Chapter #1

IMPACT OF UNILATERAL HAND CLENCHING ON COGNITION AND MOOD, AND POTENTIAL CLINICAL UTILITY: A REVIEW

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ABSTRACT

Manipulations differentially activating the left or right cerebral hemisphere influence behavior in ways congruent with known theories of hemispheric lateralization of function. Determining under what conditions, and to what extent, simple techniques can be used to alter mental and emotional state holds considerable appeal because methods might be used as adjuncts to other tactics to mitigate negative affect in clinical situations, or to improve cognition in neurocognitive impairment. One method demonstrating promise for altering cognition and emotion, and that could be used in home-settings, is sustained unilateral hand clenching. The goal of the present paper was to analyze the literature to examine i. typical methods used for this manipulation; ii. what types of tasks/domains are impacted and iii. whether one versus the other hemisphere, is particularly affected by manipulation. A literature search was conducted using relevant search terms, resulting in 24 articles. Across the literature, range of domains was examined, including memory, decision making, creativity, language, emotion, and social perception, with many examining more than one. Nine included neurophysiological measures. Results are discussed in terms of potential utility for clinical populations and the need for methodological consistency.

Keywords: hemispheric lateralization, unilateral hand clench, emotion, cognition.

1. INTRODUCTION

Delineating under what conditions, and to what extent, simple techniques can be used to alter mental and emotional state holds considerable appeal; for example, such methods might be used as an adjunct to other tactics to mitigate negative affect in clinical situations, or to improve cognition in neurocognitive impairment. Even slightly effective methods that could be easily initiated and sustained in private and as needed by individuals, rather than only within a laboratory or clinical setting, could potentially dramatically improve mental health in some populations.

If simply clenching and unclenching one versus the other hand can effectively alter emotion and cognition, this technique could offer patients an opportunity for non-pharmaceutical self-regulation, and potentially to increased self-efficacy, which is known to positively impact treatment effects. The goal of the present paper was to analyze the literature to examine i. typical methods used for this manipulation; ii. if and in what manner such movements alter cognition and/or emotion; iii. whether one versus the other hemisphere, and resultant alterations in behavior, are particularly amenable to such manipulation.

2. BACKGROUND

Manipulations that differentially activate the left or right cerebral hemisphere influence behavior in predictable ways. For example, increasing left, relative to right, hemisphere activity results in increased language ability, memory encoding, approach motivations, risk-taking, and attention to local details. Conversely, increasing right, relative to left, hemisphere activity is associated with superior spatial navigation, memory retrieval, withdrawal motivational states, risk-avoidance, and attention to global aspects of information. Some methods used to differentially activate the left or right hemisphere include mood induction (e.g.; Gable & Harmon-Jones, 2010) dichotic or monaural listening (e.g.; McCormick & Seta, 2012), unilateral gaze (e.g.; Propper, Brunye, Christman, & Januszewski, 2012), bilateral alternating gaze (e.g.; Christman, Garvey, Propper, & Phaneuf, 2003), unilateral finger tapping (e.g.: McElroy & Seta, 2004), unilateral hand clenching (e.g.; Goldstein, Revivo, Kreitler, & Metuki, 2010), unilateral nostril breathing (e.g.; Jella & Shannahoff-Khalsa, 1993) and sidewards body orientation (Drake, 1991).

For example, previous work has reported that unilateral nostril breathing might effectively alter cognitive processing in a manner consistent with hemispheric lateralization (e.g.: Jella & Shannahof-Khalsa, 1993; Niazi, Navid, Bartley, Shepherd, Pedersen, Burns, Taylor, & White, 20222022; Block, Arnott, Quigley, & Lynch, 1989; Saucier, Tessem, Sheerin, & Elias, 2004). Yogis in Ancient India initially proposed unilateral forced nostril breathing as a technique for somatic and psychological practices (Niazi, Navid, Bartley, Shepherd, Pedersen, Burns, Taylor, & White, 2022). Both Yogi practices and research reports have demonstrated that right nostril breathing results in higher arousal states, while left nostril breathing is associated with a more stress relieving state (Niazi, Navid, Bartley, Shepherd, Pedersen, Burns, Taylor, & White, 2022). Works from both Jella and Shannahof-Khalsa (1993) and Block, Arnott, Quigley, & Lynch (1989) reported that unilateral nostril breathing impacts spatial task performance, such that unilateral forced nostril breathing may enhance right hemispheric lateralized functions (Saucier, Tessem, Sheerin, & Elias, L., 2004). While unilateral nostril breathing may be a promising method for improved mood and cognitive task performance, it has not been sufficiently examined to determine its likely efficacy for home-based, clinical treatments, and comes with several limitations. For example, unilateral nostril breathing requires participants to breathe at a specific speed, and may be uncomfortable. Additionally, those with allergies, a deviated septum, or other common issues may not be able to participate in this method.

