Connecting orchestral conductors' interpretational intentions to conducting movement kinematics: A mixed-method approach using Deviation Point Analysis

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A thesis submitted in fulfilment of requirements for the degree of Doctor of Philosophy

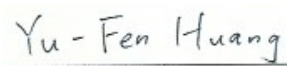
The University of Edinburgh

2018

DECLARATION

I hereby declare that this thesis, submitted in candidature for the degree of Doctor of Philosophy at the University of Edinburgh, and the research contained herein is of my own composition, except where explicitly stated otherwise in the text, and that this work was not previously submitted for the award of any other degree of professional qualification.

Parts of the data in this work have been published in Huang, Yu-Fen and Simon Coleman, Eric Barnhill, Raymond MacDonald, and Nikki Moran. 2017. ‘How do conductors’ movement communicate compositional features and interpretational intentions?’ *Psychomusicology*, 27(3): 148-157.



Yu-Fen Huang, 18 September 2017

Abstract

During orchestral performance, conductors play a role in which they provide their interpretations of the musical composition, communicating these interpretational intentions via their body movement. Pedagogical sources propose movement emblems for stock actions by which a conductor may deliver compositional and interpretational features in conducting practise. This thesis reports a mixed-methods study which provides empirical observations on the kinematic features evident in conducting practise, and which aims to explore the connection between such movements with compositional features and conductors' interpretative intentions. Six conductors' interpretational intentions were collected in interviews, and their conducting movements were recorded using a Qualisys motion capture system, while they worked on excerpts of repertoire by Mozart, Dvořák, and Bartók with a small string ensemble. In the interviews, conductors reported their general thoughts and beliefs about conducting. They were also prompted to identify the compositional events which they sought to highlight in their conducting, and to describe the conducting strategies they intended to use to highlight these musical events. The resulting qualitative data were thematically analysed. The conductor-identified compositional features were also used to guide kinematic investigations, using an innovative analysis method original to this project, Deviation Point Analysis (DPA). Conductors' movements are described using four dependent variables of baton tip (movement distance, speed, acceleration, and jerk). Results are reported for two-way repeated measures ANOVAs (repertoire x trial), and for *t*-tests revealing significant differences between cross-correlation coefficients for within-conductor trial pairs and between-conductor trial pairs. Further examination of the data using DPA serves to distinguish time-points with observable kinematic deviations from the conducting trials. These kinematic deviations were compared with conductors' stated intentions. Prominent clusters of kinematic deviations were seen to be associated with key musical events which conductors intended to emphasize temporal, melodic, dynamic, and instrumental aspects. Minor clusters of kinematic deviations were seen to be connected with interpretational intentions in a less stable manner, some occurring remotely from the conductor-identified locations. DPA method and findings are fully reported. The implications, advantages and limitations of this novel analysis approach are also discussed.

ACKNOWLEDGEMENTS

I would like to express my gratitude to my three supervisors at The University of Edinburgh: Dr Nikki Moran in The Reid School of Music, Dr Simon Coleman in The Institute for Sport, Physical Education and Health Sciences, and Professor Raymond MacDonald in The Reid School of Music. Nikki and Raymond have thoughtfully guided me through all the processes to explore, to organise pieces into a concreate project, and to overcome all the hindrances to achieve it. Simon has patiently taught me all my knowledge about statistics, biomechanics and motion capture starting from the very beginning– or else how would I know how to turn on the Qualisys system (!)? All of you have provided generous support and warm encouragement along the way of this challenging journey. I could never achieve this were not for your help and support.

I would like to give my special thanks to my colleagues: Dr Eric Barnhill, Dr Jon Kelly, Dr Alejandro Cooper, Dr Matt Gio and Michael Graham. You have provided valuable knowledge, advice, and timely help on data collection, data analysis and thesis writing, and support me to survive through all these demanding tasks. All the wonderful conductors and musicians who took part in the experiments made vast contributions to this research. Thank you all to make the completion of this project.

Above all, my gratitude goes to my families– my husband Sheng-Wei, my dad, and my mom, who is looking after me from the heaven now. You always believe in me that I can do more than I myself have ever imagined. And always give me great support, encouragement, and freedom to make me become whom I wished I could be. My dad guided me to know music when I was merely a little girl, and it has become an essential part of my life. My dear friends: Hsinyen, Mengling, Nicole, Meilin, Chia-Yi, Sabrina, Wenyu, June, Yu-Yin, Chong-Guang, and Gia Shih, have accompanied and encouraged me throughout. Thank you!

PhD study is a precious and adventurous journey for me to discover the truth and the beauty of music, and to rediscover the real me that has been hidden in the depth of my heart for such a long time. It is probably about the time to have a full stop for my doctoral journey, yet my journey to explore music is just about to begin. I wish that I can have my entire life to devote to our understanding of music, and to what I believe in music. The music of my life shall begin where words for my PhD end.

My doctoral research is supported by a scholarship from The Ministry of Education, Taiwan. The Reid School of Music and The Institute for Sport, Physical Education and Health Sciences at The University of Edinburgh have provided massive support to complete this research project.

Yu-Fen Huang

20th, September, 2017

TABLE OF CONTENTS

DECLARATION i

ACKNOWLEDGEMENTS ii

TABLE OF CONTENTS iv

LIST OF FIGURES xi

LIST OF TABLES xiv

LIST OF EXAMPLES xvi

Introduction 1

Chapter 1: Background 3

1.1. Body movements in orchestral conducting 3

1.1.1 Conducting movement emblems instructing musical features 4

1.1.2 Conducting movement coordinating musical timing and expressiveness 9

1.2. Body movements in music performance 11

1.2.1 Musical compositional structure and music performance 11

1.2.2 Music listeners' and musicians' body movements in music performance 16

1.2.2.1 Music listeners' body movement in relation to temporal structures in musical composition 16

1.2.2.2 Music performers' instrumental movement in relation to compositional structure 18

1.2.2.3 Music performers' ancillary movement in relation to compositional structure 19

1.2.2.4 Music performers' ancillary movement in relation to musical interpretation 21

1.2.2.5 Music performers' communicative movement 22

1.3. Human movement analysis: considerations from biomechanical and motor control perspectives 25

1.3.1 Biomechanical analysis of human movement 26

1.3.2 Dynamical system theory: movement variability and coordination 28

1.3.3 Movement analysis of orchestral conducting movement 30

1.4. Literature summary and thesis structure 31

1.4.1 Literature summary 31

1.4.2 Thesis aims and structure 34

Chapter 2: Conductors' ideology of orchestral conducting and musical interpretations: interviews 37

2.1. Introduction 37

2.2. Methods 38
2.2.1 Exploratory interviews 38
2.2.1.1 Exploratory questionnaire design 38
2.2.1.2 Participants 39
2.2.1.3 Procedure 39
2.2.1.4 Feedback from exploratory interviews 39
The manner by which to describe conducting movement 40
Conducting movements are compositional context dependent 41
Conducting movements are diverse across personal style 42
Body movement cooperates with other elements in conducting 42
2.2.1.5 Study development 43
2.2.2 Experimental design 44
2.2.2.1 Participants' background musical training and experience 44
2.2.2.2 Interpretations of musical excerpts and descriptions of conducting movement 45
2.2.2.3 General ideas of conducting 46
2.2.3 Ethics 46
2.2.4 Recruitment 47
2.2.5 Participants 47
2.2.6 Procedure 48
2.2.7 Data analysis 49
2.3. Result 49
2.3.1 Conductors' general ideas of orchestral conducting 49
2.3.1.1 Conductor's roles in the orchestra 50
Reveal musical compositional structure 50
Provide interpretations and present musical expressiveness 51
Manage interpersonal relationship in the orchestra 52
2.3.1.2 Criteria of good conducting 53
The knowledge of the musical composition and the preparation for the rehearsal 53
Conducting skills: the clarity of conducting and the communication with musicians 53
Related characters: having passion and being inspiring 54
2.3.1.3 Distinctive qualities of conductor's own conducting 54
2.3.1.4 Strategies to review conductor's own conducting 55
2.3.2 Conductors' interpretations of musical composition 55
2.3.2.1 The overall character of musical composition 58

The importance of the gesture for the first beat 58
2.3.2.2 Temporal structure 58
Tempo fluctuation 58
Metrical change 59
Rhythmic pattern 60
2.3.2.3 Melodic features and phrase structure 61
Specific type of melodic figure 61
Melodic contour, and combined with dynamical and harmonic elements 62
Relationship between different instrumental and counterpoint sections 64
Phrasing 66
2.3.2.4 Dynamic change 66
Subito forte, *sforzando*, and *marcato* accent 67
Diminuendo, *crescendo*, and Romantic music build up 67
2.3.2.5 Instrumental configuration 68
Instrumental sections, textural change, and playing technique 68
2.3.3 Conducting movements in relation to performance sound 69
2.3.3.1 Basic functions: Beating pattern and cuing gesture 69
Basic beating patterns and phrasing 69
Cuing gesture 69
2.3.3.2 Kinematic features: Hand position and travel distance 70
The contrast between dynamic levels and different instrumental configurations 70
Phrase structure and rhythmic pattern 71
2.3.3.3 Kinematic features: Movement smoothness and trajectory shape 71
Smooth movement with less verticality 71
The shape of movement trajectory 72
2.3.3.4 Other factors related to conducting movement 73
The connection between movement features and the performed sound 73
Palm gesture 73
Breathing, facial expression and eye-contact 73
Performance context 74
2.4. Summary and discussion of findings 74
2.4.1 Conductors' general ideas of orchestral conducting 74
2.4.2 Conductors' interpretational intentions 75
2.4.3 Conducting movement and performance sound 75

2.4.4 Discussion of findings ... 76
Diverse opinions on the relationship between the compositional structure and the conductor's interpretation ... 77
Detailed features and general characters in composition together affect conductors' interpretation ... 77
Direct connection between conducting movement and compositional features ... 79
Correspondence between conducting movement and performance sound ... 79
Chapter 3: Conducting movement kinematics ... 81
3.1. Introduction ... 81
3.2. Methods ... 82
3.2.1 Exploratory motion capture sessions ... 82
3.2.1.1 Participants ... 82
3.2.1.2 Material ... 82
3.2.1.3 Design ... 83
3.2.1.4 Procedure ... 83
3.2.1.5 Preliminary data analysis ... 85
3.2.2 Experimental design ... 91
3.2.3 Ethics ... 93
3.2.4 Recruitment ... 93
3.2.5 Participants ... 94
3.2.6 Procedure ... 94
3.2.7 Data processing ... 95
The definition of linear kinematic variables ... 95
The definition of musical beat and musical bar ... 96
Kinematic variables at musical bar level ... 97
3.2.8 Data analysis ... 98
Kinematic differences between musical excerpts and trial number: ANOVAs ... 99
Kinematic time-series similarities: Cross-correlations ... 100
3.3. Results ... 102
3.3.1 Linear kinematic differences of baton tip movement ... 102
3.3.1.1 Kinematic differences between musical excerpts and conductors: descriptive analyses 102
3.3.1.2 Kinematic differences between musical excerpts and trial number: descriptive analyses and ANOVAs ... 106

3.3.2 Linear kinematic time-series similarities of baton tip movement ... 111
3.3.2.1 Kinematic time-series similarities: descriptive analyses of cross-correlation coefficients ... 112
3.3.2.2 Kinematic time-series similarities in different musical excerpts: ANOVAs on cross-correlation coefficients ... 113
3.3.2.3 Kinematic time-series similarities within-conductor and between-conductors: *t*-tests on cross-correlation coefficients ... 115
3.4. Summary of findings ... 120
3.4.1 Conducting movement's kinematic features in three musical excerpts ... 120
3.4.2 Conducting movement's kinematic time-series similarities ... 121
Chapter 4: Connecting conducting movement kinematic variability to compositional features 123
4.1. Introduction ... 123
4.2. Methods ... 124
4.2.1 Statistical analysis ... 124
4.2.1.1 Data preprocessing ... 124
4.2.1.2 Deviation Point Analysis (DPA) ... 125
4.3. Results ... 129
4.3.1 Deviation Point Analyses in Mozart ... 131
4.3.1.1 Kinematic deviation points in relation to compositional features: Deviation Point Analyses of individual trials in Mozart ... 131
4.3.1.2 Within-conductor stability of kinematic deviation points: Deviation Point Analyses of individual conductor's mean curves in Mozart ... 138
4.3.1.3 Between-conductor kinematic variability: Deviation Point Analyses of between-conductor standard deviation in Mozart ... 142
4.3.1.4 Conducting kinematic deviations in relation to interpretational locations in Mozart 146
4.3.2 Deviation Point Analyses in Dvořák ... 149
4.3.2.1 Kinematic deviation points in relation to compositional features: Deviation Point Analyses of individual trials in Dvořák ... 149
4.3.2.2 Within-conductor stability of kinematic deviation points: Deviation Point Analyses of individual conductor's mean curves in Dvořák ... 158
4.3.2.3 Between-conductor kinematic variability: Deviation Point Analyses of between-conductor standard deviation in Dvořák ... 163

4.3.2.4 Conducting kinematic deviations in relation to interpretational locations in Dvořák 166
4.3.3 Deviation Point Analyses in Bartók 168
4.3.3.1 Kinematic deviation points in relation to compositional features: Deviation Point Analyses of individual trials in Bartók 168
4.3.3.2 Within-conductor stability of kinematic deviation points: Deviation Point Analyses of individual conductor's mean curves in Bartók 183
4.3.3.3 Between-conductor kinematic variability: Deviation Point Analyses of between-conductor standard deviation in Bartók 191
4.3.3.4 Kinematic deviation points in relation to interpretational locations in Bartók 199
4.3.4 Discussion of kinematic deviation points and movement variability in three musical excerpts 202
4.3.4.1 Kinematic deviation points in three musical excerpts 202
4.3.4.2 The connection between kinematic deviation points and compositional features 202
4.4. Summary of findings 207
Chapter 5: General discussion 210
5.1. Thesis summary 211
5.2. Summary of key findings 212
5.2.1 Conductors' interpretational intentions and descriptions of conducting strategies 212
5.2.2 Linear kinematic features in conducting movement 213
5.2.3 Connection between conducting kinematic deviations and compositional features 214
5.3. Discussion 215
5.3.1 Linking conductors' interpretational intentions to conducting kinematics: evidence from interviews and kinematic analyses 216
5.3.1.1 Conductors' ideas of musical characters in relation to movement kinematic features in conducting performance 216
5.3.1.2 Conductors' interpretational locations in relation to movement kinematic deviation points in conducting performance 217
5.3.2 Conducting emblems and movement kinematic deviation points in conducting performance 219
5.3.3 Compositional structure and movement kinematics in musical performance 224
5.3.4 Interpretational intentions and movement kinematics in musical performance 226
5.3.5 Conducting kinematic variability 227
Chapter 6: Conclusions and future directions 230

6.1. Strengths and limitations 230
6.2. Implications for future research 232
6.3. Concluding remarks 233

Appendix 1: Original quotations of conducting movement descriptions in four conducting educational manuals 235

Appendix 2: Consent forms and the permission of use of data for experiment 237

Appendix 3: Questionnaire for conductors' interviews and musicians' basic information 240

Appendix 4: Visual 3D pipeline commends for computing linear kinematic variables 256

Appendix 5: Full results of descriptive statistics for baton tip linear kinematic variables (musical excerpts and conductors) 257

Appendix 6: Full results of cross-correlations for 3213 trial pairs 259

Appendix 7: Full results of Deviation Point Analyses for 54 trials 280

References 296

LIST OF FIGURES

Figure 1.1 Hierarchical structure of musical metre (adapted from Lerdahl and Jackendoff 1983, 144, Figure 6.25). Units containing more musical beats are depicted at higher metrical levels. 13
Figure 1.2 Harmonic structure in C major scale 14
Figure 1.3 Dynamical system of conducting movement (adapted from Newell (1986)'s model)........33
Figure 1.4 Summary of thesis structure 35
Figure 2.1 Compositional and interpretational factors in conducting 78
Figure 3.1 Calibration axes and twenty-seven markers captured from the participant's upper body from frontal (left figure), lateral (middle figure), and posterior (right figure) view 85
Figure 3.2 Sample data of baton tip position on *x*-, *y*-, *z*- axes and the magnitude of position change for two conductors in pilot study 87
Figure 3.3 Equipment set up for motion capture data collection 92
Figure 3.4 Camera set up and makers captured by cameras in motion capture data collection 93
Figure 3.5 Final result of participating conductor preparation 95
Figure 3.6 Kinematic variable means and SDs in three musical excerpts and for six conductors 104
Figure 3.7 Kinematic variable means and SDs in three musical excerpts and for six conductors 106
Figure 3.8 Kinematic variable means, medians, SDs and IQRs in three musical excerpts and for three trials...109
Figure 3.9 Cross-correlation coefficient means and SDs in three musical excerpts..........................113
Figure 3.10 Within-conductor and Between-conductors cross-correlation coefficient means and SDs 117
Figure 4.1 Example of deviation point analysis of individual trials 127
Figure 4.2 Example of deviation point analysis of individual conductors' average curve 127
Figure 4.3 Example of between-conductor variability 127
Figure 4.4 Example of deviation point analysis of between-conductor variability 128
Figure 4.5 Example of deviation point summary..128
Figure 4.6 Deviation points of each trial for four kinematic variables in Mozart..............................132
Figure 4.7 Statistics of upper deviation points and lower deviation points in Mozart 134
Figure 4.8 Kinematic deviation points and summary of musical features in Mozart 135
Figure 4.9 Deviation point analyses of each conductor's mean curve of three trials conducting Mozart 139
Figure 4.10 Deviation points of each conductor's mean curve for four kinematic variables in Mozart 140
Figure 4.11 Statistics of deviation points of conductor's mean curves in Mozart 141

