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Computational Music Systems for Emotional Health and Wellbeing: A Review

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ABSTRACT

Music is a powerful stimulus, and both active and receptive methods of engaging with music provide affordances for improving physical, mental and social health. The emergence of sophisticated computational methods also underscores the potential for novel music technologies to address a wider range of wellbeing outcomes. In this review, we focus on describing the current state of the literature on computational approaches to music generation for health and wellbeing and identifying possible future directions for research in this area.

Keywords

Music technology, music generation, healthcare, well-being, emotion regulation, literature review.

INTRODUCTION

Interacting with music often leads to rich emotional, sensorimotor and cognitive experiences (Altenmüller & Schlaug, 2012), positioning music as a uniquely effective non-pharmacological tool for improving health and wellbeing. The World Health Organization (WHO) defines health as "a state of complete physical, mental and social well-being"[1], and music is able to support all of these aspects of health. Furthermore, music is appealing to the vast majority of people (Mehr et al., 2019) and studies have found that people report music listening as the leisure activity that is most important to them (Lonsdale & North, 2011).

Musical activities are used as a means of constructing and expressing one's personal identity, especially amongst adolescents (Sloboda et al., 2001), and for emotion regulation – for example, for relaxation, to enhance one's mood, and to improve motivation (Swaminathan & Schellenberg, 2015). Anthropological research indicates that music is consistently able to evoke emotional responses across a diverse array of cultures and societies (\cite{becker2001anthropological}), making it particularly attractive as an avenue for enhancing emotional wellbeing. Music has also been frequently employed to support physical activity and rehabilitation (for reviews, see Clark et al., 2016; Weller & Baker, 2011). Finally, in terms of social connection, musical collaboration has been found to enhance outcomes such as liking and honesty among group members (Harwood et al., 2016), with social ties themselves having strong links to physical and mental health (Thoits, 2011).

Given the powerful physical, affective, and social influence of music, it is unsurprising that it has been used in a variety of ways and contexts to support wellbeing. Furthermore, the emergence of computational approaches in the study of music has led to an increasing focus on cross-disciplinary work bridging the fields of music, health, and computing to develop music technology to improve health and wellbeing-related outcomes (Agres, Schaefer, et al., 2021), with promising results thus far.

In this review paper, we aim to contribute to the field of music synthesis for health and wellbeing. We are particularly interested in generative systems due to their potential for personalized functional music at scale, as one of the key limitations of using existing music for wellbeing outcomes is repetition and subsequent overfamiliarity with stimulus material (Williams et al., 2020). Our work was guided by the following research questions:

- *RQ1:* In what ways has music generation been applied to improve emotional wellbeing and other wellbeing-related outcomes?
- *RQ2:* What are the research trends in the area of music generation for wellbeing?
- *RQ3:* What are the potential research gaps in the literature?

To address these research questions, we introduce the use of music to address health and wellbeing-related outcomes and conduct a systematic literature review on the current computational approaches to music generation for emotion regulation and well-being. Based on the review, we identify research gaps and opportunities that will be the next steps in our research endeavor.

[1] https://www.who.int/about/governance/constitution

THEORETICAL BACKGROUND

Music and wellbeing

Music therapy and other music-based interventions have been associated with a broad range of positive outcomes in the domains of health and wellbeing (de Witte et al., 2020). Receptive methods, which involve listening (and possibly responding to) music, typically aim to induce relaxation or activation or to stimulate reflection. Active methods such as improvising (which can involve the spontaneous creation of music, or improvisation set to music), learning to recreate pre-composed music, and composition are also used to facilitate nonverbal expression and enhance the learning of skills or behaviors (Stegemann et al., 2019). Below, we outline how music has been applied in the areas of emotional, physical, and social wellbeing.

