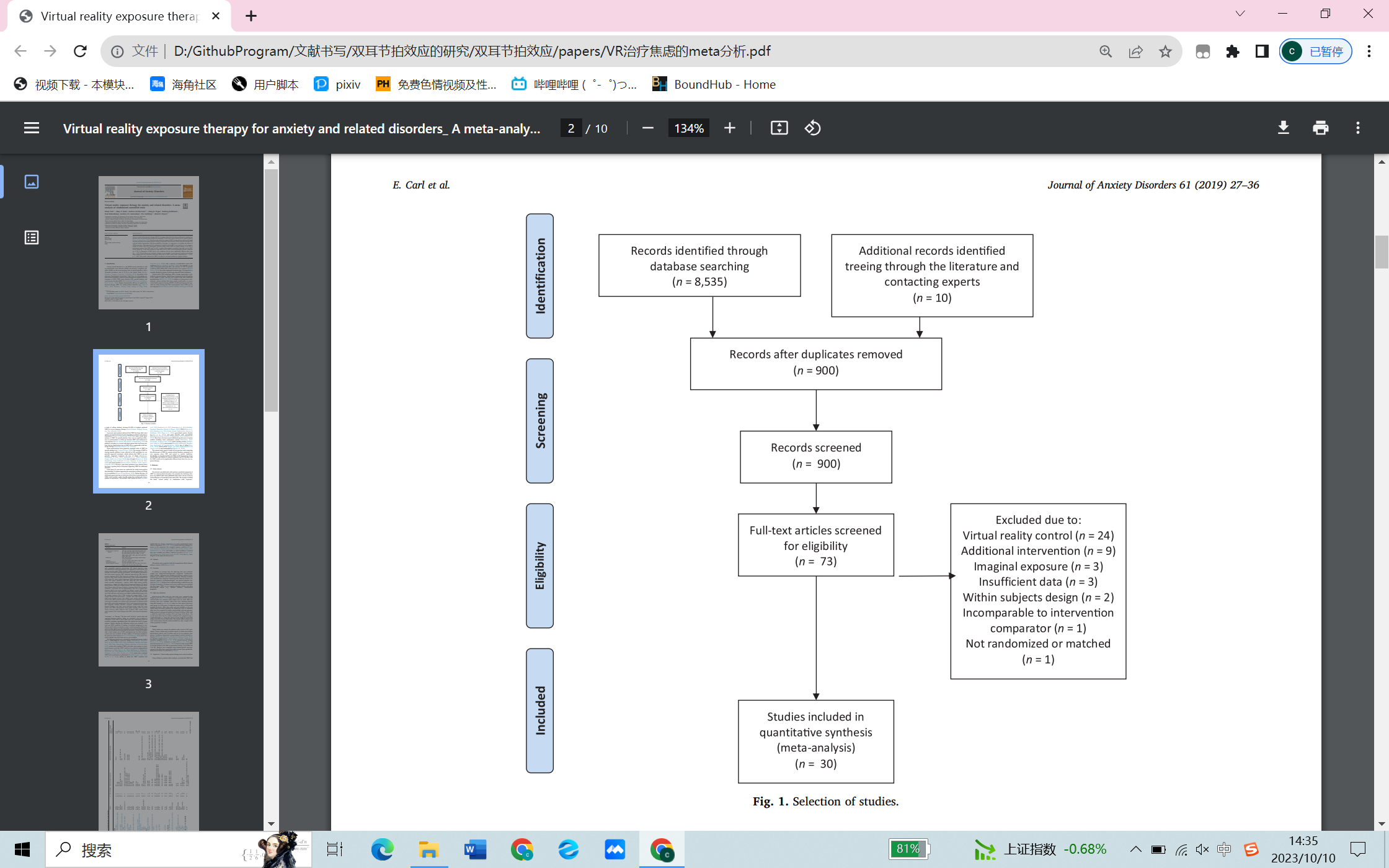
Efficacy of binaural auditory beats in anxiety and anxiety : a meta-analysis



**Methods**

**Literature search strategy**

We performed a systematic search on PubMed22 (Medline), Cochrane Library62, Web of Science20 and Embase75 databases to identify relevant studies on the subject. The search was limited to English language papers, using the keywords ”auditory beats”, ”binaural beats” , ”binaural auditory beats”,“brainwave entrainment”,”binaural lstimulation”,”hemispheric synchronization”and were searched in these databases up to June 2023. The flowchart of the meta-analysis is displayed in Fig. 1.

Two authors (Lian Cheng and reng qingqing) independently reviewed the retrieved studies, rating results were compared, and where differences were noted, they were discussed and reconciled. The methodology, design, features, and results of each study were described and coded by the first author.

**Inclusion and exclusion criteria**

To be included in the meta-analysis, studies had to fulfill four criteria: (1) use of binaural auditory beats as treatment or experimental manipulated factor; (2) experimental studies; (3) application of binaural beats in practical areas and where the number of studies in each area is at least three; and (4) the studies provided sufficient information to extract effect sizes (ES) from descriptive or inferential statistics.