Figure 4.12 The comparison of deviation points in trials and in conductor's mean curves in Mozart 142
Figure 4.13 Between-conductor kinematic variability in Mozart 144
Figure 4.14 Deviation point analysis of between-conductor kinematic variability in Mozart 145
Figure 4.15 The comparison of between-conductor variability deviation points and within-conductor deviation points in Mozart 146
Figure 4.16 Conductors' interpretational intentions and kinematic deviations in Mozart 148
Figure 4.17 Deviation points of each trial for four kinematic variables in Dvořák 150
Figure 4.18 Statistics of upper deviation points and lower deviation points in Dvořák 152
Figure 4.19 Kinematic deviation points and summary of musical features in Dvořák 155
Figure 4.20 Deviation point analyses of each conductor's mean curve of three trials conducting Dvořák 159
Figure 4.21 Deviation points of each conductor's mean curve for four kinematic variables in Dvořák 160
Figure 4.22 Statistics of deviation points of each conductor's mean curve in Dvořák 161
Figure 4.23 The comparison of deviation points in trials and in conductor's mean curves in Dvořák 162
Figure 4.24 Between-conductor kinematic variability in Dvořák 164
Figure 4.25 Deviation point analysis of between-conductor kinematic variability in Dvořák 165
Figure 4.26 The comparison of between-conductor variability deviation points and within-conductor deviation points in Dvořák 166
Figure 4.27 Conductors' interpretational intentions and kinematic deviations in Dvořák 168
Figure 4.28 Deviation points of each trial for four kinematic variables in Bartók 169
Figure 4.29 Statistics of upper deviation points and lower deviation points in Bartók 173
Figure 4.30 Kinematic deviation points and summary of compositional features in Bartók 178
Figure 4.31 Deviation point analyses of each conductor's mean curve of three trials conducting Bartók 184
Figure 4.32 Deviation points of each conductor's mean curve for four kinematic variables in Bartók 186
Figure 4.33 Statistics of deviation points of each conductor's mean curve in Bartók 188
Figure 4.34 The comparison of deviation points in trials and in conductor's mean curves in Bartók 190
Figure 4.35 Between-conductor kinematic variability in Bartók 193
Figure 4.36 Deviation point analyses of between-conductor kinematic variability in Bartók 195

Figure 4.37 The comparison of between-conductor variability deviation points and within-conductor deviation points in Bartók 197
Figure 4.38 Conductors' interpretational intentions and kinematic deviations in Bartók 201

LIST OF TABLES

Table 1.1 Summary of instructions for conducting movements associated with particular musical features 7
Table 2.1 Participants of pilot study 39
Table 2.2 Interview structure 44
Table 2.3 Questions in the first part of interview 'musical background' 45
Table 2.4 Questions in the second part of interview 'interpretations of music and descriptions of conducting movement' 46
Table 2.5 Questions in the third part of interview 'general ideas of conducting' 46
Table 2.6 Conducting experiences of interview participants 47
Table 2.7 Instrumental experiences of interview participants 48
Table 2.8 Conductors’ general descriptions of orchestral conducting 50
Table 2.9 Summary of conductors’ highlighting compositional structure and movement 56
Table 3.1 Locations of twenty-seven reflective makers in motion capture data collection 84
Table 3.2 Participating musicians 94
Table 3.3 Definition of kinematic variables 98
Table 3.4 Descriptive statistics for musical excerpts and conductors 103
Table 3.5 Descriptive statistics for musical excerpts and trials 107
Table 3.6 Results of two-way repeated measure ANOVAs (music × trial) 110
Table 3.7 Results of non-parametric Friedman’s Tests (music, trial) 110
Table 3.8 Descriptive statistics of cross-correlation coefficients 112
Table 3.9 Results of one-way repeated measure ANOVAs (Music) on cross-correlation coefficients 114
Table 3.10 Results of non-parametric Friedman’s Tests (Music) on cross-correlation coefficients ... 114
Table 3.11 Descriptive analyses of within-conductor and between-conductors cross-correlation coefficients 116
Table 3.12 Results of t-tests (Within-conductor coefficients and Between-conductors coefficients) 118
Table 3.13 Results of non-parametric Mann-Whitney Tests (Within-conductor coefficients and Between-conductors coefficients) 119
Table 4.1 Conductors’ interpretational intentions and kinematic deviations in Mozart 147
Table 4.2 Conductors’ interpretational intentions and kinematic deviations in Dvořák 167
Table 4.3 Conductors’ interpretational intentions and kinematic deviations in Bartók 200

Table 4.4 Summary of compositional features and bars showing corresponding kinematic Deviation Points in three musical excerpts 204
Table 5.1 Pedagogical conducting emblems, conductors' descriptions of movement, identified kinematic Deviation Points and examples 220

LIST OF EXAMPLES

Example 2.1 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 1-18. 59
Example 2.2 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 4-10. 60
Example 2.3 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 129-137. 60
Example 2.4 Mozart, *Serenade in G major*, K.525, 1st movement, bars 1-6. 61
Example 2.5 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 23-30. 62
Example 2.6 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 29-48. 62
Example 2.7 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 11-22. 63
Example 2.8 Mozart, *Serenade in G major*, K.525, 1st movement, bars 28-34. 64
Example 2.9 Mozart, *Serenade in G major*, K.525, 1st movement, bars 1-13. 65
Example 2.10 Mozart, *Serenade in G major*, K.525, 1st movement, bars 14-27. 65
Example 2.11 Mozart, *Serenade in G major*, K.525, 1st movement, bars 42-48. 65
Example 2.12 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 69-94. 68
Example 3.1 Elgar, *Pomp and Circumstance March*, Op.39, No.1, bars 8-25 (theme A). 89
Example 3.2 Elgar, *Pomp and Circumstance March*, Op.39, No.1, bars 77-91 (theme B). 90
Example 4.1 Mozart, *Serenade in G major*, K. 525, 1st movement, bars 14-27. 136
Example 4.2 Mozart, *Serenade in G major*, K. 525, 1st movement, bars 1-6. 137
Example 4.3 Mozart, *Serenade in G major*, K. 525, 1st movement, bars 35-55. 137
Example 4.4 Mozart, *Serenade in G major*, K. 525, 1st movement, bars 28-34. 138
Example 4.5 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 11-22. 153
Example 4.6 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 31-40. 154
Example 4.7 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 1-10. 156
Example 4.8 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 23-30 157
Example 4.9 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 41-50. 158
Example 4.10 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 1-18. 174
Example 4.11 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 118-137. 174
Example 4.12 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 169-183. 175
Example 4.13 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 39-58. 175
Example 4.14 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 59-79. 176
Example 4.15 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 158-168. 176
Example 4.16 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 80-93. 177
Example 4.17 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 138-147. 177
Example 4.18 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 19-38. 182
Example 4.19 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 148-157. 183

Example 4.20 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 95-117. 183

Introduction

What is it that orchestral conductors do when they are conducting and how do they do it? These questions are central to this thesis. Musical repertoire in the Western classical art music tradition is primarily disseminated in printed editions of musical notation, in the form of information-rich scores. It is common to approach and refer to such scores as the source of a given musical composition, and as the authoritative basis for any performed event of the composition. The nature of musical performative behaviour, however, is distinctive and highly individualised. Ensemble conductors– like instrumental performers and singers– are expected to communicate both fidelity to an authoritative work, as well as their personal insight and musical interpretation. In conducting performance, these simultaneous demands result in a complex interaction: between the compositional elements of the musical work, the conductor's own interpretational intentions, and the broader socio-cultural context of the performance activity. All these elements contribute to the diversity of conducting movement. This thesis discusses original qualitative interview data, examining the views and beliefs of a group of ensemble conductors about their own actions and intentions. These findings are considered alongside empirical kinematic analyses of conductors' performed conducting movements. Informed by biomechanics, this thesis investigates conducting movement by drawing upon the perspective of a dynamical system, which considers the variety of orchestral conducting movement as the result of interactions among multiple factors.

While musicians in the orchestra clearly use their body movements to produce musical sound, this is not the case for conductors. In orchestral performance, conductors use their body movement to communicate their musical ideas and to coordinate the individual performances by members of an ensemble. Conductors succeed in communicating specific musical instructions in aspects such as tempo fluctuation, phrase shaping, accentuation, dynamic change, articulation, and instrumental configuration. There are established conventions– commonly-agreed movement types and gestures– by which conductors may communicate these instructions. Beyond these conventional movement types, however, conducting movement tends to be idiosyncratic. Individual conductors aim to bring different interpretations to the performed composition, and use their personal conducting strategies and style to communicate their interpretational intentions.

There has been a growing body of musical movement research in recent decades. Based on systematic observations of musical movement and quantitative data collected by motion capture system, some of the ways in which musical movement associates with musical compositional structures and the music performer's expressive intentions have been identified and demonstrated. Different aspects of musical movement have been addressed, including the sound-producing, technical functions of instrumental performance, as well as the performer's communication of expressive variation and their interaction with fellow performers. However, up to now, our understanding of musical movement has been concentrated on music listeners' and musicians' body movement. Aspects in orchestral conducting movement are yet to be adequately explored. This thesis reports orchestral conducting research using mixed methods. Based on qualitative descriptions reported by conductors in interviews and quantitative kinematic analysis of conducting movement collected by a motion capture system, the connections between musical compositions, conductors' interpretational intentions, and the kinematics of conducting movement are explored.

Research motivation and preliminary assumptions about conducting

To conclude this introduction, it is important to include some personal information about my musical background and motivation for undertaking the research, since these factors have naturally informed the research process. I have been a violin player for over thirty years, and through my experience of playing in orchestra for over fifteen years, I observed massive diversities between individual conductors' conducting styles and behaviour – regardless the shared conventions of conducting movement. Well-educated and experienced orchestral musicians are expected to be able to comprehend conductors' specific instructions through those diverse movements, and to respond in their music playing accordingly. However, most existing conducting literature and research only address the general common rules of conducting, and conductors and musicians therefore acquire the knowledge of diverse conducting styles according to their individual performative experiences. The gap between what is known of conducting in literature versus lived experience may stem from a lack of empirical and systematic methods by which to answer the questions: 'How exactly do individual conductors' movements vary?' and 'How do individuals' conducting movements communicate the differences in their musical understanding?' In this thesis, empirical methods are employed to closely examine conducting movement. Conductors' descriptions of their own movement (from the first-person perspective as a conductor) and the author's observations of conducting movement motion capture data (from the third-person perspective as an orchestral musician) are compared to shape further understanding of orchestral conducting. It is expected that common tendencies should be found between different conductors' conducting, with individual small-scale variations between each conductor's conducting, which can be regarded as the representative features of their own conducting styles.

Chapter 1: Background

This chapter presents the theoretical basis for this thesis, showing the way in which various strands of existing knowledge and current research from music conducting education, music performance research, and music psychology all inform our current understanding of ensemble conductors' movement. In section 1.1, conventional conducting movement emblems are summarised from educational manuals. Evidence from empirical studies are presented to show that conducting kinematics affect musicians' movement synchronisation and uttered musical expressiveness. In section 1.2, music psychological models are discussed, which seek to define the relationship between musical composition, performance factors, and body movements in music performance. Empirical studies of the body movements of music listeners and musicians are reviewed to clarify specific connections between musical body movement, compositional elements, and performers' interpretative intentions, as well as multi-functional roles of musical movement in the context of music performance activity. These findings offer an essential groundwork and guidance to carry out the current conducting movement study. In section 1.3, the biomechanical approach and dynamical system theory are presented. These analytical methods provide the fundamental methodology for this thesis to examine conducting movement kinematics in a dynamical interactive system. On the basis of the abovementioned literature, research aims of this thesis together with the proposed research structure are then presented (section 1.4).

1.1. Body movements in orchestral conducting

In orchestral settings, conductors play the role of communicating musical interpretations based on their understanding and insights of a particular composition. They use body movements to direct individual members of an ensemble to play together in a coordinated manner, expressing these interpretations in performance. In order to accurately communicate their musical expressive intentions, conductors deliberately manipulate their body movements– deviating from the most simplistic, regular time-keeping beating movement– to communicate the specific compositional elements they intend to emphasise. This communication process in conducting thus relies on a collection of conducting movement 'norms' to instruct the conductor's intended performance.

Conducting movement is a clear case of intentional and systematised nonverbal communication, which can be discussed in a broader context, drawing on pragmatics research from scholars in psychology and linguistics. Nonverbal communication research has focused a great deal on the hand gestures which accompany speech (e.g., Duncan, Cassell and Levy 2007; Kendon 2004; 2013;

McNeill 1992; 2015). Such studies have demonstrated particular ways in which hand gestures associate with verbal communication. Kendon (2004) proposes a continuum of gesture spanning *gesticulation* to *sign language*, which highlights the versatility of this communicative modality. In Kendon's (2004) continuum, gesticulation designates gestures which lack language properties and which are meaningful only when accompanied with speech. At the other end of the spectrum, sign language conveys meaning autonomously from verbal speech, and communicates information associated with other linguistic systems, such as vocabulary and grammatical structure. In this continuum, *emblem* occupies an intermediate position between these two ends, possessing properties from both extremes of the continuum such that it can convey meaning without the accompaniment of speech, yet it lacks the potential to construct a complete grammatical structure (McNeill 1992). From the perspective of an orchestral musician, conducting movement communicates specific musical instructions. However, the connection between the movement and its meaning is not as rigid as in linguistic lexicon. Prior studies, recognising this, have drawn upon the concept of the gestural emblem in investigations of conducting movement (e.g., Freeman 2014; Gallops 2005; Sousa 1988), which have sought to specify how conductors use such conducting movement emblems to communicate particular compositional elements and musical interpretations.

The first task for this thesis is to identify and describe a selection of conventional conducting movements, to help explain the recognised functions of these movements regarding communication, coordination, and expression. As reported in the following section (section 1.1.1), this task was carried out by identifying gestural emblems from within a number of published conducting educational manuals. The subsequent section (1.1.2) are dedicated to a survey and review of findings from empirical research into conducting movements. Such studies have aimed to describe how conductors deliberately regulate the timing, size, speed, and smoothness of their body movements, in order to communicate accurate musical timing and to convey a variety of musical expressiveness.

1.1.1 Conducting movement emblems instructing musical features

The best understood role for a conductor is to coordinate the actions of musicians with respect to their timing. Conductors manipulate the timing of their movement to communicate both tempo (pace) and metrical information. The metre is delivered by specific, basic repetitive beating patterns (e.g., two-beat, three-beat, and four-beat patterns) in conducting. With wide variation according to the experience and expertise level of the conductors themselves and the members of the ensemble, some conductors may take a role which focuses almost exclusively on maintaining the tempo and metre of the performance. They may use no special movements to deliver detailed rhythm, except on some special occasions, such as when accents in syncopated or unusual rhythmic patterns are emphasised (Green, Gibson and Malko 2004; Hunsberger and Ernst 1992; Labuta 2003; Rudolf 1995).

But in addition to temporal structures of tempo and metre, proficient conductors use their body movement to communicate musical aspects of articulation, dynamics, and phrasing. These dimensions are arrived at from a mixture of compositional features dictated by visual signs in the written score, and the conductor's interpretations of the musical composition. The score may provide a general, but not thorough, framework for articulation and dynamic configurations. And yet, in the performance, the conductor's role is one of ultimate responsibility for interpreting the score, and they must decide the nuances of how these musical aspects should become voiced or articulated in the event of performance. The conducting movement manifests the compositional structures interpreted by the conductor, and thus the compositional and interpretational factors are bonded together in conducting.

It should be clarified that in this thesis, **compositional** features refer to features of pitch, timing and instrumentation instructed in the written score; **interpretational** features refer to the traits in the musical work highlighted by the performer (the musician or the conductor). However, the compositional and interpretational aspects are often inseparable in music performance sometimes, and **musical** features refer to general features mixed by these two layers. The relationship between compositional and interpretational aspects of music is further discussed in section 1.2.1.

Literature on conducting traditions includes a variety of historical documentation and instructional manuals (e.g., Boonshaft 2002; Bowen 2003; Bowles 1975; Carse 1948; Colson 2012; Jacobson 1979). Conducting styles vary by geographical region (e.g., American, Central European, English, French, Italian, and Russian traditions), as well as by individual preference (Holden 2003). Yet regardless of different preferences, in orchestral performances, conductors and orchestral musicians communicate based on a common collection of conducting movement emblems. The assembly of conducting movement emblems is an essential part of musical training, and thus is the shared basis for non-verbal communication in orchestral conducting. To better understand the representation of conducting gesture within this body of instructional manuals, six local (Edinburgh-based) conductors[1] were asked to recommend four influential conducting educational manuals. They recommended the following: *The modern conductor* by Green, Gibson and Malko (2004); *The art of conducting* by Hunsberger and Ernst (1992); *Basic conducting technique* by Labuta (2003); *The grammar of conducting* by Rudolf (1995). The texts of these conducting educational manuals were

[1] Those six conductors joined in the subsequent interviews and motion capture sessions.

reviewed with the aim of extracting instructions relating to conducting emblems, along with the descriptions of specific musical elements they are intended to illustrate.

Basic movement emblems used to communicate musical features compiled by these four influential conducting educational manuals are summarised in Table 1.1, with original quotations of complete movement descriptions from conducting manuals listed in Appendix 1. The common conducting movement emblems found in conducting textbooks are used to instruct articulation, dynamic, and phrasing aspects of the musical work. Temporal musical features (tempo, metre, rhythm) are not included in this table. Musical terms in Table 1.1 are defined according to *Oxford Music Online* (either from *Grove Music Online* or *Oxford Dictionary of Music*).

Table 1.1 Summary of instructions for conducting movements associated with particular musical features

Musical term	**Definition**	**Summary of conducting movement**
Articulation (conducting style)	'The degree to which a performer detaches individual notes from one another in practice (e.g. in staccato and legato)' (Chew 2001, 'Articulation and phrasing', para. 1)	-
Neutral	-	- passive style - lack of expressive quality - short, straight trajectory
Staccato	'Of an individual note in performance, usually separated from its neighbours by a silence of articulation' (Chew and Brown 2001, 'Staccato', para. 1)	- sudden motion followed by an abrupt stop - quick, straight motion with a stop on each count - bouncing on the down-beat - small gesture
Legato	'Of successive notes in performance, connected without any intervening silence of articulation' (Chew 2001, 'Legato', para. 1)	- smooth, sustained, flowing, curved gesture - small to very large gesture (depending on the emotional intensity of the music)
Marcato	'Each note emphasized' (Latham 2011, 'Marcato')	- heavy motion with a stop on each count - forceful, sometimes aggressive - medium to large gesture - either straight or curved trajectory (depending on the music)
Tenuto	'A holding of individual notes to their full length' (Fallows 2001, 'Tenuto', para. 1)	- smooth motion with a stop on each count - very heavy gesture - small to very large gesture
Dynamics	'The intensity of volume with which notes and sounds are expressed' (Thiemel 2001, 'Dynamics', para. 1)	-
Forte	'"Strong", i.e. loud (abbreviation *f*)' (Kennedy 2006, 'Forte')	- large gesture - the left palm faces the conductor - can be intensified by slight shaking of forearm(s) - supportive gesture in the left hand to indicate a continuing forte level
Piano	'Instruction to play softly (abbreviation *p*). Opposite of forte, loud' (Kennedy 2006, 'Piano')	- small gesture - the left palm faces musicians
Crescendo	'Gradually increase in loudness' (Kennedy 2006, 'Crescendo')	- gesture gradually becomes larger - lift the left hand, thumb up, upward palm
Diminuendo	'Gradually getting quieter' (Kennedy 2006, 'Diminuendo')	- gesture gradually becomes smaller - turn the left palm slowly toward musicians or downward - lower left hand position
Subito forte	'Suddenly increase in loudness' (Sadie and Tyrrell 2001, 'Subito', para. 1)	- suddenly enlarge the size of gesture with a fist and a rebound - move hand(s) away from the body quickly
Subito piano	'Suddenly quiet' (Sadie and Tyrrell, 2001, 'Subito', para. 1)	- suddenly compress the size of gesture - pull back hand(s) closing to the body quickly - turn the left palm toward musicians quickly
Accent, *fp*	'Perceptible alteration (usually increase) in volume ('dynamic accent')' (Thiemel 2001, 'Accent', para. 1)	- strong, large gesture suddenly
Phrasing	'Short musical units of various lengths … applied to the subdivision of a melodic line' and 'longer than a motif but shorter than a period' (Sadie and Tyrrell 2001, 'Phrase', para. 1)	- smooth, sustained, supportive gesture - larger gesture at the beginning of a phrase; smaller gesture at the end of a phrase

Note: 1) Definitions of musical terms are from *Oxford Music Online* (*Grove Music Online* or *Oxford Dictionary of Music*).

