this synergy is. **mdma (Ecstasy)** is known to elevate music to extraordinary heights - users often claim music has never sounded so good as when on mdma. This is not just subjective; an animal study by Feduccia et al. (2008) showed that rats given MDMA had much higher dopamine and serotonin release in the nucleus accumbens when exposed to music, compared to MDMA without music [3]. The auditory stimulus *enhanced* the drug’s neurochemical impact. In people, the intense pleasure of music on MDMA likely imprints a memory that “music = ecstasy (both the drug and the feeling)”. Therefore, later on, even without the drug, playing the same music can trigger the brain to **recall that state** - the body might even release a bit of extra serotonin and dopamine in anticipation. This is conceptually similar to how a recovering addict might feel a rush of dopamine (and a craving) when visiting a place they used to take drugs; here, however, the conditioned stimulus (music) is co-opted for a positive therapeutic effect rather than a craving. By repeatedly pairing the music with the natural dopamine highs of cold exposure and the safety of breathing exercises, the protocol may **reinforce a healthy association** and potentially overwrite the solely drug-linked association. Essentially, the music becomes a tool to naturally tap into the “*peak neurochemistry*” the person once experienced, without the drug.

**Long-term adaptations:** Regularly engaging in music listening as part of this practice could

have several lasting benefits. First, it **trains the brain’s reward system to respond to non-drug stimuli**. Each session ends up as a rewarding experience, which could increase the sensitivity of the reward circuit to natural joys (music, exercise, etc.) and decrease reliance on chemical highs. Neuroplastic changes might include strengthening synaptic connections in pathways that associate music and mood elevation. Over time, individuals might find that simply putting on their playlist can lift their mood or reduce anxiety, as the practice has conditioned a reliable response. Second, music is known to enhance neuroplasticity and cognitive function; learning new songs or rhythms can literally grow new connections. A 2023 review highlighted that musical training or engagement can sustain brain volume and improve domains like memory and executive function in the long run [17]. While passive listening is not the same as musical training, the immersive emotional engagement in our protocol is an active mental process that could similarly stimulate the brain.

There is also a social and existential dimension: connecting deeply with music can give a sense of **meaning, social connection (even if just remembering social times), and reduced loneliness**. These factors profoundly affect long-term mental health by buffering against stress and depression. Serotonin systems adapt slowly, but a routine that regularly produces a serotonin-rich state (via positive emotion and possibly direct serotonin release) might gradually recalibrate receptors or even gene expression related to 5-HT<sub>1A</sub>. One could speculate this might resemble the effect of repeated meditation or gratitude practice, both known to increase feelings of well-being over months (and those are partially serotonergic).

In summary, the music component capitalizes on **reward and emotional memory circuits**, primarily boosting dopamine (for pleasure/motivation) and serotonin (for emotional warmth and contentment). It transforms the physiological arousal from the cold into a deeply positive psychological experience. Mechanistically, it brings online the **affective network** of the brain - tying together auditory sensory input with limbic system (emotion) and prefrontal reflection (cognitive appreciation of the experience). As part of the synergy, music is the phase that **cements the positive reinforcement**, ensuring that the overall protocol is not just a stress ordeal but is truly enjoyable and something the participant *wants* to repeat.

### 3.3 Breathwork and Vagus Nerve Stimulation: Modulating Arousal and Enhancing Presence

**Physiological response:** The **3-4-7-4 breathing pattern** (inhale for 3, hold 4, exhale 7, hold 4) is a form of slow, deep breathing that strongly engages the **parasympathetic nervous system** through vagus nerve activation. The vagus nerve (cranial nerve X) innervates the heart, lungs, and digestive tract, and when activated it releases the neurotransmitter acetylcholine onto the heart’s pacemaker cells to **slow heart rate** and onto other organs to promote a relaxation response [19]. During the long exhale in this breathing pattern, the pressure inside the chest gently rises and stimulates baroreceptors (pressure sensors) in the arteries, which in turn signal the brain to increase vagal output. This results in an immediate drop in heart rate known as respiratory sinus

arrhythmia - essentially, every slow exhale is like a vagal nerve workout. The breath-hold after exhale further prolongs the parasympathetic surge (and also causes a mild buildup of CO<sub>2</sub>, which can enhance calm if not too excessive).

**Vagal tone and HRV:** A key indicator of parasympathetic activation is **heart rate variability (HRV)** - the beat-to-beat variation in heart rate. High vagal activity produces more variability (especially in the high-frequency band tied to respiration). Studies have shown that slow breathing ( 6 breaths per minute or fewer, which is where 3-4-7-4 falls) significantly **increases HRV and indices of vagal tone** both during the breathing and even immediately after [20]. In fact, a systematic review found that voluntary slow breathing reliably increases vagally-mediated HRV measures, reflecting activation of the parasympathetic nervous system [20]. This physiologic shift corresponds to a state of relaxation and reduced stress. By incorporating this breathing immediately after the cold and during the music, the protocol ensures that the sympathetic arousal does not remain unchecked; it is actively counter-balanced by parasympathetic drive.

**Afferent vagus and brain effects:** The vagus nerve also carries sensory (afferent) information from the gut, heart, and lungs back to the brain. Deep breathing and diaphragmatic movement stimulate these afferent fibers (for example, stretch receptors in the lungs during inhale, pressure receptors during exhale). This sensory input goes to the **brainstem (nucleus tractus solitarius)** and then influences higher brain regions including the **limbic system** and **prefrontal cortex**. One outcome is activation of the **insula**, a region that integrates interoceptive signals (how your body feels inside) and is involved in conscious awareness of bodily states. As noted in meditation studies, experienced practitioners show increased insula activity and attention to breath which correlates with diminished prediction error signals in reward regions [21]. In our context, focusing on breathing likely heightens insula activity (notably, the posterior insula) which has been linked to dampening excessive reward craving signals and anchoring attention to the present body state [21]. In other words, **breath awareness grounds the mind in the here-and-now**.