Emotional wellbeing. Emotion regulation strategies often involve situation selection, attention redirection, or response modulation. With its ability to evoke emotions (Sloboda & Juslin, 2010), induce moods (Thaut & Wheeler, 2010) and provide a distraction (Lonsdale & North, 2011), music lends itself naturally to these emotion regulation strategies. Furthermore, a review by (Moore, 2013) finds that musical characteristics and experiences produce neural activation patterns implicated in emotion regulation, which suggests that a better understanding of why and how music leads to desirable changes in brain states could inform the design of music-based interventions for emotional wellbeing. Music also provides a nonverbal avenue for emotional expression, which may help those who find it difficult to identify and express emotions understand their feelings so as to more effectively deal with them (Irle & Lovell, 2014).

Physical wellbeing. In terms of physical health, music has been applied to promote exercise as well as to improve physical rehabilitation. A review of the modulating effects of music on physical activity (Clark et al., 2016) suggests several explanations for the positive effects of music on levels of physical activity and associated health outcomes. The rhythmic nature of music facilitates physical coordination (Staum, 2000), while music is frequently employed to increase engagement and to provide structure, enjoyment and distraction from pain (Weller & Baker, 2011). Neuroimaging research also demonstrates that music listening stimulates brain structures associated with feelings of motivation and reward (Koelsch, 2010).

Social wellbeing. Finally, group music-making activities have been found to improve psychological wellbeing through its facilitation of socializing, musical expression of emotions and a sense of belonging (Irle & Lovell, 2014). Music can also be a tool for collaborative play, which serves to encourage and enhance social interactions (Tsekleves & Darby, 2020).

Approaches for Music Generation

Musical composition involves the creation of harmonic, timbral, and rhythmic sequences, often shaped to convey a certain aesthetic or affective impression (Loui, 2018; Przysinda et al., 2017). Much work has gone into developing algorithmic composition systems (i.e., music generation systems) capable of replicating this behavior. Although significant progress has been made, music generation remains a challenging task because the hierarchical structure and polyphony of realistic music pieces requires that the music generation system is capable of handling long-term harmonic, rhythmic and temporal structure as well as interdependency between voices (Dong et al., 2018). Affective music generation systems, which refer to those that can create pieces that evoke target emotions in listeners (Williams et al., 2017) present a further challenge since the system must be able to map musical parameters to affective states. A key limitation of many existing affective music generation systems is that they are rule-based, partly due to the lack of labeled music datasets that are large enough to train a learning-based system. However, work that addresses this limitation is beginning to emerge (Huang et al., 2021).

METHODOLOGY

Search strategy

We conducted a systematic literature review to analyze the literature on music generation for wellbeing, with a focus on emotional wellbeing. To do so, we searched for journal articles, conference proceedings, handbook chapters and dissertations published between January 2007 and August 2022 in four databases (Google Scholar, Web of Science, ABI/INFORM and ACM). The following search statement was used: ("music generation" OR "music synthesis") AND ("wellbeing" OR "emotion regulation" OR "emotion induction").

The initial search yielded 191 results on Google Scholar, 4 results from Web of Science, 2 results from ABI/INFORM and 7 results from ACM Digital Library. We manually identified and excluded non-English and duplicate results. The remaining articles were assessed using titles, abstracts and full texts where necessary. We selected publications that investigated how music generation could be applied to improve health and wellbeing, excluding those that (i) were focused on the technical and design aspects of a music generation system without elaborating on its applications to wellbeing; (ii) were focused on recognizing the affect conveyed by music (i.e., music emotion recognition) without elaborating on its applications to wellbeing, or (iii) where music was being created solely by humans, without any computational aspect. We also excluded reviews that simply summarized the results of existing studies but performed further backward reference searches using these reviews. Based on these criteria, we ended up with a sample of 20 publications.

		Target outcome?			
		Emotion regulation	Musical expression	Enhanced enjoyment, endurance or performance during physical exercise and rehabilitation	Collaborative play, music-making or dance
How is music generated?	Conditioned on physiological signals OR facial expressions	5	1	1	
	Conditioned on movement		4	3	3
	Playlist curation	2			
	Musical style transfer	1			

Table 1. A Publications classified by (i) approach to music generation, creation or curation and (ii) wellbeing outcomes targeted.

Study coding

We categorized the selected publications on two dimensions. First, what was the music technology being employed? Second, what was the wellbeing outcome being targeted? The results of this categorization are presented in Table 1.