2) Conducting movements are summarised from:
The modern conductor by Green, Gibson and Malko (2004); *The art of conducting* by Hunsberger and Ernst (1992); *Basic conducting technique* by Labuta (2003); *The grammar of conducting* by Rudolf (1995).
3) The term 'gesture' is used in the table since conducting manuals tend to use this term to refer to a specific conducting motion containing particular meaning, whereas the term 'movement' is used in the thesis text when discussing general features of the motion.
4) Conducting manuals do not give general descriptions regarding articulation and dynamics.

As the summary presented in Table 1.1 illustrates, from the detailed study of these conducting movements, it appears that a specific conducting emblem can be understood as a series of movement descriptions including the palm direction (upward/ downward/ facing musicians/ facing the conductor), hand position (high/ low/ away from the body/ close to the body), movement size (large/ small), speed (quick/ slow), acceleration (sudden/ gradual change of movement), smoothness (smooth/ jerky), trajectory shape (straight/ curved), movement quality (bouncing/ heavy/ sustained/ flowing/ forceful). Even 'movement qualities' can be further deconstructed into detailed descriptions: 'bouncing', for instance, can be described as a quick movement with a specific curve; 'heavy' and 'sustained' movements should be slow, smooth and with short stop on the count. These detailed descriptions of movement provide a reference to consult when observing and investigating conducting movement, either using qualitative or quantitative approaches.

It can be observed that the connection between musical features and conducting movements is flexible, that the same musical feature can be communicated by several possible conducting strategies. Instructions for *forte*, for example, can be communicated either by enlarged movements, or by specific gestures in the left hand, or even by both. Therefore, in the process of conducting, each conductor makes independent choices to decide which musical aspects to emphasise, how (or to what extent) to emphasise them and by which conducting movements to instruct such emphases. All these decisions make up each conductor's own conducting style.

The commonly-used conducting emblems discussed here are confirmed by observations of performed conducting movement. Evidence shows that such emblems can be successfully understood by the audience, though those who have had more exposure to conducting movement can identify them better than those with less experience (T. Braem and P. Braem 2001; Cofer 1998; Gallops 2005; Kelly 1997; Sousa 1988). In addition, novice conductors focus more on communicating individual musical features in dynamics, articulation, and cuing specific instrumental parts, whereas experienced conductors pay more attention to the balance among instrumental parts, and creating the overall musical style (Bergee 2005).

Overall, in orchestral conducting, systematic movements serving an emblematic function (Kendon 2004) are an important means to communicate both compositional features in the music and the conductor's interpretational ideas. These conducting emblems can be analysed and deconstructed into detailed movement features (e.g., hand position, movement size, speed, acceleration, smoothness), with the potential for further examination through empirical research methods. The subjective, qualitative description of movement on one hand, and the quantified measurement of such movement on the other, provide complimentary and mutually revealing perspectives. Following these two perspectives, qualitative descriptions of conducting movement suggested by conducting educational manuals can provide guidance to identify key events in conducting. This conducting ideology, i.e. the idea and plan for conducting movement, is executed in actual performances, and quantified measurements of movement can then be applied to examine whether theses communicative intentions from conductors can truly be observed in conducting performances.

1.1.2 Conducting movement coordinating musical timing and expressiveness

The previous section draws on pedagogical literature to set out the conventions of musical conductor behaviours, using the concept of the gestural emblem to explain links between musical intentions and actions. Meanwhile, music psychological and musical education studies provide observations of how conductors' body movements serve to regulate musicians' playing, and to communicate the conductor's general expressive intentions of the musical work. Empirical studies based on motion capture data have investigated how different features in conducting movement can affect the performed musical timing and coordinate musicians in the orchestra. The baton tip's lowest position in the vertical axis of the movement trajectory is considered to be the main cue to deliver the ictus of musical beat (Clayton 1986). Yet in real performance, the pulse of performed sound (extracted from the spectral flux of audio signals) mostly synchronises with the maximal deceleration along the movement trajectory (Luck and Sloboda 2007; 2008; Luck and Toiviainen 2006). The accuracy of musicians' synchronisation is not affected by the shape of conducting movement (larger or smaller radius of the turning point), but a tendency is found that musicians can more accurately synchronise with the prototype of conducting movement (the averaged curve of multiple conductors), compared to an individual conductor's movement (Luck and Nte 2008; Wöllner et al 2012). These results suggest that conducting kinematics such as the position and acceleration are essential factors to communicate the timing for musical beat and to regulate musicians.

Studies in music psychology and music education discuss how the kinematic features of conducting movement affect the musical expressiveness perceived by the audience. Expressiveness is 'the quality of being expressive', and 'to express, indicate, or represent' (Gilliver 2017, 'expressive'; 'expressiveness'). In music psychological studies, musical expressiveness is sometimes characterised by measurable parameters such as body movement, musical sound (e.g., tempo, loudness, articulation), and listeners' response (Goebl, Dixon and Schubert 2014). According to psychological experiments using motion capture technology, the audience tends to evaluate the conducting as more expressive when the conductor moves in larger size, higher speed, and greater variance (Luck, Toiviainen and Thompson 2010). It should be noted that in Luck, Toiviainen and Thompson (2010)'s study, acceleration and jerk do not affect audience's rating, which suggests that both movements with high or low acceleration (i.e. sudden or gradual movements), as well as movements with high or low jerk (i.e. smooth or jerky movements) can be perceived as highly expressive. In educational studies of conducting movement, the audience evaluate the conducting and the ensemble as having higher performance quality when the conductor intends to conduct in highly expressive style, which means that the audience prefers highly expressive conducting over deadpan style (Matthews and Kitsantas 2012; Morrison et al. 2014; Morrison and Silvey 2014; Napoles 2012; Silvey 2011). Such expressive manifestations of conducting movement can also help musicians play dynamic and articulation markings in the score more accurately (Sidoti 1990). In addition, the level of perceived expressiveness is affected by the conductor's facial expression and the angle from which the observer looks at the conductor. The audience perceives higher musical expressiveness when the conductor shows an approving facial expression (compared to a disapproving expression), and when they observe the conductor from the conductor's frontal and left-hand sides (compared to the conductor's back and right-hand sides) (Price and Mann 2011; Silver 2013; Wöllner and Auhagen 2008).

In summary, a certain conducting emblem can be described as a combination of movement features in size, speed, acceleration, smoothness and trajectory. Conducting movement' kinematics are able to communicate accurate beat timing and musical expressiveness. Notwithstanding these general and common schemes, conducting movements tend to show high diversity and variability. Individual conductors add their own interpretations to the written composition, and make the selection of conducting utterance according to such interpretations. Even when conducting the same piece of music, individual conductors' idiosyncratic conducting styles and their interpretational choices may lead to different conducting movements across different conductors, as well as across different performances by the same conductor. There are thus three dimensions contributing to the diversity and variability of conducting movement– compositional structure, the conductor's musical interpretation, and the strategy by which the movement communicates these two dimensions. In recent decades, research in music performance has endeavoured to explore the connection among musical composition, musical interpretation, and musical body movement. These investigations, however, mostly focus on music listeners' and music performers' body movements, rather than conducting movements in orchestra. The discussion of musical listeners' and musicians' body movement in the next section can shed light on conducting movement research.

1.2. Body movements in music performance

Music performance concerns not only the musical composition, but also the performer's musical interpretations and the body movements used to execute the performance. Studies regarding music performance have investigated how these three different dimensions– musical composition, the performer's music interpretation, and the performer's body movement– play their roles in the process of music performance. Music performers' body movements demonstrate a variety of motor skills used in music performance– internal time-keeping mechanisms, executing instructions from music scores, detailed variations of performance factors carrying musical expressiveness (e.g., micro-timing and dynamic changes), coordination with co-performers, and the interactions between these tasks (Windsor 2009). Even though orchestral conductors do not usually play an instrument while they are conducting, similar motor skills apply. In particular, through sensorimotor coupling, visual cues provided by the conductor's movement can substantially affect ensemble musicians' movements of playing instruments, and thus achieve the conductor's intended performance (Altenmuller and Schneider 2009).

In section 1.2, music listeners' and performers' body movements are discussed in the context of music performance. In section 1.2.1, music theory, music analysis, and music aesthetic literature regarding the relationship between compositional structures and music performance factors is discussed. Section 1.2.2 includes empirical studies of music listeners' and performers' body movements. It is demonstrated that these musical body movements correspond with compositional and interpretational aspects of music. Different functions of these musical movements in terms of instrument playing, musical expression, coordination, and communication are then discussed in the context of music performance.

1.2.1 Musical compositional structure and music performance

Musical composition is the scheme of music performance, but different performances based on the same musical composition may be different from one another according to each music performer's musical interpretation and performance execution. Music theory and music analysis provide an essential basis to understand compositional structure of musical works. The connection between compositional structures and performance factors has been a central issue in music aesthetics, music performance studies (e.g., Cook 1990; Rink 1995; 2002), and music psychological studies (e.g., Juslin and Sloboda 2010). It is challenging to tackle the complicated relationship between compositional structures and performance factors, because musical performers' interpretations are bonded with the reference of written scores, yet to be distinguishing performers, they are also expected to provide their own unique insight into the settled compositional structures. Section 1.2.1 addresses such issues surrounding the compositional and interpretational aspects of music and their connections. Widely-recognised theories of musical analysis are addressed to decompose a musical work into basic musical elements. Music aesthetic theories and music performance studies are reviewed to clarify the connection between the compositional and interpretational aspects of a musical work. Two psychological models are then discussed to provide a comprehensive framework to connect compositional and interpretational factors in the context of musical performance activity.

From the viewpoint of music theory and music analysis, a music composition is primarily a devised framework of temporal and pitch arrangement. The temporal configuration in a music composition includes tempo, beat, metre, and rhythm. *Tempo* is the general setting of the 'musical speed or pacing' (London 2001, 'Tempo (i)', para. 1). It can be indicated by the ratio of a musical temporal unit in relation to clock time (e.g., 80 beats per minute). *Beat* is a basic temporal unit in music: 'the basic pulse underlying mensural music, that is, the temporal unit of a composition. … The grouping of strong and weak beats into larger units constitutes metre' (Kernfeld 2002, 'beat', para. 1). *Metre* is 'the grouping of beats in a regularly recurring pattern (the bar or measure) defined by accentuation' (Kernfeld 2002, 'Meter', para. 1). On the basis of this repetitive pattern, the metrical structure is considered to have hierarchical levels. For instance, in a music composition with binary metre (e.g., music with two beats or four beats per bar), metrical cycles with longer period (e.g., eight-beat and four-beat units) are at higher level than cycles with shorter period (e.g., two-beat unit), and one-beat unit is at the ictus level in this structure (Lerdahl and Jackendoff 1983, see Figure 1.1 as an example). *Rhythm* is a more flexible temporal subdivision, a concept affiliated with, yet not constrained by the regular metre: 'rhythm signifies a wide variety of possible patterns of musical duration, both regular and irregular' (London 2001, 'Rhythm, §I: Fundamental concepts & terminology', para. 1).

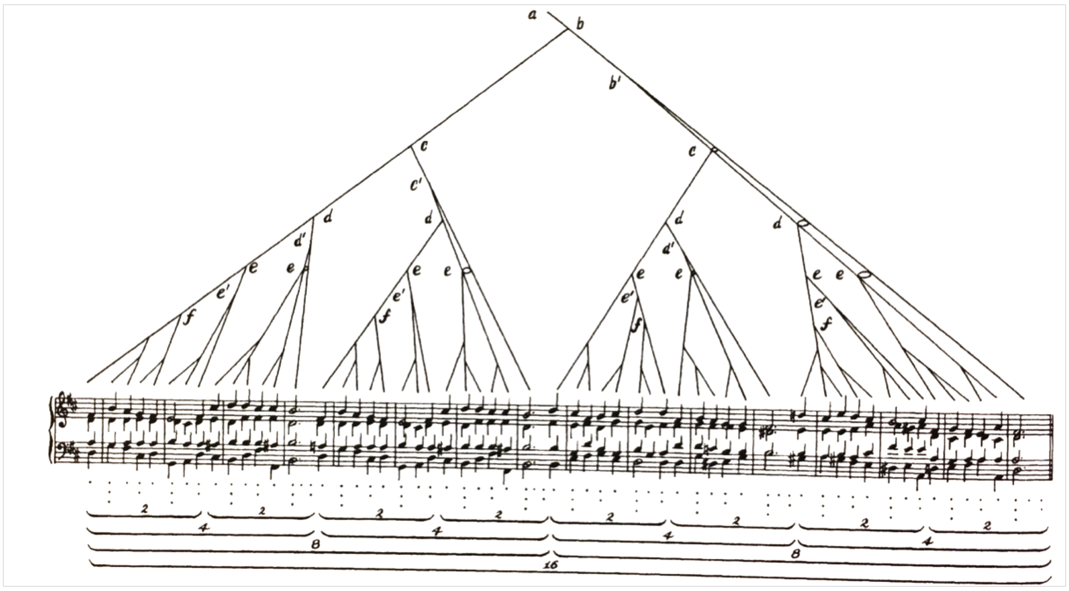


Figure 1.1 Hierarchical structure of musical metre (adapted from Lerdahl and Jackendoff 1983, 144, Figure 6.25). Units containing more musical beats are depicted at higher metrical levels.

In classical western music compositions, *pitches* are arranged according to music tonality, which refers to ‘the orientation of melodies and harmonies towards a referential (or tonic) pitch class’ and ‘the arrangement of the dominant and subdominant above and below the tonic’ (Hyer 2001, ‘Tonality’, para. 1). Within Western tonal system, harmonic progressions show a hierarchical structure led by the tonic (scale degree 1, i.e. the first note in a major or minor music scale), dominant (scale degree 5, i.e. the fifth note in a scale), and subdominant (scale degree 4, i.e. the fourth note in a scale) (Aldwell, Schachter and Cadwallader 2003; Schenker 1969, see Figure 1.2 as an example). A sequence of pitches constitute melody. *Melody* is ‘a succession of notes, varying in pitch, which have an organized and recognizable shape’ (Kennedy 2006, ‘Melody’, para. 1). The melodic line in music composition can be divided into phrases. *Phrases* are ‘short musical units of various lengths…applied to the subdivision of a melodic line’ and are ‘generally regarded as longer than a motif but shorter than a period’ (Sadie and Tyrrell 2001, ‘Phrase’).

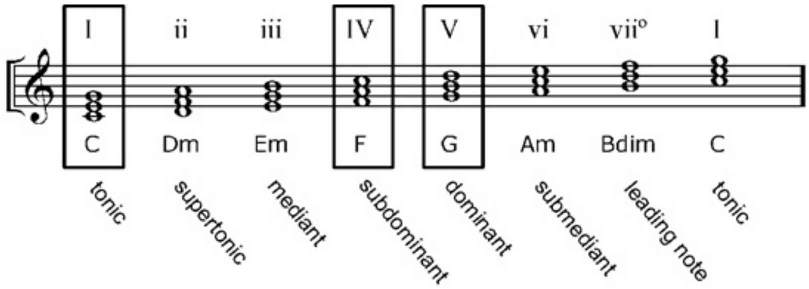


Figure 1.2 Harmonic structure in C major scale

However, for the same composition, the information provided in scores may vary depending on the edition. The score editing and publication involve considerable interpretational work in itself (Walls 2003). The devised temporal and pitch structures printed in the scores are converted into physical acoustic– the heard music– via music performance. There has been growing body of research focusing on music performance in recent decades, evidenced for example in new scholarly journals such as *Music Performance Research* (www.mpr-online.net) since 2007, and the *Journal of Musical Performance* (https://ejournals.lib.vt.edu/JRMP/index) since 2009. Other significant publications include edited volumes on Music and Gesture (Gritten and King, 2006) and New Perspectives on Music and Gesture (Gritten and King, 2011); and also two volumes of chapters, edited by John Rink (1995, 2002). Further publications have extended the reach of the field of musical performance research to include a wide variety of musical traditions (Clayton, Dueck and Leante 2014; Fabian, Timmers and Schubert 2014). As a result of such work, it is well understood that in the context of music performance, the written notation containing temporal and pitch configuration is considered as merely the framework for music, and the conventional analysis of music score is only 'a theory of unheard forms and imaginary structure' (Cook 1990, 3). The contemplation of music thus should not be constrained to the written score, but also take into account factors in music performing and perception (Dogantan-Dack 2012).

