Effects of intentional breathing practices on cognitive function: a systematic review protocol

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PROSPERO registration number: CRD420251165006

Background

Respiration is a fundamental rhythm of life. Yet, the effortless, often automatic cycle of inhalation and exhalation supports more than survival: it bridges the body and brain, shaping neurophysiological state and, consequently, cognitive performance. The connection between the breath and cognition dates back to ancient Yogic tradition, where pranayama was believed to enhance focus and mental clarity. In more recent times, a large body of evidence has accrued to reinforce this claim.

Research investigating both intentional breath control and spontaneous respiration reports effects on perception, cognition, and memory. Studies using diverse breath practices have found improvements in verbal and spatial memory (Naveen 1997, Sutarto 2010), reaction time (Akcay 2024, Buchanan & Janelle 2021, Nakamura 2018, Johannknecht & Kayser 2022, Sharma 2014, Zelano 2016), visual discrimination (Telles 2012, Zelano 2016), and decision-making (De Couck 2019, Sutarto 2010). These enhancements are most often observed after the breathing intervention but in some cases occur during the practice itself (Campelo 2025, Niranjan 2022).

Other research, primarily on spontaneous breathing patterns, highlights the modulatory role of breathing route, nostril dominance, and respiratory phase on cognitive performance. Several studies report better stimulus perception and memory with nasal breathing compared to oral breathing, although findings are mixed (Parviainen 2022). As for nostril dominance, right nostril breathing has been found to improve verbal performance, while left nostril breathing may support spatial tasks (Desai 2015, Shannahoff-Kalsa 1991, Price 2016). These lateralized benefits are more consistently seen for spontaneous breathing than for intentional breath manipulations–a discrepancy that may relate to heterogeneity in task demands and sensory modality (Parviainen 2022) or to potential gender differences (Shannahoff-Kalsa 1991).

Task timing during the breath cycle may further mold cognitive performance, as stimulus presentation during either the inspiratory or expiratory phase–depending on the task–has been tied to memory benefits, whereas presentation between these two phases can compromise performance (Nakamura 2024, Parviainen 2022). The transition from exhalation to inhalation may serve as a “reset and trigger” point during which brain state shifts, favoring sensory encoding during inspiration and more internally directed functions, such as memory consolidation, during expiration (Nakamura 2024).

The widespread impact of respiration on cognition parallels changes at the neural level, including modulations in regional brain activity and of neural oscillations. Intentional breathing practices have been found to influence areas involved in key cognitive networks, such as the frontal, insular, and cingulate cortices (Goheen 2023, Nakamura 2024, Maric 2020). These practices may also differentially alter power in the alpha, beta, and/or theta bands (Desai 2015, Campelo 2025, Zaccaro 2018), with slow breathing preferentially increasing slower oscillations and hyperventilation increasing faster ones (Goheen 2023). Alongside general changes in power, phase-locking and phase-amplitude coupling of alpha, theta, and gamma oscillations to the respiratory cycle (Heck 2017, Nakamura 2024) has been observed not only in olfactory areas, but also in the hippocampus and prefrontal cortex (Heck 2017, Heck 2019, Parviainen 2022).

Multifold mechanisms may underlie these large-scale modulations of brain and cognitive function by breathing patterns. For instance, oscillatory changes specific to nasal breathing are likely mediated by olfactory sensory neurons, which play an essential role in a global respiratory rhythm (Tort 2025). Additionally, input from respiratory motor regions to the thalamus, basal forebrain, and locus coeruleus has the potential to shape frontal circuitry, attention, and brain state (Heck 2017, Maric 2020, Nakamura 2024). Respiratory regulation of the stress response can ultimately elicit similar effects, as vagal tone has been linked to prefrontal function (Brown 2013, Maric 2020, Nakamura 2024, Zaccaro 2018). Lastly, the direct impact of breathing on gas-exchange and hemodynamic processes can influence central chemoreception (Heck 2017), cerebral blood flow (Shannahoff-Kalsa 1991), and brain tissue oxygenation (Shaw 2023, Zhang 2023).

