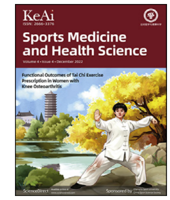
Sports Medicine and Health Science 4 (2022) 267–274

Contents lists available at ScienceDirect

Sports Medicine and Health Science

journal homepage: www.keaipublishing.com/en/journals/sports-medicine-and-health-science/



Original Article

Psychophysiological effects of rhythmic music combined with aerobic exercise in college students with minimal depressive symptoms

Ping Yang [a,b], Hui Yang [c,b], Yang Cao [b], Xin Yang [b], Benxiang He [a,*]

[a] Postdoctoral Research Mobile Station of Sports Science, Chengdu Sport University, No.2, Tiyuan Road, Chengdu, Sichuan, 610041, China
[b] Department of Physical Education, Shangrao Normal University, No. 401, Zhimin Road, Shangrao, Jiangxi, 334001, China
[c] Department of Physical Education, Jiangxi Science and Technology Normal University, No. 589, Xuefu Avenue, Hongjiaozhou Campus, Nanchang, Jiangxi, 330036, China

A R T I C L E I N F O

Keywords:
Multimodal intervention
Depression
Aerobic exercise
Rhythmic music
Attentional bias

A B S T R A C T

Mental health problems are common during the transition from adolescence to young adulthood. Previous studies reported that rhythmic music plus aerobic exercise can have a beneficial effect on emotional state. We examined whether the beneficial effect differed between aerobic exercise interventions with or without rhythmic music. A sample of 94 college students who either had no depressive symptoms ($n = 47$) or minimal depressive symptoms ($n = 47$) underwent 30-min interventions in a randomized and counterbalanced order: rest, rhythmic music, aerobic exercise and aerobic exercise plus rhythmic music. Response time and accuracy of selective attention to positive and negative images were recorded using the spatial cueing paradigm. Participants' heart rate during all conditions and perceived exertion after each condition were measured to clarify physiological and perceptual responses, respectively. The results revealed that a multimodal intervention combining aerobic exercise and rhythmic music had a significant facilitatory effect on attentional bias to positive emotional cues in minimal depressive participants ($t = -2.336$, $p = 0.024$), including less perceived exertion and higher heart rate after/during the intervention process. The single-modality intervention of aerobic exercise had significant positive effects for individuals with no depressive symptoms ($t = -2.510$, $p = 0.016$). The multimodal intervention was more effective than the single-modality intervention for individuals with minimal depressive symptoms, but the single-modality aerobic exercise intervention was more effective for individuals with no depressive symptoms, providing new evidence for the specificity of the intervention effect for people with different degrees of depressive symptoms.

Introduction

Mental health problems are common during the transition from adolescence to young adulthood.[1] College students typically undergo a critical transition period from family life with parents to an independent lifestyle, resulting in changes in psychological and cognitive characteristics.[2] This transition period has been suggested to put college students at an increased risk of mental disorders, such as depression.[3] Depressive symptoms occur more frequently in the early years of undergraduate study.[4] Effective interventions for prevention and intervention may protect against unhealthy emotional symptoms during this transition period.

A large number of studies have examined emotional regulation in patients with depression. For example, exercise, music, and video stimuli were all reported to be effective for regulating depression.[5–7] However, emotional attention characteristics changed gradually with the illness course of depression.[8] Even minimal symptoms of depression increase mortality risk after acute myocardial infarction.[9] Analysis of the difference in intervention effects between different emotional states is helpful for selecting targeted intervention approaches in specific stages of mental illness.[10] Therefore, in the early stages of depression, timely and effective intervention may be beneficial for controlling the course of the disease.

A single aerobic exercise session has been reported to be an effective approach for increasing emotional regulatory capacity among individuals at risk of, or currently experiencing, depression,[7] and music is reported to have beneficial effects for short- and medium-term depression symptoms.[6] Multimodal interventions, such as combined video and music stimuli,[5] or adding music to traditional treatment,[11] have been reported to have more beneficial effects on emotional regulation than

* Corresponding author. No.2, Tiyuan Road, Chengdu, Sichuan, 610041, China.
E-mail addresses: yangpingsrnu@163.com (P. Yang), 1210075193@qq.com (B. He).

https://doi.org/10.1016/j.smhs.2022.03.004
Received 28 November 2021; Received in revised form 25 February 2022; Accepted 11 March 2022
Available online 7 April 2022

Abbreviations

ANOVA	analysis of variance
BDI	Beck Depression Inventory
BL	baseline
BMI	body mass index
BPM	beats per minute
CAPS	Chinese affective picture system
EI	exercise intervention
EM	exercise plus music intervention
HR	heart rate
$kg.m^{-2}$	kilograms per meter squared
MDS	minimal depressive symptoms
MI	music intervention
NDS	no depressive symptoms
RPE	rate of perceived exertion
VO_{2max}	maximal oxygen consumption

single-modality interventions. Unfortunately, few studies have examined the impacts of multimodal interventions, such as the effects of combining exercise and music on emotional regulation in new college students with minimal depressive symptoms.

Impaired cognitive control in response to emotional information plays a critical role in the development and maintenance of depression and underlies emotion regulation problems that characterize depressed individuals.[12] Evidence suggests that early improvements in emotional processing, a commonly observed cognitive deficit in depression, can predict later clinical responses to interventions.[13] Therefore, emotional processing could be used to examine responses to emotional information. Individuals who are attending to the regulation of their emotional state generally pay less attention to negative than positive images,[14] whereas those in negative emotional states exhibit enhanced attention to negative events.[15] Attentional processes controlling spatial cueing effects may be stimulus-driven,[16] and can be modulated by emotional cues,[17] suggesting that the emotional-spatial cueing task could potentially be used to detect selective attentional changes after psychophysiological modulation. The emotional-spatial cueing task was applied to detect selective attentional bias to positive and negative information in college students with optimistic and pessimistic attributional styles.[18] Thus, this method could potentially be used to reveal the characteristics of attentional bias to emotional information after interventions.

Using the spatial cueing paradigm, the response time and accuracy of selective attention in relation to positive and negative images were recorded in new college students after 30 min of rest, rhythmic music, aerobic exercise, and aerobic exercise plus rhythmic music interventions. We sought to address the following research questions: (1) Does multimodal intervention comprising physiological exercise combined with auditory stimulation and single modality interventions have disparate effects on new college students with minimal depressive symptoms? (2) Does a multimodal intervention cause less exercise fatigue than each single-modality intervention alone?

Materials and methods

Participants

We recruited 103 new college students to participate in this study. All participants were right-handed and had a normal or corrected-to-normal vision. All participants were free from negative lifestyle characteristics, major neurological disorders, medical problems, psychiatric disorders, medication, and regular exercise habits at the time of the experimental period. In addition, all participants were receptive to strong rhythmic music and 30 min of exercise through the Physical Activity Readiness Questionnaire, which is designed to provide sufficient pre-activity screening to detect potential risk factors that might be exacerbated by acute exercise. Participants who did not meet the requirements above were excluded. The study procedure complied with the directives of the Helsinki Declaration. Participants were informed about the study and the experimental procedures before they signed an informed consent form. All participants provided written informed consent via a process that was approved by the Institutional Review Board of Shangrao Normal University.