Although unilateral nostril breathing is not appropriate for self-administration at in-home use, another method that has demonstrated promise for altering cognition and emotion, and that could theoretically be used in the home-setting, is sustained unilateral hand clenching. Via increased activity of one versus the other hemisphere, sustained unilateral hand clenching may result in a processing bias toward the more activated, contralateral, hemi-cortex, and to a hemisphere-concordant change in behavior. Neurophysiologically, it has been proposed that unilateral hand clenching increases contralateral activity of cortical motor areas. This cortical activity has been suggested to spread beyond motor cortex, to frontal areas involved in emotion and cognition (e.g.: Harmon-Jones, 2006), resulting in a bias in performance and experience aligned with known lateralization of hemispheric functions associated with a given (more active) hemisphere (and the one that is contralateral to the hand that is engaging in unilateral clenching).

3. METHODS

A literature search was conducted using the search terms: “unilateral hand clench*” in conjunction with “cognit*”, “emotion*”, "perception", "behavior*" brain*, neuro* and “emotion* and cognit*” in various databases. 47,989 non-duplicate studies were found. The earliest article found was from 1993, and end date was 2021. Articles referencing single unilateral forced nostril breathing, facial contractions, or contractions of other muscles or body parts, or that did not discuss the effects of unilateral hand contractions on cognition or/and emotion were excluded. Hand clenching must have been in neurotypical individuals, and articles had to have been written in English. Articles must have described empirical research, not be a review article, and must have been peer-reviewed. Articles were further screened by reading the abstract and looking for mention of domains of cognition such as perception, memory, decision making, learning, language ability and/or attention, or references to emotion, affect, or mood. Twenty-one articles were removed after a full text screen. Three articles were excluded during data extraction, as their research orientation was ambiguous, and they were ultimately excluded. A total of 47,941 articles were removed for relevance, with the final article count 24 (See Figure 1 for Prisma [Liberati, Altman, Tetzlaff, Mulrow, Gãtzsche & Ioannidis, 2009]) exclusion and inclusion application. Populations included in this review consisted entirely of adults over the age of 18, as no studies are currently available with children or older adults.

4. RESULTS

Across the literature, a wide range of cognitive, perceptual, and emotional tasks were used, over many different areas. The majority of studies examined more than one domain. Nine included neurophysiological correlates of hand clenching: Six used electroencephalograph (EEG), 1 used EEG and evoked response potentials, 1 used Functional Near-Infrared Spectrography (fNIRS), and 1 used Functional Magnetic Resonance Imaging (fMRI). Hand clenching typically resulted in contralateral hemispheric activity (6 studies), though some studies reported ipsilateral activity as well (3).

Specific techniques/instructions for unilateral hand clenching included squeezing/clenching an item (most frequently a ball, 21 studies). Participants were most frequently instructed to ‘clench as hard as you can’ (13 studies), though there were deviations in this instruction. Most commonly, participants squeezed the object for 45 seconds, followed by 15 seconds of rest, in a series of repetitions that varied from 2- 4 times per condition being examined (16 studies), though some seemingly idiosyncratic methods were also used (see Table 1).

Twenty-one of the 24 studies controlled for handedness by including only right-handed individuals. Eleven of the 24 studies included an explicit control group, while the others compared various forms of clenching against each other.

In order to examine effects of hand clenching, 20 studies using various tasks tested performance with between-subjects designs, while 4 studies utilized within-subjects. Of the between-subjects studies 18 (90%) reported significant impacts of clenching on performance. Of the within-subjects designs, 3 (75%) reported significant effects.