Taken together, these findings suggest that breathing can influence various aspects of cognition through a number of neural avenues. Intentional breathing practices may thus constitute a powerful tool for enhancing both brain and cognitive function that is universally accessible, low-risk, and cost-free. However, the current literature presents mixed and sometimes contradictory findings, precluding a coherent picture to guide breath practice implementation for cognitive performance. Research interventions are highly heterogeneous, utilizing varied breathing paces and styles–from simple nasal breathing to unilateral or alternate nostril breathing, or various pranayama combinations. Differences in participant experience level, practice length, and intervention duration may also moderate effectiveness and explain inconsistencies across studies. Despite increasing interest in this area, no formal synthesis has yet been undertaken to reconcile these disparate findings.

To address this gap in the literature, we will conduct a systematic review of interventional studies examining the effects of intentional breathing practices on cognitive performance. Our objective is to synthesize the existing evidence into a coherent account of how breathing patterns influence cognition. More importantly, we aim to translate these findings into a practical framework—offering evidence-based, actionable guidance for implementing breath practices to support cognitive performance in real-world settings.

Objectives

Primary Objective:

This systematic literature review aims to assess the impact and practical application of intentional breathing practices on cognitive function.

Methods

Eligibility Criteria

Study Designs

We will include both randomized controlled trials (RCT) and other prospective cohort and clinical studies. We will not consider case studies, retrospective observational data analyses, editorials and reviews.

Participants

We will consider studies that include human participants aged ≥ 1. Studies that include participants who are either experts or naive to intentional controlled breathing practices will be considered. We will include studies that incorporate populations with clinical diagnoses. Results may be stratified by:

- Participants with versus without clinical conditions;
- Adults (ages 19+) vs. youth (ages 1-18);
- Gender.

Interventions

We will include studies that consider any intentional, controlled breathing practice as its own intervention, whether part of the "treatment" or "control" groups. We will not consider studies that combine such breath practices with other interventions such as yoga, meditation, cognitive-behavioral therapy, qi gong, or tai chi. For breathing-related interventions that incorporate any device, the following inclusion and exclusion criteria will be followed:

- <u>Included:</u> Interventions that use devices as a means for participants to follow a regulated, paced breathing rhythm, so long as the programmed pace does not change based on measurements of the participant during the breath practice.
- <u>Excluded:</u> Interventions that use a device to measure something about the participant's breathing — like expelled CO_2 (via capnometry), breath rate, O_2, heart rate variability (HRV), positive pressure, ventilation, respiratory sinus arrhythmia (RSA) — to guide the participant's breath practice/training. As such, all biofeedback- and capnometry-based studies will be excluded, as will studies using ventilation devices, including masks and bags, that use any means outside of the participant's direct control to directly manipulate/regulate the participant's breathing or O_2/CO_2 intake.

Comparators

We will include studies that compare intentional breathing practices to waitlist controls, other control interventions, spontaneous breathing without instruction, or any other active or non-active comparator.

Outcomes

We will include studies that assess cognitive function during or following intentional breathing-based interventions. Cognitive performance outcomes will include executive functions such as working memory, cognitive flexibility, inhibition, and interference control, as well as measures pertaining to attention, sensory detection, information processing speed, spatial processing, language processing, learning, and memory. For learning and memory related outcomes we will consider verbal, visual, and spatial domains. We will consider assessments of memory processes including encoding, retention, recall. Additionally, we will incorporate both declarative and non-declarative memory, encompassing semantic, episodic, and procedural memory. Regarding sensory stimuli utilized for the assessment of cognition, we will include visual, auditory, tactile, gustatory, and olfactory means of stimulation. We will exclude studies that measure only physiological parameters, such as those related to the cardio-respiratory system including heart rate, heart rate variability, respiratory sinus arrhythmia, VO2 max, and blood pressure. Studies that focus exclusively on altered state of consciousness or affective and emotional outcomes will not be considered.

Timeline

There will be no limitation on duration of intervention.

Settings

We will include studies conducted in any geographical location, within a lab, clinic, community, or home-based setting.