To examine participants' personality characteristics and emotional state, all participants were required to complete the trait anxiety subscale of the State-Trait Anxiety Inventory (STAI),[19,20] and the Beck Depression Inventory (BDI)-II.[21,22] According to the cut-off scores on the BDI-II suggested by Beck, scores of less than 5 indicate an absence of depression, scores of 5–13 indicate minimal depression, scores of 14–19 indicate mild depression, scores of 20–28 indicate moderate depression, and scores over 28 indicate severe depression.[21] Five participants were excluded from further procedures because their BDI scores were higher than 14, and four participants withdrew from the study because they did not complete the procedures. Valid data were obtained from 94 participants who completed the whole study. Therefore, 47 participants were allocated to a group with no depressive symptoms (NDS, BDI $\leq$4), and 47 participants were allocated to a group with minimal depressive symptoms (MDS, 5 $\leq$ BDI $\leq$13) (Table 1). All the intervention and behavioral tests were designed to be double-blind so that the experimenters and participants understood the experimental procedures but not the purpose of the study.

Interventions

The present study applied a within-subjects design with a counterbalanced order to minimize learning effects. Attentional bias was examined individually in the laboratory while participants performed an emotional information task in four separate sessions with a 7-day interval. The sessions took place at the same time of day at each visit. The baseline (BL) session consisted of 30 min of quiet rest while seated. The music intervention (MI) session included 30 min of music listening, consisting of eight pieces of strongly rhythmic instrumental music with an average tempo of 128.01 bpm (beats per minute) in a randomized order. The eight pieces of music were downloaded from a music website,[23] and the identification numbers for the music pieces were 107566, 129299, 159352, 159911, 159913, 160189, 160239, 160240 on the website. The exercise intervention (EI) session comprised a 5-min warm-up period followed by cycling exercise for 20 min and a 5-min cool-down period. The exercise plus music intervention (EM) session combined both MI and EI simultaneously. The intensity of acute aerobic exercise was set at 60%–70% of the estimated maximal heart rate (calculated as 220 minus age, approximately 120–140 bpm). The participant's heart rate was assessed with a heart rate monitor (Polar Team 2, Finland) during MI, EI and EM, with the sampling rate set to one sample per second throughout the experimental process. The mean, maximum

Table 1
Participant demographics.

	None depressive symptom	Minimal depressive symptoms
No. of participants (% of males)	47(80.85%)	47(78.72%)
Mean age (years)	19.66 ± 0.92	19.96 ± 0.83
BMI ($kg.m^{-2}$)	21.16 ± 1.40	21.58 ± 1.64
VO_{2max}	46.39 ± 8.65	46.70 ± 7.59
Anxiety score	41.09 ± 6.36	42.96 ± 6.78
Depression score	1.26 ± 1.553	7.72 ± 2.36*

*$p < 0.05$.
Abbreviations: BMI, body mass index; $kg.m^{-2}$, kilograms per meter squared; VO_{2max}, maximal oxygen consumption.

and coefficient variation of heart rate were calculated during 30 min of the MI, EI, and EM interventions.

Perceptual measurement

The rate of perceived exertion (RPE) Omni scale was used as a measure for quantifying the perceived load imposed by the exercise session in the experimental conditions.[24] The RPE has been widely employed in the field of sport and exercise science as a means of measuring exertion responses (e.g., limb discomfort and breathlessness).[25] The values for perception were presented as scores out of 11 points (0–10), in which zero indicates that participants perceived the task as extremely easy and 10 indicates a maximal level of effort. Some participants felt fatigued during 30 min of cycling, and needed to be encouraged to reach the target heart rate. Participants were asked to complete the RPE Omni scale immediately after each intervention session, to evaluate their effort during the music, exercise, and exercise combined with music interventions.

Attentional bias measures

Following each intervention session, participants were instructed to conduct the attentional bias task within 15 min. The spatial cueing paradigm was programmed using E-Prime 2.0 to assess attentional bias to emotional information. Participants were told that they would be watching pictures on a computer monitor located approximately 70 cm in front of their eyes. The stimulus presentation procedure was as follows (Fig. 1A).

At the beginning of each trial, a black cross (0.7 cm × 0.7 cm) on a white background was presented at the center of the screen for a random duration between 500 and 1000 ms. An emotional image (positive or negative) was then presented for 200 ms randomly at either the left or right side of the fixation cross, and served as a location cue. If the target stimuli appeared on the same side as the cue, it was called a valid cue presentation; if the target stimuli appeared on the opposite side with the cue, it was considered an invalid cue presentation (2/3 were valid cues and 1/3 were invalid cues). The center of the cue was located at the same horizontal level with the fixation black cross. The vertical visual angle of 7.4° and the horizontal angle of 9.8° of the cue was set from the participant's perspective (Fig. 1B). After providing the cue image, the fixation cross appeared for 100 ms, and the target point located at the same horizontal level with the black cross was presented for 200 ms randomly at either the left or the right side of the fixation cross (Fig. 1C). Participants were instructed to press the “F” or “J” key on the keyboard using their index finger according to the position of the target point as quickly and accurately as possible. The screen was cleared when a key was pressed by the participant; otherwise, the black cross remained for a maximum of 1500 ms after the offset of the target point.[18,26]

Emotional images

A series of 240 images were selected from the Chinese Affective Picture System (CAPS)[27] as the experimental stimuli, including 120 positive and 120 negative pictures. Because the main goal of our study was to investigate the impacts of the interventions on selective attention to emotional categories (negative vs. positive pictures), we deliberately did not include neutral pictures in the procedure. Before the formal experiment, participants were allowed to practice the cue-target experiment until they were familiar with the procedural rules. The pictures used in the practice stage were not reused in the formal experiment. The whole experiment consisted of 240 trials, and the ratio of valid trials to invalid trials was 2:1. A break was given after 80 trials.

Statistical analysis

Trials with errors and response times that were more than three standard deviations from the mean were discarded (approximately 2% of all observations).[28] The maximum, mean, and coefficient of variation of the heart rate and the RPE score were analyzed using two-way analysis of variance (ANOVA) with the factors “intervention” (BL, MI, EI and EM) and “group” (no depressive symptoms, NDS vs. minimal depressive symptoms, MDS). The response time and accuracy were statistically analyzed using a four-way repeated-measures ANOVA with the variables “group” (NDS vs. MDS), “cue” (valid vs. invalid), “image” (positive vs.