Regarding emotion, 12 studies placed their findings within the context of affect. All significant findings were framed within known theories of hemispheric lateralization of emotion. Eight reported increased positive/approach emotions following right unilateral hand clenching, and 5 reported increased negative/withdrawal emotions following left unilateral hand clenching.

Regarding cognition, a wide range of domains were examined, including memory (4), attention (7), sports performance (3), language (1), creativity (3), social perception (4), and 2 that were unable to be classified. Much research examined more than one domain in a given article. Changes in these areas were consistent with known theories of lateralization of cortical functions.

Overall, 4 studies reported an impact of only unilateral right-hand clenching and 5 of only unilateral left-hand clenching, on behavior. Twelve reported an impact of both hand clenching conditions. Three reported no impact of hand clenching on performance.

Table 1.
Methodology as a Function of Study.

Authors	What was Clenched	How long they clenched
Andreau & Batán, (2018).	Two foam rubber balls (5 cm diameter)	45 seconds, relax for 15 seconds and then squeeze again for another 45 seconds. No instructions for squeeze strength
Baumann, Kuhl & Kazén (2005).	Soft ball	Experiment 1: Squeeze the ball for 1 minute Experiment 2: Squeeze 3 minutes. No instructions for squeeze strength
Beckmann, Fimpel, & Wergin (2021)	Racket grip or tennis ball	Squeeze racket or ball for 10-15 seconds Instructed to twice a second for 10–15 seconds with submaximal strength
Cross-Villasana, Gröpel, Doppelmayr & Beckmann (2016)	6 cm diameter soft rubber ball	45 seconds, relax for 15 seconds and then squeeze again for another 45 seconds. Instructed to squeeze the ball completely with all fingers.
Gable, Poole, & Cook (2013)	2.8-inch diameter rubber ball	45 seconds, relax for 15 seconds and then squeeze again for another 45 seconds. Instructed to squeeze as hard as they could
Goldstein, Revivo, Kreitler, & Metuki (2010).	7-cm diameter rubber ball	45 seconds, relax for 15 seconds and then squeeze again for another 45 seconds. Instructed to squeeze as hard as they could
Harlé & Sanfey (2015).	2-in. diameter rubber ball	45 seconds, relax for 15 seconds and then squeeze again for another 45 seconds. Instructed to squeeze as hard as they could
Harmon-Jones (2006)	5-cm diameter ball	45 seconds, relax for 15 seconds and then squeeze again for another 45 seconds. Instructed to squeeze as hard as they could
Hoskens, Masters, Capio, Cooke, & Uiga (2021).	Stress ball	45 seconds pre-task, ten blocks of 30 seconds during the task Instructed to firmly contract a stress ball at a self-paced rate
Mirifar, Cross-Villasana, Beckmann, & Ehrlenspiel (2020)	6 cm diameter soft rubber ball	Squeeze for 45 seconds Instructed to squeeze the ball completely with all fingers.
Moeck, Thomas & Takarangi (2020)	A moderately hard stress ball 6.37 cm diameter	45 seconds, 15-second rest Instructed to “squeeze the ball on-and-off, as hard as you can”
Nicholls, Bradshaw, & Mattingley (2001).	Just hand	2.5 – 3.5 seconds, during presentation of each stimulus No instructions for squeeze strength
Peterson, Shackman, & Harmon-Jones (2008)	Ball	45 seconds, relax for 15 seconds and then squeeze again for another 45 seconds. Instructed to squeeze as hard as they could
Peterson, Gravens, & Harmon-Jones (2010)	Toy ball	45 seconds, 15-second rest Instructed to squeeze as hard as they could
Propper, McGraw, Brunyé & Weiss (2013)	5cm diameter rubber ball	45 seconds, relax for 15 seconds and then squeeze again for another 45 seconds. Instructed to squeeze as hard as they could
Propper, Dodd, Christman, & Brunyé (2017)	Two pink, 5 cm diameter rubber racquetballs	45 seconds, relax for 15 seconds and then squeeze again for another 45 seconds. Instructed to squeeze as hard as they could
Prunier, Christman, & Jasper (2018)	Hand dynamometer	45 seconds, relax for 15 seconds and then squeeze again for another 45 seconds. Randomly assigned to squeeze the hand dynamometer at 0%, 25%, 50%, 75%, or 100% of their baseline maximum squeeze strength.
Rominger, Papousek, Fink, & Weiss (2014).	Customary training gripper	60-seconds total, followed by 60-second relaxation period No instructions for squeeze strength
Schiff & Truchon (1993)	2.5in diameter Rubber ball	45 seconds, relax for a few seconds, four times. No instructions for squeeze strength
Schiff & Lamon (1994)	2.5in diameter sponge ball	45 seconds, then relax, four times with intervals of 10 to 15 seconds between each contraction. Instructed to squeeze as hard as they could.
Schiff, Guirguis, Kenwood & Herman (1998)	5.08-cm diameter rubber ball	45 seconds, relax for 15 seconds and then squeeze again for another 45 seconds. Instructed to squeeze as hard as they could
Stanković & Nešić (2020)	Dynamometer	45 seconds, relax for 15 seconds and then squeeze again for another 45 seconds. Instructed to squeeze “as firmly as possible”
Turner, Hahn, & Kellogg (2017)	Tennis ball	45 seconds, relax for 15 seconds and then squeeze again for another 45 seconds. Instructed to squeeze as hard as they could
Walz, Doppl, Kaza, Roschka, Platz, & Lotze (2015)	Rubber ball	Instructed to press the ball with a target force of 33% MVC and 1 Hz clenching rate.

