

# Intelligent Music Intervention for Mental Disorders: Insights and Perspectives

**W**ELCOME to the first issue of IEEE TRANSACTIONS ON COMPUTATIONAL SOCIAL SYSTEMS (TCSS) of 2023. The past 2022 was again a very productive year, in which we have published 159 articles with about 1850 pages in six issues. We also received much great and exciting news.

First of all, the CitesSore of TCSS has been continuously increasing and reached a new historical high of 9.3, compared to 7.9 for 2021 and 6.1 for 2020. IEEE TCSS ranks tenth among 426 academic journals in the subject category of “Social Sciences,” ranking in the top 2.5%. Among the 303 academic journals in the subject category of “Modeling and Simulation” and the 128 academic journals in the subject of “Human–Computer Interaction,” IEEE TCSS ranks 13th and 20th in the top 5% and top 16%, respectively, from the perspective of CiteScore rankings. All statistic suggests a significant improvement compared to the last year.

Second, IEEE TCSS was added to the Web of Science Sources Citation Index Expanded (SCIE) database in April 2021 but has yet to receive an official impact factor score. This year Clarivate updated the impact factor of all journals indexed by the Web of Science in late June, and TCSS finally has its impact factor for the first time. According to the Clarivate Journal Citation Reports, the latest Journal Impact Factor of IEEE TCSS was 4.727. As a result, TCSS currently ranked 6th among 32 academic journals in the “Computer Science, Cybernetics” category, which puts us in Q1 JCR Quartile based on Journal Citation Indicator (JCI).

We shall continue to try our best to make our journal a premier journal in the computational social system and look forward to further improving TCSS’s impact factor, ranking, and influence in our community. We would also like to express our sincere thanks to our editorial team, reviewers, authors, and readers for your great effort and support devoted to IEEE TCSS. Happy New Year to you all!

In this issue, after the usual introduction of our 33 regular articles, we would like to discuss the topic of “Intelligent Music Intervention for Mental Disorders: Insights and Perspectives.”

## I. SCANNING THE ISSUE

1. “Authorship Attribution of Social Media Messages” by *Antonio Theophilo, Romain Giot, and Anderson Rocha*

In this work, the authors present a new and updated dataset for the authorship attribution problem of small messages. Two methods that outperform the current state of the art are proposed, aiming at different scenarios, respectively, and

just one message to be attributed and two or more messages from the suspect are available. Compared with the baseline of Rocha et al., this method has two additional advantages worth mentioning, that is, there is no feature engineering step and the dimension of input space is greatly reduced, from 36400 to below 280.

2. “Topology Identification of Weighted Networks Via Binary Time Series From Propagation Dynamics” by *Xin Li, Ling Lin, Qianhui Liu, Zhengmin Kong, and Li Ding*

This study focuses on a topology identification problem of weighted networks with different connection strength, where binary time series generated by propagation dynamics are utilized. An influence probability matrix reflecting the weight of connection is proposed to quantify the influence of other nodes on one node as it transfers from susceptible state to infected state. Furthermore, maximum likelihood estimate and expectation-maximization algorithm are used to obtain the influence probability matrix. Hence, the topology identification problem of weighted networks is transformed into a classification problem of connection strength. A threshold method and a weight-based identification algorithm are provided to identify connection strength.

3. “Refugee Resettlement by Extending Group Multirole Assignment” by *Qian Jiang, Haibin Zhu, Yan Qiao, Dongning Liu, and Baoying Huang*

This article formalizes the refugee resettlement issue using the Environments–Classes, Agents, Roles, Groups, and Objects (E-CARGO) model. A novel solution is designed for Refugee resettling (RS) by extending the Group Multi Role Assignment (GMRA), which applies the agent stability evaluation method as a feedback mechanism while optimally resettling refugees. Finally, thousands of varying scale simulation experiments are carried out to test the proposed assignment method’s practicability and robustness. With this proposed solution, decision-makers can swiftly resettle refugees from multiple suffering countries while appropriately ensuring host countries’ benefit.

4. “Harnessing the Power of Ego Network Layers for Link Prediction in Online Social Networks” by *Mustafa Toprak, Chiara Boldrini, Andrea Passarella, and Marco Conti*

This article is to improve link prediction performance in Online Social Networks. The social relationships of individuals are arranged along five concentric circles of decreasing intimacy and different circles have different importance in predicting new links. The authors extend popular feature extraction prediction algorithms (both unsupervised and supervised) to include social circles’ awareness, validating the prediction performance of these circle-aware algorithms against several benchmarks, leveraging two Twitter datasets comprising a community of video gamers and generic users.