**Acute psychological effects:** The immediate subjective effect of the 3-4-7-4 breathing is often described as a **wave of calm** or a “relaxation response”. As the participant lengthens their exhale, they may feel tension leaving the body, heart rate slowing, and a sense of **safety or relief**. This is the polar opposite of the fight-or-flight state - sometimes called “rest-and-digest”. Participants might notice their mind quieting; racing thoughts are replaced by a serene, focused awareness on the breath. The breathing pattern also requires a degree of concentration (counting seconds, feeling the timing), which occupies the mind and prevents rumination. This is very much in line with mindfulness practices that use breath as an anchor. By the end of a few minutes of such breathing, the **body’s chemistry has shifted**: adrenaline levels fall, norepinephrine falls (from the earlier peak), and the vagal influence causes the adrenal glands to reduce cortisol output. If measured, one might see increases in alpha brain wave activity (associated with relaxed alertness) and decreases in sympathetic nerve activity.

**Vagus nerve and neurotransmitters:** While the vagus primarily uses acetylcholine as its

neurotransmitter peripherally, its activation has secondary effects on other neurotransmitter systems. For instance, stimulating the vagus nerve (as done in medical vagus nerve stimulation therapy) can trigger the release of **serotonin and norepinephrine in the brain** by influencing the raphe nuclei and locus coeruleus, respectively, albeit in a modulatory way (this is one mechanism by which vagus nerve stimulation treats depression). Slow breathing isn't as direct as electrical stimulation, but by engaging vagal pathways, it might contribute to a gentle elevation of mood-related neurotransmitters and endocannabinoids. Moreover, the **cholinergic** effect (from acetylcholine) in the brain is linked to improved attention and memory encoding; a calm focus can facilitate better integration of the experience.

**Presence-driven prediction accuracy:** The breathing component is crucial for the concept of “**presence-driven prediction accuracy**” mentioned in the prompt. In terms of predictive processing, when one is fully concentrated on breathing and bodily sensations, the brain's internal model is tightly coupled to immediate input (the rise and fall of the belly, the sound of air flow, the heartbeat). This leaves little room for the mind to wander into predictions about the future or analyses of the past. As a result, the **discrepancy between expected input and actual input is minimized** - essentially, you expect the next breath and you feel the next breath, in synchrony [22]. A commentary on predictive coding in contemplative practice describes that during meditation, the weight of actual sensory signals increases relative to predictive signals, thereby **reducing prediction error** [22]. In such a state, the brain is not surprised by anything (since attention is fully on a predictable cycle of breathing), and this lack of surprise or error is inherently a state of neural “contentment”. Some theorists suggest that minimizing prediction error is rewarded by the brain (as it indicates successful modeling of the environment) [22]. Thus, being present could create a subtle **reward feedback loop**: the brain experiences a small reward for each correctly anticipated and observed breath, reinforcing the focus and presence further. This loop is *recursive* in that the more present you are, the more your brain's predictions match reality, the more your brain relaxes and feels satisfied, which encourages even more sustained presence. Participants may not consciously realize this is happening, but they might report a feeling of “flow” or effortlessness in maintaining their focus after a while, which is the subjective correlate of this loop.

**Acute synergy with cold and music:** Within the protocol, the breathing is interwoven with the other elements. Right after the cold, it helps **titrate down the arousal** so that the participant transitions from an adrenaline-fueled state to a **calm-yet-alert state**. This prevents the cold exposure from causing anxiety or discomfort that could overshadow the positive effects. Essentially, it **alchemizes stress into relaxation**, leveraging the biochemical cocktail in a controlled way. During the music listening, continuing slow diaphragmatic breaths can actually enhance the music's impact. How? By staying calm, the participant avoids getting distracted or overwhelmed, and can fully **attend to the music's nuances**, perhaps noticing new details in the sound [13]. The vagal activation also keeps the heart rate in a comfortable range even if the music is emotionally exciting.

This may prolong the dopamine release by preventing a premature return of stress. Additionally, breathing through emotional surges in the music can deepen one's emotional processing (e.g., breathing through tears of joy, which is a common technique in therapeutic settings to safely experience emotions).

**Long-term adaptations:** Practicing slow breathing regularly can lead to measurable improvements in baseline autonomic function. People who do breathwork or meditation often have **higher resting HRV** and a more robust vagal brake on their heart (meaning their heart rate can adapt quickly to stress and calm down quickly after). Over weeks or months, one might see reductions in baseline blood pressure if it was high, improved sleep (due to a calmer nervous system), and reduced symptoms of anxiety. There's evidence that **diaphragmatic breathing training lowers cortisol** and improves self-reported stress and anxiety levels in as short as a month of practice [23]. On the neural level, consistent breath-focused meditation is associated with increased thickness in brain regions that regulate attention and emotion, like the prefrontal cortex and anterior cingulate. This suggests improved top-down control of emotion and attention - essentially, one becomes more able to enter the present-focused, prediction-error-minimized state even outside of practice.

In terms of neurochemistry, a long-term increase in parasympathetic tone can tilt the balance away from chronic low-grade adrenaline/norepinephrine levels (often present in individuals with stress or PTSD) and allow replenishment of neurotransmitters. There's also the angle of **immune and inflammatory modulation**: vagus activity via the cholinergic anti-inflammatory pathway can reduce inflammation in the body, and chronic inflammation is linked to depression. Thus, sustained practice could improve mood partly by lowering pro-inflammatory cytokines (some depression is thought to be inflammation-driven).

Furthermore, breathing practice induces the may influence the mysterious **endogenous DMT** system indirectly. Although speculative, some forms of intense breathwork (like holotropic breathing) have been reported to induce visions or psychedelic-like effects [24, 25], which has led to conjecture that maybe **endogenous DMT is released** when the brain is in certain extreme states of oxygen/CO2 or rhythmic stimulation. Our breathing pattern is gentler and not aimed at hyperventilating to the point of hallucination. However, by creating a deeply relaxed yet aware state, we might be approximating some features of meditation where practitioners sometimes report subtle "light" or transient imagery. It's not established that slow breathing increases DMT, but if it did even a little, DMT could act as a neuromodulator at trace levels to enhance mood or cognitive flexibility (more on DMT below).