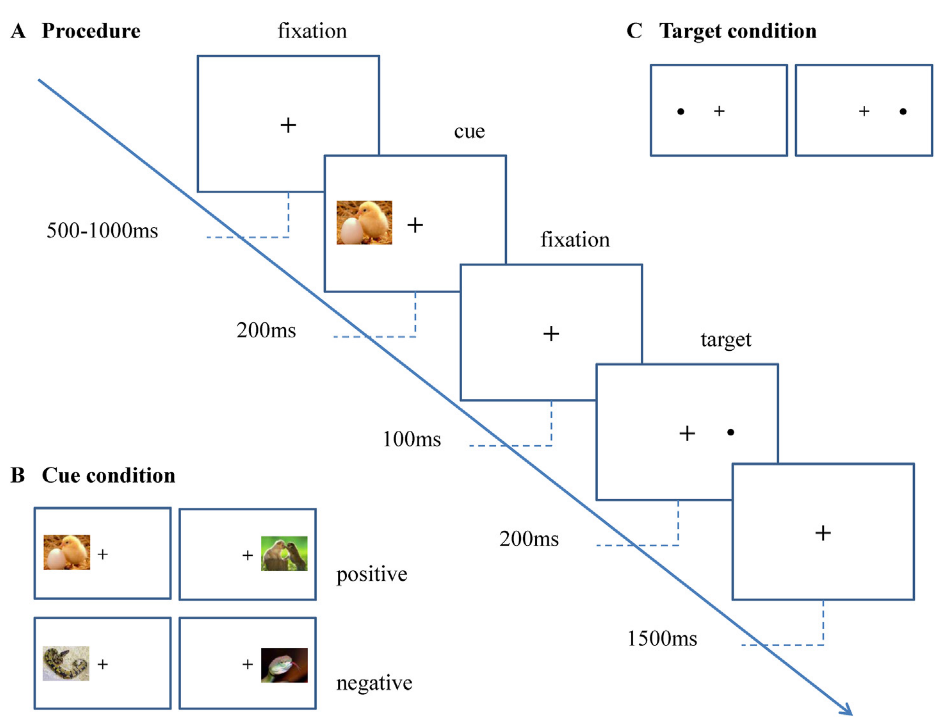


Fig. 1. Schematic of the cue-target paradigm.
(A) An example of the sequence of the invalid positive emotional cue experimental procedure; (B) four emotional cue conditions; and (C) target condition.

Table 2
Heart rate and RPE score about the three interventions (mean ± *SD*).

		None depressive symptom	Minimal depressive symptoms
Mean HR(bpm)	MI	71.76 ± 6.69	72.21 ± 6.99
	EI	134.84 ± 9.04	134.77 ± 6.17
	EM	136.32 ± 5.81	137.03 ± 5.80
Maximum HR(bpm)	MI	94.49 ± 9.17	93.83 ± 9.08
	EI	153.96 ± 11.83	151.81 ± 8.27
	EM	155.03 ± 11.03	153.81 ± 10.27
Coefficient variation of HR	MI	0.08 ± 0.03	0.07 ± 0.02
	EI	0.05 ± 0.03	0.05 ± 0.02
	EM	0.05 ± 0.02	0.04 ± 0.02
RPE score	MI	1.70 ± 1.55	1.72 ± 1.28
	EI	4.00 ± 1.85	3.32 ± 1.85
	EM	3.49 ± 1.90	2.96 ± 1.57
BDI score	MI	1.30 ± 1.23	7.32 ± 2.26
	EI	1.49 ± 1.71	7.40 ± 2.53
	EM	1.96 ± 1.60	6.62 ± 2.37

Abbreviations: BDI, Beck Depression Inventory; HR, heart rate; MI, music intervention; EI, exercise intervention; EM, exercise plus music intervention; RPE, rate of perceived exertion.

negative), and "intervention" (BL, MI, EI and EM).

Both main effects and interactions were examined. Simple and simple-simple effect analyses were applied when dual and triple interactions were significant. Data were further analyzed for multiple comparisons using the Bonferroni correction. Greenhouse-Geisser ε values were employed when the Greenhouse-Geisser correction was necessary. The effect size was determined with Cohen's d for t-tests and partial η^2 for ANOVAs (Cohen's d or partial $\eta^2 = 0.20$ was considered to indicate a small effect size, 0.50 indicated a medium effect size, and 0.80 indicated a large effect size).[29,30] SPSS software (release 20.0) was used for statistical analysis. A significance level of $\alpha = 0.05$ was used in all comparisons.

Results

Heart rate during interventions and RPE,BDI score after interventions

The means and standard deviations of the mean, maximum, and coefficient of variation of heart rate, and the BDI score are presented for each intervention in Table 2. There were significant differences among interventions in mean heart rate, maximum heart rate, and coefficient of variation. The mean and maximum heart rates for EM and EI were significantly higher than that for MI ($F_{2,\,184} = 3089.845$, $p < 0.01$, $\eta^2 = 0.971$, $\varepsilon = 0.901$ for mean heart rate, Fig. 2A; $F_{2,\,184} = 1324.041$, $p < 0.01$, $\eta^2 = 0.935$ for maximum heart rate, Fig. 2B). The mean heart rate for EM was higher than that for EI, although this difference was marginally significant ($p = 0.053$, Fig. 2A). For the coefficient of variation of heart rate, MI exhibited significantly higher values than EI and EM ($F_{2,\,184} = 60.527$, $p < 0.01$, $\eta^2 = 0.397$; Fig. 2C).

For the RPE score after each intervention, a significant main effect was observed for the "intervention" factor ($F_{3,\,276} = 52.930$, $p < 0.01$, $\eta^2 = 0.365$, $\varepsilon = 0.734$). Multiple comparisons revealed that (1) RPE score after EI was significantly higher than that after EM, and (2) RPE score after EM was significantly higher than that after MI (Fig. 3, Table 2). No significant differences were found between groups for heart rate or RPE scores, and no significant interaction was found between "group" and "intervention". No significant differences were found for BDI scores.

Response time of selective attentional bias in processing emotional information

A significant main effect for response time was observed for the factors "cue" ($F_{3,\,276} = 52.930$, $p < 0.01$, $\eta^2 = 0.365$, $\varepsilon = 0.734$), "image" ($F_{1,\,92} = 9.493$, $p = 0.003$, $\eta^2 = 0.094$, $\varepsilon = 1$) and "intervention" ($F_{3,\,276} = 3.312$, $p = 0.025$, $\eta^2 = 0.035$, $\varepsilon = 0.908$). The interactions between "cue" and "group" ($F_{1,\,92} = 4.777$, $p = 0.031$, $\eta^2 = 0.049$), between "image" and "group" ($F_{1,\,92} = 6.575$, $p = 0.012$, $\eta^2 = 0.067$), between "cue" and "intervention" ($F_{3,\,276} = 3.004$, $p = 0.036$, $\eta^2 = 0.032$, $\varepsilon = 0.908$), and between "cue," "image" and "intervention" ($F_{3,\,276} = 4.042$, $p = 0.009$, $\eta^2 = 0.042$) were significant, and thus a simple-simple effects analysis was conducted.