Result shows that social awareness generally provides significant improvements, beating also state-of-the-art solutions such as node2vec and SEAL, and without increasing the computational complexity.

5. “Multiple-Walrasian Auction Mechanism for Tree Valuation Service in NFV Market” by *Wuyunzhaola Borjigin, Kaoru Ota, and Mianxiong Dong*

Efficiently deploying the functions to different consumers is the major difficulty presented in network function virtualization (NFV). This article is the first work to define the virtualized service as a tree valuation in the NFV market. The multiple-Walrasian auction graphic model combined with virtual network functions (VNFs) of different bundled tree nodes based on Vickrey–Clarke–Grove (VCG) payment and a novel algorithm with the valuation structure algorithm and auction strategy are proposed. The results of comprehensive simulation confirm that the tree valuation mechanism outperforms the backpack auction model and reserve auction model with respect to social welfare.

6. “Joint Multi-Grained Popularity-Aware Graph Convolution Collaborative Filtering for Recommendation” by *Kang Liu, Feng Xue, Xiangnan He, Dan Guo, and Richang Hong*

This article develops a novel recommendation Joint Multi-grained Popularity-aware Graph Convolution Collaborative Filtering Model (JMP-GCF), which applies the idea of joint learning to incorporate multigrained popularity features, layer semantics, and high-order interactions into embedding generation. In addition, a multistage stacked training strategy is designed to speed up the model convergence of JMP-GCF. The authors conduct extensive experiments on three public datasets and achieved the state-of-the-art performance. Further experimental analysis verified the effectiveness and rationality of each component of JMP-GCF.

7. “Data Analytics and Visualization of Adaptive Collaboration Simulations” by *Renata Wachowiak-Smolíková and Haibin Zhu*

This article presents a visual analytics (VA) approach to studying dynamics involved in adaptive collaboration (AC) for large, multiagent simulation model using new open-source tools. An interactive VA system for analyzing complex adaptive collaborative systems is designed in this article. The preliminary results underscore the synergistic relationship between AC and VA and indicate future directions of the integration of collaboration research, AC, and big data analytics. Besides, the results also show that time-varying systems can be steered for optimal performance and assessing adaptations using VA dashboards.

8. “Impact on Cooperation of Altruism, Tenacity, and Need of a Resource” by *Oswaldo Terán and Christophe Sibertin-Blanc*

Using a well-grounded theoretical and computational framework, this article develops an approach for improving understanding of complex environmental and social problems caused by the management of common resources. The intricate interactions between altruism, tenacity, the necessity or importance of a resource, in particular a common resource, and the number of participants and their impacts on cooperation within a system of organized action are investigated using a free rider model. The factors of altruism, stakes, tenacity, and number

of actors are ranked in order of significance, with a strong interaction between altruism and stakes.

9. “On the Performance and Effectiveness of Digital Contact Tracing in the Second Wave of COVID-19 in Italy” by *Leonardo Maccari*

This article examines the data from Immuni, an Italian app, and demonstrates that Immuni was set up to create a significant number of notifications. Furthermore, this article calculates the testing resources that the health system would require if the app had been downloaded by 100% of the adult population and every informed person had to be tested. This article compares Immuni’s effectiveness to existing literature on other applications, finding that Immuni during the second wave was extremely imprecise with an intolerable amount of false positives.

10. “Efficient Storage Management for Social Network Events Based on Clustering and Hot/Cold Data Classification” by *Yulai Xie, Shuai Tong, Pan Zhou, Yuli Li, and Dan Feng*

This article provides a method for managing social network event storage based on microblog text clustering and hot/cold data classification. First, for the microblog text data, this article creates a keyword provenance graph. Then, this research uses provenance-based community partition (PCP) with local modularity to cluster the events. This article can also use incremental clustering to filter noisy data. The experimental findings demonstrate that utilizing clustering and hybrid storage policy, query time may be lowered by more than 70% and clustering purity can reach more than 93%.