Table 1. PICOS Statement

Component	
Population	Humans aged 1+ Expert or naive to intentional controlled breathing practices
Intervention	Intentional or controlled breathing practices
Comparators	Spontaneous breathing, breath awareness, alternative interventions (e.g. mindfulness, physical activity, yoga), or no intervention.
Outcomes	Measurements of cognitive function (attention, memory, executive function)
Study Design	Randomized controlled trials, prospective cohort and clinical studies.

Settings	Conducted in any geographical location, within a lab, clinic, community, or home-based setting.

Information Sources

Electronic searches will be conducted in the following databases:

- PubMed
- Scopus
- PsychInfo
- Cochrane CENTRAL

We will also manually reference-mine select previously published reviews and key clinical trials. We'll include the following:

- Brown 2013
- Campelo 2025
- Chetry 2024
- Desai 2015
- Goheen 2023
- Heck 2017
- Heck 2019
- Maric 2020
- Nakamura 2024
- Parviainen 2022
- Price 2016
- Roj 2025
- Shannahoff-Kalsa 1991
- Tort 2025
- Varga 2017

We will attempt to contact study authors in cases of unclear, unavailable or unsupported data.

Search strategy

PubMed Search Terms:

((breath[Title/Abstract]) OR (breathing[Title/Abstract]) OR (breathwork[Title/Abstract]) OR (diaphragmatic[Title/Abstract]) OR (respiration[Title/Abstract]) OR ("respiratory therapy"[Title/Abstract]) OR (pranayama[Title/Abstract]) OR ("respiratory intervention"[Title/Abstract]) OR ("nadi shodhana"[Title/Abstract]) OR ("respiration"[MeSH Terms]) OR ("breathing exercises"[MeSH Terms]))
AND

((cognition[Title/Abstract]) OR (attention[Title/Abstract]) OR (memory[Title/Abstract]) OR (learning[Title/Abstract]) OR ("cognitive function"[Title/Abstract]) OR ("cognitive performance"[Title/Abstract]) OR ("cognition"[MeSH Terms] OR "memory"[MeSH Terms] OR "attention"[MeSH Terms] OR "learning"[MeSH Terms]))

Filters: Clinical Study, Clinical Trial, Comparative Study, Controlled Clinical Trial, Pragmatic Clinical Trial, Randomized Controlled Trial, English, Humans

SCOPUS Search Terms:

TITLE-ABS-KEY (breath OR breathing OR breathwork OR "breathing exercises" OR diaphragmatic OR respiration OR "respiratory therapy" OR pranayama OR "respiratory intervention" OR "nadi shodhana") AND TITLE-ABS-KEY (cognition OR attention OR memory OR learning OR "cognitive function" OR "cognitive performance") AND TITLE-ABS ("randomized controlled trial" OR "clinical trial" OR {RCT} OR "clinical study" OR "comparative study") AND NOT TITLE (review OR "systematic review" OR "narrative review" OR "meta-analysis" OR "meta analysis" OR "case study" OR "case report" OR "observational study") AND NOT TITLE-ABS-KEY (rat OR rats OR mouse OR mice OR murine OR animal OR dogs OR cats OR rabbits OR pig OR pigs) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "NEUR") OR LIMIT-TO (SUBJAREA , "BIOC") OR LIMIT-TO (SUBJAREA , "PHAR") OR LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO (SUBJAREA, "HEAL") OR LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))

Cochrane CENTRAL Search Terms:

#1: ((breath):ti,ab OR (breathing):ti,ab OR (breathwork):ti,ab OR (diaphragmatic):ti,ab OR (respiration):ti,ab OR (respiratory therapy):ti,ab OR (respiratory intervention):ti,ab (pranayama):ti,ab OR ("nadi shodhana"):ti,ab)
#2: ((cognition):ti,ab OR (cognitive function):ti,ab OR (cognitive performance):ti,ab OR (attention):ti,ab OR (memory):ti,ab OR (learning):ti,ab)
#3: MeSH descriptor: [Cognition] this term only
#4: MeSH descriptor: [Memory] this term only
#5: MeSH descriptor: [Attention] this term only
#6: MeSH descriptor: [Learning] this term only
#7: MeSH descriptor: [Respiration] this term only
#8: MeSH descriptor: [Breathing Exercises] this term only
Final Search: (#1 OR #7 OR #8) AND (#2 OR #3 OR #4 OR #5 OR #6)