Figure 1.
Prisma inclusion/exclusion application.

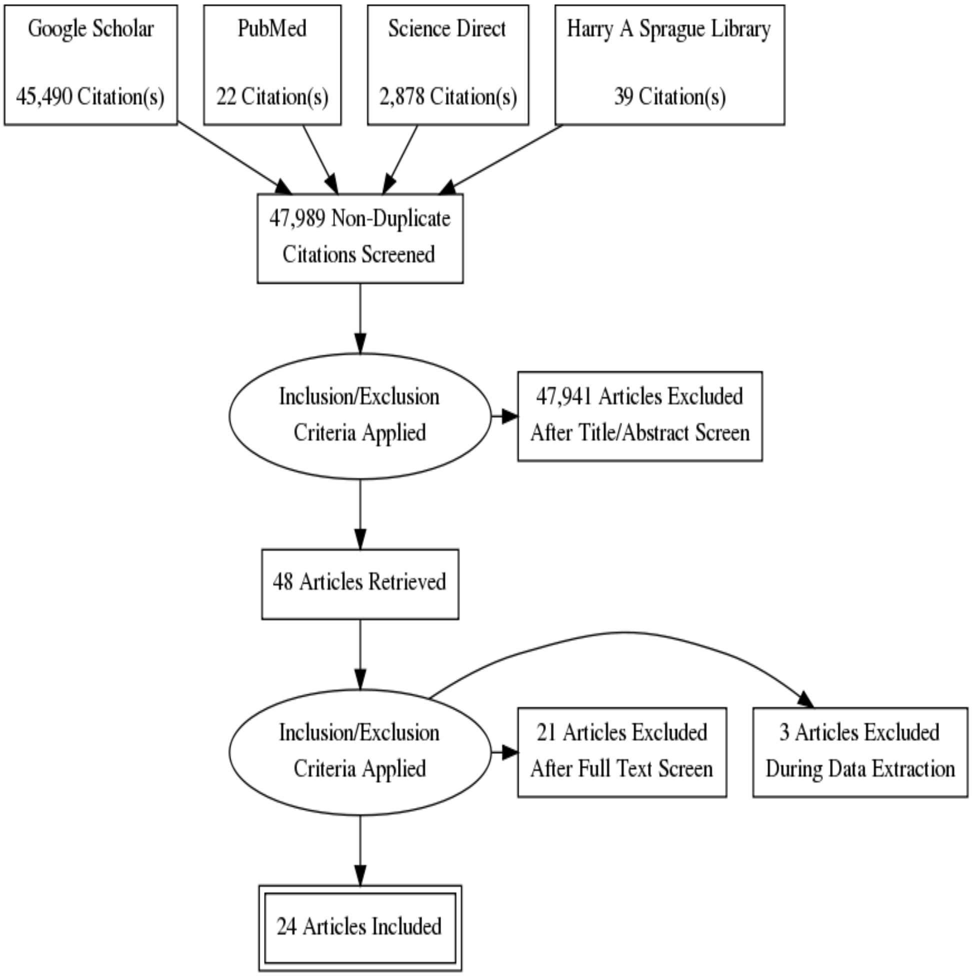

Table 2.
Effect Sizes and Control Groups.

