

Evidence of Binaural Beats in Pain Management: Take a look at what they heard

Holly Watson, PhD., ANP-BC

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Disclosures

- Holly Watson is a certified Empowered Relief® instructor. Empowered Relief® skills training includes the use of relaxation audio files that utilize binaural beats

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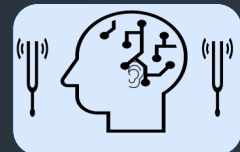
Learning objectives

1. Recognize the physiological mechanisms involved in auditory pathways of binaural beat perception
2. Identify opportunities and challenges in current binaural beat research
3. Evaluate select research on binaural beats in the context of pain

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Binaural beats discovered in 1839

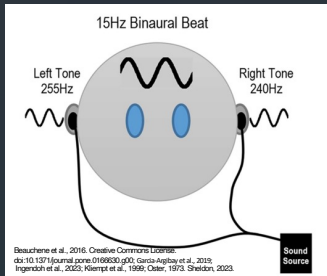
- 1839: H.W. Dove found that when two tuning forks of slightly different frequencies were held up to the same ear, beats were heard that disappeared when one tuning fork was removed
- The beats returned when one tuning fork was held to each ear simultaneously



Stewart, 1917

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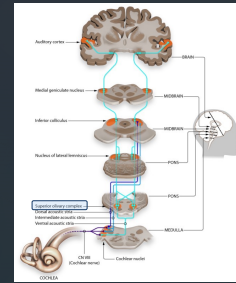
Binaural beats: the difference between simultaneous frequencies



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A psychoacoustic phenomenon

- Separate auditory input from each ear is integrated by structures within the brainstem, specifically at the location of the superior olivary nuclei within the pons
- The resulting single frequency is perceived as binaural beats
- The binaural beat frequency can be measured in the cerebral cortex via electroencephalogram (EEG)



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Mechanism of action

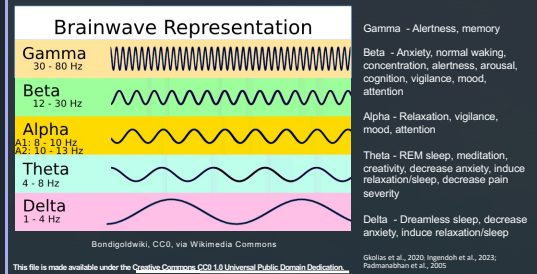
Entrainment of brain waves

- Binaural beats can induce the brain's electrocortical activity to be enhanced at the frequency of the auditory signals
- Some studies indicate that the resulting frequency can be entrained throughout the brain and facilitate specific connectivity patterns within neural networks
- The binaural beat frequency can be selected to produce EEG-associated states
- In one analysis the duration of stimulation to induce entrainment ranged from 5-15 minutes

Huang & Charyton, 2008; Ingendoh et al., 2023; Obleser & Kayser, 2019
Grosse-Peterson et al., 2020; Padmanabhan et al., 2005

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EEG frequency bands: Psychological and physiological states



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Can binaural beats enhance brainwave entrainment?

Author (year)	Purpose
Beauchene et al. (2016)	Determine the effects of binaural beats (BB) on cortical connectivity.
Perez et al. (2020)	Do gamma frequency binaural beats entrain brainwaves and facilitate a heightened attention cognitive state?
Ingendoh et al. (2023)	Do published BB studies support the brainwave entrainment hypothesis?

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Can binaural beats improve working memory?

Study	Purpose	Methodology	Population	Results	Conclusion
Beauchene et al. (2016)	Determine the effects of binaural beats (BB) on cortical connectivity and associated changes in performance of a memory task	-3 control and experimental conditions -concurrent EEG to assess entrainment	28 healthy adults - Mean age ~27 years	Enhanced EEG beta band Performance at 15Hz BB significantly more accurate (+3%) than all other conditions (dec. 1-3%)	-15Hz BB positively influenced memory accuracy

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Do binaural beats entrain brainwaves and affect attention or mood?

Study	Purpose	Methodology	Population	Results	Conclusion
Orozco Perez et al. (2020)	Characterize brain responses, relaxation and alertness in pure tone vs. binaural beat conditions	experimental conditions - Pure tone theta - BB theta - Pure tone gamma - BB gamma • Continuous EEG • Analogue scales: relaxation and depth of mental absorption	16 healthy volunteers	<ul style="list-style-type: none"> • BB elicited cross-frequency activity • No mood modulation • No evidence entrainment was stronger with binaural beats vs. pure tone 	Impact of BB on cognitive performance and mood measures require further investigation

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Binaural Beats: Entrainment and connectivity

Study	Purpose	Methodology	Population	Results	Conclusion
Ingendoh et al. (2023)	Do published BB studies support the brainwave entrainment hypothesis?	-Systematic review (14 studies)	Healthy adults	-6 supported entrainment hypothesis	Unable to conduct meta-analysis secondary to heterogeneity in study designs

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Why does there seem to be no clear answer about binaural beats (BB) and brainwave entrainment?