In summary, the breathwork component serves as the **regulator and integrator** of the protocol. It ensures that the participant remains in an optimal arousal zone - not too anxious, not too lethargic - to fully benefit from the dopamine and serotonin being released by cold and music. It brings the **mindful presence** into the experience, which is crucial for internalizing the positive effects (so they are consciously felt and encoded to memory). Mechanistically, breathwork increases parasympathetic (vagal) output and likely reduces the adverse effects of stress hormones, while

contributing to a state of clarity and enhanced mind-body connection. Over time, this translates into improved autonomic balance and possibly structural brain changes that support emotional well-being.

### 3.4 Role of Endogenous DMT A Hypothetical Peak Experience Modulator

One unique element included in our exploration is **endogenous DMT (N,N-dimethyltryptamine)** - sometimes dubbed the brain's own psychedelic. DMT is a powerful hallucinogenic compound found in certain plants (and used in ayahuasca) but it is also produced in small quantities in mammalian bodies, including humans. For a long time, the function of endogenous DMT was unknown and it was even doubted whether the brain made enough to have any effect. However, recent studies have confirmed that the **enzyme INMT needed to make DMT is present in the human brain (in areas like the cortex and pineal gland)** and that neurons can synthesize DMT in live rats [26]. Microdialysis experiments in rats detected baseline DMT in the visual cortex at about 1 nM concentration, which is on the order of other monoamine neurotransmitters like serotonin [26]. Interestingly, when those rats were subjected to induced **cardiac arrest (a model of clinical death)**, cortical DMT levels spiked significantly, independent of the pineal gland [26]. This finding supports the hypothesis that the brain might release DMT in extreme conditions, such as near-death experiences, possibly contributing to the vivid experiences reported in those states.

**In our protocol, we are not inducing anything as extreme as cardiac arrest!** However, we are intentionally pushing the body-mind to a kind of **edge of intense experience** (cold shock followed by deep relaxation and emotional elevation). One could ask: might there be a small participation of the DMT system in such a peak experience? While direct evidence is lacking, it's worth speculating based on what we know of DMT's effects and release triggers:

- DMT is structurally similar to serotonin (it even binds to many of the same receptors, especially 5-HT<sub>2A</sub>) and is known to cause altered perception, feelings of unity, and euphoria at psychedelic doses [26]. At trace physiological levels, it might act as a **subtle neuromodulator** that influences mood or sensory processing. Some researchers have proposed it could play a role in dreams or mystical states.
- DMT has notable **"plasticity-promoting" effects** when given exogenously. It has been shown to boost the growth of neuronal dendrites and promote neurogenesis in certain contexts [26]. This is an effect it shares with other psychedelics; it suggests that if the brain releases even small amounts of DMT during extraordinary experiences, it could serve as a signal to kick-start neural plasticity and growth processes.

In the context of our protocol, if a participant achieves a profound state of *awe or transcendence* - say they feel a moment of ego-dissolution while listening to a powerful piece of music in this hyper-primed state - it's conceivable that a slight increase in **endogenous DMT** could be involved. Perhaps the intense sensory contrast (cold vs warmth, silence vs music, fear vs joy) coupled with deep meditation-like breathing provides a trigger for a tiny DMT release as the brain shifts states. This is admittedly hypothetical, but it offers a tantalizing explanation for why sometimes natural

practices can yield experiences people describe as spiritual or psychedelic.

Even without actual increased release, the existing baseline DMT in the brain might exert more influence when other neurotransmitter systems are aligned a certain way. For instance, during meditation or under influence of rhythmic stimuli, if the serotonin system is engaged (as it is with music and recall of MDMA feelings), the **5-HT<sub>2A</sub> receptors** are more active/excitable, which are also the receptors DMT primarily activates [26]. Endogenous DMT might piggyback on this state to slightly amplify the sense of **novelty, depth or meaning** of the experience.

What would be the functional role? Perhaps to mark the experience as salient and facilitate learning. If indeed a bit of DMT is released (or its effect heightened) at the culmination of our protocol, it could act to **open a “window” of neuroplasticity** - similar to how a psychedelic therapy session is thought to open the brain to rewiring. This might help the brain form new positive associations (e.g., “I can achieve euphoria naturally” or “Cold is not threatening but invigorating”) and weaken old negative patterns (like fear of discomfort or dependence on substances). Supporting this notion, DMT administered to rodents has shown **antidepressant effects and increased expression of plasticity-related genes** [26]. So, an endogenous drip of DMT could potentially contribute to an antidepressant, plasticity-enhancing milieu in the brain after such a session.

It’s important to state that **current science cannot definitively link breathing exercises or music to quantifiable DMT release** - this remains a theoretical piece of the puzzle. But future research might measure DMT in microdialysis during meditation or intense breathwork to explore this. For now, we include endogenous DMT as a reminder that the body has *its own pharmacy* capable of synthesizing even psychedelic compounds, and these may be part of the extreme end of the natural range of experiences. At minimum, the notion of endogenous DMT underscores how **rich and altered a state of consciousness can become from purely physiological triggers** - in some reports, people after cold exposure and music have described feeling “high” or seeing the world with fresh eyes, which parallels the after-effects of a psychedelic experience (clarity, appreciation of life, renewed mood). DMT might be one of the contributors to that peak.

### 3.5 Summary of neuromodulators roles

To tie everything together, let’s briefly recap what each key neuromodulator is contributing in this stacked protocol:

- **Dopamine:** Elevated strongly by cold, and further kept up by music. Dopamine provides the *reward*, pleasure, and drive. Acutely, it makes the experience feel rewarding and energizing. Long-term, repeated dopamine activation in this controlled way can reinforce the habit (so you feel motivated to do it again) and may enhance reward learning (finding joy in healthy stimuli). Dopamine also promotes focus and engagement (one reason music feels absorbing).
- **Norepinephrine (NE):** Skyrockets during cold, then normalizes as breathing kicks in. NE contributes to alertness, enhancing perception of the music and bodily sensations. It’s like

turning up the brightness on your awareness. If too high it causes anxiety, which is why the breathing is needed to moderate it. Over time, the controlled NE surges could improve the brain's capacity to focus (like a form of attention training) and perhaps strengthen stress resilience circuits.