11. “A Clinical-Oriented Non-Severe Depression Diagnosis Method Based on Cognitive Behavior of Emotional Conflict” by *Mi Li, Jinyu Zhang, Jie Song, Zijian Li, and Shengfu Lu*

This article proposes a diagnosis method of nonsevere depression (NSD) based on cognitive behavior of emotional conflict to improve the diagnosis accuracy of NSD, which has obvious performance advantages and provides technical support for improving the accuracy of clinical depression diagnosis. Compared with the results of others in recent years, it has a better performance. Furthermore, it also provides a new idea and method for the diagnosis and screening of depression.

12. “On Evolutionary Vaccination Game in Activity-Driven Networks” by *Dun Han and Xiang Li*

This article explores a comprehensive evolutionary vaccination game in activity-driven networks, which incorporates both human’s active characteristics and risk perception into epidemic spreading. According to the weighting effect, the individuals’ activity rate thresholds are obtained in different cases under the framework of the pure Nash equilibrium. In addition, how the number of connected edges of activated individuals  $m$  and infection rate  $\lambda$  affect individuals’ vaccination and decision-making is theoretically analyzed. It is proven that some unvaccinated individuals gradually become vaccinated individuals with the increase of  $m$  or  $\lambda$ .

13. “A Deceptive Reviews Detection Method Based on Multidimensional Feature Construction and Ensemble Feature Selection” by *Shudong Li, Guojin Zhong, Yanlin Jin, Xiaobo Wu, Peican Zhu, and Zhen Wang*

To address the shortcomings that models based on single text features to detect deceptive reviews are not necessarily

effective, a deceptive review detection method based on multidimensional feature construction and ensemble feature selection is proposed. The method addresses the limitation of single dimension features and can provide useful detection. Experimental results area under the curve show that the proposed method performs well in the task of deceptive review detection on two Amazon datasets.

14. “Dual-Population Social Group Optimization Algorithm Based on Human Social Group Behavior Law” by *Chao Wang, Xianqi Zhang, Yi Niu, Shan Gao, Jing Jiang, Zezhan Zhang, Peifeng Yu, and Hairong Dong*

This article proposes a new swarm intelligence algorithm named the dual-population social group optimization (DPSGO) algorithm inspired by the behavior law of human social groups, which simulate the behavior law of actual human social groups. The experimental results and performance comparison show that the DPSGO algorithm has a better searchability and convergence rate. This article is of great significance to the design and optimization of swarm intelligence algorithms by using the behavior law of human social groups and provides valuable guidance for enhancing the safety monitoring of aeroengines.

15. “Extending Group Role Assignment With Cooperation and Conflict Factors via KD45 Logic” by *Qian Jiang, Haibin Zhu, Yan Qiao, Dongning Liu, and Baoying Huang*

This article proposes a method to improve group role assignment with cooperation and conflict factors (GRACCFs), which is a creative social computing method for team establishment. It can maximize the new team’s performance through role assignment considering potential cooperation or conflict factors among agents. It overcomes the difficulty of collecting the pertinent cooperation or conflict information, and is more sustainable. Large-scale simulation experiments indicate that the proposed solution is practicable and robust. It provides a solid decision-making reference for administrators when establishing a sustainable team.

16. “Service-Splitting-Based Privacy Protection Mechanism for Proximity Detection Supporting High Utility” by *Qiuling Chen, Ayong Ye, Baorong Cheng, and Chuan Huang*

Aiming at the internal attack initiated by location-based service providers (LSPs) in location-based social network service (LSNS) to deal with user privacy, this work introduces an architecture with two servers, and proposes a new privacy protection method to support proximity detection by segmenting sensitive location information. It divides the proximity detection service into two independent subservices, and ensures that each subservice provider can only access part of the user’s location information. In addition, this article also proposes a prefix and suffix partition algorithm, which can ensure privacy and availability at the same time. Finally, a large number of experimental analyses prove the effectiveness of the scheme.

17. “Predicting STC Customers’ Satisfaction Using Twitter” by *Latifah Almuqren and Alexandra I. Cristea*

This article’s main contributions are defining the traceable measurable criteria for customer satisfaction with telecommunications (telecom) companies in Saudi Arabia and providing telecom companies’ recommendations based on monitoring

real-time customers’ satisfaction through Twitter. It is the first work to evaluate customers’ satisfaction with telecom company in Saudi Arabia using both social media mining and a quantitative method. It has been built by a corpus of Arabic tweets, using a Python script searching for real-time tweets that mention telecom company using the hashtags to monitor the latest sentiments of telecom customers continuously.