Response times with valid cues were significantly shorter than those with invalid cues, regardless of group, image and intervention ($p < 0.01$). This finding is in accord with a previous report that valid spatial cue information facilitated responses to the target stimulus.[31]

A complex relationship among interventions was observed for different groups. For the NDS group, no significant differences were found among interventions ($p > 0.05$, Fig. 4A). For the MDS, response times after EM were significantly shorter than those of BL for both positive and negative images under valid ($F_{3,\,138} = 3.746$, $p = 0.020$, $\eta^2 = 0.075$, $\varepsilon = 0.798$ for positive image; $F_{3,\,138} = 4.966$, $p = 0.005$, $\eta^2 = 0.097$, $\varepsilon = 0.800$ for negative image, Fig. 4B) and invalid cue conditions ($F_{3,\,138} = 3.770$, $p = 0.019$, $\eta^2 = 0.076$, $\varepsilon = 0.801$ for positive image; $F_{3,\,138} = 3.010$, $p = 0.044$, $\eta^2 = 0.061$, $\varepsilon = 0.804$ for negative images, Fig. 4B).

For the NDS group, response times were significantly shorter for positive images than those for negative images under the invalid cue condition after the exercise intervention ($t = -2.510$, $p = 0.016$, Cohen's $d = 0.062$; Fig. 5A). For the MDS group, response times for positive images were significantly shorter than those for negative images under the invalid cue condition after the exercise plus music intervention ($t = -2.336$, $p = 0.024$, Cohen's $d = 0.079$; Fig. 5B).

Accuracy of selective attentional bias in processing emotional information

The main effect for the "cue" factor was significant ($F_{1,\,92} = 79.990$, $p < 0.01$, $\eta^2 = 0.465$, $\varepsilon = 1$). Multiple comparisons revealed that the accuracy for valid cues was significantly higher than that for invalid cues.

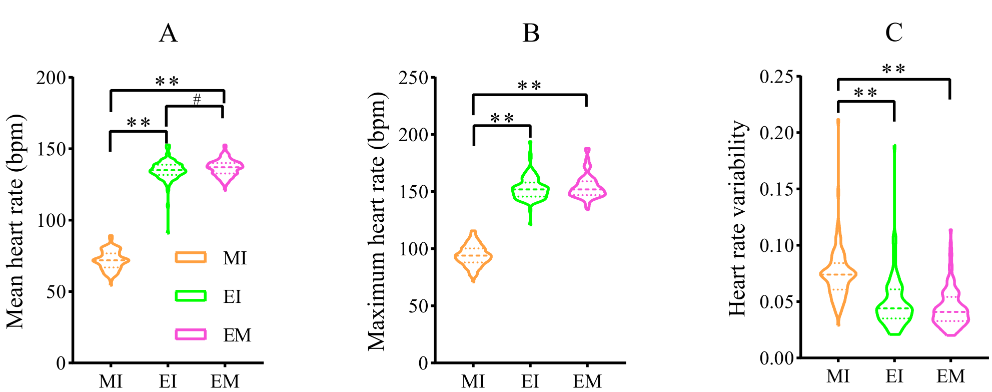


Fig. 2. Median and quartiles of heart rate during the MI, EI, and EM interventions.
A, mean heart rate; B, maximum heart rate; C, heart rate variability; MI, music intervention; EI, exercise intervention; EM, exercise plus music intervention. "**" indicates that the difference between interventions is extremely significant ($p < 0.01$), "#" indicates that the difference between interventions is marginally significant ($0.05 < p < 0.10$).

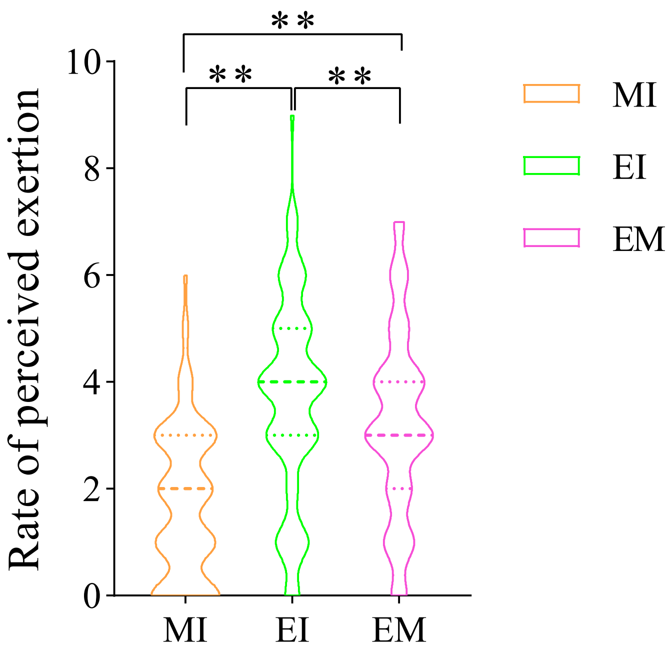


Fig. 3. Median and quartiles of rate of perceived exertion after MI, EI, and EM. MI, music intervention; EI, exercise intervention; EM, exercise plus music intervention. "**" indicates that the difference between interventions was extremely significant ($p < 0.01$).

This result was consistent with the notion that informative cues enhance perceptual representation, enabling observers to perform target identification more accurately in valid trials compared with invalid trials.[32]

Discussion

The spatial cueing paradigm was used to explore variations in attentional bias after interventions for individuals with minimal depressive symptoms. For this purpose, we examined how different intervention procedures influenced behavioral responses reflecting emotional attention after treatments, examining whether music stimulation combined with aerobic exercise can help individuals with minimal depression by improving emotional states.

Adding rhythmic music to exercise was superior to exercise alone for improving emotional attention

The results of the present study revealed that a multimodal intervention induced faster emotional attention responses compared with baseline (Fig. 4B). A similar study reported that music plus video stimuli led to the highest affective valence and enjoyment scores during and after exercise, regardless of intensity, on the basis of an assessment scale,[5] and a meta-analysis revealed that music therapy plus treatment as usual was more effective than treatment, as usual alone for improving both clinician-rated depressive symptoms and patient-reported depressive symptoms.[11] Emotional attention improvements were achieved with multimodal intervention (aerobic exercise plus rhythmic music), on the basis of behavioral response time to emotional images in the current