The relationship between the compositional structures and the performer's musical interpretations is a common theme in the strand of performance studies. Musical interpretation is 'the rendering of a musical composition, according to one's conception of the author's idea', and 'possible embodying understandings of what is taken to be latent in the score but also his or her own view of the best way to conveying that idea' (Davies and Sadie 2001, 'Interpretation', para. 2). These interpretative decisions may 'apply not only at the micro level (affecting subtleties of attack, intonation, phrasing, dynamics, note-lengths and the like) but also at the macro level (concerning the overall articulation of the form, the expressive pattern etc.)' (Davies and Sadie 2001, 'Interpretation', para. 5). In a music performance, performers do not necessarily produce musical sound exactly following the dictations in the score. In fact, an utterly accurate execution to play the exact duration, dynamic, and every aspect of the written notes in the score can be regarded as an undesirable 'deadpan' performance (such as a performance played by a computer). Based on their understanding and interpretations of the composition, music performers plan subtle deviations from existing compositional structures, and it is considered to be an essential part of musical performance (Clarke 1988; Leech-Wilkinson and Prior 2014). In particular, according to evidence from music psychological experiments, the performer's individualistic interpretations of music can be communicated by deliberate deviations from the written score in aspects of note timing, dynamics, and articulation (Gabrielsson 2003; Gabrielsson and Juslin 1996; Juslin 2000; Kendall and Carterette 1990; Repp 2000).

Psychological studies provide comprehensive models to connect these two musical aspects: compositional structure and performance factors. The psychological viewpoint regarding music performance can be represented by two influential models– the KTH rule system (standing for KTH Royal Institute of Technology, Stockholm, Sweden) and the GERM model (containing components of generative rules, emotional expression, random variations, and movement principles). The KTH rule system (Friberg, Bresin and Sundberg 2006; Sundberg, Frydén and Friberg 1995) discusses how music performance deviates from the compositional structure in aspects such as micro-level timing and articulation. Such performance deviations are associated with musical expressions. Similarly, in the GERM model (Juslin, Friberg and Bresin 2001), compositional structures and stylistic deviations in performance are discussed, and performance deviations are considered to carry the performer's intended musical expressions. In addition to this, the GERM model further connects performance deviations with body movement of music making. It is argued that performance aspects (e.g., timing of playing notes) are in accordance with biological movement, and limitations of human motor-control mechanisms (e.g., internal time-keeping variance and motor delay) thus reflect in music performance execution. In general, these two models provide a structure to discuss different aspects of music performance together, and to explain factors leading to the variability of music performance by analysing the interactions across the composition, the performer's interpretative decisions, and the performer's biological movement.

In summary, music compositions consist of temporal and pitch configuration. According to music performance studies and psychological models, performers add their own interpretations to the composition, and communicate their intended musical expressions in ways that could be described as micro-deviations from the pitch and timing information as presented in the written score. These deviations in performance are executed using the performer's body movement, and such movement thus should reflect compositional structures in the written score, as well as show variations in accordance with the performer's interpretative intentions. In the next section (section 1.2.2), musical movement's connections with compositional structures and the performer's interpretative intentions are discussed in detail.

1.2.2 Music listeners' and musicians' body movements in music performance

In music performance, musicians' body movement can serve multiple functions. Wanderley et al. (2005) categorised musicians' movements based on their functions including movements to produce sound (instrumental movement), to convey expressive intention (ancillary movement) and to communicate with co-performers (communicative movement). The term 'musical movement' has a specific definition in this thesis. In music aesthetic theories, the terms 'gesture' and 'motion' are sometimes used in a metaphorical manner to describe musical qualities such as the sympathetic sense of motion arising from musical structure (described as 'composer's pulse' in Clynes 1995), or mental directional force caused by the tonal system (e.g., Kurth 1991; Larson 1997). In this thesis, 'musical movement' specifically refers to the observed biological body movement in music performance.

The discussion in section 1.2.2 thus covers empirical studies of music listeners' and performers' body movement, either using approaches of systematic observation of body movement through visual data collections, including film or digital video for example, or based on movement data collected by motion capture technologies. It is discussed how musical body movements bond with compositional structures (section 1.2.2.1, 1.2.2.2 and 1.2.2.3) and the performer's interpretational intentions (section 1.2.2.4). These connections also reveal musical movements' functions in terms of sound producing, conveying expressiveness, and coordinating with fellow performers (section 1.2.2.5).

1.2.2.1 Music listeners' body movement in relation to temporal structures in musical composition

When music listeners spontaneously move their body to music, they may move in different ways according to the music they are listening to. Empirical studies based on motion capture data have demonstrated that the periodic patterns of music listeners' body movement may reflect the overall temporal structures of music including tempo, metre, and rhythm. Regarding the metrical structure, music listeners' body movements appear to reflect hierarchical metrical levels of musical beats and subdivisions. In an experiment in which music listeners freely moved their body along with four-beat instrumental blues, listeners' kinetics of body movement show a periodicity synchronising with music metre, in a way such that both the potential energy (related to the vertical position, i.e. height) and the kinetic energy (related to the body mass's velocity and angular velocity, i.e. wriggle) show their peaks matching up with musical beats. The movement patterns of individual body segments further reflect the hierarchical metrical structure of music, that higher metrical levels mostly correspond to horizontal movements of the trunk, whereas lower metrical levels correspond to vertical movements of extremities. Specifically, listeners show horizontal body movement (e.g., lateral swaying, body rotation) for four-beat cycle, horizontal body and arm movement for two-beat cycle, and horizontal plus vertical arm movement for one-beat cycle (Toiviainen, Luck and Thompson 2010). These findings focus on listeners' periodic movements which show repetitive patterns across cycles.

Whereas music listeners may move their body spontaneously and without conscious planning, choreographed body movement describes pre-planned movements performed with musical accompaniment. The convention of a certain 'type' of dance is formed by a series of specific movements connecting to the music (Naveda and Leman 2010). The repetitive patterns in dance mirror the binary metrical cycles in music, for example, in Samba and Charleston, in which dancers' hands pose in a specific position at the first beat per cycle, and then move to another position for the second beat. Comparing positions across different cycles, their hand positions are more similar on beats, whereas hand positions are more varied on 1/2 beat and 1/4 beat, which means that a dancer's hand positions are more consistent and vary less across cycles on the first and second beats, and tend to move in a more flexible manner during the transition period between beats (Naveda and Leman 2010). Interestingly, in order to accurately reach these specific positions on beat, dancers' hands slow down on the first and second beat, and then speed up when they depart from these target regions (Leman and Naveda 2010). These results demonstrate that the metrical structure in music is not only embodied in the movement pattern, but also shown in the variability of movement, in such a way that movement patterns are more consistent across cycles with the reference of musical beat, and become more divergent when away from these musical timing reference. Therefore, although these findings indicate targeted body position on specific time-points, the continuous pattern of movement, i.e. the trajectory of how the body segments move from one region to the next, is still unknown.

In addition to the metrical structure, music listeners' body movements also connect with surface-level rhythmic features in music (Burger et al. 2012; 2013). In an experiment in which listeners freely moved their body with different styles of popular music, music listeners' body movement kinematics reflected rhythm-related acoustic features extracted from the musical sound such as the pulse clarity (the strength of rhythmic pulse), percussiveness, and sub-band spectral flux in high frequency (6400-12800 Hz) and low frequency (50-100 Hz). Clear pulse and high percussiveness in music induce movements with higher kinematic values in speed, angular velocity, the distance between hands, and the amount of movement (travelled distance of all markers on body). Strong high frequency spectral flux induces higher speed in head and hands, wider distance between hands, and more overall movement, whereas strong low frequency spectral flux only affects the head speed (Burger et al. 2012; 2013). These findings connect holistic movement kinematic traits to the overall feature of the musical excerpt. It has not been shown, however, how listeners' movement alter according to the variations of these acoustic features within one single piece of music.

Overall, tempo does not significantly affect the connection between listeners' body movement, metre and rhythmic patterns according to the findings of the aforementioned studies (Burger et al. 2012; 2013; Leman and Naveda 2010; Naveda and Leman 2010; Toiviainen, Luck and Thompson 2010). This suggests a consistent mirroring between the music listener's body movement and musical temporal structures of metre and rhythm, in which the listener's body movement reflects hierarchical metrical levels in music; dancers' conventional basic movement patterns match with metrical structure; listeners' movement is affected by rhythmic acoustic features in music. These analyses reveal the periodicity of movement, and thus focus on the overall movement features of the whole trial, or body positions at specific time-points in the reference of musical beats. The results demonstrate the general trend that listeners' body movement is associated with musical temporal structures. However, since musical structure is a complex mixture of multiple compositional aspects that continually change through time, the features in a listener's movement may also not be constant throughout the whole music piece. Therefore, it is not clear whether, during a music piece, whether a listener's movement changes in predictable ways according to the variation of music compositional features.

1.2.2.2 Music performers' instrumental movement in relation to compositional structure

Music listeners move their body with the music they hear, whereas musicians use their body movement to play instruments and actually produce musical sound. Musicians play instruments following instructions in the written score, and their instrumental movements thus bond with compositional elements in musical works. Empirical observations of musicians' body movement confirmed the close connection between instrumental movement and compositional structure in pianists', string players', and drummers' performance (Dahl 2004; 2006; MacRitchie and Zicari 2012; Repp 1996; 1997; Winold, Thelen and Ulrich 1994). For pianists, they intentionally selected different 'touch' according to the given compositional context. A specific touch is described as the weight and the position for their fingers to attack the keyboard, and a touch is executed by a combination of different movements in shoulder, arm and wrist (MacRitchie and Zicari 2012). There are not only the movements in the hands; the key stroke and the pedal pressing are coordinated by diverse strategies in different tempo settings (Repp 1996; 1997). For string players, cellists show different body movement patterns when they play compositions written by different composers, i.e. having different music styles. Even when these compositions share a common pattern of note, cellists' bowing movements are still distinct for each composer's composition. Cellists' movements in elbow and wrist are used to achieve intended stroke timing, amplitude, and bow pressure, and show different patterns when playing compositions composed by Schubert and Brahms (Winold, Thelen and Ulrich 1994). For drummers, they use different movements in drumstick, hand, lower and upper arm when playing in different dynamic levels, tempi, and on different striking surfaces. When playing at higher dynamic levels, their drumsticks start from a higher position to prepare for a greater velocity on the stroke, and the opposite movement is used for lower dynamic levels. They also use the sticks' rebound from the drum surface to play fast, complicated rhythmic patterns and rolls instructed in the score (Dahl 2004; 2006). The aforementioned studies in pianists', cellists', and drummers' instrumental movements demonstrate, unsurprisingly, that the features of musicians' body movement vary according to the style and compositional elements in music. Complicated variations in compositional configurations contribute to the diversity of musical movement.

1.2.2.3 Music performers' ancillary movement in relation to compositional structure

In addition to instrumental movements which are required to produce sound, a range of empirical observations have suggested that musicians' ancillary movements reflect compositional elements such as phrasing, and prominent features in melodic, dynamic, and harmonic aspects. Individual musicians have their own idiosyncratic ancillary body movements when playing instruments (Mitchell and MacDonald 2012). Even though such ancillary body movements may vary according to the performer's expressive intentions and the performance context, it appears that these movements share an underlying periodicity reflecting the phrasing structure in music. Phrasing segments are reflected in the patterns of pianists' head movement, body swaying and breathing, as well as woodwind players' knee bending and circling motion of the instrument. It is suggested that players use these movements to help create the sense of direction toward the end of a phrase (Davidson 2012; King 2006a; Thompson and Luck 2008; Wanderley et al. 2005). In addition to these detailed movements in individual body segments, for pianists, their overall motion profile of the whole body also connects with the phrasing structure. Even though individual pianists show different movement patterns compared to one another, in each pianist's playing, their movement shows consistent patterns across phrases throughout a musical work (MacRitchie, Buck and Bailey 2013). The connection between the performer's ancillary movement and phrasing is evident such that the audience can accurately identify time-points of phrase boundaries when watching the performer's body movement without hearing the performed sound (MacRitchie, Buck and Bailey 2009; Vines et al. 2006).

Musicians' body movements are not only associated with phrasing, but also reflect salient musical features in compositions. Musicians' movement profiles contain a series of peaks and troughs. Detailed movements in body segments and small-scale local maxima of movement profiles correspond to the phrasing structure, whereas global maxima of the overall movement profile mostly associate with prominent musical structural features including melodic, dynamic, or harmonic climax, cadence, and important sectional boundaries between two sub-sections (Davidson 2012; MacRitchie, Buck and Bailey 2013). Interestingly, throughout a music work, performers tend to show more divergent movement across performances, i.e. higher movement variability, at these important structural points (Thompson and Luck 2011). This suggests that musicians tend to apply different movements to execute key events in the same musical composition in repeated performance. These key musical events are thus not only in accordance with salient movements within one single performance, but also coincide with high movement variability across different performances.

In summary, the aforementioned studies suggest that music compositional structure is embodied in musicians' ancillary movement despite each musician's idiosyncrasies. Musical phrasing is embodied in local maxima in musicians' movement profile of the whole body, as well as detailed movements in individual body segments including pianists' head and body, and woodwind players' knees and the instrument. Salient movements (global maxima of the overall movement profile) associate with prominent structural features in melodic, dynamic and harmonic aspects. High movement variability tends to match with these prominent musical structures, which suggests that musicians apply flexible strategies to achieve these salient movements at featured musical key events. These findings indicate that musicians' movement reflects compositional features at both local level and at higher hierarchical structural levels in predictable ways. Structural musical key events are not only highlighted by salient movements within one single performance, but are also in accordance with diverse movements across different performances. This suggests that musicians apply different movements to express remarkable compositional structures in the given performance context. However, such selection of featured compositional structures is not directly dictated in the written score, but depends on each musician's interpretative choices and their expressive intentions in each performance.

1.2.2.4 Music performers' ancillary movement in relation to musical interpretation

Since musical interpretation appears to arise from performance details which are not directly instructed by the composer in the score; the performer is thus expected to make decisions regarding how these details should be performed in practice. According to empirical observations of music performance, the patterns of musicians' body movement reflect their musical interpretative choices, which include the musician's selection of emphasized compositional elements, and the overall expressive intention of music. In observations of clarinet players' and pianists' body movement, the musicians emphasise compositional elements using body movements such as large circular movements in the clarinet bell, and pianists' head nodding and shaking, body swaying, wrist rotation, hand and arm lift. A specific example is that pianists sometimes lift their left hand to move with the resolving chord in a cadence when their left hand is not playing notes. These salient movements corresponding to highlighted musical structures are more observable in body segments not directly used to produce sound (e.g., head, torso), compared to body segments responsible to produce sound (e.g., hands). Even though the tendency is observed that certain types of movement usually correspond to specific musical features, in each performance, these movements may show different details in terms of their amplitude and speed. Most of the salient movements match up with intended targeted musical key events annotated by the performer, yet some movements do not match with these locations (Davidson 1994; 2007; Desmet et al. 2012). The more obvious ancillary movement in torso than in hands is probably because the performer's torso is less restricted by sound producing movements, and thus can much more freely express the performer's intentions (Moran 2013). The movement variability observed across performance suggests that performers' ancillary movement associates with their interpretative selections in a flexible manner. There is no one-to-one correspondence between movement type and expressed intention; instead, one movement can have many different meanings.

In addition to emphasising selective musical key events, performers' ancillary movement may also reflect their overall expressive intentions of the musical composition. A series of research in EyesWeb and MEGA (Multisensory Expressive Gesture applications) projects developed a platform for analysing digital video of movement, and aim to explore how music performers' body movements communicate their expressive intentions of music. Musicians' (piano, saxophone and marimba players) body movements were observed and analysed when they had different expressive intentions. In these experiments, 'expressive intentions' were described as emotional states (e.g., happy, sad, anger, fear) or musical utterance (e.g., over-expressive, deadpan). Identified movement cues responsible for communicating these expressive intentions include low-level features (e.g., velocity, acceleration, jerk) of individual body segments (e.g., head, torso, limbs) and high-level features related to the whole body (e.g., Quantity of Motion, body position's stability and mobility, Effort and Space in Laban Movement Analysis). For instance, the intention to express happiness in music performance relates to large and fast movements, whereas the intention to express sadness relates to slow and smooth movement in musicians (Camurri et al. 2000; 2005; Castellano et al. 2008). From the audience's perspective, these movement features connect with each expressive intention in a stable manner such that the audience members are able to identify the performer's expressive intention when watching their movements without hearing the performed sound, even though some expressive intentions such as happiness and sadness are more easily identified by the audience than the other intentions such as fear (Dahl and Friberg 2007).

In summary, music performers choose to emphasise selective compositional structures in the performance, and such selections manifest in their ancillary movement, both in individual body segments' detailed movements and the overall movement profile of the whole body. Comparing different body segments, the head and torso can better communicate the performer's expressive intentions than hands, which are mostly bonded to sound producing movements. Even though there is no strict movement 'lexicon' representing specific ideas being expressed, audience can successfully identify the performer's general expressive intentions via the performer's body movement. However, as noted by Fabian, Timmers, and Schubert (2014, xii), musical 'expressiveness is not the same as emotion' and musical 'expressiveness is dependent on historical and cultural context'. Since some of the aforementioned experiments directly parallel musical expressiveness with emotion categories (e.g., Camurri et al. 2000; 2005; Castellano et al. 2008), the explanations of their results should be reconsidered carefully, not only because these emotional descriptions can not fully represent musical expressiveness, but also because each subject may interpret these descriptions of emotion differently. Not to mention that the isolated, controlled environment in experiments is not the same as in a real music performance, where the performance will occur within a historical and cultural context that will differ considerably according to the genre of music.

1.2.2.5 Music performers' communicative movement

Studies of musical joint action have investigated how musicians' body movements serve as non-verbal cues to coordinate co-performers in ensembles in different performance contexts (Keller and Appel 2010). Inter-performer coordination describes the mutual adjustment between co-performers that is required to keep performed musical timing together. This co-ordination depends on learned skills of anticipation and reaction. Such non-verbal communication can be made via audio (performed sound) and/or visual (performed movement) cues in performance to communicate specific variations in timing, dynamics, articulation, timbre, transition points, and important structural boundaries (Goodman 2002). In an ensemble, such as in a piano duo, a string quartet, or a singer-pianist duo, such information can be implied by head nods, body sway, hand lift, and eye-contact (Keller 2014; Keller and Appel 2010; King and Ginsborg 2011).

Performers' bodies may move in different ways according to the interactions among performers in the ensemble, as well as the cultural conventions in different music genres. As emphasised by multiple scholars (Goodman 2002; Hargreaves, MacDonald and Miell 2005; Moran 2014), communication in music performance is not a one-way transmission of information, but rather a dynamical interaction among the composition, performers, listeners, and the environment. Factors in individual and social context thus should be taken into account when investigating body movement in music performance. Regarding individual factors, each musician plays a particular role in the ensemble (Davidson and Good 2002; King 2006b) and this may be reflected in their body movement. For instance, the first violinist generally acts as the chief player in a string quartet, and indeed, it appears that the first violinist's body movement communicates more information than the other co-performers in the string quartet, especially when unexpected musical variations appear (Badino et al. 2014; Glowinski et al. 2013). Evidence suggests that musicians and singers tend to move more frequently to communicate with partners they are familiar with, or partners with similar skill levels to them, compared to new partners or partners with different skill levels, and during the course of rehearsal, body movements between partners become more synchronised (Keller 2014; King and Ginsborg 2011). These results confirm that music performers' body movements are context-dependent. The interactions among different performers should be considered when investigating musical body movement.

