3 Music and Creativity: The Auditory Mirror System as a Link between Emotions and Musical Cognition

Barbara Colombo

3.1 Introduction

Mirror neurons (part of the mirror neuron system—MNS) diverge from motor and sensory neurons due to the fact that they become active both with the performance of an action and with the observation of another performing the action [1, 2]. In humans, the MNS helps understand others' actions and the intentions behind them [3], and it has also been suggested that it has an important role in mediating empathy [4]. Recent research suggested that the mirror system is not activated only by visual stimuli and involves the auditory system as well. This has been proven by the fact that a group of audiovisual neurons in the ventral premotor F5 area seems to be able to discriminate between different actions with extremely high accuracy when only seen or only heard [5, 6]. Following up on this line of research, more evidence highlighted how there are auditory mirror neurons in humans that fire in response to the sounds of actions that individuals are capable of performing [7]. Since the representation of sensory and motor information in the human brain is integrated at many levels, seeing or hearing action-related stimuli automatically cues the movements required to respond to or produce them, in order to guide the perception of musical stimuli [8]. Studying this fascinating relationship, the role that the MNS might play in facilitating or mediating the understanding of music has been investigated [9]. Focusing on the role of the MNS in professional musicians when they were listening to music, a recent study [10] found that auditory mirror activation only occurred when listening to a passage from a song that participants were taught to play, and did not happen when listening to a passage of an unfamiliar song. The researchers explained this finding by hypothesizing that only sounds within our motor repertoire will activate the auditory MNS; hence, the musicians did not respond to songs they had not been

B. Colombo (✉)
Behavioral Neuroscience Lab—Champlain College, Burlington, VT, USA
e-mail: bcolombo@champlain.edu

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taught due to their unfamiliarity with them [10]. Another study [11] discussed how musicians could have a good understanding of the piano without either motor or auditory stimuli, because of their deeper knowledge of both auditory and motor components of piano playing. This reading stands on the assumption that professional musicians would show more MNS activity in response to both familiar and new music than other individuals. Other research data supports the fact that mirror neuron activation is modulated by musical expertise and that MNS activation in musicians. Moreover, this specific activation could be linked to a unconscious form of imagery, which leads to imagining themselves playing the piece that they are hearing. This would also explain why the activation is presumably stronger when musicians listen to music performed on their main instrument [12].

As we briefly mentioned above, it suggests that the MNS serves as a link and common neural substrate when processing motor information and emotional as well as some other high-level cognitive information (for example, some form of learning) [13]. The link with emotions has been proven to be very interesting for researchers [14, 15] who, in the light of the possible existence of a specific auditory MNS, explored its role in helping to discriminate emotions. Results from this line of research highlighted how, when listening to different vocalizations, distinct functional subsystems within the auditory–motor mirror network respond differently to their emotional valence and arousal properties. For example, it has been reported [14] how listening to nonverbal vocalizations (which can be compared to some extent to musical sounds in the sense that they are nonverbal) can lead to an automatic preparation of specific responsive gestures. This happens fastest and more frequently for positive-valence and high-arousal emotions. If the connection between these results and possible similar responses activated specifically by music might seem logic, the specific role and the specific response played by the MNS when musicians listen to music featuring their main instrument has only been partially explored [16].

The study discussed in this chapter aimed to provide some additional evidence on if and how the level of activation of the MNS affects either the emotion response triggered by the music or the evaluation of musical creativity in a sample of professional musicians.

We decided to add a specific focus on creativity for two main, research-based, reasons.

First, the relationships between creativity and empathy (and hence creativity and the MNS) is supported by the notion that creativity is linked to and supported by social aspects [17]. For this reason, an individual will be more creative when connected to other people's minds and feelings [18]: as we discussed above, this aspect is also linked to and promoted by the activation of the MNS. Creative activities, such as painting [19] or creative dancing [20], have been shown to be a useful resource to promote empathy and other related social skills [21]. Empathy not only can be increased by creative activities, but it also affects how individuals perceive and emotionally respond to performing arts, like music [22]. It is not surprising that these findings can be applied to music since not only music has been defined as a type of creative thinking [23], but since music listening and music performing are generally social activities, just listening to music in humans has been reported to involve empathic responses [22, 24–26].