- **Adrenaline (epinephrine):** Provides the initial “get-up-and-go” during cold (and possibly during any initial shock of music-induced emotion). It raises heart rate and blood flow, essentially pumping the system. While mostly peripheral, adrenaline crossing into the brain (or high NE which has similar effect) can sharpen memory encoding - so the emotional peaks of the session might be well remembered because of this adrenergic activation. Long-term, learning to quickly toggle out of an adrenaline state via breath might improve emotional regulation.
- **Serotonin (5-HT):** Brought into play by the emotional and social content of the music and memory. Serotonin adds the dimension of **contentment, emotional resonance, and social connection**. In the short term, this leads to feelings of peace, empathy, and even spiritual significance. Long-term, repeatedly invoking serotonin in positive contexts can help **gradually elevate mood baseline** (similar to how regular positive experiences or SSRIs can slowly build up mood) and reinforce neural networks for positivity and social reward.
- **Endogenous Opioids (endorphins):** From cold and possibly from musical pleasure, these provide pain relief, stress relief, and *physical* pleasure (a warm glow in the body). Acutely, endorphins help make the unpleasant aspects of cold tolerable and transform them into pleasure. They likely contribute to the relaxed, blissful sensation during the music as well. With repetition, endorphin release can lead to increased pain tolerance and might reduce inflammation. Psychologically, knowing that one's body can produce these good feelings can lessen reliance on external substances for comfort.
- **Oxytocin:** Though not explicitly listed in the prompt, oxytocin may be released due to the positive emotional recall and perhaps the relief after cold. Oxytocin would enhance feelings of trust, bonding (even if it's bonding with oneself or the memory of friends), and reduce fear. This can make the session feel **heart-opening** and safe. Over time, if the protocol is done in group settings or with a partner (imagine couples doing contrast showers then meditating with music), oxytocin could strengthen social bonds and communal aspects of healing.
- **Acetylcholine (ACh):** Released by the vagus nerve onto the heart and also from certain brainstem nuclei when one is calm and focused. ACh supports attention and learning - it's what allows you to sink into the music with full concentration. It also counters the sympathetic effects on organs. Long-term, higher cholinergic tone is associated with better memory (since ACh is crucial for memory circuits).



- **Endocannabinoids:** Another endogenous system not explicitly mentioned, but worth a nod - deep breathing, exercise, and music can all stimulate the production of **endocannabinoids** (like anandamide), which cause a mild sense of bliss and pain relief. They often work in tandem with endorphins. If present, they contribute to the “afterglow” feeling of relaxation and well-being. Regular activation of endocannabinoid pathways (naturally) might improve stress recovery and mood stability.
- **DMT:** Potentially a tiny player in extreme moments, hypothetically contributing to **altered perception and neuroplastic kick**. If engaged, it could make the experience feel profound or insightful, adding a touch of the mystical or novel. Long-term, if any DMT-related plasticity is triggered, it could aid in breaking old mental patterns and fostering new perspectives.

Each of these molecules has unique effects, but they **interact in complex ways**. For instance, dopamine and serotonin traditionally have some opposing effects (dopamine = desire, serotonin = satisfaction), but in a balanced high (like after exercise or during music) they can complement each other - dopamine drives engagement while serotonin brings contentment, yielding a state of *enthusiastic peace*. The protocol’s genius is in engaging multiple systems so that one doesn’t dominate to an extreme. The result is a **whole-brain orchestration**: the brainstem, limbic system, and cortex all participate in creating a rich, multidimensional experience of well-being.

## 4 Discussion

The combined protocol we’ve outlined is more than the sum of its parts. By **stacking dopaminergic, serotonergic, and vagal stimuli**, we create a complex neurophysiological state that would be hard to achieve by any single method alone. In this Discussion, we interpret how these mechanisms interact dynamically and consider the implications for affect, motivation, and neuroplasticity. We also explore the idea of a **recursive reward feedback loop** driven by presence and predictive processing, and how that might reinforce continued practice. Finally, we place this approach in the context of experimental mental health interventions and potential research directions.

### 4.1 Synergy and Interaction of Mechanisms

One of the striking aspects of this protocol is how each component **primes the next**. The initial cold exposure is like lighting a fire: it mobilizes the body’s resources, floods the brain with catecholamines, and essentially **creates the biochemical conditions for euphoria** (dopamine + endorphins) but in a raw form that on its own might be unpleasant for some. The subsequent breathing is like tempering that fire: it harnesses the arousal, preventing it from overshooting into anxiety, and channels it into a focused calm. Then the music pours that controlled energy into an emotionally meaningful framework, **catalyzing a powerful positive experience**. By the end, the practitioner has gone through a full cycle - from stress to release to reward to calm - touching many neurochemical points along the way.

An important concept here is “**neural layering**”. Each intervention targets different neural circuits that nevertheless overlap and communicate. For example, cold exposure activates the locus coeruleus (NE) and ventral tegmental area (DA), while breathing engages the nucleus ambiguus (vagal output) and NTS (sensory input), and music engages the nucleus accumbens (DA/5-HT) and auditory cortex. These regions are interconnected: the locus coeruleus’s norepinephrine can modulate auditory cortex responsiveness (making music sound more vivid when you’re alert), the vagus through NTS can inhibit locus coeruleus firing (helping calm down after the cold), and dopamine from the VTA enhances plasticity in the cortex (making the musical experience more ingrained). Thus, there is a **beautiful reciprocity** where each system’s output becomes another system’s input.

One could visualize it as a **symphony orchestra**: Cold provides the brass and percussion (intense, bright, loud signals of dopamine and NE), breathwork brings in the strings (smooth, regulatory tones of vagal activity), and music is the woodwinds and vocals (melodic serotonin and emotional harmonies). When timed correctly, these sections produce a coherent “music” that is the experience of flow, joy, and presence. If any one section dominated or was out of time, the music would sound off (e.g., too much brass = anxiety, too much strings = drowsiness, too much melody without rhythm = sentiment without energy). The protocol ensures **balance**.