Regarding the social and environmental context, music performers' body movements have been analysed using systematic observations of performance video collections in the context of different music genres. In Western classical music performance, performers tend to apply more communicative movement in a concert than in a rehearsal (Moelants et al. 2012; Moran 2013). Body movements between co-performers are more synchronised when audio feedback is eliminated, which suggests that visual cues become more important when audio cues are not available (Goebl and Palmer 2009). In addition to Western classical music performance, the ways in which performers move their bodies can vary a lot according to different genres of music and the cultural and historical convention of performance. For example, in North Indian raga performance, co-performers improvise together based on a basic musical outline. They use particular movements in head, hands, body, and eye-contact to coordinate tempo, to indicate critical musical marks and transitions, to imply musical patterns and contour, as well as to maintain the relationship with listeners (Clayton 2005; 2007; Moran 2011).

During this process, the independent movement rhythms of individual performers (and listeners) become more synchronised, i.e. they exhibit entrainment. Even though the voice arrangement is designed so that each performer should play a different rhythm to one another simultaneously, their body movements still exhibit a stable periodicity with a fixed ratio across co-performers (Clayton 2007). As for popular music performance, performers use their body movement and facial expressions to coordinate co-performers, to provide narrative and emotional information on the music, and to communicate with listeners (Kurosawa and Davidson 2005).

In summary, in joint actions in music performance, co-performers communicate via body movement to coordinate their intended musical changes in timing, dynamic, articulation, and timbre aspects. Great stress should be placed on individual factors and the social context when considering body movement in music performance. Music performers tend to behave differently according to their skill level, familiarity with each other, their roles in the ensemble, and the performance context in a rehearsal or in a concert. In particular, each music genre has its own cultural convention of communication during performance. From this viewpoint, musical movement is a complicated assemblage of actions to fulfil various functions (e.g., playing instrument, showing expressiveness, communicating) in a specific performance context.

According to the discussions in section 1.2, empirical studies of musical movement have demonstrated that music listeners' and performer's body movements (including instrumental, ancillary and communicative movement) correspond to compositional features of temporal structure, phrasing and salient musical event, as well as the performer's interpretational intentions. Particularly, analyses of motion capture data and systematic observations of performance video corpus provided solid evidence for these connections. However, it is somewhat challenging to directly compare all the findings from empirical studies of musical movement, because these studies tend to: 1) apply various methods to collect different types of data such as motion capture data, video observation, performer's self-statement and score annotation, viewers' or listeners' self-reported response; 2) explore different dimensions and functions of musical movement such as spontaneous movement when listening to music, instrumental playing, musical expression, coordination with fellow performers; 3) set up diverse performance scenarios such as music listening, music performing (e.g., solo, ensemble, instrumental, and singing performing), and different cultural context (e.g., Western classical music performance, Indian raga performance, and live popular music concert); 4) hold different assumptions of musical movement that lead to diverse focuses of data analysis and interpretation (e.g., assumption that musical movement has regularity and repeated patterns). Conducting movements are complex in such a way that they are dependent on the compositional and interpretational aspects, and affected by various factors in the performance context. The general conducting movement emblems suggested by conducting educational manuals may vary in their execution in performance contexts. It is thus necessary to observe *how* conductors actually apply such idea movement emblem collection in actual performances, and clarify various factors that may give rise to the variability of conducting movement that are witnessed in actual performance events. Kinematic analysis using biomechanical approach and dynamical system theory from motor control perspective can offer an appropriate means to tackle this issue.

1.3. Human movement analysis: considerations from biomechanical and motor control perspectives

As outlined above, analyses of motion capture data have demonstrated that music listeners' and musicians' body movement kinematics are in accordance with compositional structures and the performer's musical interpretation (section 1.2). Kinematics in conducting movements have been found as important cues to communicate musical timing and expressiveness (section 1.1.2). As observed from conducting educational manuals, specific conducting movement emblems are used to instruct compositional elements and interpretational intentions. Qualitative descriptions of such movement emblems appear to involve a series of kinematic features (section 1.1.1). Kinematic analysis using biomechanical approaches can be applied to further confirm how conducting movement kinematics communicate compositional elements and the conductor's musical interpretations in conducting performance. Considering the complicated interactions among the factors from the musical composition, performer(s), and performance context, dynamical system theory serves as an appropriate framework to discuss orchestral conducting movement.

In section 1.3.1, features of biomechanical analysis for cyclic and projectile movements in sports are summarised based on selective examples of study. In section 1.3.2, dynamical system theory in motor control research is introduced, and movement variability and movement coordination are discussed in this context. In section 1.3.3, it is proposed that biomechanical analysis approach and dynamical system theory can be applied to the investigation of musical conducting movement, particularly the exploration of conducting movement variability, which is the consequence of influences from various factors.

1.3.1 Biomechanical analysis of human movement

Most movements of the human body can be described as a combination of linear and rotational motions, and their kinematic features are thus defined as linear and angular displacement, velocity, acceleration, and jerk. In the past couple of decades, motion tracking technologies have become standard tools in biomechanical research greatly facilitating the recording and analyses of human movement. In order to analyse movement patterns in detail, key events with critical features are identified to divide the movement into different phases, and kinematic and kinetic changes are then investigated according to particular functions and traits of each phase (Bartlett 2014; Hamill, Knutzen and Derrick 2015; Hamilton, Weimar and Luttgens 2012).

Biomechanical studies have focused on different parameters in cyclic and projectile movements according to their individual characteristics. Cyclic movements in walking, running, cycling, and swimming have repetitive patterns. Walking and running cycles are divided into stance phase and swing phase, and key parameters for gait pattern include the ratio of these two phases, flexion/ extension angles of joints in lower extremity (hip, knee, and ankle), synchronised and sequential movements of lower body segments (thigh, shank, and foot), and the coordination between joints, body segments, and two legs. Comparisons are made across different subject groups and conditions, based on the participant's gender, age, runner type (i.e. sprinter or distance runner), walking/ running speed, and subject with health condition/ medical issue (e.g., anterior cruciate ligament injury, patellofemoral injury etc.) (e.g., Barton et al. 2009; Buldt et al. 2013; Racic, Pavic and Brownjohn 2009 for walking; Ciacci, Michele and Merni 2010; Koblbauer et al. 2014; Louw and Deary 2014 for running). In swimming, the stroke cycle is divided into phases (e.g., pull and push, insweep and outsweep, based on the swimming type studied) and parameters including cycle frequency and cycle length are investigated. The kinetic and kinematic analyses not only focus on the maxima, minima, and means of joint angle, linear and angular displacement, velocity, acceleration, but also pay attention to the general trends and how these measurements vary during a movement cycle. Comparisons are made across swimmer types (sprinter and distance swimmer), and breathing and non-breathing conditions (e.g., Connaboy et al. 2016; Figueiredo et al. 2012; McCabe 2008; Psycharakis and McCabe 2011). For studies investigating the effect of fatigue in cycling, swimming and marathon running, the continuous change of kinematic measurements during the whole movement course is the main focus. Comparisons are made across different movement stages (e.g., initial and final stages in movement) (Kelly 2007; Oliveira, Saunders and Sanders 2016; Reenalda et al. 2016).

Projectile movements involving throwing, striking, and kicking objects are divided into three phases: backswing (from the initial movement to the key event of reaching the rearmost position), action (from the rearmost position to the object impact), and recovery phases (after the object impact).

The object's ballistic trajectory is affected by the release height, speed, and angle. For accuracy-dominated skills (e.g., basketball), the accuracy is achieved by carefully controlling the release height, speed, and angle, and more synchronised movements of body segments are applied. However, for distance-dominated skills (e.g., javelin), the goal is to maximise the impulse applied to the object by increasing the acceleration path of movement, and more sequential movements of body segments are applied. Most projectile-based sports are the combination of accuracy and distance tasks and are achieved by a series of both synchronised and sequential movements (Bartlett 2014; Hamill, Knutzen and Derrick 2015). For basketball throws, key parameters are the release height of the ball, the linear displacement and velocity, and the angular displacement and velocity of shoulders, elbows and wrists, and the angle of knees. It is found that individual subjects have their own movement patterns, which are distinguishable from patterns of other players, although subjects with higher skill levels tend to have higher movement consistency, compared to subjects with lower skill levels (Ammar et al. 2016; Button et al. 2003; Schmidt 2012). For golf swings, movements in body and club are both crucial. Key parameters affecting the ball direction and velocity are the rotations in the upper torso and pelvis, torso tilting, body weight-shifting during the swing, sequential movement of the arms and wrists, as well as the angle of the golf club. It is found that subjects with higher skill levels tend to have more angular displacement (rotation) in upper torso and pelvis, more force production, and higher movement consistency (Chu, Sell and Lephart 2010; Coleman and Anderson 2007; Coleman and Rankin 2005; Lindsay, Mantrop and Vandervoort 2008).

Targeted hand actions such as reaching and grasping objects involve the initial planning of movement and subsequent corrections during the movement execution (Fitts 1964). For movement planning, individuals appear to adjust the plan for movement in order to adapt to different conditions. For instance, participants in fatigue or injury conditions tend to have different initial positions to start movement compared to the others (Monjo and Forestier 2016; 2017; Portney 2017). During the moving process, we rely on eye-hand coordination to optimise the movement execution, and thus to achieve the goal (Cohen and Rosenbaum 2011). For instance, it has been shown that visual guidance can improve the accuracy of targeted hand actions (Michaels et al. 2017; Vaz 2017; Welsh and Pratt 2008). For complex movement, the whole movement process can be divided into several components (i.e. phases). It has been demonstrated that different movement components tend to affect one another during the movement execution. Specifically, in sequential aiming movement, the positions of succeeding targets affect the movement trajectory to reach the previous target (Adam et al. 2000; Helsen et al. 2001; Hoffmann 2017). Those studies on targeted hand actions demonstrate that various factors influence the plan and the execution of movement.

Biomechanical analysis has been applied to a wide range of research topics. A comprehensive and detailed review of biomechanical research is not appropriate for the work of this thesis.

Nonetheless, several tendencies can be observed from the brief outline of the aforementioned selected examples of biomechanical analysis: 1) kinematic analysis provides a method to deconstruct both cyclic and projectile movements into detailed linear and angular parameters (displacement, velocity, acceleration) in body segments and joint rotations in different directions (axes). 2) Key events with critical features should be identified first to divide the movement into phases, and then target parameters are selected to be investigated according to the movement traits and functions of each phase. 3) In addition to the maxima, minima and means of parameters, the continuous patterns of how parameters vary during the course of movement can also reveal important features of the movement. 4) Different types of movement variability can be classified: within-cycle and between-cycle variability for cyclic movement, within-trial variability, between-trial variability, within-subject variability, and between-subject variability. All movements are constructed by a lot of interactive factors, within which the between-trial and between-subject movement variability can best demonstrate the interactions among participant factors (e.g., gender, age, health condition, skill level), task constraints (e.g., sprint or distance running/ swimming), and environmental factors (e.g., equipment, venue). 5) The coordination among different body segments and joints is an important aspect of movement. Individual kinematic parameters may have their own patterns, yet it is the synchronised and sequential coordination of these parameters which accomplishes the overall action of movement.

To consider the interactions between participant, task, and environmental constraints, and the coordination among different body segments and joints, it should be beneficial to take the viewpoint from dynamical system theory (Newell and Corcos, 1993). Biomechanical analysis focuses more on the movement pattern of musculoskeletal system, whereas dynamical system theory can better explain the neuromuscular mechanisms by which human beings organise and control our body movements. Dynamical system theory offers a viewpoint to explain how conductors achieve their goal–to communicate their interpretational intentions– under the influences and interactions from various factors in the performance context. The concept of dynamical system is discussed in section 1.3.2.

1.3.2 Dynamical system theory: movement variability and coordination

In orchestral performance, conductors adapt their conducting movement according to various demands: the structure of composition that they are conducting; their interpretational choices of compositional elements; their learned conducting strategies and style. They must also react to the ensemble members' individual performances, as well as other factors of a live performance context such as adjustments according to room acoustics (Colson 2012). Dynamical system theory is an appropriate framework to discuss such complex interactions. In this section, the concepts of movement variability and coordination are discussed in the context of dynamical system theory. In motor control research of human movement, the conventional information processing theory considers human being's motor control mechanism as motor programmes regulated by pre-determined meta-rules, yet this approach can not fully explain how human movement can effectively adapt to complex changes of multiple factors (Davids, Bennett and Newell 2006). Dynamical system theory takes another viewpoint in regard to human movements as self-organised patterns operating according to the constraints in subject, task, and environmental factors in an interactive system, but not dependent on settled motor programmes (Kurz and Stergiou 2004; Schmidt and Lee 2011; Schoner and Kelso 1988).

In movement analysis, movement variability is usually defined as the variance or the standard deviation from the mean from the statistical viewpoint. High movement variability is sometimes deemed as an undesirable indicator of non-proficient skills or signal noise. However, in the context of a dynamical system theory, variability is an important inherent property of movement, which has its practical function to make movements able to adapt to complex changes (Davids et al. 2006; Emmerik et al. 2016; Thelen and Ulrich 1991). Emerged movement variability in a dynamical system thus reflects the change in subject, task, and environmental factors. For instance, it is found that the movement variability tends to be lower in movements with medium acceleration, whereas the variability is higher in movements with high or low acceleration (Sternad 2006). When the movement switches between different patterns, subjects with higher skill levels display sharper transitions between states, compared to subjects with lower skill levels (Schoner and Dineva 2007).

There are numerous possible ways for the human body to move to achieve the same goal (e.g., pick up a ball, or reach a cup), and this is called the degrees of freedom problem of movement (Bernstein, 1967). The coordination of movement can effectively reduce the degrees of freedom to obtain complex self-emerged movement pattern. The coordination between two body segments or two subjects can be analysed by their relative phase, in which they show in-phase relationship (synchronisation), anti-phase relationship (movements synchronised but having opposite directions), or show phase offset (delayed or decoupled coordination). Coupled movement cycles possess the properties of phase locking (having fixed phase relationship) and entrainment (interacting between cycles) (Kelso 1995; Verheul 2004). The phase relationship between two cycles may change according to the variations in subject and environmental constraints. For instance, for bimanual coordination, musicians perform better than non-musicians in bimanual coordination tasks (Verheul and Geuze 2004a); Parkinson's patients show obvious asymmetry in their bimanual movement compared to normal subjects (Verheul and Geuze 2004b).

Newell (1986) proposed a framework to consider movements as self-organised patterns shaped by the constraints in subject, task, and environmental factors, and this model can be applied to discuss the body movement in music performance (see Figure 1.3 as an example). Dynamical system theory has been applied to the investigation of musicians' body movement in a few instances, notably Demons, Chaffin and Kant (2014) and Maes (2016). Using a non-linear dynamical approach, it has been demonstrated that dynamic changes and phrase structures in musical composition affect the regularity of musicians' body movement (Demos, Chaffin and Kant 2014). Musical body movements not only change according to the performed music composition, but also interact with the musicians' auditory system. It has been shown that relying on sensorimotor interaction, ancillary body movements can help musicians to maintain a more stable tempo when playing music (Maes 2016). In the context of this research, body movement is treated as a continuous, time-evolving process interacting with physical, mental, and social factors in music performance. The concept of dynamical theory can be further applied to the research of orchestral conducting and explain the diversity and variability of conducting movement.

1.3.3 Movement analysis of orchestral conducting movement

In orchestral conducting, the conductor's hands and baton move in a basic repetitive beating pattern per musical bar, which corresponds to the metrical structure in each music composition. In addition to this basic cyclic movement, the conductor deliberately changes detailed movement features in each cycle to communicate compositional changes in melodic, harmonic, dynamical, and instrumental aspects. In this process, the conductor continuously interacts with musicians, and adjusts conducting movements according to the musical sound played by musicians. Given such properties of conducting movement, kinematic analysis using a biomechanical approach and considerations of movement variability from dynamical theory viewpoint will be applied to musical conducting movement in the current study, particularly in methodological aspect:

1) Kinematic analysis will be applied to describe conducting movement's features including movement distance, speed, acceleration, and jerk. Biomechanical studies in sports mostly examine movement's displacement, velocity, and acceleration. However, scalar kinematic variables without directional information– distance, speed, scalar acceleration, and scalar jerk along the movement trajectory– will be selected as target parameters to be investigated in the current study, considering that a) methods and findings in previous musical movements research (e.g., Burger et al. 2012; 2013; Camurri et al. 2000; 2005; Thompson and Luck 2011); b) the fact

that musical conducting movement contains a lot of complicated curved movement; c) the exploratory nature of this study.

2) Anticipated key events in conducting will be identified in advance by means of music score analysis and conductors' interpretative annotations. Then critical features in conducting movement will be identified to test whether these features in conducting movement match up with key events in musical composition.

3) In kinematic analysis, not only the single values of maxima and means, but also the continuous change of kinematic variables should be considered. Time-series analysis techniques, including cross-correlation will therefore be applied in this study.

4) It appears that movement variation is an essential means for conductors to communicate music compositional structures and musical interpretations. In this study, different types of movement variability will be investigated: a) within-trial variability: kinematic change between movement cycles (musical bars) within the same trial will be investigated in order to identify salient movements (kinematic deviations) in conducting movement; b) between-trial variability: kinematics in different trials conducted by the same conductor will be compared in order to determine whether the movements are similar when the same conductor conducts the same music composition repeatedly; c) between-subject variability: previous two types of variability are within-subject variability, whereas different conductors' kinematics will be compared to determine whether individual conductors apply similar or diverse strategies when conducting the same music composition.

5) To consider conducting movement in the context of a dynamical system, different factors in the conductor, in music composition, and in performance environment should be considered when investigating conducting movement.