Filters: English

PsychInfo Central Search Terms:

((tiab(breath) OR tiab(breathing) OR tiab(breathwork) OR tiab(diaphragmatic) OR tiab(respiration) OR tiab("respiratory therapy") OR tiab("respiratory intervention") OR tiab(pranayama) OR tiab("nadi shodhana") OR MAINSUBJECT.EXACT("breathing techniques") OR MAINSUBJECT.EXACT("respiration")) AND (tiab(cognition) OR tiab("cognitive function") OR tiab("cognitive performance") OR tiab(attention) OR tiab(memory) OR tiab(learning) OR MAINSUBJECT.EXACT("cognition") OR MAINSUBJECT.EXACT("memory") OR MAINSUBJECT.EXACT("attention") OR MAINSUBJECT.EXACT("learning"))) AND rtype.exact("Journal Article") AND me.exact("Clinical Trial" OR "Followup Study" OR "Quantitative Study" OR "Empirical Study") AND la.exact("English") AND po.exact("human")

Filters: journal article, human, empirical study / quantitative study / followup study / clinical trial, English

Data Management

All screening will be performed using Rayyan.ai (Ouzzani 2016), a web-based tool designed for managing systematic review.

Full-text articles of final accepted articles will be downloaded to and saved in a Google Drive folder. Data will be extracted into a Google form that will automatically export results into a Google Sheet.

Selection Process

Five authors will be involved in the review process. For each article, two reviewers will independently screen the title and abstract of all articles identified through the database search, applying the predefined inclusion and exclusion criteria. In case of a disagreement between two reviewers, the assigned reviewers will discuss and come to an agreement. If disagreement remains after discussion, the title or abstract will be evaluated by a third reviewer. For any articles where the compliance with inclusion and exclusion criteria is unclear, the article will be carried forward into the full-text review. The full-text of the remaining papers will be retrieved, and independently evaluated by two reviewers to determine if all inclusion and exclusion criteria is met.

Data Extraction Parameters

General Study and Intervention Data Abstraction

- Study identification (e.g., Timestamp, RefID, Author, Title)
- Is a measure of cognitive performance the primary outcome?
- Journal

- Year
- Study design (e.g., RCT, non-randomized prospective trial, etc.)
- Inclusion criteria
- Exclusion criteria
- Study population (healthy youth, healthy adults ages 18-65, healthy adults 65+, known cognitive deficit, other clinical condition, other)
- Other population descriptions
- Setting
- Geographic location
- Sample size: Total enrolled in this study
- Sample size: Notes
- % Female overall
- Age: Mean - Overall
- Race/Ethnicity (% each) overall
- Intervention name, type (Name and description of the type of breathwork the intervention encompasses)
- Intervention other: parameters, components, etc. (What situations is the breath protocol being used?)
- Control group description
- Measurement tools: related to cognitive performance
- Measurement tools: other
- Results: related to cognitive performance
    - Outcome description
    - Cognitive domain measured (e.g., working memory, attention, declarative memory, etc)
    - Statistically significant improvement? (yes/no)
    - N analyzed for outcome
    - Outcome statistics (p-value, effect size, mean, SD)
- Other results: related to cognitive performance
- Other results: not related to cognitive performance
- Subgroup results
- Limitations
- Implications
- Paper summary

<u>Framework Data Abstraction</u>

- Study identification (i.e., Timestamp, RefID, Author, Title)
- Intervention identification
- Cognitive performance as primary outcome (yes/no)

<u>Outcomes</u>

- Significant effect benefit on cognitive performance (yes/no)

    - Improvement or decrement to performance?
- Measurement timing relative to the breathing intervention (e.g., during, immediately after, etc)
- Cognitive domain measured for this outcome (e.g., working memory, spatial processing, declarative memory, etc)
    - If declarative memory, which subtype? (semantic, episodic, etc)
    - If declarative memory, what did this outcome measure? (recall, recognition, retention, etc)
- Stimulus modality (e.g., visual, audible, olfactory, etc))
- RCT? (yes/no)
- How many times were the outcomes measured?
- Total # of participants randomized (for RCT) or initially enrolled (for non-RCT) into study