Second, something that has been clearly established within the academic field is the direct relationship between empathy and the MNS [27]. This relationship includes a positive correlation between motor and facial mimicry and empathy scores [28], affecting both visual and auditory pathways in the MNS, as well as a positive correlation between perspective taking empathy scale scores and the activation of the mirror system [7]. Moreover, the relationship between cognitive empathy and emotional states that allows us to understand others' emotions by referring to our own experience [29] can be seen as similar to the process that allows individuals (especially musicians, as discussed above) to refer back to their own motor experience to better "frame" and understand a sound produced by another individual [7, 10].

Starting from this background, in this chapter we present and discuss some data aimed at exploring the involvement of the auditory MNS in professional musicians when they listen to music. In our study, we used transcranial direct current stimulation (tDCS) to inhibit the activation of the MNS, and the measured professional musicians' emotional and cognitive responses to a new piece of music involving the instrument they play. To be more specific, we investigated how cathodal tDCS stimulation of musicians' brain area associated with the MNS would affect their judgment of how creative the music was as well as their emotional response to it.

Since cathodal tDCS has been proven to reduce the activation of the targeted area, we expected that participants who received cathodal tDCS would rate the music as less creative when compared to participants in the sham condition, given the fact that their auditory MNS would be impaired. Similarly, we hypothesized that cathodal tDCS would impact self-reported emotional reactions to music, by way of reducing the intensity of reported emotions.

3.2 Methods

The study has been reviewed and approved by Champlain College IRB.

3.2.1 Sample

Forty young musicians (age range: 18–22, mean = 19.80; SD = 1.56; $z = 15$) joined the study and were randomly assigned either to the experimental group (cathodal stimulation) or to the control group (sham stimulation).

Participants were screened before being invited to join the experiment by checking that their principal instrument would be either piano, violin, or cello (the instruments played in the piece of music used during our experiment). We also verified that they would practice a minimum of 4 h a day and have performed in public in a professional setting at least 5 times. Of the recruited participants, 16 were piano players, 14 were violinists, and 10 cellists.

3.2.2 Procedure and Instruments

Procedure is described in Fig. 3.1.

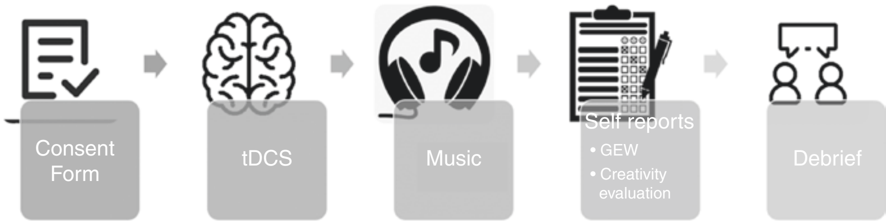


Fig. 3.1 Procedure

3.2.2.1 tDCS Equipment

In this study, we used 1300A 1 × 1 transcranial direct current low-intensity stimulator by Soterix Medical to deliver brain stimulation to our participants. We used two 5 × 5 cm rubber electrodes enveloped in saline-soaked sponges covered with conductive gel. For the experimental conditions (cathodal), the stimulation was set at 1.5 mA for 20 min. In the control (sham) condition, the equipment started the stimulation normally and ramped up to the target intensity of 1.5 mA; it decreased to 0 mA after 5 s. This gave participants the impression of receiving stimulation, when in reality the stimulation lasted only 5 s, thus having no actual effect on brain functions. For the experimental condition, the electrodes were placed on the left ventral premotor cortex using the 10–20 system (F5 location). The anodal electrode was placed on the upper right forearm. The same montage was used for the sham condition.