1.4. Literature summary and thesis structure

1.4.1 Literature summary

Taking previous findings in conducting educational manuals, empirical investigations of conducting and musical movements in performance, and biomechanical approach all together, various factors in orchestral conducting can be integrated in Newell's (1986) model (as presented in Figure 1.3). In music performance, both compositional factors (e.g., temporal and pitch configurations) and performance factors (e.g., articulation and timbre) should be taken into account when considering musical movement. Empirical investigations of body movements in music listeners and musicians has demonstrated evident connections between the periodicity of body movement kinematics and compositional structures of phrasing and hierarchical metrical levels. Prominent body movements also correspond to key events in compositional structures (e.g., melodic, dynamic, harmonic climax, cadence, important sectional boundaries). Given these observed general tendency, each musician's body movement tends to be idiosyncratic, particularly at compositional key events. The variability of movement appears to be an important trait to highlight compositional key events and the performer's interpretative selections. In addition, serving as the means to communicate, musical movement should be considered in the performance context, which contains complex interactions among factors in individual performers (e.g., expertise level, particular role in the ensemble) and social context (e.g., cultural convention, concert/rehearsal, listeners' response).

The aforementioned findings in musical movement research provide a substantial groundwork for the further investigation of orchestral conducting. Conducting educational manuals provided instructions for conductors to use systematic movement emblems to communicate compositional features they intend to highlight. It is observed that conducting emblems tend to be associated with a certain collection of movement kinematic features. And it has been demonstrated that kinematic features of conducting movement play important roles in synchronising musicians and conveying musical expressiveness. In the existing literature, however, it is still not clear whether these conducting movement emblems suggested by conducting educational manuals can truly be observed in conducting performances as movement kinematic variations. In the current study, time-series patterns of conducting kinematics and critical kinematic deviations will be explored using a biomechanical approach. Elements in compositional structure and individual conductor's musical interpretations both contribute to the variability of conducting movement. The connection between compositional factor, conductor's interpretational factor, and conducting kinematic variability will be examined from the perspective of dynamical system theory.

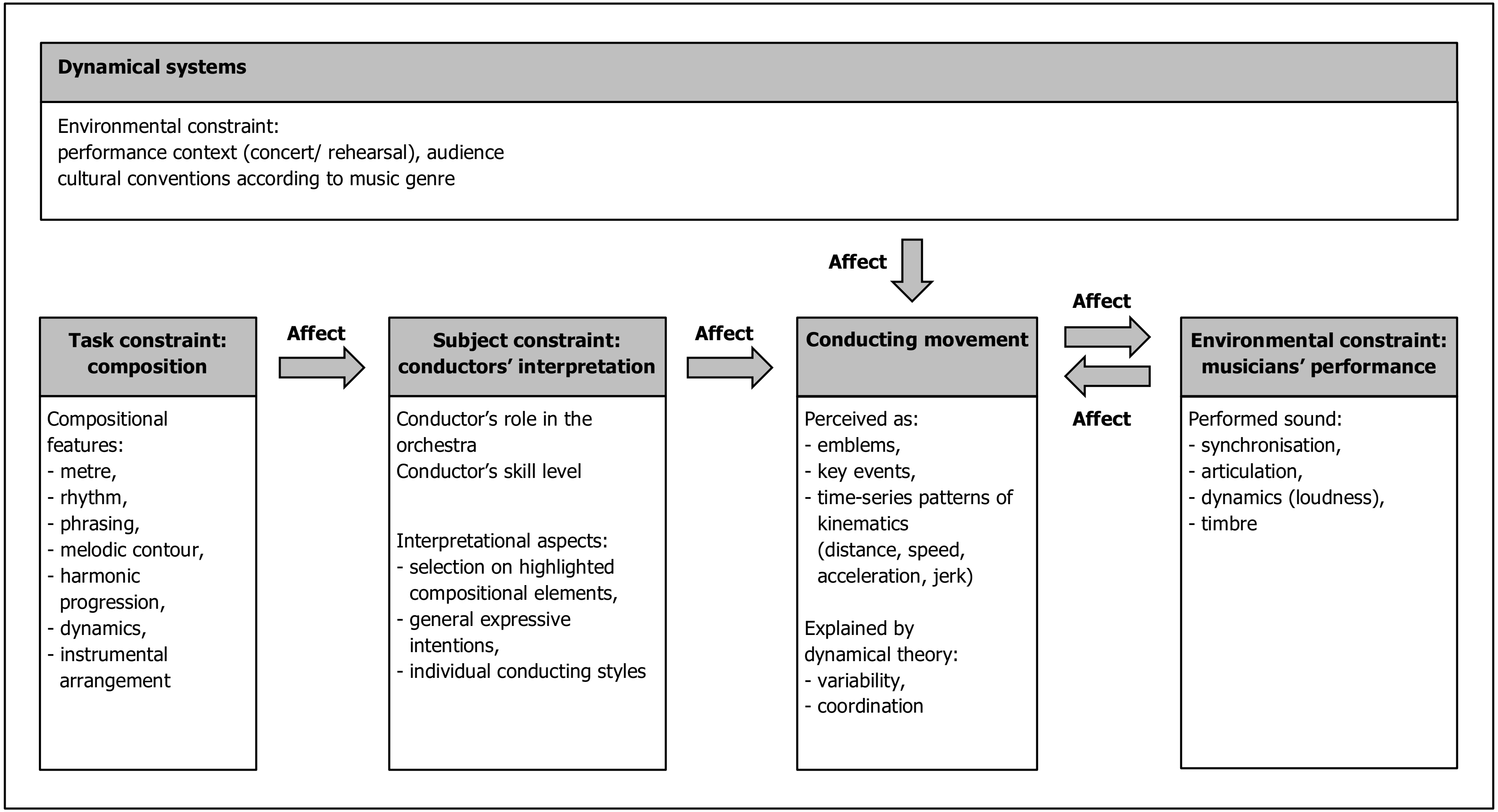


Figure 1.3 Dynamical system of conducting movement (adapted from Newell (1986)'s model)

1.4.2 Thesis aims and structure

Due to the complicated interactions among various factors within the complex dynamical system of conducting movement in Figure 1.3, it is inevitable that this thesis can only focus on limited aspects of conducting movement. Those selected are the compositional structure, the conductor's musical interpretation, and kinematics of conducting movement (Figure 1.4). This thesis aims to investigate 1) which specific connections between conducting movement kinematic variations and compositional elements can be observed from actual conducting performances, and 2) in what specific ways conductors' musical interpretational intentions are revealed in their conducting movement kinematic variations in performance.

Conductors play an important role in the orchestra to provide their insights into musical composition and communicate such interpretations using their conducting movement. By exploring conducting movement, this thesis tackles a core matter of musical performance research regarding the relationship between the compositional structure and the music performer's expressive intention, pursuing some answers to the simplistic yet fundamental questions, 'What is it that conductors do when they are conducting?' and 'How are they doing that?'. This thesis first asks, 'What are conductors *told* to do?' (research question 1), then 'What do conductors *say* they are doing?' (research question 2), and 'What do conductors *do* in the process of conducting?' (research question 3). To answer these questions, influential conducting educational manuals have been reviewed and analysed (section 1.1.1; for research question 1). The current study collected conductors' self-reported interpretational intentions from interviews (Chapter 2; for research question 2) and observed conductors' movement kinematic features based on motion capture data (Chapter 3 and Chapter 4; for research question 3). By comparing data collected using qualitative and quantitative approaches, this thesis contributes to musical performance research in such a way that the two sources of evidence– conductors' own thoughts and beliefs about their actions, and detailed biomechanical description of their actions– are triangulated with reference to the composer-annotated scores. The research approach of the current study is original and distinct from previous studies in such a way that it seeks to identify prominent kinematic deviations shown at specific time-points during the action of conducting movement, which can be directly linked to dominant ideas of conducting movement, as understood through the evidence from popular conducting textbooks and the conductors' own accounts of their art.

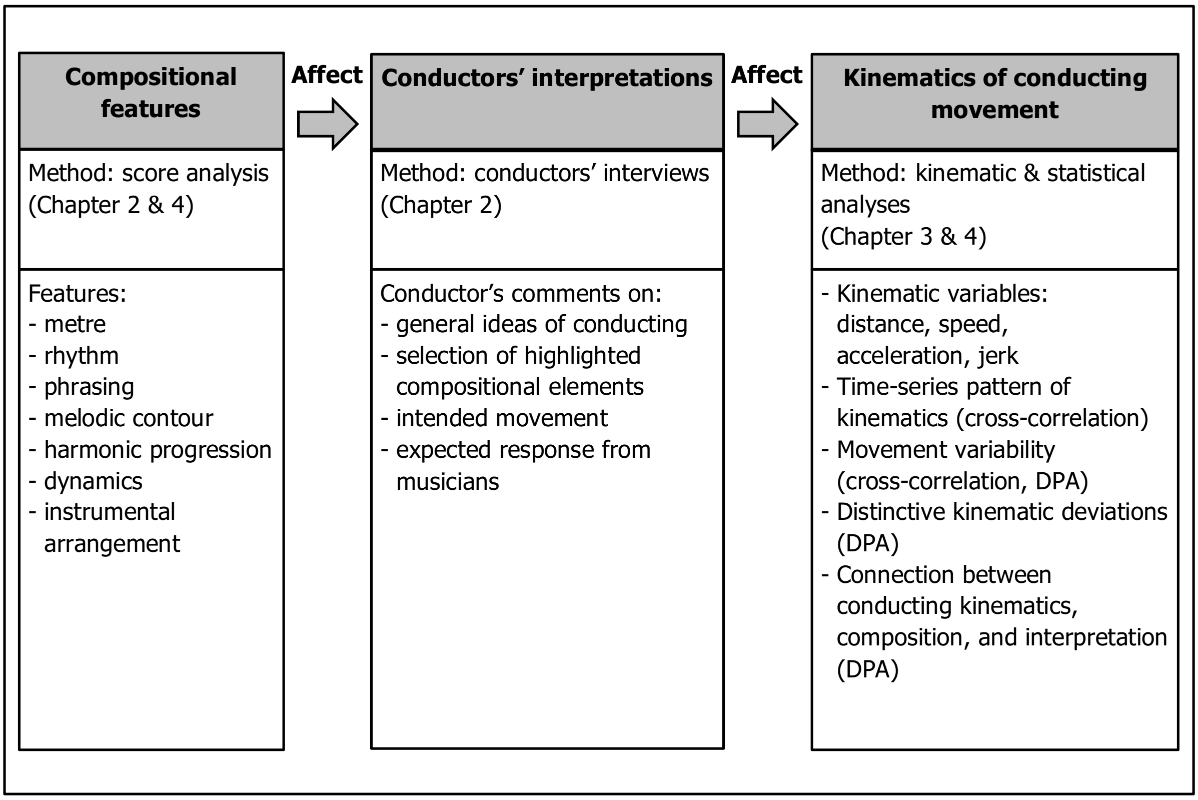


Figure 1.4 Summary of thesis structure

In Chapter 2, conductors’ interpretations of music compositions are explored via structural interviews with six conductors (further details about the interview procedure are given in section 2.2.2). Conductors’ general ideas of conducting, as well as interpretative intentions of three selected music compositions are analysed using thematic analysis accompanied with music score analysis. The results draw attention to general considerations when examining conducting movement, as well as providing guidance on specific musical key events conductors intended to highlight, which were compared with subsequent results of conducting kinematic analyses.

Following interviews, the same group of conductors conducted the three selected music compositions with a small string ensemble. Each conductor’s interview was followed by a motion capture session in the same day (further details about the procedure for motion capture session are given in section 3.2.2 to section 3.2.6). The movements of twenty-seven passive markers on conductor’s upper body and the baton were recorded using a motion capture system, Qualisys. In Chapter 3, time-series patterns of their conducting kinematics (distance, speed, acceleration, jerk) are investigated. Using descriptive analyses, particular kinematic features corresponding to each music composition are explored. Using cross-correlations, within-conductor kinematic variability (repeated performances by the same conductor) and between-conductor kinematic variability (performances by different conductors) of movement are examined and then compared using *t*-tests.

In Chapter 4, an innovative analysis method for movement variability– Deviation Point Analysis (DPA) is described. This was developed to detect salient kinematic deviations during the action of conducting. These identified kinematic deviations in conducting are matched with prominent features in metric, rhythmic, melodic, harmonic, dynamic, and instrumental aspects in the composition, as well as the conductor's stated interpretational intentions. These kinematic deviation points are further examined to test whether they reiterate and attach to the same musical key events in repeated performances by the same conductor, and performances by different conductors. The within-conductor kinematic variability and between-conductor kinematic variability are analysed to investigate whether these conducting kinematic deviations are unique features for individual conductors, or common traits for all conductor's conducting.

In Chapter 5, the findings from the qualitative study based on data collected through interviews with conductors (Chapter 2), and the results from the kinematic analyses (Chapter 3 and Chapter 4) are brought together and examined in detail. These results are discussed in the context of the apparent idea and aims of conducting, as understood from this current chapter's exploration of the directions contained in accepted conducting instructional texts. The limitations and potential application of this study are addressed, and then concluded.

Chapter 2: Conductors' ideology of orchestral conducting and musical interpretations: interviews

2.1. Introduction

According to the discussion in Chapter 1, although there has been a growing body of research investigating body movement in musical performance, further empirical studies focusing on orchestral conducting movement are still required. The general ideology of conducting movement has been established based on instructions in conducting educational manuals. However, within this, individual conductors provide their own musical interpretations of the performed composition, and purposely use their body movement to communicate these. Individual conductors thus may contribute different insights into the composition and also have different schemes of their conducting movement according to their musical interpretations. This chapter aims to explore conductors' thoughts on orchestral conducting via interviews. Six conductors' self-reported statements were collected in interviews, and their conducting movements were recorded in subsequent motion capture sessions. The findings in interviews regarding conductors' general thoughts of conducting, musical interpretational annotations, and qualitative descriptions of their planned conducting movements thus provided guidance for successful kinematic analyses of their conducting movement. The research questions addressed in this study of conductors' interviews are:

2.1. What are conductors' general thoughts about orchestral conducting, regarding conductors' functions in an orchestra and criteria to judge the quality of conducting?

2.2. What are conductors' interpretations of the three musical excerpts they were going to conduct in the motion capture sessions?

2.3. What do conductors view as the key features of their body movement by which they communicate their specific musical interpretations?

2.2. Methods

2.2.1 Exploratory interviews

2.2.1.1 Exploratory questionnaire design

The exploratory questionnaire explored the conductors' thoughts on conducting movements and their interpretations of the three musical excerpts selected as experimental materials. Conductors' responses on these questions helped identifying major features of conducting movements, which provided guidance for the subsequent motion capture data analysis. The questionnaire design used closed questions, with the aim that these precise responses can directly connect with motion capture data from the same group of participants. The results and feedback from the exploratory questionnaire informed the revision of the study design and the procedure of the following formal interviews.

The questionnaire included four parts: 1) conductors' musical background; 2) the body parts they use to deliver specific compositional structures in their conducting; 3) the movement features they use to deliver these compositional structures, and 4) compositional structures they intended to highlight in the three musical excerpts. The first part investigated the conductors' musical backgrounds, such as the extent of their conducting experience. The second and third parts consisted of questions about their conducting movement, focusing on body parts they tend to use in their conducting. Seven-point scales were used to evaluate the importance of ten segments (baton, right hand, right forearm, right upper arm, left hand, left forearm, left upper arm, head, torso, lower body) and four movement features (the amplitude, velocity, acceleration, and trajectory of movement) when conductors convey five compositional aspects (beat, rhythm, melody, articulation, loudness). A seven-point scale is commonly used in social science research because as a closed-question format, it can clearly distinguish subjects' different opinions. (Rossi et al. 1983; Saris and Gallhofer 2007). In the fourth part of the questionnaire, conductors marked in the scores, specifying targeted musical events they would like to highlight in their conducting, and also the compositional features they would like to emphasise at these marked time-points. The three musical excerpts chosen as experimental material shared some similar features which made them comparable, yet were composed in three different music eras and were representative of different styles of music, as identified by commonly known eras of classical Western music history (Grout, Burkholder, and Palisca 2005). Mozart's Serenade in G major, K.525, first movement was selected as representative of the Classical Period (1750-1820); Dvořák's Serenade in E major, Op.22, first movement for the Romantic Period (late 18th century and the 19th century); Bartók's Divertimento, Sz. 113, third movement for the 20th Century music. They are all in binary metres (4/4 metre in Mozart and Dvořák and 2/4 in Bartók) and are performed at tempi ranging from moderato to allegro (roughly 90 to 120 beats per minute). An example was provided to inform conductors of the conventions for marking their annotations in the score.

2.2.1.2 Participants

The exploratory questionnaire was then given to four conductors. The preview group consisted of two participants who work with professional orchestras (CP1 and CP2) and two participants who work with student orchestras (CP3 and CP4). Their average conducting experience was 11.3 years (SD=3.40). Participants' basic information are listed as Table 2.1:

Table 2.1 Participants of pilot study

Participant	Type of orchestra working with	Conducting experience (year)
CP1	Professional	10
CP2	Professional	16
CP3	Student	8
CP4	Student	11

2.2.1.3 Procedure

Each conductor completed the questionnaire individually with the researcher present. The pilot session started with a brief introduction to explain the purpose of this study. The conductors then took as long as they needed to answer the questionnaire, and this was followed by a discussion to provide feedback on the questionnaire design. Each conductor spent approximately one to two hours to complete the questionnaire and discussion. Discussion was audio recorded and handwritten notes were taken.

2.2.1.4 Feedback from exploratory interviews

All four conductors finished the first and fourth parts of the questionnaire. However, they reported that it was difficult for them to effectively answer questions in the second and third parts, which asked conductors to report the body parts and movement features they intend to use to deliver specific compositional structures when conducting. Due to the incomplete questionnaire responses, the analysis focused on the conductors' feedback and the difficulties reported by them in the follow-up discussion part, which could inform the development of the study design. According to conductors' opinions, it was challenging for them to complete the questionnaire mainly because: 1) the manner by which the questionnaire described conducting movement was different from the conventions conductors were used to. Conductors tended to consider conducting movement as an entire indivisible whole rather than deconstruct it into individual features. 2) Conducting movements are closely attached to the musical context and conductors did not think that these could be discussed separately. 3) Conducting movements are known to vary depending on the performance context and each conductor's personal style, thus it was challenging for them to generalise conducting features. And 4) conducting movements do not work alone but are accompanied by other important elements such as facial expression.

The manner by which to describe conducting movement

Conductors found that it was difficult for them to deconstruct the conducting movement into individual elements since they are more used to consider the conducting movement as a complete entirety.

> *Conducting should be considered as a whole instead of separated movement features or body parts. (CP2)*

Conductors not only paid attention to the overall conducting movement, they also tended to describe conducting movement using subjective expressions and abstract metaphor. This is different from the design of questionnaire, which evaluated movement using quantitative measurements.