<u>Breathwork Intervention Details</u>

- Intervention breathing type used (slow, fast, combined fast-slow, etc))
- Slow breathing type(s) (if used)
- Fast breathing practice types (if used)
- Breath pattern used, if any? (count/cadence, inhale/exhale holds)
- Breaths per minute
- Other breath practice characteristics (i.e., holds, nasal or oral breathing, extended exhales, etc)
- Human-guided training (yes/no)
    - Type of human guidance
    - Number of human guided sessions
    - Number of minutes per human-guided training session
- Device-guided breath training/pacing (yes/no)
    - Type of device
    - Number of device-guided training sessions
    - Number of minutes per device-guided training session
- Intervention: group or individual
    - Number of group sessions
    - Minutes per group session
- Intervention homework (yes/no)
    - Homework description
    - Total number of homework breath sessions
    - Length of homework breath sessions (minutes)
- Intervention duration (days)
- Multiple (≥1) sessions (yes/no)
- Number of breath practice sessions, total known
- Length of sessions
    - Length of general breath practice sessions (minutes)
    - Length of group sessions (minutes)

- Long-term practice (yes/no)
- Sessions continued through outcome measurement (yes/no)
- Control includes (e.g., no control/usual care/no intervention)
- Does this intervention meet at least 1 of the criteria of the “breath-stress” framework? (human-guided training, multiple sessions, long-term practice , long-term practice AND practices continued throughout measurement period) (yes/no)
    - Which criteria were included (if any)?
- How many of the above criteria were included (if any)?
- Practice-specific factors that may account for any observed discrepancy between the intervention's adherence to “breath-stress” criteria and its efficacy on cognitive outcomes

Data Extraction Process

Full-text articles deemed potentially eligible will be retrieved and assessed independently by two reviewers, where data extraction will be performed in duplicate, with each reviewer logging the extracted data into a Google Form auto-populating a spreadsheet. A third reviewer will review the extracted data for accuracy and consistency between the previous two reviewers. Any discrepancies will be discussed and resolved by a consensus among all three or four reviewers.

Risk of Bias Assessment

For randomized controlled trials (RCTs), we will use the Cochrane Risk of Bias 2.0 tool (RoB 2), which evaluates potential bias across five domains: the randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result, rated on a discrete scale as either “low risk,” “some concerns,” or “high risk.”

For non-randomized interventional studies, we will use the Mixed Methods Appraisal Tool (MMAT), version 2018 (Hong QN 2018), which provides a structured validated framework to assess methodological quality across a range of empirical study designs. This tool provides a balance between rigorous appraisal criteria, applicable to a wide range of design studies, and practical time efficiency. MMAT includes a set of five core criteria tailored specifically for quantitative non-randomized studies, evaluating aspects such as participant selection, measurement quality, and confounder control.

Data Synthesis

Given the heterogeneity of breathing interventions, outcome types, and measurement modalities across included studies, meta-analytic approaches are expected to not be feasible, therefore we will perform a structured narrative synthesis, in line with Cochrane’s guidelines for qualitative data synthesis.

Namely, findings will be organised thematically by intervention type, outcome domain (cognitive performance domains such as memory, attention, executive function) and study population. A tabular matrix will be created to display these study characteristics, breathing protocols, outcome measures and results, with direction and statistical significance, as well as risk-of-bias ratings.

Where feasible, we will extract and tabulate reported effect size estimates (e.g., standardized mean differences, correlation coefficients, or percent changes), alongside confidence intervals, and p-values. These will be descriptively summarized within thematic subgroups. In cases where reported data are sufficiently detailed, we may convert estimates to a common effect size metric (e.g., Cohen’s d) for comparability across studies. However, we will not perform any statistical pooling or meta-analysis of these estimates.

Timeline

- Article searching - 2 weeks
- Title screening - 6 weeks
- Abstract screening - 4 weeks
- Full-text screening - 4 weeks
- Data abstraction - 8 weeks
- Data analysis & synthesis - 2 weeks
- Manuscript preparation - 12 weeks

Funding

This study is being conducted in the absence of any external funding.

Conflicts of Interest

The authors have no conflicts of interest.