3.2.2.2 Geneva Emotional Scale (GEW)

The Geneva Emotion Wheel (GEW) [30, 31] measures emotional reactions to objects, events, and situations. Participants are asked to indicate the emotion(s) they experienced by choosing intensities for a single emotion or a blend of several emotions out of 20 different options. The emotions are arranged in a wheel shape, with the axes being defined by two major dimensions of emotional experience: high vs. low control and positive vs. negative valence. Five degrees of intensity are being proposed, represented by circles of different sizes. In addition, “None” (no emotion felt) and “Other” (different emotion felt) options are provided.

3.2.2.3 Creativity Evaluation

We asked participants to rate specific factors that have been reported in the literature to be associated with creativity: interest [32–34], innovation [35–37], and excitement [38, 39]. Participants were asked to rate the creativity of the musical piece by rating how interesting, innovative, and exciting the piece was on a 9-points Likert scale. To be more specific, participants were told: “You are now asked to evaluate the creativity of the piece you just listened to. How interesting/innovating/exciting you think it is?”

3.2.2.4 Music

Dreaming Cities is a five-movement piano trio (violin, cello, piano) by Damon Ferrante (see Fig. 3.2). In this experiment, participants listened to the third movement. The third movement is a slow movement whose material is a variation of the musical theme that occurs at the beginning of the work. The third movement’s sparce,

Fig. 3.2 Excerpt from “Dreaming Cities,” reproduced with permission from the author

lyrical texture highlights the characteristic musical voices of each instrument. It was not written with a specific emotional tone in mind, but, rather, focusing on the slow, melodic interplay of the instruments. This piece of music was not familiar to any participant (a familiarity check was performed at the end of the experiment).

3.3 Results

To explore the effects of the brain stimulation on emotional reaction as well as creative evaluation of the musical piece, we ran a GLM MANOVA, using the condition as an independent variable and the three creative evaluation scales (interest, innovation, and excitement) and self-report of emotional response (categorized into two variables: sum of positive valence emotions and sum of negative valence emotions) as dependent variables. Figures 3.3 and 3.4 show the mean scores for creative evaluations and emotional responses for the two tDCS conditions.

The test of between-subject effects returned a significant main effect of stimulation condition on the evaluation of the creativity of the piece. Two of the considered dimensions were significantly affected: how innovative the piece was ($F_{1;34} = 45.76$, $p < 0.001$, $\eta^2 = 0.57$) and how exciting it was ($F_{1;34} = 53.73$, $p < 0.001$, $\eta^2 = 0.61$). In both cases, cathodal stimulation decreased the reported perception of creativity.

Focusing on the self-report emotional response to the piece, cathodal stimulation significantly affected emotions with negative valence ($F_{1;34} = 17.93$, $p < 0.001$, $\eta^2 = 0.34$). Cathodal stimulation decreased the intensity of negative emotions reported by participants.

When analyzing the effect of tDCS on specific positive emotional responses that can be affected by listening to music (namely, interest and admiration), we see how cathodal stimulation also reduced them (see Fig. 3.5), with the difference being significant for interest ($F_{1;40} = 7.60$, $p = 0.009$, $\eta^2 = 0.318$). Adding age as a covariate, it had a significant effect in moderating the relationship between the tDCS condition and the emotional response, as can be seen in Fig. 3.6, with admiration being affected substantially in older musicians and the effects being less pronounced overall in younger musicians.