Types of music technology employed

We identified four types of music generation technologies: (i) those conditioned on physiological signals and facial expressions, (ii) those conditioned on physical movement, (iii) playlist curation and (iv) musical style transfer.

Wellbeing outcomes targeted

We identified four target wellbeing outcomes: (i) emotion regulation, (ii) musical expression, (ii) enhanced enjoyment, endurance or performance during physical activities (exercise, rehabilitation) and (iv) collaborative musical activities.

LITERATURE ANALYSIS

Research Trends

Generally, interest in computational music-based approaches to improving health and wellbeing appears to be increasing. The earliest article in our sample was published in 2014, and the number of articles each year is generally trending upwards, albeit with some fluctuations. This aligns with the increased adoption of music technology in music therapy to support data collection efforts and explore new opportunities for treatment (Agres, Foubert, et al., 2021; Agres, Schaefer, et al., 2021).

Of the eight publications that addressed outcomes related to emotion regulation, one (Ramirez et al., 2015) reported the results of a musical intervention after a prolonged (ten weeks, two sessions per week) period of use, while the remaining seven reported results from a one-time intervention. Interventions that target emotion regulation outcomes most frequently employed music generation systems conditioned on physiological signals. This is to be expected given that the increasing sophistication of wearable devices enables real-time collection of many types of physiological data without restricting the participant's activities or movement, and that state of the art techniques achieve fairly accurate emotion recognition from physiological signals (e.g., Dissanayake et al., 2022). As such, these systems can generate music on-the-fly corresponding to the current physiological state of the participant. The music functions as a means of providing participants with immediate feedback on their current state, facilitating emotional awareness, and could also help participants modulate their affect towards a more desirable state (Edilgiriyeva et al., 2018).

Research Gaps and Opportunities

Based on the brief literature review on computational approaches to music generation for health and wellbeing that we have described in this paper, we suggest two broad limitations that future work could look to address – firstly, the lack of multimodal musical interventions, and secondly, insufficient longitudinal studies to understand the use and effectiveness of musical interventions "in the wild" over extended periods of time.

Multimodal interfaces. The majority of music generation systems reviewed use music as a unimodal intervention to address wellbeing outcomes. However, several studies aimed for physical movements used to control the music generation system to be reminiscent of dance, enabling users to express themselves not just through the music but also through dancing (Bergsland & Wechsler, 2016), or explicitly studied their musical intervention in the context of dance (Brown & Paine, 2019; Françoise et al., 2022).

There are several theoretical reasons as to why we might expect multimodal generation systems to increase the effectiveness of musical interventions, especially with regards to emotion regulation and musical expression. Firstly, they enable more robust communication of emotion – evidence from neuroimaging studies (e.g., Kreifelts et al., 2007) suggests that having congruent information from multiple modalities improves emotion recognition as

compared to unimodal conditions, and from an intuitive standpoint, we can also sense how music can be used to underscore key moments in multimodal media such as film. As such, multimodal generation systems could facilitate greater awareness and understanding of a participants' affective state as compared to unimodal systems, both of which are important dimensions of emotion regulation (Gratz & Roemer, 2004). Additionally, other modalities may provide affordances that support different aspects of the wellbeing outcome targeted than music. For example, an intervention that generated novel poetry based on facial expressions to provoke emotional reflection and regulation (Rajcic & McCormack, 2020) found that participants tended to make sense of the poetry by connecting it back to their own life, and that this sense-making process helped them conceptualize their emotions. Interventions that combine music with modalities such as poetry, for example, could target emotion regulation outcomes in a more holistic manner.

Longitudinal field studies. Most of the studies included in our review used an experimental design that involved only a single session with the musical intervention. Given that musical interventions are non-invasive and non-pharmacological, and that music is often an important part of our daily lives, we believe that there is great potential to develop more extended music-technology interventions that have greater and/or longer-lasting impacts on the user. One goal is to better understand the efficacy of using these interventions "in the wild", outside of a controlled lab setting, and over an extended period of time. Researchers should explore whether aspects of a real-world environment challenge the effectiveness of musical interventions, and if so, how the design of the interventions should be modified to address these challenges.