From a neurochemical perspective, the synergy also lies in **preventing negative feedback loops** that would normally limit the effect of any single intervention. For instance, one reason a single cold exposure might not alone sustain mood improvement is that the body might respond to the stress by later reducing sensitivity (homeostasis) or the person might feel exhausted. But adding music (which is inherently rewarding) immediately reframes the cold’s aftereffects as pleasurable rather than depleting. Similarly, music alone can sometimes make one wistful or sad when it ends (especially if it brings up nostalgia). But here, the afterglow of cold (which includes Endorphins and a sense of accomplishment) likely prevents any post-music melancholy - instead, the music ends and one feels physically invigorated and mentally peaceful due to the prior steps. Breathing acts as a **stabilizer** throughout: it’s hard to feel overwhelmed by emotion or sensation if you keep a steady breath; conversely, it’s hard to feel numb or apathetic if you are intentionally breathing deeply (since that tends to stir some feeling).

- Cold’s “downside” of stress is mitigated by breathing’s stress relief.
- Cold’s “upside” of dopamine is amplified by music providing something rewarding to focus that dopamine on.
- Music’s “downside” of emotional vulnerability is mitigated by the comfort from endorphins and the groundedness of breath.
- Music’s “upside” of joy is amplified by cold’s prior dopamine and by the mindful awareness from breath, which together allow deeper immersion in the joy.

- Breathing’s potential “downside” of boredom (for some) is obliterated by doing it in the context of dynamic stimuli (cold and music), keeping it engaging.
- Breathing’s “upside” of calm is amplified by the relief felt after cold and by the contentment of music, making the calm state one that is positive and not empty.

This synergistic interplay likely produces a state that can be described as **“high arousal positive affect with inner calm”** - a somewhat rare combination. People often think of calm as low arousal (contentment) and high arousal as potentially anxiety or excitement. Here we get a blend: high physiological arousal (as evidenced by neurotransmitters) but subjectively calm and in control. This is a state reported by elite athletes or meditators in flow states - they are intensely engaged (high dopamine/NE) but also have a sense of effortlessness and peace (high vagal/serotonin). Such a state is extremely conducive to peak performance, learning, and emotional healing because the person is **fully present and positively energized** without the distraction of stress or the dullness of relaxation.

## 4.2 Recursive Reward Feedback Loop and Predictive Processing

A key question is: what makes someone stick to this protocol or any beneficial routine? The hope is that the **intrinsic rewards** of the practice are reinforcing enough that a feedback loop is established. We propose that a **“recursive reward feedback loop”** is indeed formed, heavily reliant on the element of **presence** achieved through the practice.

When fully engaged in the cold-water challenge, then the guided breathing, then the music, the participant is repeatedly practicing being present. In each of those stages, being present (as opposed to mentally checking out or resisting) tends to yield a better experience: - In the cold, if you stay mentally present and accept the sensations, you pass through the discomfort quicker and then feel the euphoria, whereas if you panic or dissociate, the cold feels worse. - In the breathing, presence is almost given (you are literally focusing on the present breath). If your mind wanders, you lose count - immediate incentive to stay present. - In the music, being present lets you hear every note and lyric with fresh appreciation; if you start thinking about unrelated things, you miss the best parts of the song.

Thus, presence is continuously rewarded by the environment of the protocol itself. This is a **learning signal for the brain**: it learns “when I pay attention here-and-now, I feel good.” Neuroscientifically, this could be explained by **predictive coding and reward prediction error** theories. When you accurately anticipate or align with what is happening (e.g., “the water will feel like needles - now it does, but I’m okay”; “the next note will resolve this tension in the song - yes, it resolved beautifully”), your brain registers a sort of competence or reduced error. Some fMRI studies in experienced meditators show reduced reward prediction error signals, meaning they are not oscillating between expectation and surprise in the usual way, but rather maintaining a steady

equilibrium [21]. That equanimity could itself trigger dopaminergic neurons in a tonic way - a small steady drip of dopamine for being *right* about the present moment continuously.

To frame it simply: **Presence = low prediction error; low error = brain satisfied; satisfaction = reward**. That reward (likely mediated by dopamine and opioids) then positively reinforces the state of presence, making the person want to continue focusing or return to the practice next time. It's a self-reinforcing loop. Over repeated sessions, this might generalize: the individual finds it easier to be present in daily life because their brain now associates presence with reward, not boredom or pain.

This loop is *recursive* in that each moment of presence begets a tiny reward which encourages the next moment of presence, and so on, possibly snowballing into what people describe as *blissful states* or *flow*. During the music, this could manifest as a feeling that time has slowed or even that one is “one with the music,” a sign of immersive presence. And at the end, reflecting on the experience, the person often feels gratitude or accomplishment - emotions that will predictively encourage them to do it again (closing the loop when next session arrives, the memory of reward motivates starting the cold again despite its difficulty).

From a behavioral standpoint, it is crucial that the practice is rewarding *intrinsically*. Many health behaviors fail because the reward is extrinsic or delayed (you exercise now for a weight loss goal months later). Here, the reward is immediate (a rush, a high, a deep peace right after). That is a strong positive reinforcement. Additionally, because multiple systems are engaged, even if one day the cold isn't as intense or the music choice wasn't perfect, other aspects (like the relaxation) can still make it rewarding - a redundancy of reward sources. It's like having multiple circuits of reinforcement: physiological (endorphin/dopamine), emotional (serotonin/oxytocin), cognitive (mastery/presence). The likelihood that *none* of those fire is low, which makes the routine reliably rewarding.