18. “Ensemble Hybrid Learning Methods for Automated Depression Detection” by *Luna Ansari, Shaoxiong Ji, Qian Chen, and Erik Cambria*

This study is conducted with the goal of identifying depression in three social media datasets. As a result, various text classification methods have studied and characterized a connection between language usage and depression. The key objective is to improve depression detection performance by examining and comparing two sets of methods: hybrid and ensemble. The results show that ensemble models outperform the hybrid model classification results. Different sentiment lexicons are used and combined with deep learning pipelines. The effect of single-lexicon features and combined lexicons is examined. The combined set of features is demonstrated in deep learning-based and logistic regression models.

19. “Autonomic Nervous Pattern Recognition of Students’ Learning States in Real Classroom Situation” by *Shi Chen, Zhaonian Hu, Shanshan Li, Xiaorou Hu, Guangyuan Liu, and Wanhui Wen*

This article first designs an experiment to collect electrocardiogram (ECG) data, and then uses a machine learning method to establish a physiological pattern recognition model to identify students’ learning state. There were significant differences in autonomic nervous activity between different learning states. Two consecutive R waves (RR) interval features are used to quantify the abovementioned neurophysiological differences. Data analysis results show that it is effective and feasible to use physiological measurement to monitor multiple learning states in class teaching and learning.

20. “LPP2KL: Online Location Privacy Protection Against Knowing-and-Learning Attacks for LBSs” by *Zhuo Ma, Shuai Xu, Bo Liu, and Jiuxin Cao*

Based on a new knowing-and-learning (KL) attacker, this article studies the location privacy disclosure in the open-use protection framework. A notable inference attack is found and implemented, which is fully customized for open protection. In this paper, a comparative location privacy protection framework Online Location Privacy Protection Against Knowing-and-Learning Attacks for LBSs (LPP2KL) is proposed to defend against potential deep learning reasoning attacks under controlled utility. The experiments in typical LBSs show that the proposed model performs well in location protection and utility control.

21. “A Deep Learning Approach for Semantic Analysis of COVID-19-Related Stigma on Social Media” by *Lin Liu, Zhidong Cao, Pengfei Zhao, Paul Jen-Hwa Hu, Daniel Dajun Zeng, and Yin Luo*

This article proposes a deep learning-based method to detect stigmatized contents on online social network (OSN) platforms in the early stage of COVID-19, and establishes a COVID-19-related (COR) stigma detection model based on

deep learning and outlines the early prevalence of COR stigma on the Chinese OSN platform from the contextual, temporal, spatial, and user levels. The method performs a semantic-based quantitative analysis to unveil essential spatial-temporal characteristics of COVID-19 stigmatization for timely alerts and risk mitigation. The advanced Bidirectional Encoder Representation From Transformers Model performs well to detect stigma posts on the OSN platform.

22. “Self-Attentional Multi-Field Features Representation and Interaction Learning for Person–Job Fit” by *Miao He, Dayong Shen, Tao Wang, Hua Zhao, Zhongshan Zhang, and Renjie He*

This article proposes a novel model based on the self-attention mechanism, named MUltiField Features representation and INteraction (MUFFIN) learning for person–job fit. All the features of resumes and jobs into several fields are grouped to explore meaningful feature representations and interactions, and a module is introduced to learn the hidden vectors of feature correlations in each feature field. Along this line, this article proposes a module with the multihead self-attention mechanism and a residual connection to further model the feature field interactions. Moreover, a multilayer perceptron is utilized to measure the matching score between a resume and a job.

23. “Analyzing the Stock Volatility Spillovers in Chinese Financial and Economic Sectors” by *Jingyu Li, Lu Cheng, Xiaolong Zheng, and Fei-Yue Wang*

By regarding the Chinese financial and economic sectors as a system, this article studies the stock volatility spillover in the system and explores its effects on the overall performance of the macroeconomy in China. Considering that the stock volatility spillover may vary over distinct timescales, the spillovers are disclosed through innovatively constructing the multiscale spillover networks, followed by connectedness computation, based on variational mode decomposition and generalized vector autoregression process.