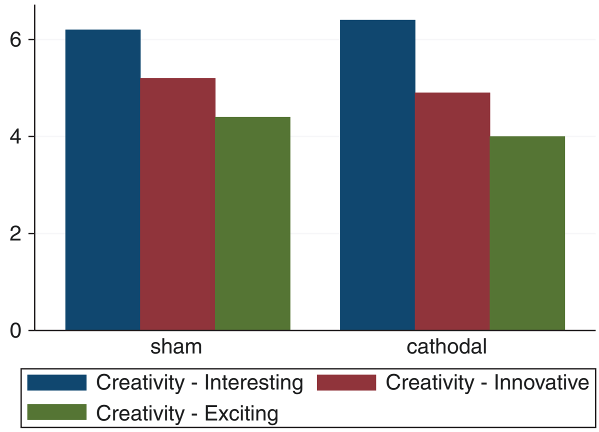


Fig. 3.3 Mean scores of creative evaluation by condition

Fig. 3.4 Mean scores of emotional valence by condition

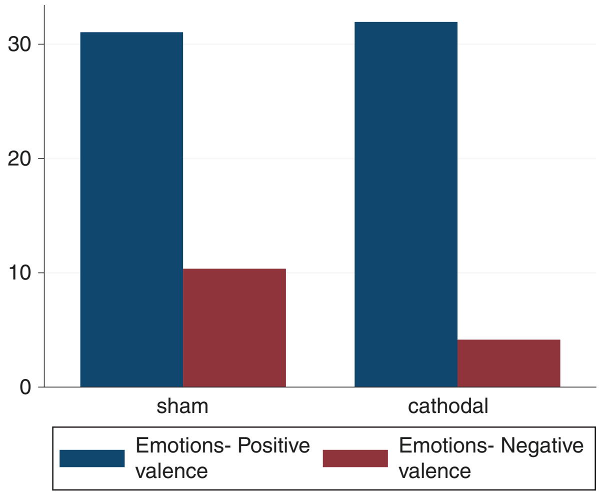


Fig. 3.5 Mean scores of interest and admiration by condition

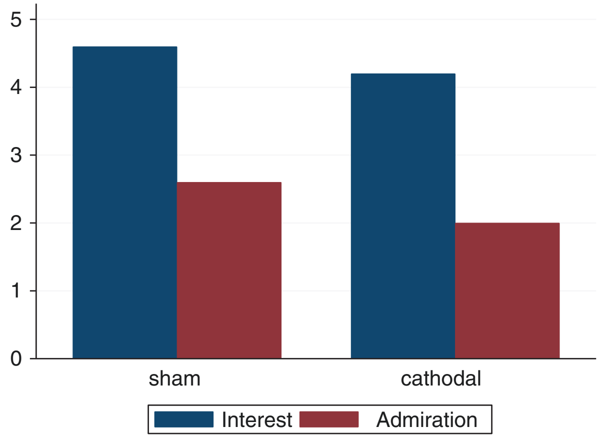
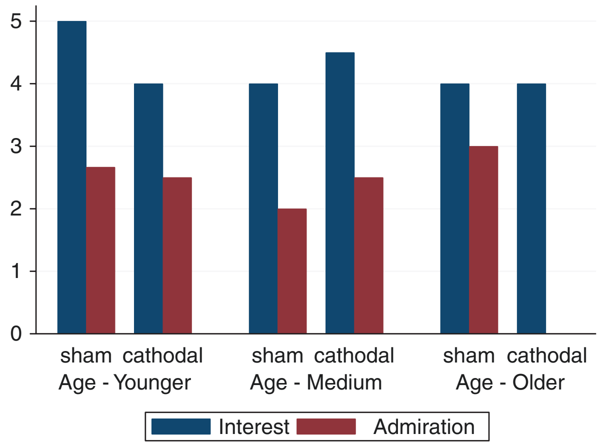


Fig. 3.6 Mean scores of interest and admiration by condition and by age groups



3.4 Discussion and Conclusions

In this chapter, we presented some data on the role of the auditory mirror system in influencing the evaluation of creativity as well as the emotional reactions of professional musicians when listening to music.

We were especially interested in exploring the effect of cathodal stimulation in reducing the perceived creativity of the new piece of music. This interest was inspired by research evidence that reports how the auditory MNS plays a role in musicians' response to music [10, 11] and also that the MNS's role is linked to processing not only motor information but also emotional and other higher-level cognitive information, like, for example, creativity [13]. As we discussed in the introduction, empathy, affected by the MNS [4, 7, 29], plays a role in affecting how individuals evaluate performing arts, including music [22].