Authors	**Effect Size (Cohen's d, unless otherwise stated)**	**Controlled for Handedness of Participants**
Andreau & Torres Batán, (2018).	● Experiment 1: ○ R/L vs R/R: .94[1] ○ R/L vs. L/R: 1.9 ○ R/L vs. N/N: 1.39 ● Experiment 2 ○ R/R vs. R/L: .81 ● Experiment 3 ○ No differences among conditions ● Experiment 4 ○ R/L vs L/R: 1.21 ○ R/L vs. L/L: 1.9 ○ R/L vs. N/N: .9	[1]*Right-handed participants only (assessed via Edinburgh Handedness Inventory[3])
Baumann, Kuhl & Kazén (2005).	● Experiment 1: ○ Source discriminability x left-hemispheric activation: .79 ○ Source discriminability x right-hemispheric activation: .69 ● Experiment 2: ○ Source discriminability x left-hemispheric activation: .79 ○ Source discriminability x right-hemispheric activation: .95	*Right-handed participants only (assessed via Edinburgh Handedness Inventory)
Beckmann, Fimpel, & Wergin (2021)	● Homogeneity of groups: .31 ● Cognitive Anxiety left and right hand group ○ Pre-test: .76 ○ Post-test: .41 ● Somatic Anxiety left and right hand group ○ Pre-test: .6 ○ Post-test: .18 ● Accuracy left and right hand group ○ Pre-test: .32 ○ Post-test: .5	*Right-handed participants only (assessed via self-report)
Cross-Villasana, Gröpel, Doppelmayr & Beckmann (2016)	● Alpha amplitudes before contractions vs during contractions: .74 ● Alpha amplitudes before contractions vs after contractions: .92 ● Alpha amplitudes during contractions vs after contractions: 1.27	Right-handed participants only (assesse via Edinburgh Handedness Inventory)
Gable, Pool & Cook (2013)	● Errors to local targets after left vs. right hemisphere activation: .51 ● Errors to global targets after left vs. right hemisphere activation: .3	Right-handed participants only (assessed via self-report)
Goldstein, Revivo, Kreitler, & Metuki (2010)	● Line bisection index following right vs. left hand contractions: .74 ● Post-test line bisection trials: .83 ● Left hand contraction group vs. right hand contraction group: .59 ● Left hand contraction group vs. control group: .032	*Right-handed participants only (assessment not stated)

Authors	**Effect Size (Cohen’s d, unless otherwise stated)**	**Controlled for Handedness of Participants**
Harlé & Sanfey (2015).	● Effect size, mean, SD not listed.	*Right-handed participants only (assessment not stated)
Harmon-Jones (2006)	● Asymmetry following left vs. right hand contractions ○ Mid-frontal: .51 ○ Lateral frontal: .004 ○ Anterior temporal: .39 ○ Central: .53 ○ Parietal: .51 ○ Posterior temporal: .27 *Effect size, r	Right-handed participants only (assessment not stated)
Hoskens, Masters, Capio, Cooke, & Uiga, (2021)	● Self-report technique change ○ Left vs. Right: .11 ○ Left vs. Control: .18 ○ Right vs. Control: .28 ● Recall accuracy ○ Left vs. Right: .38 ○ No listed SD for control group.	[2]*Right-handed participants only (assessed via self-report)
Liu, Shan, Zhang, Sahgal, Brown, & Yue (2003)	● Effect size, mean, SD not listed.	*11 right-handed and 1 left-handed (assessment not stated)
Mirifar, Cross-Villasana, Beckmann, & Ehrlenspiel (2020)	● Left dynamic handgrip pre- to post-test[4] ○ Frontal right- hemisphere: −0.41 ○ Frontal left-hemisphere: −0.47 ○ Temporal right-hemisphere: −0.56 ○ Temporal left-hemisphere: −0.62 ○ Sensorimotor right hemisphere: −0.50 ○ Sensorimotor left-hemisphere: −0.47 ○ Parietal Occipital-right-hemisphere: −0.60 ○ Parietal Occipital-left-hemisphere: −0.58 ● Right dynamic hand grip pre- to post-test ○ Frontal Right-hemisphere: 0.28 ○ Frontal Left-hemisphere: 0.17 ○ Temporal Right-hemisphere: 0.06 ○ Temporal Left-hemisphere: 0.08 ○ Sensorimotor right-hemisphere: 0.01 ○ Sensorimotor left-hemisphere: 0.08 ○ Parietal occipital-right-hemisphere: −0.21 ○ Parietal occipital left-hemisphere: 0.19 ● Electrodes pre- to post- test (left hand) ○ P2 - P1:−0.45 ○ F6 - F5: −0.43 ○ AF8 - AF7: 0.03 ● Electrodes pre- to post- test (right hand) ○ C6 - C5: 0.56 ○ T8 - T7: 0.43	Right-handed participants only (assessment not stated)
Moeck, Thomas & Takarangi (2020)	● Effect size, mean, SD not listed.	Right-handed participants only (assessed via Flinders Handedness Inventory)

