Universiteit
Leiden
The Netherlands

Interaction with sound for participatory systems and data sonification

Liu, D.

Citation

Liu, D. (2023, November 21). *Interaction with sound for participatory systems and data sonification*. Retrieved from https://hdl.handle.net/1887/3663195

Version:	Publisher's Version
License:	Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden
Downloaded from:	https://hdl.handle.net/1887/3663195

Note: To cite this publication please use the final published version (if applicable).

Interaction with Sound for Participatory Systems and Data Sonification

Proefschrift

ter verkrijging van
de graad van doctor aan de Universiteit Leiden,
op gezag van rector magnificus prof.dr.ir H. Bijl,
volgens besluit van het college voor promoties
te verdedigen op dinsdag 21 november 2023
klokke 12.30 uur

door

Danyi Liu

geboren te Wuhan, China

in 1990

Promotores:
Prof.dr.ir. F.J. Verbeek
Prof.dr. A. Plaat

Promotiecomissie:
Prof.dr. M.M. Bonsangue
Prof.dr. H.C.M. Kleijn
Prof.dr. M. Fiocco
Dr. K. Fedorova
Dr. R. Saunders
Prof.dr. J.N. Kok (University of Twente, the Netherlands)

Copyright © 2023 Danyi Liu
Cover design by Rentao Li (李任涛)
Layout design by Koen van der Blom and Danyi Liu
Printed by Proefschrift.nl
ISBN: 978-94-6473-270-2

The studies described in this thesis were performed at the Leiden Institute of Advanced Computer Science (LIACS), Leiden University, Leiden, The Netherlands.

The research was partially supported by the China Scholarship Council (No.201607720047).

To my mom

Contents

1 General Introduction **1**

1.1 Background . . . 2
1.2 Participatory Sound Interaction Models . . . 4
1.3 Data Sonification: Interaction & Design . . . 5
1.4 Evaluation of Data Sonification . . . 7
1.5 Research questions . . . 7
1.6 Structure of this Thesis . . . 9
1.7 Contribution of this Thesis . . . 10
1.8 Other publications . . . 11

2 Framework for Participatory Sound Interaction **13**

2.1 Introduction . . . 14
2.2 Participants . . . 15
2.2.1 Audience & Performers . . . 16
2.2.2 Audience Only . . . 16
2.3 Participation Journey Map . . . 18
2.3.1 Passive Participation . . . 19
2.3.2 Active Participation . . . 19
2.4 Performance Model and Sound Production . . . 22
2.4.1 Inherent Performance Model . . . 23
2.4.2 Responsive Performance Model . . . 25
2.5 Discussion . . . 26
2.6 Conclusion . . . 28

3 Bǎi/摆: an Interactive Sound Installation **31**

3.1 Introduction . . . 32
3.2 Interaction Design for Participation . . . 34

3.2.1 Technical Requirements . . . 35
3.2.2 The Pendulum Speaker . . . 37
3.2.3 The Space . . . 37
3.2.4 Software Development . . . 38
3.3 Sonification Design for Motion Data . . . 40
3.3.1 Sound from the Pendulum Speaker (PMSon) . . . 41
3.3.2 Sounds from the Surrounding Speakers (MBS) . . . 42
3.4 Observations and Discussion . . . 44
3.5 Conclusion . . . 48

4 Interactive Auditory Navigation in Molecular Structures 51
4.1 Introduction . . . 52
4.2 Interaction Design . . . 56
4.2.1 Speaker Setup . . . 56
4.2.2 Interactive Navigation of Structural Formulas . . . 57
4.3 Sonification Design . . . 63
4.3.1 Sound Synthesis Techniques . . . 64
4.3.2 Sound Composition . . . 68
4.4 Conclusion and Discussion . . . 76

5 Evaluating the Sonification of Molecular Structures: Validation I 79
5.1 Introduction . . . 80
5.2 Experiment Design . . . 82
5.2.1 Materials . . . 82
5.2.2 Software and Hardware . . . 83
5.2.3 Experimental Procedures . . . 84
5.3 Experimental Results . . . 85
5.3.1 Elements . . . 89
5.3.2 Directions . . . 92
5.3.3 Structures . . . 92
5.4 Conclusion and Discussion . . . 93
5.5 Further Analysis and Future Development . . . 95

6 Evaluating the Sonification of Molecular Structures: Validation II 97
6.1 Introduction . . . 98
6.2 Experiment Design . . . 100

6.2.1 Materials . . . 101
6.2.2 Software and Hardware . . . 101
6.2.3 Experimental Procedures . . . 102
6.3 Experimental Results . . . 103
6.3.1 Elements . . . 105
6.3.2 Directions . . . 108
6.3.3 Observations from Training . . . 108
6.4 Conclusion and Discussion . . . 109
6.5 Limitations and Future Development . . . 111

7 Conclusions and Discussion **113**
7.1 Conclusions . . . 114
7.1.1 Framework for Participatory Sound Interaction . . . 116
7.1.2 Interactive Sound System from Framework . . . 116
7.1.3 Sonification Design from Framework . . . 118
7.1.4 Evaluation of Sonification Design . . . 119
7.1.5 Navigation through Sonification . . . 120
7.1.6 Dialogue for Sonification . . . 122
7.2 Future work . . . 122

Appendix A Supplementary materials for Chapter 4 125

Appendix B Supplementary materials for Chapter 5 127

Appendix C Supplementary materials for Chapter 6 131

References 137

Samenvatting 143

Summary 147

中文摘要 149

Acknowledgements 151

Curriculum Vitae 153