> *Conducting is a flow. The motion could be still and the still could be motion. The two become a coherent entirety in the flow of music. (CP1)*

> *Conducting is an art which cannot be analysed, not to say to describe them by numbers. (CP1)*

Conductor' feedback suggested that the questionnaire would be more effective if the second and third part could focus more on conductors' general thoughts on the overall conducting movement, rather than distinguishing movement features of different body parts. It would also be preferred to include more open questions to allow conductors to describe conducting movements using their own vocabulary, rather than ask them to evaluate conducting movement using quantitative methods such as seven-point successive scale.

Conducting movements are compositional context dependent

Conductors stated that when conducting, they focus their attention on their imagined evocation of the musical work (hereafter described as ‘the music’) rather than on their physical movements. Especially for experienced conductors, the body movement was considered as the ‘surface layer’ of conducting, which is merely a tool to communicate their musical ideas.

> *When conducting, you don’t focus on the corporeal movement but the spirit of music in your mind. The movement is just a superficial thing but not the core. (CP1)*

> *Beginners of conducting might think of their movement when conducting. But for experienced conductors, the movement itself is not the main focus at all. (CP2)*

Since conductors centre their attention on the music, their conducting movement is highly musical context-dependent. Different movements can be applied to similar compositional features given diverse musical contexts. Conductors strongly suggested that the discussion of conducting movement should be based on a specific musical context.

> *When I give an accent, there are thousands of ways to do it. It depends on what kind of accent it is and what does the accent mean in this context of music. There are so many differences among each of these and this is the magic of conducting. I really cannot give a general answer to these questions. (CP3)*

> *The movement changes a lot according to the musical context and even the mood of the conductor. Conducting movement could work in many ways. It is almost impossible to generalise them into certain rules. (CP4)*

Based on conductors’ suggestions, questions regarding conducting movement (the second and third part of questionnaire) would be combined together with the discussion of their musical interpretation (the fourth part of questionnaire) in the revised version of study. In order to discuss conducting movement in a specific musical compositional context, music scores would be presented together with questions.

Conducting movements are diverse across personal style

Conductors highlighted the diversity of conducting movement between individual conductors. Diverse conducting styles were regarded as an important feature of conducting.

> *Every conductor has their own fashion to convey their ideas of music. For example, even the very basic thing- the time delay between the beat of conducting movement and the time when the sound is actually produced- varies a lot according to the conducting style. (CP3)*

In addition to this, the performance context can also influence conducting movement. Conductors perceive the sound produced by musicians and adjust their conducting strategy accordingly.

> *Conducting is not a one-way process. It's an interaction with the orchestra. You are not only using your body, but also your ears and mind. You should listen carefully what the orchestra gives back to you. (CP4)*

According to these comments, the analysis of conducting movement should not only focus on common patterns of all conductors' conducting. Individual difference between conductors and how the conductor interacts with musicians should also be considered.

Body movement cooperates with other elements in conducting

Conductors stated that in conducting, many other elements work together with body movement. For instance, facial expression and breathing can convey important information to musicians:

> *Conductors not only conduct using their body. Excellent conductors can conduct the orchestra even when they are only allowed to use their facial expression. Breathing is also important in conducting. Breathing is the cue to make the whole orchestra stick together. (CP2)*

This comment informed the limitation of this study. Even though this study mainly focuses on the body movement in conducting, it should be noted that body movement is not the only means by which conductors communicate their musical ideas. Musicians may react to conductors' facial expression and breathing as well. However, the fact that conductors emphasised the unity coherence of their total actions suggests that body movement alone may provide a valid proxy for other dimensions.

2.2.1.5 Study development

The main issues emerging from conductors' opinions in the exploratory questionnaire produced several pointers for the development of the study:

1) The questions dividing movement features and body parts were replaced by questions about conductor's thought on overall conducting movement.

2) To provide an appropriate musical context to discuss conducting movement, questions regarding conducting movement in the second and third parts were also combined with questions about musical interpretation in the fourth part. These questions were presented together with music scores alongside.

3) Closed questions with seven-point successive scale about body movement were replaced by open questions to obtain conductors' qualitative descriptions of their own conducting movement.

4) One-to-one interviews were carried out instead of questionnaires to communicate with conductors more effectively, documenting their deeper thoughts of conducting movements regarding specific musical excerpts.

Conductors' suggestions in the exploratory study also informed the methods of data analysis:

1) Conductors' comments on conducting movement need to be considered in conjunction with their interpretations of the musical excerpts. Therefore, their interpretational annotations in interviews were connected with their movement features observed from motion capture data.

2) The investigation of conducting movement examined the common movement patterns for all conductors, as well as differences between conductors.

2.2.2 Experimental design

Based on the findings from the exploratory study, the questionnaire was converted into an interview structure consisting of three parts: 1) participants' background musical training and experience; 2) interpretations of three musical excerpts and descriptions of conducting movement; and 3) general ideas of conducting. The first part, 'music background', included five-point successive scales, force-choice and open questions. Open questions were used for the second part, 'interpretations of music and descriptions of conducting gesture', and the third part, 'general ideas of conducting'. The structure of interview was thus as follows:

Table 2.2 Interview structure

Interview part	**Question type**	**No. of question(s)/ response(s)**	
1. Musical background	5-point scale	1 question x 5 comments	13
	Forced-choice	4	
	Open	4	
2.1 Musical interpretation	Open	2 questions x 5 comments x 3 musical excerpts	30
2.2 Conducting movement	Open	2 questions x 2 comments x 3 musical excerpts	12
3. General ideas of conducting	Open	4	

2.2.2.1 Participants' background musical training and experience

The first part of the interview consisted of nine questions regarding the conductor's musical background (Table 2.3), including basic information (Q1.1, Q1.2), instrumental experience (Q1.3, Q1.4, Q1.5), experience playing in an orchestra (Q1.4, Q1.5), conducting experience (Q1.6, Q1.7, Q1.8, Q1.9). In conducting experience, the interview covered questions regarding the conductor's experience level (Q 1.6, Q1.7, Q1.8), the types of orchestra they work with (Q1.8), and the familiarity of different types of music (Q9). Mixed question types were applied, which include four open questions, four force-choice questions, and one five-point successive scale question.

Table 2.3 Questions in the first part of interview 'musical background'

Question		Question type	Options provided
Q1.1	Gender	Force-choice	Male/ Female/ Prefer not to say
Q1.2	Handedness	Force-choice	Right-handed/ Left-handed
Q1.3	Which instrument(s) do you play (if any)?	Open	Specify instrument (Specify No. of years playing)
Q1.4	Which instrument(s) do you play in the orchestra (if any)?	Open	N/A
Q1.5	For how many years have you played in the orchestra (if ever)?	Open	N/A
Q1.6	How many years is it since you began conducting?	Open	N/A
Q1.7	How would you describe your status as a conductor (tick all that apply)?	Force-choice	Professional conductor/ Professional music educator/ Advanced student/ Amateur
Q1.8	Which of these orchestra(s) are you regularly conducting (you can select more than one)?	Force-choice	Student orchestra/ Amateur orchestra/ Professional orchestra (Specify No. of years conducting; No. of hours conducting a week)
Q1.9	How often do you conduct the following repertoire?	5-point scale	Music before 1750/ Music in Classical Period/ Music in Romantic Period/ 20th century music/ Other genres of music (specify) (Scale options: Not at all/ Not very often/ Sometimes/ Often/ A great deal)

2.2.2.2 Interpretations of musical excerpts and descriptions of conducting movement

In the second part, open questions were asked with reference to music scores (Table 2.4). Questions covered conductors' interpretational intentions of three musical excerpts they were going to conduct in the subsequent motion capture session, and also their intended conducting movements to communicate these interpretations. In the part of musical interpretations, participants were expected to provide at least five annotations on each musical excerpts, by freely marking musical time-points in the score and specifying the compositional features they would like to emphasise in their conducting at these moments. An example was presented to illustrate the conventions to mark the score. According to the interpretational annotations conductors provided in the music score, they were asked subsequent questions to describe their intended conducting movement for delivering such interpretational purposes. Participants were instructed to choose two out of the five annotations in each musical excerpt for further discussion about their conducting movement, in which they were encouraged to describe their movement features using adjectives and to explain how the orchestra should respond to this movement.

Table 2.4 Questions in the second part of interview 'interpretations of music and descriptions of conducting movement'

Aspect	Question	Response form	No. of responses	
Musical interpretation	Q2.1 Select 5 musical time-points you would like to highlight in your conducting.	Mark the score	5 x 3 musical excerpts	15
	Q2.2 Which music features you would like to highlight in these time-points?	Mark the score	5 x 3 musical excerpts	15
Conducting movement	Q2.3 Could you describe the key features of this gesture using adjectives?	Oral explanation	2 x 3 musical excerpts	6
	Q2.4 How should the orchestra respond if they receive this gesture properly?	Oral explanation	2 x 3 musical excerpts	6

2.2.2.3 General ideas of conducting

In the third part of interview, participants were asked questions regarding their general thoughts on conducting, and their conducting experience (Table 2.5). General questions included the conductor's roles in an orchestra and the criteria they use to evaluate the level of conducting. Regarding their individual conducting experience, they were asked to describe their own distinctive features of conducting, and also the methods they use to review their conducting.

Table 2.5 Questions in the third part of interview 'general ideas of conducting'

Aspect	Question	
General conducting	Q3.1	What do you think are the most important roles a conductor should play in an orchestra?
	Q3.2	What do you think makes good conducting?
Personal experience	Q3.3	What do you consider to be the distinctive qualities of your conducting?
	Q3.4	Do you find that you review your own conducting performances? How do you do that? (at least 3 comments)

2.2.3 Ethics

Based on the Research Ethics Policy and Procedures of the College of Arts, Humanities and Social Sciences, University of Edinburgh, this project was approved by College Research, Ethics and Knowledge Exchange Committee. The instructions of ethic procedures were complied with. Informed consent forms including permissions for the use of data (see Appendix 2) were understood and signed by participants.

2.2.4 Recruitment

Recruitment information was disseminated via two email lists, which consisted of student and professional conductors respectively. The recruitment email was sent to the music school email list in University of Edinburgh through the school secretary, and also the Scottish Chamber Orchestra's email list through the Connect Director for the orchestra. The four participants joining in the previous exploratory study were excluded from the recruitment. The email contained basic information about this study and indicated the honorarium of £50 for the completion of both interview and motion capture sessions.

2.2.5 Participants

Six participants completed the interview (Table 2.6). The same group of participants were expected to complete following motion capture sessions so that the data from interviews can be compared with motion capture data. All of them were right-handed males, with an average conducting experience for 10.6 years (SD=9.37). At the time of participation, they conduct for 4.4 hours per week on average (SD=2.38). Three respondents described their conducting status as 'advanced student', whereas three respondents considered themselves as 'professional conductor' or 'professional music educator'.

Table 2.6 Conducting experiences of interview participants

Participant	**Status**	**Conducting experience (year)**	**No. of hours conducting (per week)**
C1	Advanced student	7	8
C2	Professional music educator	10	2
C3	Advanced student	4	3.5
C4	Professional conductor/ professional music educator	10	2
C5	Professional conductor/ professional music educator	29	6
C6	Advanced student	4	5

Based on conductors' responses in interviews, they had an average experience of playing an instrument for 19.5 years (SD=11.61, based on the instrument each conductor played for longest time), and an average experience of playing in the orchestra for 11 years (SD=9.38). Conductors' instrumental training experience is summarized in Table 2.7.

Table 2.7 Instrumental experiences of interview participants

Participant	Instrument(s) playing/ No. of years playing	Instrument(s) playing in the orchestra/ No. of years playing in the orchestra
C1	Piano (8); Organ (7); Clarinet (9)	Clarinet (8)
C2	Piano (20); French horn (10); Electric bass (10)	French horn (7)
C3	Piano (8); Trumpet (12)	Trumpet (8)
C4	Piano (35); Trumpet (30)	Trumpet (5)
C5	Piano (32); Violin (30); Viola (25)	Violin & Viola (30)
C6	Piano (4); Bass Trombone (9); Double Bass (6); Guitar (9)	Bass trombone & Double bass (8)

2.2.6 Procedure

The interview was conducted immediately prior to each conductor's motion capture session because 1) conductors' interpretational annotations in interview sessions would be similar to their intentions when conducting in motion capture sessions; and 2) conductors gave their interpretational thoughts before they conducted the ensemble, so that they would not be able to revise their comments based on their memory of what they had done in the motion capture session.

The interview was carried out by an experienced interviewer as confederate, to avoid bias with the experimenter. The interview duration was approximately one hour, and the sessions were audio-recorded and hand-written notes were taken. The interview began with a short explanation of the three main parts of the session. In the first part 'music background', conductors were provided the questionnaire and instructed to complete questions with the interviewer's explanations if needed. In the second part, conductors made annotations of their musical interpretational intentions in scores. They were allowed to take as long as they needed to complete the marking on each musical excerpt. The interviewer then asked follow-up questions about their intended conducting movement based on the conductor's marking. After completing the marking and questions on three musical excerpts, conductors were asked questions regarding their general thoughts of conducting in the third part of interview. When the interview was finished, they were invited to the waiting room next to the motion capture laboratory to prepare for their motion capture session.

2.2.7 Data analysis

Forced-choice and Likert-type responses in the first part of interview were analysed to provide descriptive data regarding participants' musical training and experience (Table 2.6 and Table 2.7, p.48). Open answers from the second and third parts of the interview were analysed using thematic analysis (Guest et al. 2012) to identify key features in conductor's musical interpretations and body movements. Line-by-line coding was conducted on transcripts initially. Then identified key features were organised based on common themes emerging from different conductors' responses. Those themes were allocated to three categories— general descriptions of conducting, highlighted compositional structures, and conducting movement features. Compositional features highlighted by conductors and their reported descriptions of conducting movement would be compared with kinematic features of their conducting in the subsequent motion capture sessions. The participants recommended four conducting educational manuals that they are familiar with, and their opinions collected in interviews would be compared with the conducting instructions indicated in the four conducting textbooks (wee Table 1.1). The results would be discussed together in Chapter 5.

2.3. Result

2.3.1 Conductors' general ideas of orchestral conducting

In the third part of the interviews, conductors provided their general thoughts regarding four specific topics. These included: the conductor's roles within the orchestra; criteria with which to evaluate the quality of conducting; participants' views of the distinctive features of their own conducting; and finally, the methods by which participants review their own conducting. Their opinions are summarised in Table 2.8.

Table 2.8 Conductors' general descriptions of orchestral conducting

Topics	Summary of description(s)	
Conductor's roles	Reveal musical structure	- Provide insights of deeper musical structure - Value historical and cultural context of musical compositions
	Provide musical interpretations	- Unify the musical interpretation - Balance different musical aspects (e.g., tempo, phrasing, articulation)
	Present musical expressiveness	- Transfer musical emotion - Balance between structural and expressive aspects of the composition
	Build interpersonal relationship with musicians	- Act as a director/encourager, co-operator, and supporter/facilitator
Criteria of good conducting	Sufficient knowledge of the musical composition	
	Sufficient preparation before rehearsal	
	The clarity of conducting	- Unambiguous conducting gestures
	Good communication	- Good relationship with musicians
	Desirable character	- Have passion
		- Be inspiring
Distinctive qualities of conducting	Musical knowledge and understanding	
	Precision of conducting	
	Communicative skills	- Flexibility of conducting gestures - Ability to react to problems
	Musical expressiveness	- Expression of musical emotion, - Personal engagement
	Experience of conducting diverse types of music	
Review strategies	Video and audio recording	
	Review and analyse themselves	
	Feedback from musicians/ audience/ peers	

2.3.1.1 Conductor's roles in the orchestra

According to conductors' opinions, the conductor's main roles in an orchestra include: delivering musical structures; providing musical interpretations; presenting musical expressiveness; and serving as the link between the musical composition and musicians.

Reveal musical compositional structure

Conductors all agreed that in conducting, they should aim 1) to reveal compositional structures based on their knowledge of music; 2) to provide their own interpretations on the composition; and also 3) to emphasise the expressiveness in a musical work. However, there was disagreement over whether a conductor should focus more on presenting the inherent structure in a composition, or adding their own interpretations on music.

Regarding compositional structures, it was suggested that the conductor should have sufficient knowledge, not only of apparent aspects of the composition, but also the underlying, deeper structure– they should ‘know the score in such the depth that they know about the connection between notes’ (C3). Conductors were expected to have their own insights into nuances in aspects such as motivic development, harmonic progression, and counterpoint structure. In addition, conductors thought that their insight arises not only from considering the musical composition as an isolated object, but also from an understanding of the historical and cultural context of the composition. It was considered to be a part of a conductor’s role to be informed of the knowledge ‘about this composer, this excerpt, or about the composer’s other excerpts’ (C3).

Yet there was no agreement on the relationship between the compositional structure and the conductor’s interpretation. It was believed that conductors’ role is to ‘make the music piece speak’ (C2) and to ‘set the character of the music as dictated by the score’ (C5). One conductor took a very strong position on this, stating:

> *Conductor should encourage the orchestra to play the music as it’s written in the score...I believe that the conductor’s role is NOT to set an interpretation, because once you start to do things like that, then the performance starts to become more about you rather than about the music itself. (C5)*

In this comment, a conductor is regarded as an agent to communicate the composer’s musical dictations written in the musical score. The visual presentation in different editions of scores may have different musical dictations, yet it was not mentioned in the interviews.

Provide interpretations and present musical expressiveness

In addition to delivering compositional structures as mentioned previously, it was also argued that the conductor has the responsibility and authority in matters of musical interpretation. Even the conductor who gave the previous comment mentioned that ‘different conductors bring something different [for the same music piece] through their presence in front of the orchestra’ (C5), and if ‘there is something not clear in the score, that would be the issue of the balancing’ (C5). It appeared that conductors should provide their interpretations when the scored composition is ambiguous. It was stated that conductors should ‘interpret the music as one thing’ (C3) in many musical aspects such as ‘articulation, phrasing and tempo’ (C3), so that they should ‘take responsibilities to make these decisions' (C3), to 'show interesting things in the music' (C2), and to 'find special moments and figure out the way of having that be heard' (C2).

In addition to such interpretation, it was argued that conductors should show the expressiveness of musical composition. It was described that a conductor should 'take the emotions from the music piece and then transfer them' (C6). Yet this effort should be moderated by the balance between the expressive and structural aspects of the composition: 'expression [of music] sometimes is either glorified or not spoken enough of it, it should be something between it' (C2).