The results described in this chapter provide interesting new insights. After cathodal stimulation, musicians tended to perceive music as less innovative and exciting when compared to musicians who underwent sham stimulation. On the other hand, their evaluation of the level of interest was not significantly affected by the stimulation. Our data seem to confirm the role of the MNS in evaluating the creativity of a music piece, but the role seems to be rather specific. Both the cognitive evaluation of the creative process (the innovation of the piece) and the emotional reaction to it (excitement) appear to be influenced by the activation of the MNS. When the activation is lowered by cathodal stimulation, the piece is perceived as less innovative and less exciting. On the other end, how interesting the piece is appears to be examined through a different circuit. We might hypothesize that this evaluation can be related to individual differences and hence not being directly affected by the modulation of the MNS. This reading is supported by research data stating that music preference is significantly influenced by a combination of the individuals' perception of the cognitive, emotional, and cultural functions of music, together with the physiological arousal and familiarity [40]. This reading is also supported by the fact that, when taking age into consideration, the effect of the tDCS in influencing how mush participants admired the piece or found it interesting varied considerably by age group, implying, maybe, an important role of expertise in mediating the effect of the brain stimulation. Further research might include the evaluation of these variables into a tDCS design similar to the one presented in this chapter. Something else that would be interesting to consider, and that wasn't controlled for in this study, is participants' level of attention [41, 42].

We also examined the effect of tDCS on participants' reported emotions after listening to the music. This interest was inspired by the evidence supporting the fact that the auditory MNS plays a significant role in responding to auditory stimuli with emotional valance [14, 15], like, for example, music. We found and reported a significant effect of cathodal stimulation on participants' self-report of emotions with a negative valence: after cathodal stimulation, musicians involved in the study reported less emotion with a negative valence. We can explain this by referring to the specific music we were using for our study. Even if the movement that we used was not written with a specific emotional tone, it has a slow tempo and it is mainly written in the tonality of D minor. Minor keys and lower tempos tend to be associated with more negative emotions like sadness [43], so the effect of neuromodulation might have been more pronounced for emotions that are linked to sadness. Also, fMRI data suggest that familiarity seems to play an important role in making the listeners emotionally engaged with music [44], and our piece was unfamiliar to all our participants.

Even if the data that we discussed here cannot be considered final, and more evidence is needed, it sheds some light on the role of the auditory MNS in evaluating specific aspects of musical creativity (innovation and excitement) and in influencing, to some extent, the emotional response to the same music, by offering some more evidence that can help clarify the role of the auditory MNS in evaluating music.

These data also offer some food for thought regarding practical applications. They suggest concrete possibilities for new uses of music to promote creativity as well as social skill in different educational settings. To be more specific, the fact that music can affect both creativity and empathy could be used to build specific interventions aimed at working with youth with autism spectrum disorders [45] but could also be used to inform assessment in music composition [46].

Future studies should include anodal stimulation to compare the effects of a different activation of the MNS; they could also use music characterized by different tempo and/or keys and take musicians' age and expertise into consideration by using a larger sample.