CONCLUSION

Musical interventions show promise as a scalable, accessible alternative avenue for improving health and wellbeing that can be used in isolation or to complement other medical interventions. We focus on computational approaches to music generation for health and wellbeing in terms of both the music generation technology evaluated, and the wellbeing outcome being targeted. With these two aspects in our purview, this review critically examines a sample of twenty publications on music generation for wellbeing and identifies research trends, limitations of existing studies, and directions for future work in this area.

REFERENCES

1. Agres, K. R., Foubert, K., & Sridhar, S. (2021). Music therapy during COVID-19: Changes to the practice, use of technology, and what to carry forward in the future. *Frontiers in Psychology*, *12*, 1317.
2. Agres, K. R., Schaefer, R. S., Volk, A., van Hooren, S., Holzapfel, A., Dalla Bella, S., Müller, M., De Witte, M., Herremans, D., Ramirez Melendez, R., & others. (2021). Music, computing, and health: A roadmap for the current and future roles of music technology for health care and well-being. *Music & Science*, *4*, 2059204321997709.
3. Altenmüller, E., & Schlaug, G. (2012). Music, brain, and health: Exploring biological foundations of music's health effects. *Music, Health, and Wellbeing*, 12–24.
4. Bergsland, A., & Wechsler, R. (2016). Turning movement into music: Issues and applications of the MotionComposer, a therapeutic device for persons with different abilities. *SoundEffects-An Interdisciplinary Journal of Sound and Sound Experience*, *6*(1), 23–47.
5. Brown, C., & Paine, G. (2019). A Case Study in Collaborative Learning via Participatory Music Interactive Systems: Interactive Tango Milonga. In *New Directions in Music and Human-Computer Interaction* (pp. 285–306). Springer.
6. Clark, I. N., Baker, F. A., & Taylor, N. F. (2016). The modulating effects of music listening on health-related exercise and physical activity in adults: A systematic review and narrative synthesis. *Nordic Journal of Music Therapy*, *25*(1), 76–104.
7. de Witte, M., Spruit, A., van Hooren, S., Moonen, X., & Stams, G.-J. (2020). Effects of music interventions on stress-related outcomes: A systematic review and two meta-analyses. *Health Psychology Review*, *14*(2), 294–324.
8. Dissanayake, V., Seneviratne, S., Rana, R., Wen, E., Kaluarachchi, T., & Nanayakkara, S. (2022). SigRep: Toward Robust Wearable Emotion Recognition With Contrastive Representation Learning. *IEEE Access*, *10*, 18105–18120.
9. Dong, H.-W., Hsiao, W.-Y., Yang, L.-C., & Yang, Y.-H. (2018). Musegan: Multi-track sequential generative adversarial networks for symbolic music generation and accompaniment. *Proceedings of the AAAI Conference on Artificial Intelligence*, *32*(1).
10. Edilgiriyeva, L., Chernova, A., Smolev, V., & Denef, S. (2018). Musebeat: Experience real-time music generation in sync with heartbeat. *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems*, 1–4.
11. Françoise, J., Fdili Alaoui, S., & Candau, Y. (2022). CO/DA: Live-Coding Movement-Sound Interactions for Dance Improvisation. *CHI Conference on Human Factors in Computing Systems*, 1–13.
12. Gratz, K. L., & Roemer, L. (2004). Multidimensional assessment of emotion regulation and dysregulation: Development, factor structure, and initial validation of the difficulties in emotion regulation scale. *Journal of Psychopathology and Behavioral Assessment*, *26*(1), 41–54.
13. Harwood, J., Qadar, F., & Chen, C.-Y. (2016). Harmonious contact: Stories about intergroup musical collaboration improve intergroup attitudes. *Journal of Communication*, *66*(6), 937–959.
14. Huang, R., Li, Y., Kang, D., Chen, Y., Yu, C., & Wang, X. (2021). Melody Generation with Emotion