24. “Offsetting Unequal Competition Through RL-Assisted Incentive Schemes” by *Paramita Koley, Aurghya Maiti, Sourangshu Bhattacharya, and Niloy Ganguly*

This article investigates the dynamics of competition among organizations with unequal expertise. Multiagent reinforcement learning (MARL) has been used to simulate and understand the impact of various incentive schemes designed to offset such inequality. For training a designed game Touch-Mark, this article proposes a novel controller-assisted MARL algorithm controller-assisted multiagent deep deterministic policy gradient (C-MADDPG), which empowers each agent with an ensemble of policies along with a supervised controller that by selectively partitioning the sample space and triggers intelligent role division among the teammates. Using C-MADDPG as an underlying framework, an incentive scheme is proposed for the weak team such that the final rewards of both teams become the same.

25. “An Evolutionary Guardrail Layout Design Framework for Crowd Control in Subway Stations” by *Jinghui Zhong, Tiantian Cheng, Wei-Li Liu, Peng Yang, Ying Lin, and Jun Zhang*

How to properly design the guardrail layout is a complex black-box optimization problem. This article proposes an

evolutionary framework, in which a novel guardrail layout encoding method can facilitate the algorithm to generate regular guardrail layout design solutions. Furthermore, a new fitness evaluation function is proposed to effectively measure the quality of a given guardrail layout design strategy. To validate its effectiveness, the proposed framework is applied to two scenarios with different characteristics. The simulation results have demonstrated that the proposed framework can provide promising guardrail layout designs, which can alleviate the congestion of subway stations effectively.

26. “An Overlapping Community Detection Approach Based on Deepwalk and Improved Label Propagation” by *Hongtao Yu, Ru Ma, Jinbo Chao, and Fuzhi Zhang*

The authors propose an overlapping community detection approach based on DeepWalk and the improved label propagation. They use the DeepWalk model to learn the network’s topology to obtain low-dimensional vector representations that reflect the spatial location of nodes and construct the weight matrix through vector dot product operation, and use a label propagation algorithm with a preference selection strategy can obtain stable overlapping communities by exchanging information with fixed neighbors on the basis of preserving the nodes’ own labels. The experimental results on the real network and synthetic datasets show better accuracy and stability than the baseline methods.

27. “Modeling Influencer Marketing Campaigns in Social Networks” by *Ronak Doshi, Ajay Ramesh, and Shrisha Rao*

This work presents an agent-based model (ABM) that can simulate the dynamics of influencer advertising campaigns in a variety of scenarios and can help discover the best influencer marketing strategy. The system is a probabilistic graph-based model that provides the additional advantage to incorporate real-world factors such as customers’ interest in a product, customer behavior, the willingness to pay, a brand’s investment cap, influencers’ engagement with influence diffusion, and luxury and nonluxury. The results exemplify the circumstance-dependent nature of influencer marketing and provide insights into which kinds of influencers would be a better strategy under respective circumstances.

28. “Understanding Public Opinion Toward the #StopAsianHate Movement and the Relation With Racially Motivated Hate Crimes in the US” by *Hanjia Lyu, Yangxin Fan, Ziyu Xiong, Mayya Komisarchik, and Jiebo Luo*

The authors conduct a social media study of public opinion toward the #StopAsianHate and #StopAAPIHate movement based on 46058 Twitter users across 30 states in the United States ranging from March 18, 2021, to April 11, 2021. To facilitate fine-grained analyses, the demographic information of the Twitter users, including age, gender, race/ethnicity, social capital, political affiliation, geolocation, family, income, and religious status, is either retrieved from the user profiles or inferred using classifiers. They find that the movement attracts more participation from women, younger adults, Asian, and Black communities.

29. “Influential Spreaders Identification in Complex Networks With TOPSIS and K-Shell Decomposition” by *Xiaoyang Liu, Shu Ye, Giacomo Fiumara, and Pasquale De Meo*

This article proposes a hybrid method based on K-shell decomposition to identify the most influential spreaders in complex networks. First, the method is used to decompose the network, which is regarded as a hierarchical structure from the inner core to the periphery core. Second, the existing centrality methods such as H-index are used as the secondary score of the proposed method to select nodes in each hierarchy of the network. In addition, the Technique for Order of Preference by Similarity to Ideal Solution method is introduced to calculate highest comprehensive score of node in each round.