References

1. Kilner JM, Lemon RN. What we know currently about mirror neurons. Curr Biol. 2013;23(23):R1057–62.
2. Rizzolatti G. The mirror neuron system and its function in humans. Anat Embryol. 2005;210(5–6):419–21.
3. Cattaneo L, Rizzolatti G. The mirror neuron system. Arch Neurol. 2009;66(5):557–60.
4. Baird AD, Scheffer IE, Wilson SJ. Mirror neuron system involvement in empathy: a critical look at the evidence. Soc Neurosci. 2011;6(4):327–35.
5. Keysers C, Kohler E, Umiltà MA, Nanetti L, Fogassi L, Gallese V. Audiovisual mirror neurons and action recognition. Exp Brain Res. 2003;153(4):628–36.
6. Kohler E, Keysers C, Umilta MA, Fogassi L, Gallese V, Rizzolatti G. Hearing sounds, understanding actions: action representation in mirror neurons. Science. 2002;297(5582):846–8.
7. Gazzola V, Aziz-Zadeh L, Keysers C. Empathy and the somatotopic auditory mirror system in humans. Curr Biol. 2006;16(18):1824–9.
8. Stephan MA, Lega C, Penhune VB. Auditory prediction cues motor preparation in the absence of movements. NeuroImage. 2018;174:288–96.
9. Jiang J, Liu F, Zhou L, Jiang C. The neural basis for understanding imitation-induced musical meaning: the role of the human mirror system. Behav Brain Res. 2019;359:362–9.
10. Lahav A, Saltzman E, Schlaug G. Action representation of sound: audiomotor recognition network while listening to newly acquired actions. J Neurosci. 2007;27(2):308–14.
11. Bangert M, Peschel T, Schlaug G, Rotte M, Drescher D, Hinrichs H, Heinze H-J, Altenmüller E. Shared networks for auditory and motor processing in professional pianists: evidence from fMRI conjunction. NeuroImage. 2006;30(3):917–26.

12. Hou J, Rajmohan R, Fang D, Kashfi K, Al-Khalil K, Yang J, Westney W, Grund CM, O'Boyle MW. Mirror neuron activation of musicians and non-musicians in response to motion captured piano performances. Brain Cogn. 2017;115:47–55.
13. Ramachandra V, Depalma N, Lisiewski S. The role of mirror neurons in processing vocal emotions: evidence from psychophysiological data. Int J Neurosci. 2009;119(5):681–91.
14. Warren JE, Sauter DA, Eisner F, Wiland J, Dresner MA, Wise RJ, Rosen S, Scott SK. Positive emotions preferentially engage an auditory–motor “mirror” system. J Neurosci. 2006;26(50):13067–75.
15. Banissy MJ, Sauter DA, Ward J, Warren JE, Walsh V, Scott SK. Suppressing sensorimotor activity modulates the discrimination of auditory emotions but not speaker identity. J Neurosci. 2010;30(41):13552–7.
16. Colombo B, Anctil R, Balzarotti S, Biassoni F, Antonietti A. The role of the mirror system in influencing musicians' evaluation of musical creativity. A tDCS study. Front Neurosci. 2021;15:298.
17. Glaveanu V, Lubart T, Bonnardel N, Botella M, De Biaisi P-M, Desainte-Catherine M, Georgsdottir A, Guillou K, Kurtag G, Mouchiroud C. Creativity as action: findings from five creative domains. Front Psychol. 2013;4:176.
18. Form S, Kaernbach C. More is not always better: the differentiated influence of empathy on different magnitudes of creativity. Eur J Psychol. 2018;14(1):54.
19. Gerry LJ. Paint with me: stimulating creativity and empathy while painting with a painter in virtual reality. IEEE Trans Vis Comput Graph. 2017;23(4):1418–26.
20. Batson G. Chapter 6: Sharing creativity through the mirror neuron system: embodied simulation through dance. In: Creativity and entrepreneurship: changing currents in education and public life. Cheltenham: Edward Elgar Publishing Ltd; 2013. p. 66.
21. Morizio LJ. Creating compassion: harnessing creativity for empathy development. Boston: University of Massachusetts; 2021.
22. Wöllner C. Is empathy related to the perception of emotional expression in music? A multimodal time-series analysis. Psychol Aesthet Creat Arts. 2012;6(3):214.
23. Antonietti A, Colombo B. Musical thinking as a kind of creative thinking. In: Creativity research: an inter-disciplinary and multi-disciplinary research handbook. Milton Park: Routledge; 2014. p. 233.
24. Balteș FR, Miu AC. Emotions during live music performance: links with individual differences in empathy, visual imagery, and mood. Psychomusicol Music Mind Brain. 2014;24(1):58.
25. Sittler MC, Cooper AJ, Montag C. Is empathy involved in our emotional response to music? The role of the PRL gene, empathy, and arousal in response to happy and sad music. Psychomusicol Music Mind Brain. 2019;29(1):10.
26. Cross I, Laurence F, Rabinowitch T-C. Empathy and creativity in group musical practices: towards a concept of empathic creativity. In: The Oxford handbook of music education, vol. 2. Oxford, Oxford University Press; 2012.
27. Bekkali S, Youssef GJ, Donaldson PH, Albein-Urios N, Hyde C, Enticott PG. Is the putative mirror neuron system associated with empathy? A systematic review and meta-analysis. Neuropsychol Rev. 2020;1:1–44.
28. Sonnby-Borgström M, Jönsson P, Svensson O. Emotional empathy as related to mimicry reactions at different levels of information processing. J Nonverbal Behav. 2003;27(1):3–23.
29. Schnell K, Bluschke S, Konradt B, Walter H. Functional relations of empathy and mentalizing: an fMRI study on the neural basis of cognitive empathy. NeuroImage. 2011;54(2):1743–54.
30. Scherer KR. What are emotions? And how can they be measured? Soc Sci Inf. 2005;44(4):695–729.
31. Scherer KR, Shuman V, Fontaine J, Soriano Salinas C. The GRID meets the wheel: assessing emotional feeling via self-report. In: Components of emotional meaning: a sourcebook. Oxford: Oxford University Press; 2013.
32. Li H, Li F, Chen T. A motivational–cognitive model of creativity and the role of autonomy. J Bus Res. 2018;92:179–88.