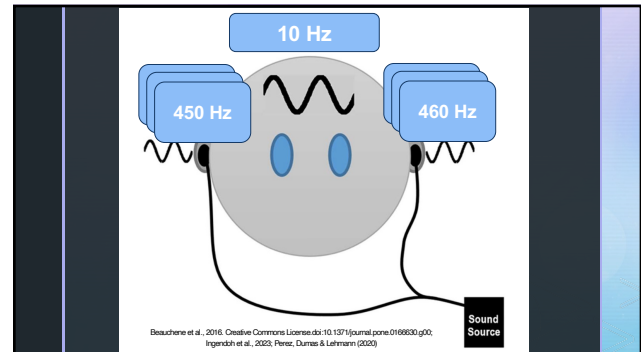
BB frequencies: 1-40 Hz

Duration of BB exposure: 1, 3, 4, 5, 8, 20, 30 minutes

BB carrier frequencies: 100 – 900 Hz

Ingendoh et al., 2022.

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BB carrier frequencies: 100 – 900 Hz

Embedded in music, white noise, pink noise, voice-overs

Ingendoh et al., 2022.

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Binaural beats are often embedded in other sounds

- White noise – includes all audible frequencies at equal power
- Pink noise - includes all frequencies but has more power at lower frequencies. Has a softer, more rumble-like sound
- Brown noise – Further enhances lower frequencies compared to pink noise and decreases in power as frequency increases

Færevik et al., 2025

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Why does there seem to be no clear answer about binaural beats (BB) and brainwave entrainment?

- BB frequencies: 1-40 Hz
- Duration of BB exposure: 1, 3, 4, 5, 8, 20, 30 minutes
- BB carrier frequencies: 100 – 900 Hz
- Embedded in music, white noise, pink noise, voice-overs
- Control conditions are often described, but there is seldom inclusion of a control group
- Washout times between experimental and control conditions is highly variable (none – minutes – a week)
- Timing of exposure (prior to task or during task) is variable and not always described

Ingardsh, et al., 2022.

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A prospective, randomised, controlled study examining binaural beat audio and pre-operative anxiety in patients undergoing general anaesthesia for day case surgery.

Padmanabhan et al., (2005).

- Purpose: Examine the effect of BB on pre-operative anxiety
- Methods: Randomized to 30 min BB v. music alone v. no intervention
Used a propriety BB program (Delta)
- Population: 108 pts >16 yrs/age scheduled for general anaesthesia/elective surgery
 - Initial STAI-S scores were higher in BB group
- Results
 - BB had significantly decreased anxiety compared to no intervention
 - 26.3% decrease for BB vs. 3.8% no intervention (p<0.001)
- Conclusion
 - BB has the potential to decrease pre-procedural anxiety

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The effect of music with and without binaural beat audio on operative anxiety in patients undergoing cataract surgery: a randomized controlled trial.

Wiwatwongwana, et al.(2016).

- Purpose: Determine the effect of BB/music vs. music alone vs. no intervention on anxiety in pts undergoing cataract surgery under local anesthesia
- Methods: Randomized to BB/music, music alone, no sound
 - Anxiety measured prior to intervention and after surgery
 - BB at 20 Hz decreased q 5min to 10Hz and maintained for 50 min
- Sample: 141 pts undergoing cataract surgery w/ lens implant
- Results: Anxiety significantly decreased post-op for BB/music compared to no sound
 - HR was significantly lower in the BB group compared to music alone or no sound
- Conclusion: The addition of BB to music may further decrease anxiety
 - Further studies that examine ANS effects in correlation with EEG are needed

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Brainwave entrainment to minimise sedative drug doses in paediatric surgery: a randomised controlled trial.