Authors	**Effect Size (Cohen's d, unless otherwise stated)**	**Controlled for Handedness of Participants**
Nicholls, Bradshaw, & Mattingley (2001).	● Effect size, mean, SD not listed.	Right-handed participants only (assessed via Edinburgh Handedness Inventory)
Peterson, Shackman, & Harmon-Jones (2007)	● Effect on Aggression x Right Hand Clench: 3.05 ● Effect on Aggression x Left Hand Clench: 1.05 ● Left vs. Right Hand Contraction x Region ○ Frontal-polar: .09 ○ Midfrontal: .35 ○ Lateral-frontal (F7/8): .40 ○ Central (C3/4): .62 ○ Frontal-central (Fc3/4): .36 ○ Frontal-temporal (Ft7/8): .48 ○ Central-parietal (Cp3/4): .53 ○ Anterior temporal (T3/4): .43 ○ Posterior temporal (T5/6): .03 ○ Parietal (P3/4): .31 ○ Occipital (O1/2): .11 *Effect size, r	Right-handed participants only (assessment not stated)
Propper, McGraw, Brunyé & Weiss (2013)	● Written ○ Renc/Lrec vs. Lenc/Lrec: 1.19[5] ○ Renc/Lrec vs. Renc/Rrec: .84 ○ Renc/Lrec vs. Lenc/Rrec: 1.08 ○ NENR vs. Lenc/Lrec: .85 ○ NENR vs. Lenc/Rrec: .74 ● Hits ○ Renc/Lrec vs. Lenc/Lrec: 1.12 ○ Renc/Lrec vs. Lenc/Rrec: .98 ○ Renc/Lrec vs. Renc/Rrec: .64 ○ NENR vs. Lenc/Lrec: .90 ● Corrected scores ○ Renc/Lrec vs. Lenc/Lrec: .98 ○ Renc/Lrec vs. Lenc/Rrec: .81 ○ NENR vs. Lenc/Lrec: .82	*Right-handed participants only (assessed via Edinburgh Handedness Inventory)
Propper, Dodd, Christman, & Brunyé (2016)	● Left hemisphere O2Hb left vs. right clench: .71 ● Left hemisphere O2Hb Post clench: .9 ● Left vs. Right hemisphere O2Hb - Left hand clench: .32 ● Post-Left Clench: Left vs. Right hemisphere O2Hb: .2 ● Left vs. Right hemisphere O2Hb - Right hand clench: .53 ● Post-Right Clench: Left vs. Right hemisphere O2Hb: .67 ● Sadness - Baseline vs. Post-Left Clench: .45 ● Sadness - Baseline vs. Post-Right Clench: .25 ● Nervousness- Left hand vs. Right hand Post-Clench: .94 ● Calmness - Baseline vs. Post-Clench: .47	Right-handed participants only (assessed via self-report and Edinburgh Handedness Inventory)
Prunier, Christman, & Jasper (2017)	● Effect size, mean, SD not listed.	*Consistent vs Inconsistent handers (assessed via Edinburgh Handedness Inventory)
Rominger, Papousek, Fink, & Weiss (2014).	● Global figural creativity index x Pre and Post- Left-hand Contractions: .22 ● Global figural creativity index x Pre and Post- Right-hand Contractions: .1	Right-handed participant only (assessed via standardized hand skill test)