33. Moreira IX, da Costa A, Belo L, dos Santos GA, Savio R. Impact of creativity and interest in learning on student achievement Instituto superior Cristal students. J Innovat Stud Char Edu. 2020;4(1):70–8.
34. Fürst G, Grin F. A comprehensive method for the measurement of everyday creativity. Think Skills Creat. 2018;28:84–97.
35. Acar S, Burnett C, Cabra JF. Ingredients of creativity: originality and more. Creat Res J. 2017;29(2):133–44.
36. Lee A, Legood A, Hughes D, Tian AW, Newman A, Knight C. Leadership, creativity and innovation: a meta-analytic review. Eur J Work Organ Psy. 2020;29(1):1–35.
37. Rietzschel EF, Ritter SM. Moving from creativity to innovation. In: Individual creativity in the workplace. Amsterdam: Elsevier; 2018. p. 3–34.
38. Fink A, Reim T, Benedek M, Grabner RH. The effects of a verbal and a figural creativity training on different facets of creative potential. J Creat Behav. 2020;54(3):676–85.
39. Paulus PB, Nijstad BA. The Oxford handbook of group creativity and innovation. Oxford: Oxford Library of Psychology; 2019.
40. Schäfer T, Sedlmeier P. What makes us like music? Determinants of music preference. Psychol Aesthet Creat Arts. 2010;4(4):223.
41. Li H, Duan H, Zheng Y, Wang Q, Wang Y. A CTR prediction model based on user interest via attention mechanism. Appl Intell. 2020;50(4):1192–203.
42. Peters C, Pelachaud C, Bevacqua E, Mancini M, Poggi IA. Model of attention and interest using gaze behavior. In: International workshop on intelligent virtual agents. Berlin: Springer; 2005. p. 229–40.
43. Webster GD, Weir CG. Emotional responses to music: interactive effects of mode, texture, and tempo. Motiv Emot. 2005;29(1):19–39.
44. Pereira CS, Teixeira J, Figueiredo P, Xavier J, Castro SL, Brattico E. Music and emotions in the brain: familiarity matters. PLoS One. 2011;6(11):e27241.
45. Forti S, Colombo B, Clark J, Bonfanti A, Molteni S, Crippa A, Antonietti A, Molteni M. Soundbeam imitation intervention: training children with autism to imitate meaningless body gestures through music. Adv Autism. 2020;6:227–40.
46. Deutsch D. Authentic assessment in music composition: feedback that facilitates creativity. Music Educ J. 2016;102(3):53–9.