30. “Re-Think Before You Share: A Comprehensive Study on Prioritizing Check-Worthy Claims” by *Yavuz Selim Kartal and Mucahid Kutlu*

In this article, how to prioritize claims according to their inspection value is studied. This article proposes a hybrid model, which combines the bidirectional encoder representation from the transformer (BERT) model with various features, including controversial topics, word embedding, part-of-speech tags, etc. In addition, the influence of training data on the BERT model and the proposed model is studied. Various methods have been explored to increase the size of tag data to effectively train the model, such as increasing positive samples, active learning, and using tag data in other languages. In addition, this paper discusses whether cross-language training is effective for tasks worth checking.

31. “SSTD: A Novel Spatio-Temporal Demographic Network for EEG-based Emotion Recognition” by *Rui Li, Chao Ren, Chen Li, Nan Zhao, Dawei Lu, and Xiaowei Zhang*

In this study, a novel sing-link end-to-end spatio-temporal demographic network (SSTD) is proposed, which can achieve electroencephalography (EEG)-based emotion recognition to more effectively represent the EEG signals. At the same time, an adaptive time window is used to fully consider individual differences. Then, the gate recursive unit (GRU) and symmetric positive definite matrix network (SPDNet) are used to calculate the advanced spatio-temporal domain features, and the spatio-temporal domain features are combined with demographic factors. Finally, a large number of experiments are carried out on two common datasets. The experimental results show that the SSTD model has good recognition performance.

32. “Goal Orientation in Music Composition and Other Social Behaviors Leading to the Common Quantitative Law” by *Nan Nan and Xiaohong Guan*

This article finds that goal orientation is the driving reason for the power-law distribution in typical social behaviors and construct a unified model to formulate the goal orientation mechanism in many social systems. Three mathematical characteristics of tonal music melody are found and the constrained entropy maximization model is constructed and the power-law distribution of melodic intervals is the result of solving the problem formulated in this model. The goal orientation behaviors of linguistics/informatics, economics, and design of complex engineering systems are analyzed. The results show that the models quantifying different social behaviors with goal orientation are consistent with the unified model.

33. “Aspect-Based Sentiment Analysis With Heterogeneous Graph Neural Network” by *Wenbin An, Feng Tian, Ping Chen, and Qinghua Zheng*

Currently, employing attention-based neural methods leads to lower model performance on aspect-based sentiment analysis. This paper proposes a heterogeneous aspect graph neural network to learn the structure and semantic knowledge from intersentence relationships. The model contains three different kinds of nodes: word nodes, aspect nodes, and sentence nodes, which can pass structure and semantic information between each other and update their embeddings to improve the performance of this model. It is the first to use a heterogeneous graph to capture relationships between sentences and aspects. The experiment results on five public datasets show the effectiveness of this model outperforming some state-of-the-art models.

## II. INTELLIGENT MUSIC INTERVENTION FOR MENTAL DISORDERS: INSIGHTS AND PERSPECTIVES

It has been well-established that music can have a “healing” effect on the mind and body, in line with ancient cross-cultural beliefs that music can be used a therapeutic way [1]. Over the past few decades, considerable efforts were made to explore the feasibility of music therapy as a nonpharmacological treatment for people with mental disorders. The mechanisms of how music affects the human brains remain unclear even though encouraging results from previous studies have been published showing the promising potential of music therapy. Furthermore, due to the wide variety of different mental disorders, a more precise and personalized music therapy regimen is needed to address the various differences. To this end, we want to share our view on how to make future music intervention more intelligent in this era of Artificial Intelligence (AI).

### A. Where Do We Stand?

When reading over existing literature, it is not difficult to find encouraging results from music therapy. For example, Bernardi et al. found that slow or meditative music can induce measurable and reproducible cardiovascular and respiratory effects, which may help to find a novel management method of cardiovascular diseases [2]. In another case, Wan et al. indicated that many children with autism may enhance their ability to focus and interact with others by participating in musical activities [3]. Moreover, music was found to be an enhancer of memory in patients with Alzheimer’s disease [4]. There is a strong evidence that music can be more effective when combined with standard care for depression intervention [5]. Maratos et al. gave a possible explanation that the fact that music can be used for depression intervention is because music can offer a patient opportunities for new aesthetic, physical, and relational experiences [6]. Cook was additionally considering the usage of music therapy in the context of oncology [7]. For example, the benefits of music for generalized anxiety disorder and primary insomnia were demonstrated in the experiments reported in [8], [9], and [10].