Authors	**Effect Size (Cohen's d, unless otherwise stated)**	**Controlled for Handedness of Participants**
Schiff & Truchon (1993)	● Left negative ○ Left vs. right hand: .69 ○ Left hand vs. control: .17 ○ Right vs. control: .51 ○ Left vs. overall: .34 ○ Right vs. overall: .36 ○ Control vs. overall: .16 ● Left Positive ○ Left vs. right hand: .2 ○ Left hand vs. control: .25 ○ Right vs. control: .04 ○ Left vs. overall: .15 ○ Right vs. overall: .06 ○ Control vs. overall: .08 ● Overall ○ Left vs. right hand: .25 ○ Left hand vs. control: .13 ○ Right vs. control: .38 ○ Left vs. overall: .03 ○ Right vs. overall: .02 ○ Control vs. overall: .17	*Right-handed participants only (assessed via six-item hand-usage questionnaire modeled after Porac and Coren (1981))
Schiff & Lamon (1994)	● Effect size, mean, SD not listed.	*Right-handed participants only (assessed via six-item hand-usage questionnaire modeled after Porac and Coren (1981))
Schiff, Guirguis, Kenwood & Herman (1998)	● Experiment 2 ○ Puzzle 1 - Left vs Right: .7 ○ Puzzle 1 - Left vs Control: .87 ○ Puzzle 1 - Control vs Right: 1.25 ○ Puzzle 2 - Left vs. Right: .89 ○ Puzzle 2 - Left vs Control: .88 ○ Puzzle 2 - Control vs Right: 1.29 ○ Puzzles 1&2- Left vs. Right: .89 ○ Puzzles 1&2 - Left vs Control: .99 ○ Puzzles 1&2 - Control vs Right: 1.43 ● Experiment 2 ○ Puzzle 1 - Left vs Right: .62 ○ Puzzle 2 - Left vs. Right: .88 ○ Puzzles 1& 2- Left vs. Right: .83	*Right-handed participants only (assessed via six-item hand-usage questionnaire modeled after Porac and Coren (1981))
Stankovic & Nesic (2019)	Intrahemispheric Condition: Match Trials ● Perception accuracy on the face-matching task ○ Happy vs. sad faces: 10.0 ○ Happy vs. neutral faces: 2.0 ○ Sad vs. neutral faces: 8.0 ● Reaction times on the face-matching task ○ Happy vs. sad faces: 3.09 ○ Right visual field vs. Left visual field: 1.50 Intrahemispheric Condition: Mismatch Trials ● Perception accuracy on the face-matching task	Right-handed participants only (assessed via Edinburgh Handedness Inventory)

	○ Left visual field vs. Right visual field: 2.0 Interhemispheric Condition: Match Trials ● Perception accuracy on the face-matching task ○ Happy vs. sad faces: 9.0 ○ Happy vs. neutral faces: 3.0 ○ Sad vs. neutral faces: 6.0 ● Reaction times on the face-matching task ○ Happy vs. sad faces: 5.09 ○ Happy vs. neutral faces: 6.2 ○ Sad vs. neutral faces: 1.0 Interhemispheric Condition: Mismatch Trials ● Visual field accuracy on the face-matching task ○ Across field vs. within field: 2.53	
Turner, Hahn, & Kellogg (2016)	● Line bisection task - Experiment 1 ○ Left vs. Right: .41 ○ Left vs. Control: .27 ○ Right vs. Control: .17 ● Line bisection task - Experiment 2 ○ Left vs. Right: 2.47 ○ Left vs. Control: 1.47 ○ Right vs. Control: 1.08 ● Line bisection task - Overall ○ Left vs. Right: 1.32 ○ Left vs. Control: .76 ○ Right vs. Control: .64	*Mixed-handed individuals and right-handed individuals (assessed via Edinburgh Handedness Inventory)
Walz, Doppl, Kaza, Roschka, Platz, & Lotze (2015)	● Effect size, mean, SD not listed.	Right-handed participants only (assessed via Edinburgh Handedness Inventory)

5. DISCUSSION

Sustained unilateral hand clenching demonstrates an impact on cognition and emotion in a manner aligned with known hemispheric lateralization of functions. Via increased activity of one versus the other hemisphere, sustained unilateral hand clenching may result in a processing bias toward the more activated, contralateral, hemi-cortex, and to a hemisphere-concordant change in behavior.