### 4.3 Implications for Affect, Motivation, and Neuroplasticity

**Affect (mood and emotions):** This protocol can be viewed as a form of **controlled affective therapy**. By design, it swings the participant through a range of affective states - initial discomfort, surprise, relief, joy, tranquility - in a short time. This may have a effect akin to “**emotional stretching**”: like interval training for emotions, it expands one's capacity to feel and regulate different intensities. This can be very useful for people with blunted affect (like in depression) because it forces a bit of emotional activation (the cold will make you feel something, guaranteed!) and then attaches positive feelings to it (so you end on a good note). For people with anxiety, it teaches that one can go into a deliberately stressful situation and come out not just okay, but better than before - a direct disconfirmation of anxious predictions, which is powerful for therapeutic learning (exposure therapy principles). The rapid alternation between sympathetic and parasympathetic might also help “reset” an over-tense system.

Long-term mood improvement could come from several angles:

- Biologically, repeated elevation of monoamines (like dopamine, serotonin) can lead to downstream changes like increased receptors or sensitivity. For instance, exercise (which also boosts these monoamines) is known to increase serotonin receptor expression and BDNF levels over time, contributing to antidepressant effects. Our stack might similarly induce those beneficial adaptations.
- Psychologically, the practice empowers individuals. There’s a growing field around **behavioral activation** for depression - basically doing positive activities to lift mood. This protocol is a supercharged behavioral activation with clear steps. Successfully doing it regularly likely boosts self-esteem and a sense of agency (“I can actively improve my mood and state, I’m not a passive victim to feelings”). That improved self-efficacy is a buffer against helplessness, a key component of depression.
- Affect regulation skills improve: Through breath focus, one learns how to **self-soothe** and maintain equanimity even when the body is in extremes. This can translate to daily stressors - e.g., using breathing to calm down when upset, or using a brief cold splash on the face to interrupt a panic attack (a known trick).
- Perhaps the combination even rekindles a natural **sense of pleasure** in life’s simple stimuli. Anecdotally, those who do cold immersion often report feeling *more alive* and appreciative of warmth, a hot drink after, etc. Combined with music, it could make listening to music in general more rewarding as one’s brain becomes tuned to get a serotonin/dopamine hit from it sans substances.

**Motivation:** Dopamine is often called the motivation molecule. By repeatedly boosting dopamine in a context of healthy behavior, this protocol might rewire motivation circuits to seek these kinds of stimuli rather than less healthy ones. For example, someone recovering from substance use might find that this routine scratches the itch for novelty and intensity (via cold) and bliss (via music) and thus reduces cravings. In general, engaging the **mesolimbic pathway** with natural rewards can reduce anhedonia (the inability to feel pleasure) and increase one’s motivation to engage with life. There’s an aspect of **goal-directed behavior** here too: one has to overcome the hurdle (“Do I really want to step into that cold shower?”). Each time one does, and is rewarded, it reinforces that *effort leads to reward*. This is opposite to the vicious cycle in depression where effort feels pointless due to lack of reward. So we are essentially **rebuilding the motivational circuitry** by guaranteeing that effort (the discomfort) will be followed by a reward (the post-cold high and musical joy). Over time, this could generalize to other efforts - e.g., one might feel more drive to tackle difficult tasks at work, trusting that pushing through discomfort yields satisfying results.

Furthermore, the **predictive brain aspect**: if each session confirms the prediction “This is worth it,” the brain’s confidence in that prediction increases. Eventually it becomes a habit: the

body might start *craving* the cold plunge and music because it predicts the great feeling that comes after. That craving is dopamine-driven and is now working for positive behavior. We often hear about negative feedback loops in mental health; this is a design for a **positive feedback loop**: motivation → action → reward → more motivation.

**Neuroplasticity:** Perhaps one of the most exciting prospects of this stacked approach is its potential to **accelerate neuroplastic changes**. Neuroplasticity refers to the brain’s ability to form new connections and reorganize itself, which underlies learning and recovery from mental illness or trauma. Each element of the protocol has some evidence of promoting plasticity:

- Cold exposure (as a hormetic stress) can induce **cold-shock proteins** like RBM3 in the brain, which are implicated in synapse preservation and neurogenesis (studies in hibernating animals and in cooling therapies suggest this).
- Dopamine is crucial for plasticity: it flags important experiences so that the brain rewires to remember them. The strong dopamine present means the brain is in a **“learn this” mode** during the session. What is it learning? Possibly, new emotional associations (like re-associating sensations of cold with pleasure, or associating being present with reward).
- Serotonin, especially via 5-HT<sub>2A</sub> receptor (which as noted can be engaged during meaningful music, and possibly slight DMT action), promotes cortical plasticity. Psychedelic research shows transient increase in dendritic spines and synaptic density after serotonergic psychedelic exposure [26]. Our protocol is like a mini-psychedelic experience repeatedly, which could cumulatively induce beneficial neural remodeling - albeit likely more subtly.
- Deep breathing and meditative practice increase **functional connectivity** in brain networks associated with attention and reduce connectivity in the default mode network (the self-referential “wandering mind” network). This is a form of neuroplastic change (shifting network dynamics) that correlates with improved mental health (e.g., less rumination).
- Endogenous BDNF both acute stress (in moderate dose) and aerobic exercise raise BDNF, a growth factor that facilitates synaptic plasticity and neurogenesis. A short cold shock might do the same; plus the euphoric aftermath and exercise-like element (shivering can count as exercise in a way) might also raise BDNF. Music engagement can also raise BDNF as seen in some studies of music therapy and exercise combined. Therefore, each session could spike BDNF, which then helps consolidate new learning and mood benefits.
- The repetition of crossing from high stress to safety and pleasure could rewire the **amygdala** and **hippocampus**. Someone who maybe had trauma associated with sudden shocks might relearn that a sudden shock (cold) can be controlled and lead to positive outcomes, potentially **rewriting fear associations**. The hippocampus, which encodes context, might become more tuned to contexts of empowerment rather than helplessness.

- If any endogenous DMT release is happening (as we speculated), even tiny amounts could engage the **Sigma-1 receptor** (which DMT activates and is involved in cell resilience and neuroplastic regulation) [27]. Sigma-1 has been implicated in neuroprotective mechanisms. This is highly theoretical in our case but an interesting angle.