Constraint. *Proceedings of the 2021 5th International Conference on Electronic Information Technology and Computer Engineering*, 1598–1603.
15. Irle, K., & Lovell, G. (2014). An investigation into the efficacy of a music-based men's group for improving psychological wellbeing. *Music Therapy Perspectives*, *32*(2), 178–184.
16. Koelsch, S. (2010). Towards a neural basis of music-evoked emotions. *Trends in Cognitive Sciences*, *14*(3), 131–137.
17. Kreifelts, B., Ethofer, T., Grodd, W., Erb, M., & Wildgruber, D. (2007). Audiovisual integration of emotional signals in voice and face: An event-related fMRI study. *Neuroimage*, *37*(4), 1445–1456.
18. Lonsdale, A. J., & North, A. C. (2011). Why do we listen to music? A uses and gratifications analysis. *British Journal of Psychology*, *102*(1), 108–134.
19. Loui, P. (2018). Rapid and flexible creativity in musical improvisation: Review and a model. *Annals of the New York Academy of Sciences*, *1423*(1), 138–145.
20. Mehr, S. A., Singh, M., Knox, D., Ketter, D. M., Pickens-Jones, D., Atwood, S., Lucas, C., Jacoby, N., Egner, A. A., Hopkins, E. J., & others. (2019). Universality and diversity in human song. *Science*, *366*(6468), eaax0868.
21. Moore, K. S. (2013). A systematic review on the neural effects of music on emotion regulation: Implications for music therapy practice. *Journal of Music Therapy*, *50*(3), 198–242.
22. Przysinda, E., Zeng, T., Maves, K., Arkin, C., & Loui, P. (2017). Jazz musicians reveal role of expectancy in human creativity. *Brain and Cognition*, *119*, 45–53.
23. Rajcic, N., & McCormack, J. (2020). Mirror ritual: An affective interface for emotional self-reflection. *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 1–13.
24. Ramirez, R., Palencia-Lefler, M., Giraldo, S., & Vamvakousis, Z. (2015). Musical neurofeedback for treating depression in elderly people. *Frontiers in Neuroscience*, 354.
25. Sloboda, J. A., & Juslin, P. N. (2010). At the interface between the inner and outer world. *Handbook of Music and Emotion*, 73–97.
26. Sloboda, J. A., O'Neill, S. A., & Ivaldi, A. (2001). Functions of music in everyday life: An exploratory study using the Experience Sampling Method. *Musicae Scientiae*, *5*(1), 9–32.
27. Staum, M. (2000). Music for physical rehabilitation: An analysis of the literature from 1950–1999 and applications for rehabilitation settings. *Effectiveness of Music Therapy Procedures: Documentation of Research and Clinical Practice*, *3*, 65–108.
28. Stegemann, T., Geretsegger, M., Phan Quoc, E., Riedl, H., & Smetana, M. (2019). Music therapy and other music-based interventions in pediatric health care: An overview. *Medicines*, *6*(1), 25.
29. Swaminathan, S., & Schellenberg, E. G. (2015). Current emotion research in music psychology. *Emotion Review*, *7*(2), 189–197.
30. Thaut, M. H., & Wheeler, B. L. (2010). *Music therapy.*
31. Thoits, P. A. (2011). Mechanisms linking social ties and support to physical and mental health. *Journal of Health and Social Behavior*, *52*(2), 145–161.
32. Tsekleves, E., & Darby, A. (2020). The role of playfulness and sensory experiences in design for public health and for ageing well. In *Sensory Arts and Design* (pp. 49–66). Routledge.
33. Weller, C. M., & Baker, F. A. (2011). The role of music therapy in physical rehabilitation: A systematic literature review. *Nordic Journal of Music Therapy*, *20*(1), 43–61.
34. Williams, D., Hodge, V. J., & Wu, C.-Y. (2020). On the use of ai for generation of functional music to improve mental health. *Frontiers in Artificial Intelligence*, *3*, 94.
35. Williams, D., Kirke, A., Miranda, E., Daly, I., Hwang, F., Weaver, J., & Nasuto, S. (2017). Affective calibration of musical feature sets in an emotionally intelligent music composition system. *ACM Transactions on Applied Perception (TAP)*, *14*(3), 1–13.