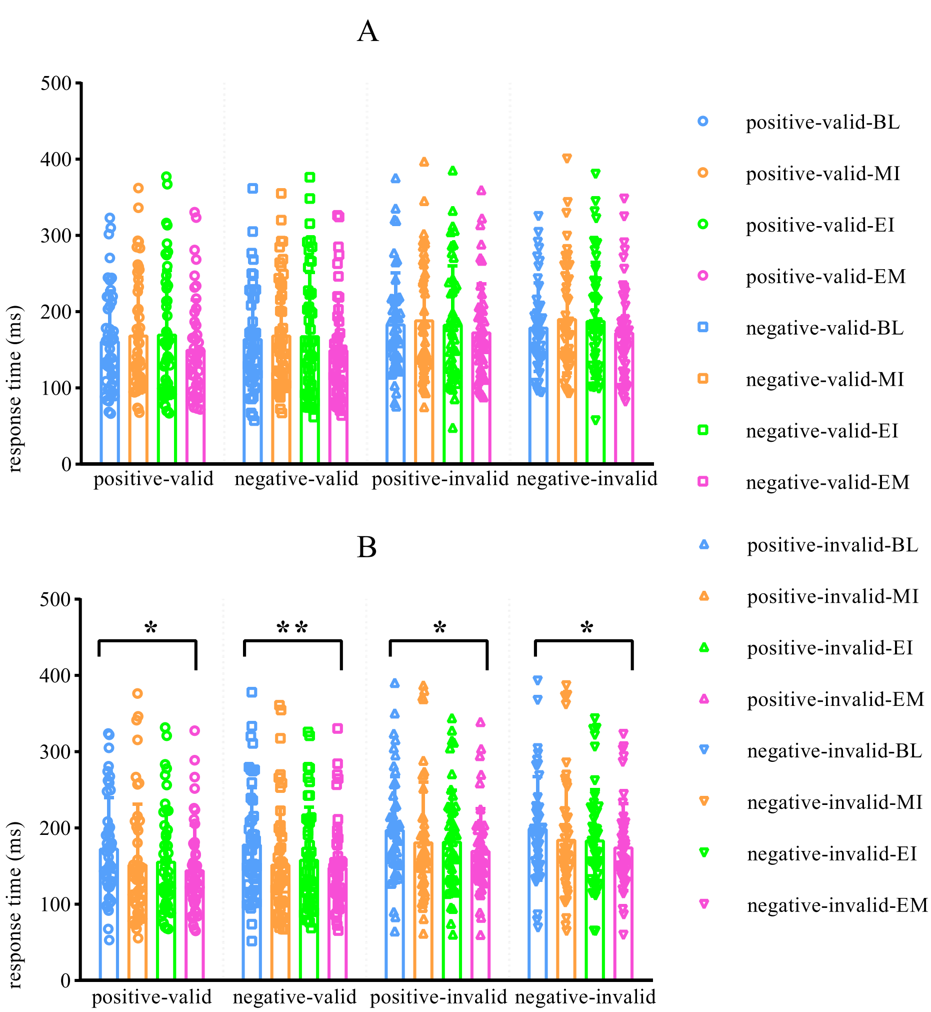


Fig. 4. Means and standard deviations for response times after different interventions in the group with no depressive symptoms (A), and the group with minimal depressive symptoms (B), with respect to positive and negative images under valid and invalid cue conditions.
BL, baseline; MI, music intervention; EI, exercise intervention; EM, exercise plus music intervention. The blue, orange, green, and pink circles (○) represent the response times of the positive emotional pictures served as valid cues after the intervention of BL, MI, EI, and EM, respectively; squares (□) represent the negative emotional picture served as valid cues; triangles (△) represent the positive emotional picture served as invalid cues; and inverted triangles(▽) represent the negative emotional picture served as an invalid cues. Each "*" indicates that the difference between BL and EM was significant ($p < 0.05$). "**" indicates that the difference between BL and EM was extremely significant ($p < 0.01$). Only significant differences discussed in the main text are shown.

study. Estimations with behavioral responses were less dependent on subjective preferences than the assessment scale, and thus more accurate.

It should be noted that positive effects of exercise have been observed not only in healthy individuals but also in those suffering from mood disorders.[33] These previous findings are not entirely consistent with the current findings of significant differences in response times between positive and negative emotional stimulation under invalid cue conditions after EI only in participants with no depressive symptoms (Fig. 5A), but not in those with minimal depressive symptoms (Fig. 5B). This difference between our findings and previous reports may have resulted from the different criteria of the BDI-II for grouping. For instance, previous studies used BDI scores below 9,[34] 12,[33] or 14[35] as criteria for remission of depressive symptoms, ignoring differences between participants with no depressive symptoms and those with minimal depressive symptoms.

The use of music therapy could improve and optimize the ability of college students to eliminate negative emotions, helping students develop a healthy psychological state.[36] Rhythmic music can entrain psychophysiological cadence during aerobic exercise.[37] A previous study reported that music with a strong beat entrained brain activity through increased activation of the bilateral caudate nucleus, and the consonance of music enhanced activity in attentional networks visualized by functional magnetic resonance imaging.[38] During exercise, music was found to up-regulate beta waves of brain electroencephalography, inducing more positive affective responses.[39] In addition, participants were reported to experience more positive affect in an isometric ankle-dorsiflexion task when music was presented, compared with performing the task without music.[40] Thus, adding rhythmic music to aerobic exercise may activate more brain areas related to positive emotional states.

The selective attentional bias to emotional information could be modulated by interventions combining music and aerobic exercise

Exercise is well known to enhance a variety of mood states. For instance, people were reported to experience less unpleasant or less intense negative feelings in response to emotional stimuli after aerobic exercise.[41] Acute exercise could reduce angry mood and mitigate angry mood induction through an index of event-related brain activity (e.g., early posterior negativity and late positive potential).[42] These results suggest that exercise, as an effective emotion regulation strategy, can play a positive role in emotional health interventions. Specifically, it is likely that decreases in negative feelings in response to emotional pictures after exercise might be associated with biased processing of positive emotional stimuli by attentional processes.[41] These previous studies are in accord with our findings that responses were faster to positive images compared with negative images under invalid cue conditions after the EI and EM interventions (Fig. 5A and B), suggesting that more resources were allocated to selective attention to positive emotional cues after the intervention.