There is no need to illustrate all the promising results shown by music intervention here. More importantly, the question is why music can work playing the role of a “drug” for mental disorders. And a more fundamental problem, i.e., how music affects the brain, requires additional attention.

### B. Enter Artificial Music Intelligence

It seems broadly accepted that the field of computing offers great potential to the idea of music for health [11]. In particular, the field of music informatics has long since witnessed the entry of AI for high-level comprehensive music analysis, but also generation. In light of personalization and intervention, this includes the abilities to recognize and generate personalized music in different emotions and styles or pick the emotionally and beyond suiting musical piece(s) automatically in situ [12]. AI-based creating of “emotionally congruent music” has, for example, already been addressed by [13]. Generating music by AI in a target emotion is furthermore increasingly becoming popular, such as in [14]. Steering listeners’ emotions by rendering emotionally suited music in a personalized manner has, e.g., been shown in [15]. As users may prefer existing music over newly created tunes, targeted music playlist generation in an automated manner offers an alternative [16]. In fact, it has been observed in [17] that such an approach can lead to a “clinically significant reduction in depression symptoms”. In [18], the authors use Reinforcement Learning (RL) to study a user’s listening habits in the context of emotion offering an elegant solution to this problem.

Beyond music, sound analysis [19] and synthesis from an emotional perspective have been successfully targeted, and could hence be featured in the context of health interventions.

In general, using some kind of smart feedback loop, e.g., endowed by (potentially deep) RL seems promising when directly combining AI-based music generation or selection at semi or fully automatic designing interventions. Naturally, this comes at a risk during an RL algorithms exploration phase, where it could choose or generate emotionally or otherwise inappropriate music. From an ethical point of view, this demands for a potential human supervision of such algorithms.

### C. Further Opportunities and Challenges

We have witnessed the milestones achieved based on the guidance of Computational Psychophysiology (CPP) [20] toward quantitative recognition of mental disorders. We believe that, by leveraging the power of AI, big data, wearables, and other advanced information technologies, music therapy can undergo great progress and play a more important role in mental disorder intervention. We would like to share our insights and perspectives by indicating the opportunities and challenges in this young field as follows.

- 1) First of all, the mechanism of music therapy has never been thoroughly studied. We cannot find a clear map of music affects our human brain, which is a crucial fundamental knowledge. The efficient mathematical and/or physical approaches could be helpful to disclose the secrets between music and brain activity. As mentioned

in [21], in a view from the field’s perspective, music may trigger an interaction between the subject’s psychological field and the acoustic field.

- 2) In previous studies, we have found some encouraging results by using music as a nondrug intervention way for mental disorders. However, a closed loop negative feedback is lacking, which is quite important for providing the subject with a precise and personalized intervention. Therefore, one should consider introducing the quantitative methods in evaluating the performance of music therapy. At the same time, the music therapy strategy should be adaptive to the individual’s psychophysiological status. In addition, generating a copyright-free and personalized therapy music should be taken into account.
- 3) With the efforts and results of modeling and quantitative analysis on music melody [22] and brain recognition [20], it would be possible to establish quantified impact of selective music works on mental disorders. Therefore, music therapy targeting a particular disorder with quantitative guidance may become feasible.
- 4) Last but not the least, the concept of music should be extended to a more general one, i.e., audio. In fact, it is almost a common sense that some natural sounds (e.g., bird sounds, wind sounds, or ocean sounds) can have an effect on the humans’ emotions. How to use general audio for playing as a kind of another “music genre” in mental disorder intervention warrants additional attention.

### D. Conclusion

There is no doubt that music and the more general cover class—audio—have a great potential to explore a nonpharmacological treatment for mental disorders. On the one hand, we can easily find encouraging results demonstrating the efficiency of music therapy in clinical practice. On the other hand, revealing the inherited mechanism that makes music work in such way is still up in the air. Furthermore, how to evaluate an intervention’s performance in a quantitative way and how to realize a more precise and personalized experience for the subjects are not well studied.

Yet, now it is the time for a call to duty for the scientists, engineers, musicologists, and psychiatrists to work together for not only studying the fundamentals of music therapy but also making the intervention approach more intelligent than ever before. This may include the automatic analysis and synthesis of emotionally adequate and personalized music. Beyond that, it can also include partially or fully automated music interventions with some feedback loop to control the success and effect.

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