Three of the 24 studies (12.5%) found no effect of UHC. Several different rationales for these discrepant findings have been proposed, and include the possibilities that hemispheric activation was not achieved, or that the processes investigated used tasks that do not demonstrate sufficient lateralization. For example, Nicholls, Bradshaw, and Mattingley (2001) proposed that it may be possible that the general weakness of right hemisphere lateralization of spatial functions (here, measured via line bisection and discrimination of brightness), combined with the strong leftward bias for gray scales may have partly been responsible for null effects.

After completing six experiments, Moeck, Thomas, and Takarangi (2019) found that intermittent UHC had no effect on visuospatial attention asymmetries, as measured by a landmark test during and after UHC. Moeck, Thomas, and Takarangi (2019) argued there were no effects of UHC because the landmark test could be insensitive to changes in hemispheric activation that result from UHC. Thus, task characteristics could result in Type II error. Moeck, Thomas, and Takarangi (2019) further suggested muscle innervation itself could impact performance as a function of contralateral versus ipsilateral hand clench.

Finally, Hoskens, Masters, Capio, Cooke, and Uiga (2021) reported no effect of UHC on self-report or objective measures of verbal-analytical engagement. In fact, unlike other studies performance for hand contraction groups was worse than control groups. It was suggested that the UHC did not induce hemispheric asymmetry, a suggestion supported by findings from the line bisection results, which demonstrated no effect of hand clenching condition. Therefore, null findings in the three unilateral hand clenching studies may reflect, at the least, lack of hemispheric activation or lack of lateralization of functions examined.

Overall, there is some degree of consistency between studies in methodological instructions for clenching. The majority used a ball and required participants to squeeze it as hard as possible, for varying amounts of time, for varying numbers of repetitions. The idiosyncratic nature of other instructions makes between-study comparisons difficult; however it is notable that despite these inconsistencies in methodologies there is remarkable agreement between the reported results. Neurophysiological mechanisms underlying the impacts of unilateral hand clenching on performance have been proposed, and different techniques have been supportive of the hemispheric activation theory of UHC action.

It is notable that most of the literature reviewed here used both some form of control group and additionally controlled for other potential confounds, such as hand-use preference. Additionally the effect sizes within the literature for the impacts of hand clenching are, overall, very high. Taken as a whole, the research supports an impact of hand clenching on emotion, cognition, and performance, and has potential as a therapeutic adjunct.

6. FUTURE RESEARCH DIRECTIONS

Future research should examine the utility of unilateral hand clenching on cognition and emotion in clinical settings and populations. Sustained unilateral hand clenching might be a useful adjunct to traditional therapies in these circumstances. Future work should consider using a standardized method of hand clenching in order to further compare results between studies. One limitation of generalizing previous findings is that research mainly addresses young adults between the ages of 18 and 50. Future work should consider studying the effects of UHC on both younger and older populations. Older adults demonstrate greater inter-hemispheric interaction, which is generally thought to combat the effects of aging on cognitive processes (Fling, Peltier, Bo, Welsh, and Seidler, 2011). Children younger than age 10, on the other hand, tend to have decreased inter-hemispheric interaction (Banich, Passarotti, & Janes , 2010). How, and if, unilateral hand clenching would interact with these different cortical organizations could help to elucidate not only the impact of hand clenching on performance, but also brain mechanisms involved in lateralization generally (e.g., inhibitory versus excitatory colossally mediated hemispheric interaction).

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ENDNOTES

[1] Right Encoding/Right retrieval [R/R], Right Encoding/Left retrieval [R/L], Left Encoding/Left retrieval [L/L], Left Encoding/Right retrieval [L/R], None Encoding/None retrieval [N/N]

[2] Studies with a * denote the inclusion of a control condition in addition to controlling for hand dominance.

[3] The Edinburgh Handedness Inventory and Flinders Handedness survey are assessments intended to measure hand dominance in everyday activities.

[4] Effect sizes calculated by Mirifar, Cross-Villasana, Beckmann, & Ehrlenspiel (2020)

[5] Right Encoding/Right recall [Renc/Rrec], Right Encoding/Left recall [Renc/Lrec], Left Encoding/Left recall [Lenc/Lrec], Left Encoding/Right recall [Lenc/Rrec], None Encoding/None recall [NENR]