Regarding cue validity, previous studies of selective attention using various paradigms (e.g., Stroop and flanker tasks) demonstrated that control over attentional processes can be cued rapidly and without awareness in response to processing of contextual features that are not directly task-relevant.[16] This result is consistent with the current finding that response times under valid cue conditions were significantly shorter than those under invalid cue conditions, regardless of groups, images,

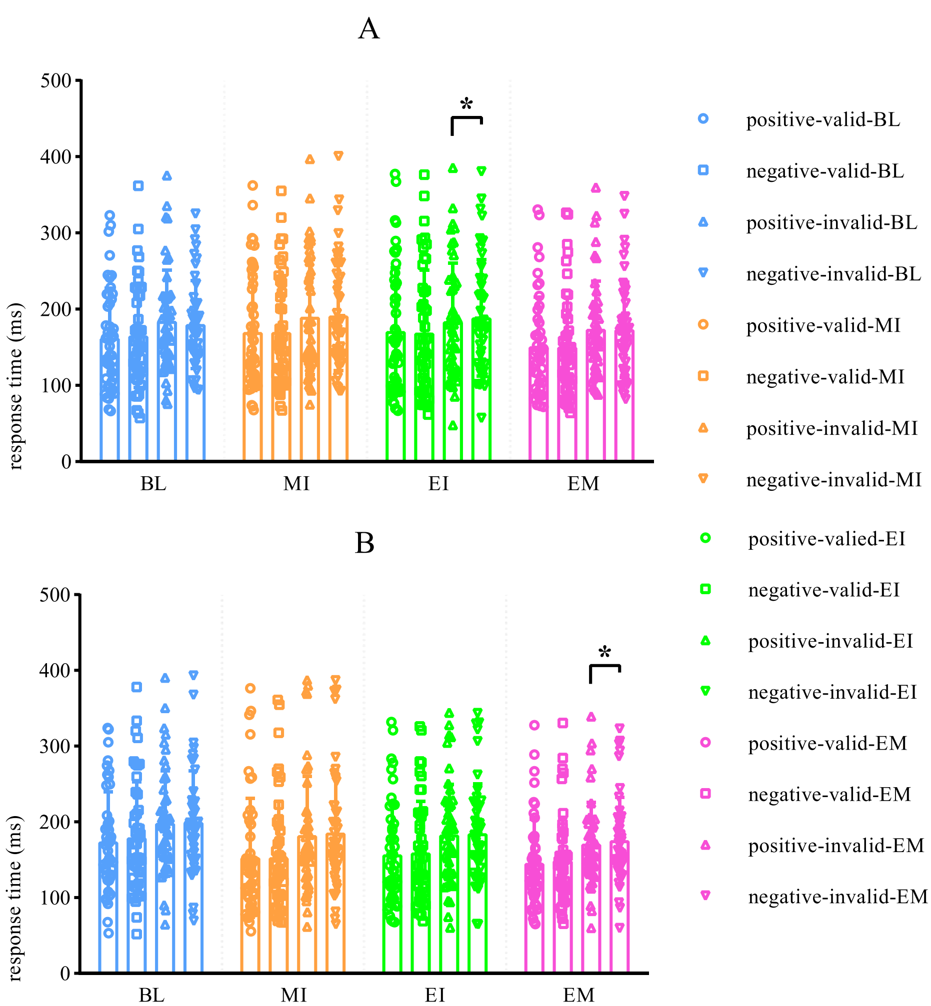


Fig. 5. Means and standard deviations for response times of positive and negative images in the group with no depressive symptoms (A) and the group with minimal depressive symptoms (B) under valid and invalid cue conditions after the intervention of BL, MI, EI, and EM.
BL, baseline; MI, music intervention; EI, exercise intervention; EM, exercise plus music intervention. The blue, orange, green, and pink circles (○) represent the response times of the positive emotional pictures served as valid cues after the intervention of BL, MI, EI, and EM, respectively; squares (□) represent the negative emotional picture served as valid cues; triangles (△) represent the positive emotional picture served as invalid cues; and inverted triangles(▽) represent the negative emotional picture served as an invalid cues. Each "*" indicates that the difference between positive and negative images was significant ($p < 0.05$). Only significant differences discussed in the main text are shown.

and interventions. Moreover, significant differences were found under invalid spatial position conditions between positive and negative emotional cues after the EI and EM interventions (Fig. 5B), which is in accord with the results of a previous study using the spatial cueing task, in which the contexts regarding the cue and target were defined emotionally and spatially.[16]

Individuals were found to effectively adapt to two different contexts (e.g., emotion and position), and could make effective use of cognitive control processes.[16] This phenomenon could be explained by the conflict monitoring model, which suggests that the anterior cingulate cortex monitors the levels of conflict in information processing, and that this information is used to regulate the influence of neural centers responsible for goal-driven control.[43] Compared with location information of the cue, emotional information became the main driving factor of the cognitive task. Therefore, the differences in the invalid cue conditions of the spatial cueing task in the present study may have reflected the processing characteristics of emotional cognitive control, representing participants' emotional attention variation before and after interventions.

Physiological effects of aerobic exercise plus rhythmic music

An increase in the intensity of exercise can induce an attentional shift from an external focus on the surrounding environment to an internal focus on bodily sensations such as muscular contraction and respiration.[44] When a given exercise load is sustained for a long duration, the levels of perceived exertion associated with that exercise load increase over time. This phenomenon is consistent with our finding that RPE scores after intervention were the highest for EI among all interventions (Fig. 3). Because the RPE level was lower for the EM than the EI intervention, this finding appears to be in accord with the extensive use of music stimuli for reducing the ratings of perceived exertion during repetitive endurance activities.[45] A pleasant audiovisual stimulus could ameliorate fatigue-related symptoms and reduce the physiological stress induced by exercise sessions.[25]

Music can evoke prescribed cadences and metabolic intensities. For instance, in a previous study, trials with music entrainment exhibited greater metabolic intensity compared with self-paced trials.[37] Similarly, in the present study, a marginally significant increase in mean heart rate was found for the EM intervention compared with the EI intervention ($p = 0.053$, Fig. 2A). It was previously reported that when exercise intensity reached 75% of maximal heart rate, extra-rhythmical characteristics of music were necessary to maintain or increase working heart rate levels.[37] This physiological mechanism could be attributed to the spontaneous tendency of people to synchronize their movements to music, which facilitates the development of strategies for tempo adaptation of simple repetitive movements.[46]

In the present study, the average tempo of the music was 128.01 bpm, which is within the target heart rate range during aerobic exercise interventions (approximately 120–140 bpm). However, we found no direct evidence for a clear correlation between music tempo and heart rate during exercise. A meta-analysis supported the use of music listening across a range of physical activities to promote more positive affective valence, enhance physical performance (i.e., ergogenic effects), reduce perceived exertion, and improve physiological efficiency.[47] Interventions involving aerobic exercise plus rhythmic music may sustain a higher heart rate and cause a lower RPE level if participants' cadence is entrained to musical tempos.

Conclusion

The findings of the present study demonstrated that the multimodal intervention involving aerobic exercise plus rhythmic music effectively modulated emotional attention processing toward a positivity bias (i.e., toward preferential processing of pleasant material) in participants with minimal depressive symptoms, whereas a single-modality aerobic exercise intervention was more effective for individuals with no depressive symptoms. Our results suggested that the combination of aerobic exercise and rhythmic music is an effective approach of emotional regulation in college students with minimal depressive symptoms. Compared with other interventions, participants could benefit from acute aerobic exercise plus rhythmic music to sustain a higher heart rate and induce a lower RPE level.