All combined, the protocol is likely to make the brain more plastic during and after each session. If we imagine therapy or learning integrated with this - say someone listens to positive affirmations or does psychotherapy right after when they are open and blissful - it might sink in deeper because the brain is primed to rewire. One could see a future research study where this protocol is used adjunctively with mental health therapy to facilitate faster improvement, akin to how MDMA-assisted therapy works by creating a biochemical state conducive to emotional breakthroughs.

#### 4.4 Considerations and Future Directions

It is important to acknowledge that while the neurochemical rationale is strong, empirical testing is needed. Controlled studies could measure mood and cognitive changes in participants who follow this protocol vs control groups (or vs groups doing individual components only). Biomarkers like cortisol, BDNF, inflammatory cytokines, and gene expression changes could be tracked over time to see if the combination has unique effects. Neuroimaging studies (fMRI, PET scans) during the protocol would be fascinating - for instance, PET imaging of dopamine receptors could confirm the large dopamine release; fMRI could show the sequence of brain activations (first insula and brainstem, then as music plays, nucleus accumbens and auditory cortex light up, while PFC shows mindful control).

An interesting future direction is to see if **subjective reports of “peak experiences”** correlate with any physiological measure like heart rate patterns or brainwaves. The mention of DMT begs the question: could we measure endogenous DMT in humans non-invasively? Perhaps not yet, but maybe CSF samples pre- and post- an intensive program might hint at changes (in animals it's easier to check). Alternatively, we might use EEG to see if any brainwave signatures resemble those seen in psychedelic states.

From a practical standpoint, customizing the protocol for individuals would be key. Not everyone can do intense cold - gradual adaptation, or using milder cold for longer, might be needed for sensitive individuals. Music preference is highly personal; the right music is crucial for the serotonin emotional part. Breathwork techniques could also vary (some might prefer a classic 4-7-8 or simply slow 6-count breathing, which is fine - the principle of slow diaphragmatic breathing is what matters, not the exact counts).

Safety-wise, each component has some cautions (e.g., cold water can trigger rare arrhythmias in vulnerable people, hyperventilation breathing can cause dizziness if done incorrectly, music at loud volumes can harm hearing, etc.), but when done responsibly these risks are low. It's worth researching if there are any contraindicated combinations (for example, someone on certain medications might need to be careful with extreme cold or breath holds).

One could also explore the **additive vs synergistic** nature more formally: is the effect of doing all three in one session greater than doing each separately on different days? Our hypothesis says yes, due to acute interactions. A trial could have four arms: (A) Cold only, (B) Music only, (C) Breathing only, (D) All combined, to compare outcomes. We'd expect  $D \geq A+B+C$  if synergy is real (supra-additive effects). Also, measuring which neurotransmitters are actually elevated in participants (maybe via blood draws for peripheral indicators like plasma NE, or microdialysis in animal models performing similar tasks) would validate our mechanistic understanding.

#### 4.5 Applications in Experimental Mental Health

This integrative protocol aligns with the emerging trend of “**psychophysiological self-care**” - techniques that harness the body to heal the mind. It could be positioned as a complementary therapy for conditions such as depression, anxiety, PTSD, and substance abuse, or simply as a mental wellness practice for the general population. Some specific scenarios:

- - **Depression:** The protocol's dopamine boost can counter anhedonia; the forced activation and quick reward can break the cycle of apathy. Cold showers have been proposed as a treatment for depression due to catecholamine increases [28], and here we enhance that with psychological components. Also, the structure and effort involved can give a depressed person a routine and sense of purpose each day.
- - **Anxiety and PTSD:** Exposure to cold is a form of stress inoculation. When paired with the immediate calm of breathing, it trains the nervous system that stress can be turned off at will. Over time, this could reduce baseline anxiety (as the person's locus coeruleus becomes less hypervigilant due to regular NE surges in safe context). The positive emotional flooding from music might help overwrite traumatic emotional memories - not unlike how MDMA therapy allows people with PTSD to revisit trauma with a sense of safety and positive emotion. While we're not explicitly revisiting trauma in our protocol, creating *new* positive emotional experiences repeatedly can build resilience and possibly indirectly ease PTSD symptoms by strengthening positive neural pathways.
- - **Substance Use / Addiction:** This protocol provides **natural highs** that can substitute for drug cravings. The role of music in MDMA users or ex-users is particularly salient - it offers a chance to feel some of that remembered euphoria without the substance. The dopamine and endorphin rush from cold can satisfy some of the physiological cravings (there's an interesting anecdotal literature on cold showers reducing drug cravings or sexual urges, due to affecting dopamine pathways). Moreover, doing hard things like cold immersion builds distress tolerance, which is crucial in addiction recovery (to tolerate withdrawal or cravings). If adopted by recovering individuals, it could become a daily “dose” of endorphins and dopamine that keeps withdrawal at bay while also reinforcing a healthy routine.



- - **Cognitive Enhancement and Productivity:** On a less clinical note, this stack might be used by healthy individuals to enhance focus, creativity, and learning. For example, someone could do a short version in the morning (cold shower + breathing) to prime their brain, then listen to music while visualizing goals. The heightened neuroplastic state could facilitate learning new information or creative thinking. There is synergy with the concept of “**habit stacking**” in productivity - here we stack not just habits but neurochemical events.
- - **Community and Group Therapy:** While described as an individual practice, one could adapt it to a group (like guided group cold immersion, then group breathing, then a shared musical experience such as group drumming or singing). That would add a social dimension that could further increase oxytocin and endorphins [29]. Group rhythmic breathing is essentially a meditation circle. Combined with music, it’s reminiscent of indigenous practices (sweat lodge or sauna then cold plunge then group song). This modern scientific framing might validate such practices and encourage their inclusion in wellness programs.