Schmid et al., (2020)

- Purpose: Assess brainwave entrainment as a means of lowering propofol sedation in children undergoing surgery with caudal analgesia
- Methods: Investigator-blinded, randomized, controlled study.
 - Brainwave entrainment vs. no stimulation
 - Included both BB and visual stimulation
 - BB: 10 Hz titrated down to 1-2 Hz
- Population: 54 boys aged 1-6 yrs
- Results
 - Propofol requirements were significantly decreased compared to control: 3 mg/kg/hr vs. 4.2 mg/kg/hr
- Conclusion
 - Brainwave entrainment is capable of generating effective results during pediatric surgery
 - Further studies needed, including those to determine the optimal choice of frequencies for brainwave entrainment

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Efficacy of theta-binaural beats for the treatment of chronic pain

Zampini, D. D. (2015)

- Purpose: Assess the impact of theta (4-8Hz) BB on chronic pain
- Methods: Quantitative, experimental, repeated measures crossover study
 - Initiated BB at 20 Hz – 6 Hz – 20 Hz over 20 minutes. Sham = 300 Hz
 - (BB or sham) for 20 min/day x 14 d, then crossed over to the alternative treatment x 14 d
- West Haven-Yale Multidimensional Pain Inventory (pre-test, post-test after each 2-week intervention)
- Population: N=36; self-identified chronic pain
- Results: Pain severity decreased in the BB intervention: 4.6 at baseline to 2.74 for BB vs. 4.6 at baseline to 4.17 after sham ($p < .001$)
- Conclusion: Theta BB were effective in reducing perceived pain severity

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Reduced pain and analgesic use after acoustic binaural beats therapy in chronic pain: A double-blind randomized control cross-over trial.

Gkolias, et al., (2020)

- Hypothesis: Brain entrainment with BB at 5Hz can decrease pain and medication use in patients with chronic pain
- Methods:
 - 5Hz BB for 30 minutes with concurrent EEG compared to sham
 - Crossover after 1 week washout
- Population
 - 21 pts with chronic pain (48% male)

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Reduced pain and analgesic use after acoustic binaural beats therapy in chronic pain: A double-blind randomized control cross-over trial.

Gkolias, et al., (2020)

- 30-minute results
 - BB EEG theta power significantly increased
 - Current pain significantly decreased from baseline with BB (from 5.6 to 3.4, $p < .001$) while sham did not (from 5.2 to 4.8, $p = .79$)
 - Clinically significant pain reduction of $\geq 30\%$ was greater for BB (odds ratio 3.00, CI 1.18-7.65, $p < .01$)
 - Sleep-HQ decrease in both BB and sham; BP unchanged
- 1-week results
 - Current pain significantly decreased from baseline with BB (from 5.6 to 3.9, $p < .001$) while sham did not (from 5.2 to 5.5, $p = .83$)
 - BB significantly reduced mean daily pain from baseline (8.9 to 5.9, $p < .001$) while sham did not (from 6.8 to 6.3, $p = .87$)
 - However, mean daily pain for BB compared to sham was not significant (5.9 vs. 6.3, $p = .21$)
 - Clinically significant pain reduction of $\geq 30\%$ was greater for BB (odds ratio 5.00, CI 1.26-19.85, $p < .01$)
 - BB Analgesic drug use significantly decreased from baseline and was significantly decreased compared to sham: (3.0-3.7g vs. 4.6-4.4g, $p < .05$)
 - Sleep reduction compared to baseline remained significant only for BB
 - Pts had statistically significant preference for BB vs. sham

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Pre-sleep alpha brain entrainment by audio or visual stimulation for chronic widespread pain and sleep disturbance: A randomised crossover feasibility trial.

Halpin et al., (2025)

- Purpose: Assess the impact of alpha stimulation on sleep and pain: feasibility study
- Methods: Smartphone-based program; 10 Hz visual or audio (not both); 30 min then stops
 - 1-wk baseline > randomized to sham vs. treatment for 2 wks > 1-wk washout > 2-wk sham or treatment
- Results: N = 13 for analysis; 12 chose audio intervention
 - Pain and sleep quality improved with 10 Hz compared to baseline and sham but was of small magnitude : Pain at night: Baseline 6.8 - BB 6.1 - Sham 6.6. ($p < .001$)
- Conclusion
 - Further study with larger scale trials is needed

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Summary

- 2 Studies documented significantly decreased anxiety for BB/music versus no sound, but not for BB/music versus music alone
 - One used delta range, one used alpha range BB
- 1 study demonstrated decreased intraoperative propofol dosing for pediatric patients treated with delta range audio/visual stimulation
- 3 studies in chronic pain demonstrated significant decreases in pain intensity using BB daily for 1-2 wks, 20-30 min/day: 2 theta range, 1 alpha range
 - 2 studies had pain intensity decrease that was potentially clinically meaningful
- Consider BB therapy for future research initiatives

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Closing thoughts....

- Resources
 - YouTube
 - Binaural beat generator
 - App: Search binaural beats or brainwaves
 - Huberman Lab Essentials podcast
- Practice
 - BB require earbuds or headphones
 - BB generally are not discernable
 - Keep volume low

Questions: holly409@icloud.com
Please include BB or binaural beats in the subject line

Disclaimer: I have no connection of any kind to any of these resources, but rather they are those that I have used personally and am aware of.

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