Limitations

The current study had several limitations. First, we did not find any significant differences in BDI scores between interventions. It is possible that participants remembered some questions of the scale (participants were tested five times, 1 week apart), potentially affecting the scores. Future studies should focus on the relationship between behavioral responses and emotional status after interventions. Second, the current study was not able to reveal differences in intervention effects between healthy participants and those with mild, moderate or severe depression. The effects of the intervention on emotional attention between groups with different baseline levels should be further explored, including lifestyle factors, depression degree, physical fitness, exercise habits, and music preferences. Third, because of the physical fitness requirements for completing the 30-min aerobic exercise intervention, most of the participants in this study were male. Thus, we were unable to examine gender differences in the effects of aerobic exercise combined with music on emotional attention. This issue should be examined in more depth in future studies.

Ethical approval statement

The study procedure complied with the directives of the Helsinki Declaration. Participants were informed about the study and the experimental procedures before they signed an informed consent form. All participants provided a written informed consent via a process that was approved by the Institutional Review Board of Shangrao Normal University.

Funding

This work was supported by the Social Science Planning Project of Jiangxi Province (China) "Evidence-based Practical Research on the Exercise Promotion of College Students' Emotional Health in the Context of Healthy China" [grant number 19TY16], 2021–2022 Innovation Project of the Institute of Sports Medicine and Health Science/Institute of Zheng Huaixian Bone Injury, Chengdu Sport University (China) [grant number CX21B01] and Basic Education Research Project of the Department of Education, Jiangxi Province (China) [grant number SZUSYTY2019-991] to Ping Yang, and National Key Research and Development Program (China) [grant number 2019YFF0301704] to Benxiang He.

Submission statement

Our work has not been published previously, that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere including electronically in the same form, in English or any other language, without the written consent of the copyright-holder.

Authors' contributions

Ping Yang has given substantial contributions to the design of the manuscript, and the analysis and interpretation of the data. Hui Yang, Yang Cao and Xin Yang contributed to the acquisition of the data. All authors have participated to drafting the manuscript, Benxiang He revised it critically. All authors read and approved the final version of the manuscript.

Conflict of interest

The authors declare that there is no conflict of interest.

Acknowledgments

We are grateful to Yezhong Tang and Guangzhan Fang from Chengdu Institute of Biology, Chinese Academy of Sciences for discussion and/or comments on early drafts of this article. We thank Benjamin Knight, MSc, from Liwen Bianji (Edanz) (www.liwenbianji.cn) for editing the English text of a draft of this manuscript.