Risk of bias

The risk of bias for each included study was assessed using the criteria suggested in the Cochrane Handbook for Systematic Reviews of Interventions.16 This guideline uses the following 7 domains to evaluate the risk of bias: (1) random sequence generation; (2) allocation concealment; (3) blinding of participants and personnel; (4) blinding of outcome assessment; (5) incomplete outcome data; (6) selective reporting; and (7) other bias. The 2 reviewers (S.J.W. and A.T.L.) individually assessed the risk of bias and categorized each study's risk of bias as “low,” “high,” or “unclear.” Any disagreements between the reviewers were resolved with discussion involving the third author (Dingyang).

**Data extraction**

The following information was extracted from the studies that met the inclusion criteria: surname of the first author, year of publication, study design, type of participant, binaural-beat frequency used, time under exposure, moment of exposure, comparison group, type of sound used to mask the binaural beat (if any), number of participants in each condition, and outcome measurement.

The literature search yielded 68 studies of which 43 were excluded since the studies did not meet the inclusion criteria for the meta-analysis. Three additional studies could not be included as the reported data were insufficient for the calculation of effect sizes. This resulted in a total of 22 studies (k = 35 ESs) that were included in the present analysis.

**Quality assessment**

The frst author conducted a quality assessment for each potentially relevant study before including them for the fnal analysis. The quality assessment was based on the following methodological questions: (a) randomization or double blinding; (b) sample characteristics; (c) presence of control or a comparison group or a baseline measurement; (d) detailed process of the BB intervention; and (e) validity of assessments to measure the outcome variables (GarciaArgibay et al., 2019b). Only those studies that reported the information mentioned above were included for the fnal meta-analysis.

**Statistical analysis**

**Efect size calculation**

Since most studies had a small sample size and continuous outcome variables, we used Hedge’s g to calculate the efect sizes of each outcome of the study (Harrer et al., 2019). If the study had more than one outcome, we used a separate table to calculate their efect sizes (Basu, 2017). In some studies, the efect size was drawn from the mean diferences and standard deviations, while in other cases, it was drawn from the respective p (independent t tests) and f values (one-way ANOVA tests). Table 1 summarizes the study, subgroup, sample sizes (participants in experimental and control conditions), Hedges’ g, and variance of the efect size for the included studies in the meta-analysis.

**Analysis**

All computations were conducted in the RStudio software version 3.4.1. The R codes for the analysis are attached in Appendix. The computations for the efect sizes were conducted using the compute.es package. We estimated efect size g and its variance for each study using the meta package. A random-efects model with Restricted Maximum Likelihood Estimation (REML) was computed since the treatment efects of the selected studies were not identical in the population (Harrer et al., 2019). The treatment efects varied in terms of duration of the BB intervention, frequencies, and comparison tones. REML estimations were utilized as they do not underestimate the variance (Garcia-Argibay et al., 2019b; Thompson & Sharp, 1999).

Further, we conducted a moderator analysis to evaluate whether the entrainment efect difers between attention and memory studies (Polanin, 2021). We installed the metafor, dplyr, robumeta, and clubSandwch packages. Moderator analysis was also conducted on the moderators identifed through systematic review of the selected studies, such as frequency of the intervention, masking noise, entrainment type, and number of participants in the experimental and control groups. The fndings of the moderator analysis assisted in providing information regarding the moderator’s statistical signifcance. Meta-regression was also conducted to examine the relationship between the multiple variables in the selected studies and their efect sizes, using the REML estimator (Polanin, 2021). The probable infuence of publication bias was assessed with the funnel plot and Egger’s test of the intercept (Harrer et al., 2019).

To visualize a lack of studies with small efect sizes, we generated a funnel plot on RStudio software, using funnel(). To quantify the funnel plot, we performed the Egger’s test using the dmetar package.

The fndings are discussed in light of both systematic review and meta-analysis of the selected studies.

**Result**

((binaural beats) OR (auditory beats) OR (brainwave entrainment) OR (binaural therapy) OR (binaural tones) OR (binaural therapy) OR (binaural stimulation) OR (hemispheric synchronization))AND ((mental disorders) OR (psychiatric disorders) OR (psychological disorders) OR (mental illness) OR (psychiatric conditions) OR (Post-traumatic stress disorder) OR (Schizophrenia) OR (Depression OR Anxiety disorders) OR (Bipolar disorder) OR (Attention-deficit/hyperactivity disorder))

双耳节拍

10HZ缓解抑郁[1]

256 Hz的声学频率和另一只耳朵的260 Hz[2]减轻结肠镜检查的不适感。

[1] P. Daengruan, R. Chairat, R. Jenraumjit, D. Chinwong, A. Oon-Arom, J. Klaphajone, P. Arunmanakul, Effectiveness of Receptive Music Therapy with Imbedded 10 Hz Binaural Beats Compared with Standard Care for Patients with Major Depressive Disorder: A Randomized Controlled Trial, Complement Ther Med 61 (2021) 102765.

[2] A. Tani, G. Tartarisco, G. Vagheggini, C. Vaccaro, S. Campana, F. Tomaiuolo, Binaural beats reduce feeling of pain and discomfort during colonoscopy procedure in not-sedated patients: A randomized control trial, Complement Ther Clin Pract 48 (2022) 101605.