#### 4.6 Limitations

It is worth acknowledging limitations and individual differences: - Not everyone responds the same way to these stimuli. Genetic differences in neurotransmitter systems (e.g., some people naturally have lower dopamine receptor availability - they might need longer or more intense cold to feel the same reward, or conversely might feel it too intensely). - Some might find one element aversive enough to not continue (e.g., someone absolutely hates cold water). For them, gentler cold exposure or substitution (like intense exercise which also raises dopamine and endorphins) might be necessary. - The protocol demands some physical capability - though cold showers are safe for most, those with cardiovascular issues should get medical advice. - Timing and environment matter: doing this in a safe, controlled environment (at home or in a guided setting) is important. If done haphazardly (like loud music with distracting environment, or too long in cold beyond comfort leading to exhaustion), it could backfire (cause stress or injury). - We also don’t know how long the positive effects last with each session. It could be hours of improved mood, perhaps longer with cumulative practice. But if someone is severely depressed, will this lift them for only a brief time or gradually improve baseline? That requires clinical trials.

#### 4.7 Overall

The mechanisms and synergy described in this paper illustrate the **rich potential of multi-modal interventions**. By engaging the **mind-body connection** on multiple fronts, we can activate an ensemble of neurotransmitters that collectively drive a powerful positive experience and promote brain health. This approach resonates with holistic traditions (cold exposure has roots in Nordic cultures, breathwork in yoga and meditation, music in virtually every culture’s healing rituals) - here we have translated it into the language of modern neuroscience.

Our exploration shows that dopamine, norepinephrine, adrenaline, serotonin, endorphins, and even trace neuromodulators like DMT are not isolated players; they form a **network of influence on our affective and cognitive states**. A structured protocol can orchestrate this network toward a desired state: in this case, one of heightened yet serene awareness, joy, and openness to change.

Moving forward, this concept invites an **interdisciplinary collaboration**: neuroscientists can provide empirical backing and refinement, psychologists can integrate it into therapeutic practice, and individuals can self-experiment in safe ways to find what combination works best for them. It exemplifies a paradigm where instead of pharmacologically blasting one receptor (as many psychiatric medications do), we **gently coax the body to release a symphony of its own neurochemicals** in harmony.

## 5 Conclusion

In this white paper, we presented a comprehensive exploration of a **synergistic mind-body protocol** that combines cold exposure, music-induced emotional recall, and diaphragmatic breathing to activate multiple neural pathways and neuromodulatory systems. We detailed how each component influences key neurotransmitters - **dopamine, norepinephrine, adrenaline, serotonin, endogenous opioids, and potentially endogenous DMT** - and how these influences translate into acute changes in affect and motivation, as well as set the stage for long-term neuroplastic adaptations.

The protocol’s power lies in its ability to **simultaneously engage the sympathetic “fight-or-flight” response and the parasympathetic “rest-and-digest” response, and to couple both to positive reward and emotional meaning**. Cold immersion provides an initial dopaminergic and adrenergic jolt that elevates mood and alertness [8], which is then modulated by slow breathing to produce a calm focus. Into this primed state comes music, which rekindles serotonergic feelings of joy and social connection associated with past peak experiences [17, 15]. The result is a layered neurochemical state approximating a naturally induced “high” - featuring the **pleasure and drive of dopamine, the contentment of serotonin, the pain-free tranquility of endorphins, and the centered awareness from vagal activation**.

We also discussed the concept of **presence-driven prediction accuracy** - when a person is fully attuned to the present moment (facilitated by breath and intense sensory input), the brain’s predictive model aligns closely with reality, minimizing prediction errors [22]. This state, we argued, can itself trigger a reward feedback loop, whereby the brain reinforces its own accurate, mindful state, encouraging the individual to remain present and engaged. This mechanism offers a compelling insight into why practices that cultivate mindfulness and interoceptive focus (like meditation, yoga, or indeed this protocol) often lead to sustained improvements in well-being: they tap into the brain’s intrinsic reward system for aligning with the now.

From the perspective of experimental neuroscience and psychophysiology, this protocol pro-

vides a **testbed for integrative theories**. It touches on neurochemistry, autonomic physiology, emotion, cognition, and behavior. Its effects can be objectively measured (hormone levels, neuroimaging, HRV, etc.) and subjectively reported, allowing correlation between the two. It thus invites research that could deepen our understanding of how complex emotional states are constructed in the brain and how we might leverage endogenous systems to improve mental health.

For practitioners, such as therapists or coaches in mental health and wellness, the insights here underscore the value of **multimodal approaches**. A client dealing with low motivation might benefit from adding a cold-shower-and-music routine to their morning, not as a replacement for therapy or medication, but as a powerful adjunct that gives them a tangible boost and sense of control. Someone with anxiety might use the protocol in modified form to learn that they can navigate intense sensations and emotions safely. The ultimate vision is a toolkit of **non-pharmacological interventions** that can be tailored to individuals, with this protocol being one example of a “stack” that people can try.

Importantly, we maintained a focus on peer-reviewed evidence throughout this paper to back each aspect of the protocol’s rationale. We cited studies on cold exposure’s effects on catecholamines [8], music’s engagement of reward circuitry [3] and modulation of serotonin [8], breathwork’s impact on vagal tone [20], and even the emerging research on endogenous DMT [26]. While the **integration** of these findings is novel, each piece stands on a scientific foundation. This interdisciplinary synthesis demonstrates that age-old practices (cold water plunges, breathing exercises, rhythmic music) can be understood in modern neurobiological terms, and when combined, might produce profound effects that are *ripe for scientific exploration*.

In conclusion, the synergistic activation of neural pathways via this structured protocol shows promise as a means to boost mood, enhance motivation, and potentially facilitate neural plasticity in a holistic manner. It exemplifies a proactive approach to mental wellness - one that triggers the body’s own pharmacy rather than relying solely on external substances. The affective and neurochemical states achieved hint at what is possible when we intentionally engage with our biology: a state of energized calm, present and joyful, resilient and adaptive. We encourage further research and experimentation in safe settings to refine this approach, investigate its benefits and limitations, and ultimately, harness its principles to enrich mental health interventions. By bridging somatic and cognitive techniques, we move toward a more **integrative neuroscience of well-being**, one that empowers individuals to literally *take their brain chemistry into their own hands* - or cold showers, as the case may be - and emerge healthier and happier for it.

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