References

1. Buchanan JL. Prevention of depression in the college student population: a review of the literature. *Arch Psychiatr Nurs*. 2012;26(1):21–42. https://doi.org/10.1016/j.apnu.2011.03.003.
2. Kenyon DYB, Koerner SS. College student psychological well-being during the transition to college: examining individuation from parents. *J Adolesc Health*. 2007;40(2-supp-S):S45–S46. https://doi.org/10.1016/j.jadohealth.2006.11.116.
3. Auerbach RP, Mortier P, Bruffaerts R, et al. World health organization world mental health surveys international college student project (WMH-ICS): prevalence and distribution of mental disorders. *J Am Acad Child Psychiatr*. 2018;57(10):S297. https://doi.org/10.1016/j.jaac.2018.07.723.
4. Fonseca LB, Pereira LP, Rodrigues PRM, et al. Incidence of depressive symptoms and its association with sociodemographic factors and lifestyle-related behaviors among Brazilian university students. *Psychol Health Med*. 2021:1–15. https://doi.org/10.1080/13548506.2021.1874432.
5. Jones L, Karageorghis CI, Ekkekakis P. Can high-intensity exercise be more pleasant? Attentional dissociation using music and video. *J Sport Exerc Psychol*. 2014;36(5):528–541. https://doi.org/10.1123/jsep.2013-0251.
6. Erkkilä J, Brabant O, Saarikallio S, et al. Enhancing the efficacy of integrative improvisational music therapy in the treatment of depression: study protocol for a randomised controlled trial. *Trials*. 2019;20(1):244. https://doi.org/10.1186/s13063-019-3323-6.
7. Brush CJ, Olson RL, Bocchine AJ, et al. Acute aerobic exercise increases respiratory sinus arrythmia reactivity and recovery to a sad film among individuals at risk for depression. *Int J Psychophysiol*. 2020;156(5):69–78. https://doi.org/10.1016/j.ijpsycho.2020.07.006.
8. Moirand R, Galvao F, Brunelin J. Early shifts of emotional attention as a possible predictor of remission in patients with depression receiving ECT: preliminary results of an eye-tracker study. *L'Encéphale*. 2019;45(Supplement 2):S73. https://doi.org/10.1016/j.encep.2019.04.026.
9. Bush DE, Ziegelstein RC, Tayback M, et al. Even minimal symptoms of depression increase mortality risk after acute myocardial infarction. *Am J Cardiol*. 2001;88(4):337–341. https://doi.org/10.1016/S0002-9149(01)01675-7.
10. Martini J, Leopold K, Pfeiffer S, et al. Early detection of bipolar disorders and treatment recommendations for help-seeking adolescents and young adults: findings of the Early Detection and Intervention Center Dresden. *Int J Bipolar Disord*. 2021;9(1):23. https://doi.org/10.1186/s40345-021-00227-3.
11. Aalbers S, Fusar-Poli L, Freeman RE, et al. Music therapy for depression. *Cochrane Datebase Syst Rev*. 2017;11(3). https://doi.org/10.1002/14651858.CD004517.pub3. CD004517.
12. Demeyer I, Lissnyder ED, Koster E, et al. Rumination mediates the relationship between impaired cognitive control for emotional information and depressive symptoms: a prospective study in remitted depressed adults. *Behav Res Ther*. 2012;50(5):292–297. https://doi.org/10.1016/j.brat.2012.02.012.
13. Godlewska BR, Browning M, Norbury R, et al. Early changes in emotional processing as a marker of clinical response to SSRI treatment in depression. *Transl Psychiatry*. 2016;6(11):e957. https://doi.org/10.1016/j.encep.2019.04.026.
14. Cai X, Isaacowitz DM. Aiming at happiness: how motivation affects attention to and memory for emotional images. *Motiv Emot*. 2006;30(3):243–250. https://doi.org/10.1007/s11031-006-9032-y.
15. Yiend J. The effects of emotion on attention: a review of attentional processing of emotional information. *Cognit Emot*. 2010;24(1):3–47. https://doi.org/10.1080/02699930903205698.
16. Gough A, Garcia J, Torres-Quesada M, et al. Control of spatial orienting: context-specific proportion cued effects in an exogenous spatial cueing task. *Conscious Cognit*. 2014;30:220–233. https://doi.org/10.1016/j.concog.2014.09.014.
17. Harrison NR, Davies SJ. Modulation of spatial attention to visual targets by emotional environmental sounds. *Psychol Neurosci*. 2013;6(3):247–251. https://doi.org/10.3922/j.psns.2013.3.02.
18. Shi YM, Luo YJ. Attentional bias to affective information in college students with optimistic and pessimistic attributional style. *Chin Ment Health J*. 2017;31(5):395–399. https://doi.org/10.3969/j.issn.1000-6729.2017.05.011.
19. Spielberger CD, Gorsuch RL, Lushene RE. *Manual for the State-Trait Anxiety, Inventory*. Palo Alto: CA: Consulting Psychologist; 1970.
20. Perpiá-Galvañ J, Richart-Martínez M, Cabañero-Martínez MJ, et al. Content validity of the short version of the subscale of the State-Trait Anxiety Inventory (STAI). *Rev Lat Am Enfermagem*. 2011;19(4):882–887. https://doi.org/10.1590/s0104-11692011000400005.
21. Beck AT, Steer RA, Brown GK. *Manual for the Beck Depression Inventory-II*. San Antonio, TX: Psychological Corporation; 1996.
22. Reiland SA. Beck depression inventory. In: Zeigler-Hill V, Shackelford TK, eds. *Encyclopedia of Personality and Individual Differences*. Cham: Springer International Publishing; 2017:1–3.
23. QingFeng. DJ Music Netword. QingFeng https://www.vvvdj.com/2018. Accessed November 27, 2018.
24. Robertson RJ, Goss FL, Dubé J, et al. Validation of the adult OMNI scale of perceived exertion for cycle ergometer exercise. *Med Sci Sports Exerc*. 2004;36(1):102–108. https://doi.org/10.1249/01.MSS.0000106169.35222.8B.
25. Barreto-Silva V, Bigliassi M, Chierott iP, et al. Psychophysiological effects of audiovisual stimuli during cycle exercise. *Eur J Sport Sci*. 2018;18(4):560–568. https://doi.org/10.1080/17461391.2018.1439534.
26. Neuhaus AH, Urbanek C, Opgen-Rhein C, et al. Event-related potentials associated with attention network test. *Int J Psychophysiol*. 2010;76(2):72–79. https://doi.org/10.1016/j.ijpsycho.2010.02.005.
27. Bai L, Ma H, Huang YX, et al. The development of native Chinese Affective Picture System-A pretest in 46 college students. *Chin Ment Health J*. 2005;19(11):719–722. https://doi.org/10.1016/j.molcatb.2005.02.001.
28. Rijsdijk FV, Riese H, Tops M, et al. Neuroticism, recall bias and attention bias for valenced probes: a twin study. *Psychol Med*. 2009;39(1):45–54. https://doi.org/10.1017/S0033291708003231.
29. Cohen J. A power primer. *Psychol Bull*. 1992;112(1):155–159. https://doi.org/10.1037//0033-2909.112.1.155.
30. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Front Psychol*. 2013;4(4):863. https://doi.org/10.3389/fpsyg.2013.00863.
31. Jackson CPT, Miall RC, Balslev D. Spatially valid proprioceptive cues improve the detection of a visual stimulus. *Exp Brain Res*. 2010;205(1):31–40. https://doi.org/10.1007/s00221-010-2330-3.
32. Prinzmetal W, Mccool C, Park S. Attention: reaction time and accuracy reveal different mechanisms. *J Exp Psychol*. 2005;134(1):73–92. https://doi.org/10.1037/0096-3445.134.1.73.
33. Keating LE, Suzanna B, Katie MC, et al. Effects of a 12-week running programme in youth and adults with complex mood disorders. *BMJ Open Sport Exerc*. 2018;4(1), e000314. https://doi.org/10.1136/bmjsem-2017-000314.
34. Henner H, Alice M, Oliver F, et al. Effects of endurance exercise modalities on arterial stiffness in patients suffering from unipolar depression: a randomized controlled tial. *Front Psychiatr*. 2017;8:311. https://doi.org/10.3389/fpsyt.2017.00311.
35. Rodkjaer L, Laursen T, Christensen NB, et al. Changes in depression in a cohort of Danish HIV-positive individuals: time for routine screening. *Sex Health*. 2011;8(2):214–221. https://doi.org/10.1071/SH10067.
36. Liu YQ. Research on mental health intervention of college students based on music therapy. *Rev Bras Med Esporte*. 2021;27(spe):40–42. https://doi.org/10.1590/1517-8692202127012020_0106.
37. Perry DC, Moore CC, Sands CJ, et al. Using music-based cadence entrainment to manipulate walking intensity. *J Phys Activ Health*. 2019;16(11):1039–1046. https://doi.org/10.1123/jpah.2019-0097.
38. Trost W, Frühholz S, Schön D, et al. Getting the beat: entrainment of brain activity by musical rhythm and pleasantness. *Neuroimage*. 2014;103:55–64. https://doi.org/10.1016/j.neuroimage.2014.09.009.
39. Bigliassi M, Karageorghis CI, Hoy GK, et al. The way you make me feel: psychological and cerebral responses to music during real-life physical activity. *Psychol Sport Exerc*. 2019;41:211–217. https://doi.org/10.1016/j.psychsport.2018.01.010.
40. Bigliassi M, Karageorghis CI, Nowicky AV, et al. Cerebral mechanisms underlying the effects of music during a fatiguing isometric ankle-dorsiflexion task. *Psychophysiology*. 2016;53(10):1472–1483. https://doi.org/10.1111/psyp.12693.
41. Ligeza TS, Maciejczyk M, Wyczesany M, et al. Acute aerobic exercise enhances pleasant compared to unpleasant visual scene processing. *Brain Cognit*. 2020;143:105595. https://doi.org/10.1016/j.bandc.2020.105595.
42. Thom NJ, O'Connor PJ, Clementz BA, et al. Acute exercise prevents angry mood induction but does not change angry emotions. *Med Sci Sports Exerc*. 2019;51(7):1451–1459. https://doi.org/10.1249/mss.0000000000001922.
43. Barch DM, Braver TS, Akbudak E, et al. Anterior cingulate cortex and response conflict: effects of response modality and processing domain. *Cerebr Cortex*. 2001;11(9):837–848. https://doi.org/10.1016/S1053-8119(00)91037-1.
44. Hutchinson JC, Karageorghis CI, Jones L. See hear: psychological effects of music and music-video during treadmill running. *Ann Behav Med*. 2015;49(2):199–211. https://doi.org/10.1007/s12160-014-9647-2.
45. Karageorghis CI, Priest DL. Music in the exercise domain: a review and synthesis (Part II). *Int Rev Sport Exerc Psychol*. 2012;5(1):67–84. https://doi.org/10.1080/1750984x.2011.631027.
46. Maes P-J, Lorenzoni V, Six J. The SoundBike: musical sonification strategies to enhance cyclists' spontaneous synchronization to external music. *J. Multimodal*. 2019;13(3):155–166. https://doi.org/10.1007/s12193-018-0279-x.
47. Terry PC, Karageorghis CI, Curran ML, et al. Effects of music in exercise and sport: a meta-analytic review. *Psychol Bull*. 2020;146(2):91–117. https://doi.org/10.1037/bul0000216.