Manage interpersonal relationship in the orchestra

Conducting involves the knowledge and capacity to clarify compositional structure, provide original interpretations, and highlight the musical expressiveness. But conductors can communicate these musical aspects to the audience only by coordinating musicians. According to the conductors' opinions, they would achieve this goal by performing different roles in an orchestra including 1) director/encourager; 2) co-operator; and 3) supporter/facilitator in the orchestra.

As the director of the orchestra, it was noted that a conductor should 'encourage musicians' (C2) and 'give them confidence' (C2). For the role of co-operator, respondents gave comments like: 'a conductor should work in cooperation with players' (C1), 'respect musicians' (C5), and 'appreciate musicians' musicianship' (C1). As for the role of supporter and facilitator, a conductor would 'give a proper platform for musicians to play' (C3), even though musicians tend to need different levels and forms of support in different types of orchestra, for instance, in a professional compared to an amateur orchestra.

The interviews also touched on the audience's role in a conducting context, particularly during concerts. It appeared that conductors have different views on how the audience may influence the conductor-musician relationship. One conductor expressed that he 'intends to not worry too much about the audience' because it might 'create an off-balance of the relationship with the orchestra', whereas another conductor considered the audience to be the target of his communicative efforts by 'channel[ling] all these energies from the players to the audience' (C3).

2.3.1.2 Criteria of good conducting

Regarding the criteria to evaluate conducting, conductors' comments connect with their descriptions of a conductor's roles. There was agreement that to achieve a better quality of conducting, a conductor should have 1) adequate knowledge of compositional structure and preparation for the rehearsal; 2) competent skills concerned with the clarity and efficiency of conducting gesture, and the communication with musicians; 3) positive characters including having passion and being inspiring.

The knowledge of the musical composition and the preparation for the rehearsal

All conductors stated that knowledge of compositional structure and adequate preparation before rehearsal are fundamental elements for good conducting. The conductor should 'know the music inside and out' and 'understand not only the notes, but also the structure of what is going on'. It was also expected that conductors should 'prepare [understand] the score before rehearsal' (C5) and 'know exactly what they want and what they need in advance of the first rehearsal' (C5). Only by sufficient knowledge and preparation beforehand, the conductor can 'convince musicians to take these interpretations on board' (C1). These opinions echoed participants' previous comments regarding conductor's main roles.

Conducting skills: the clarity of conducting and the communication with musicians

It is an important aspect of conducting to use clear, unambiguous conducting gestures to indicate beats and musical ideas. Yet it is not only about the clarity of conducting movement, but also concerned with the communicative process by which 'the conductor addresses players' (C1) and 'structures a rehearsal' (C1). To have good communication with musicians, the conductor should 'make sure that the ensemble knows why you [the conductor] are going to do this gesture' (C2). A good relationship with musicians was also considered to be crucial in conducting because 'unless you [the conductor] have the key link with your players, it won't be as effective' (C1). Conductors also 'have to create music in the right environment for that to work. You can't be in the tension of a lot of personal problems behind music' (C1).

Related characters: having passion and being inspiring

It appeared that being passionate about music is vital for conductors – an attribute identified as being present when 'people feel like they want to play [music] with you' (C3). But passion can only be delivered by adequate conducting skills, as a conductor stated, 'you can't add passion without technique' (C6). A good conductor should also have a positive influence on musicians to encourage or inspire them. It was described that a conductor should 'let the players have the sense that they have achieved something, that they have more confidence of their ability of performance' (C1). One conductor even thought that it is a privilege for him to 'be in the position where you are responsible for creating someone else's musical experience' (C5), and 'in the position where you can inspire people, not necessarily through yourself, but to help them to be inspired by the music' (C5).

2.3.1.3 Distinctive qualities of conductor's own conducting

When conductors were asked to describe distinctive qualities of their own conducting, their answers reflected the criteria they used to evaluate the quality of conducting. It was reported that they have advantages in their 1) knowledge of musical composition; 2) conducting skills and musical expressiveness; or 3) personal conducting experience, all of which make them specialised in a certain aspect of music conducting.

Regarding musical knowledge and understanding, one of the most experienced conductors, having twenty-nine years of conducting experience, reported that he has learnt standard repertoire since he was very young and it was considered to be one of his strengths. He added: 'I would hope that I would be able to convey that music is deeply inside me' (C5).

As for conducting skills, three conductors considered 'precision' to be one of the virtues of their conducting. They tended to 'keep things simple' (C4) and 'prefer being precise over exaggerating emotions' (C2). The communication skills such as 'the flexibility of conducting gesture' (C1) and 'the ability to react to problems' (C1) in performance were also thought to be merits in conducting. Besides conducting skills, three conductors reported that they intend to 'create the music expressiveness' (C2) in their own conducting. One conductor emphasised: 'I don't focus on the technical side more than the side that is about communicating meaning and emotion' (C3), and 'I'm really looking for my own interpretation and personal engagement' (C3) when conducting. Another conductor considered 'passion' as the most important thing he would like to convey in his conducting, and that he does this 'through his facial and whole body's movement' (C6).

In terms of individual conducting experience, two conductors felt that they have distinctive experiences of conducting. One conductor has considerable experience of conducting twentieth-century music, so he tends to 'let the orchestra have more freedom of expression' (C2), whereas another conductor has been involved in conducting various types of music, including film music, which made him think that one of his strengths is that he is well-adapted to different conducting performance contexts.

2.3.1.4 Strategies to review conductor's own conducting

It appeared that conductors generally use three different types of method to evaluate and improve the outcome of their conducting— 1) video and audio recording; 2) review and analyse themselves, in practice or in performance; and also 3) feedback from other people.

Four of six conductors (C3, C4, C5, C6) reported that they have recorded themselves when conducting. When they review the recordings, they would focus on the outcome of their conducting that they tend to 'pay attention to the performance sound' (C3), and analyse 'what works and what doesn't work' (C5). Yet one conductor (C1) had doubt about recording himself and tended to review his conducting 'in the moment of rehearsal' because that is when he is 'actually at the moment of music when you have to make very quick decisions in your own gesture'. He thought that his conducting would improve through the experience of rehearsal and 'try[ing] out different gestures'. Two conductors (C3, C5) considered that analysing and criticising their own conducting performance was very important to improve their skills, whereas one conductor (C2) said that he would practice in front of mirror and adjust his own gestures. Five conductors (C1, C2, C4, C5, C6) have asked feedback from musicians, the audience, peers, or more experienced conductors. One conductor pointed out that he might ask for musicians' suggestions, but he is aware that it 'could be double-edged sword' (C4). He would weigh the advantages and disadvantages carefully before he does this.

2.3.2 Conductors' interpretations of musical composition

In the second part of the interviews, conductors provided their interpretational annotations on three musical excerpts. Based on their reports, in their conducting, they intended to highlight compositional aspects including the overall musical character, temporal structure, melodic features and phrasing, dynamic change, and instrumental configuration. Their interpretational annotations are summarised in Table 2.9.

Table 2.9 Summary of conductors' highlighting compositional structure and movement

Compositional feature			Movement feature	No. of comment	Conductor	Example
Overall character of musical composition	The gesture for the first beat		- Unambiguous and precise gesture, - Breathing - Specify tempo and dynamic level	4	C1, C4, C5, C6	Mozart: bar 1 Dvořák: bar 1 Bartók: bar 1
	Legato, lyrical style of music		- Smooth movement - Less verticality	4	C1, C4, C5, C6	Dvořák
Temporal structure	Tempo fluctuation	Poco rall	- Clear gesture - Subdivision of beat	4	C1, C2, C4, C5	Bartók: bar 13
	Metrical change	4/4 to 2/4	- Different beating patterns	3	C2, C4, C5	Dvořák: bar 10
		2/4 to 3/4	- Subdivision of beat	1	C2	Bartók: bar 132
	Rhythmic pattern	Semiquavers	- Smaller movement	4	C2, C4, C5	Mozart: bar 5 Dvořák: bars 7-8
Melodic feature and phrase structure	Specific type of melodic figure	Trill	--	1	C2	Dvořák: bars 24-27
		Glissando	- Clear gesture - Large circle	2	C2	Bartók: bars 45, 61
	Melodic contour combined with dynamic and harmonic features	Melodic leap or melodic climax with *crescendo*	--	5	C2, C3, C4, C5, C6	Dvořák: bars 14, 16-22
		Downward melody with imperfect cadence	- Pull out a line	2	C5, C6	Mozart: bar 31
	Relationship between counterpoint sections	Highlight the top melody	- Encouraging gesture - Eye-contact	2	C3, C4	Mozart: bar 21 Dvořák: bar 13
		Bring out counter-melody	- Cueing gesture - Palm-up gesture - Encouraging gesture - Eye-contact	5	C1, C2, C3, C5, C6	Mozart: bars 6, 8, 16, 31, 47
		Balance counterpoint sections	--	1	C4	Dvořák: bar 14
	Phrasing	Distinction between active and passive beats	- Bigger and active movement at the beginning of a phrase	3	C2, C3, C5	-

Dynamic feature	*Subito forte* or *sforzando*		- High hand position - Broad travel distance - Back off very quickly	5	C1, C2, C3, C4, C6	Mozart: bars 18, 19
	Marcato accent		- Offer bounce - Heavy but with lift	1	C6	Bartók: bar 37
	Diminuendo		- Narrower travel distance - Downward-palms	1	C4	Dvořák: bar 21
	Crescendo		- Higher hand position - Broader travel distance - Further distance between 2 hands/ hands & body	3	C1, C5, C6	Mozart: bars 20-21 Dvořák: bars 14-20
	Pianissimo		- Low hand position - Narrow distance between hands and body	1	C6	Dvořák: bars 1-4
Instrumental configuration	Instrumental sections	*Solo/ tutti*	- Narrower travel distance for solo - Broader travel distance for tutti	3	C1, C3, C5	Bartók
	Textural change	Textural reduction	--	1	C1	Dvořák: bars 29-30
		From individual melodies to union (with *forte*)	- Large circle - More horizontal movement	1	C6	Bartók: bar 82
	Playing technique	*pizzicato*	- More pointed upbeat	1	C5	Dvořák: bar 5

2.3.2.1 The overall character of musical composition

The importance of the gesture for the first beat

Four of the six conductors (C1, C4, C5, C6) stated the importance of the very first beat in conducting a musical composition. The preparative upbeat gesture was considered to be the crucial key to set up the overall character of the performance, alongside setting the tempo and dynamic level. Conductors described that the very first conducting gesture 'has to be very precise' (C1), 'unambiguous' (C4), and 'settled' (C4). This gesture was also connected with conductor's breathing. According to the conductors' opinions, each musical composition has its' own distinctive characters. Mozart's excerpt was connected with 'vigorous' (C5) impression, whereas Dvořák's excerpt was described as '*legato* style' (C1), 'calm' (C5), 'lush' (C4), 'not too impulsive' (C4), and Bartók's excerpt was considered to have an 'impulsive, 'energetic, 'aggressive, and rowdy' (C4) character. Conductors also reported that they would use different movement to deliver such characters. For instance, they would use more smooth movement with less verticality to start Dvořák's excerpt, compared to the other two musical excerpts.

2.3.2.2 Temporal structure

One of the basic functions of conducting is to synchronise the timing of musicians' playing. The temporal structure in a music composition consists of multiple hierarchical layers including 1) the overall tempo setting of the composition; 2) the configuration at metrical level of repetitive accented downbeats and non-accented upbeats; and 3) rhythmic patterns within local groupings heard in the sounded notes (Lerdahl 1983). In interviews, conductors gave responses to these three layers of musical temporal structures including the tempo fluctuation, metrical change, and detailed rhythmic features.

Tempo fluctuation

In performance, it is often necessary for musicians to change the tempo of the music. This direction might be indicated in a score, or might be the result of a conductors' musical interpretation. It was reported that to carry out tempo changes, conductors would use distinct gestures to instruct musicians about the exact timing of beats, and these gestures may be very different from repetitive conducting patterns. Four conductors (C1, C2, C4, C5) gave comments about tempo fluctuation. They all pointed to bar 13 in Bartók as an example (Example 2.1, p. 59). Two conductors mentioned the *poco rall* instructed by Bartók and said they would 'slow down' (C2) or 'postpone' (C1) the second beat of bar 13, whereas the other two conductors highlighted the comma between the first and second beat, and stated that the music should 'pause' (C4) or 'completely stop' (C5). Despite the divergence of their musical interpretations, all these four conductors chose to subdivide the beats into two-beat conducting pattern in bar 13 to indicate the exact timing for the crotchet upbeat and the tempo change, while due to the fast tempo of composition, they intended to conduct by one-beat per bar through the rest of this excerpt. One of the conductors thought that the tempo change in this bar is 'very difficult' (C5), and two other conductors (C1, C4) supposed that to perform the tempo change satisfactorily, it might take several times to rehearse and explain verbally to musicians.

Example 2.1 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 1-18.

Metrical change

Tempo change refers to a performed tempo variation with the same time signature, whereas metrical change refers to the alteration of time signature. It is not surprising that conductors chose different beating patterns according to the metrical change, but it appeared that they tended to use different strategies to communicate metrical changes according to the musical context. Three conductors (C2, C4, C5) marked the metrical change from 4/4 to 2/4 in bar 10 in Dvořák (Example 2.2, p. 60), which is the only bar having different time signature in this except. They thought that this bar should be noted in conducting because the 2/4 metre interrupts the regular phrase structure in the music, in which a phrase usually consists of four bars. All the three conductors reported that in their conducting, they would change the basic beating pattern corresponding to the metrical change. One conductor (C2) noted the signature change from 2/4 to 3/4 in bar 132 in Bartók (Example 2.3, p. 60), and he would choose to subdivide the beat – which is a different strategy from the one he used in Dvořák – to deliver the metrical change.

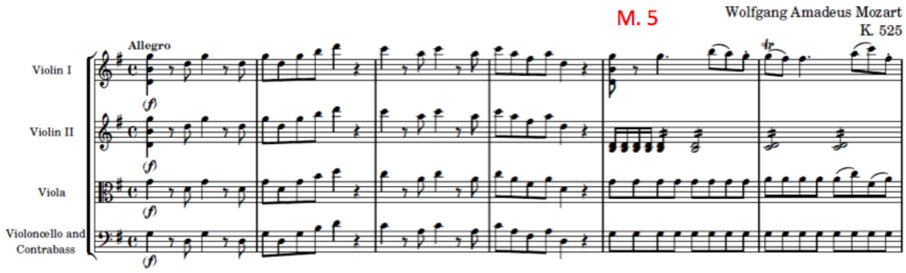
Example 2.2 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 4-10.

Example 2.3 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 129-137.

Rhythmic pattern

At the local temporal level, conductors drew attention to several rhythmic patterns. They might allocate different features to the same rhythm according to the musical context. One conductor (C2) gave two comments of the semiquaver rhythm in Mozart and Dvořák and he intended to express different characters of these semiquavers according to the musical context. He described that the second violinist with the semiquavers in bar 5 of the Mozart (Example 2.4, p. 61) 'should have a strong downbeat' and 'play with precision', while the semiquavers played by the first violin in bars 7-8 in Dvořák (Example 2.2, p. 60) should have the character of 'bounce'.

Example 2.4 Mozart, *Serenade in G major*, K.525, 1st movement, bars 1-6.



2.3.2.3 Melodic features and phrase structure

Conductors' comments in melodic aspect referred to: 1) specific types of melodic figure (e.g., *mordent* and *glissando*); 2) features of melodic contour (e.g., melodic climax), especially combined with compositional characters including dynamic change and harmonic structure; 3) the relationship between melodic lines by different instruments; 4) general conducting techniques to articulate phrase structure. Conductors were likely to emphasise melodic features in Mozart and Dvořák probably because of 'the natural musicality' (C5) of Mozart and 'the lyric style' (C5) of Dvořák as they stated. The melody was especially described as a prominent feature in Dvořák and conductors would 'focus on the energy flow rather than dividing the beats' (C3) in order to 'draw lines of the beats' (C3).

Specific type of melodic figure

Conductors would use specific movements to deliver melodic figures such as *mordent* and *glissando*. One conductor (C2) mentioned that he would instruct the mordents in bars 24-27 in Dvořák (Example 2.5, p. 62) in his conducting. He also noted the *glissando* in bar 45 and bar 61 in Bartók (Example 2.6, p. 62) and he would make clear, big gestures to distinguish the figure of *glissando* from the previous and later melody.

Example 2.5 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 23-30.

Example 2.6 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 29-48.

Melodic contour, and combined with dynamical and harmonic elements

In the comments about melodic contour, conductors mainly focused on big leaps and climaxes of the melody. One comment marked the big melodic leap by the first violin in bar 14 in Dvořák (Example 2.7, p. 63), and stated that it 'should be well crafted and controlled' (C2). Another comment from the same conductor noted the subsequent phrase in bars 16-22 in Dvořák (Example 2.7, p. 63) – where the melodic contour reaches the climax on f♯3 in bar 20 – and described the upward melodic contour combined together with the *crescendo* creating the 'higher emotional excitement' of music (C2). On the other hand, downward melody could combine with the imperfect cadence, for instance, in bar 31 in Mozart (Example 2.8, p. 64). One conductor would 'pull out a line' (C6) from the melody to create the cadence, and another conductor stated that he would 'get a slight stress on downbeat' (C5) to 'phrase the direction of music' (C5) on this occasion.

Example 2.7 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 11-22.

Example 2.8 Mozart, *Serenade in G major*, K.525, 1st movement, bars 28-34.

Relationship between different instrumental and counterpoint sections

Conductors also highlighted selected melodic lines or sought to balance melodies played by different instrumental sections. Since individual conductors' musical interpretations might be diverse, they used different conducting gestures to emphasise selected instrumental sections, either to highlight the top melody, to bring out a counter-melody, or to balance between several simultaneous melodies in order to show a counterpoint structure.

Two conductors chose to highlight top melodic lines in Mozart and Dvořák. The highlighted melodies were bar 21 in Mozart (Example 2.10, p. 65), where the melody moves upward and reaches the climax in the next bar, and bar 13 in Dvořák (Example 2.7, p.63), where the melody by the second violin joins in the music. Conductors would make efforts to show the voice-leading, and to 'give the musicians having this melody enough space to play'.

On several occasions, conductors chose to bring out counter-melodies when specific instrumental sections either 1) have prominent features; or 2) are considered as an important counter-melody. For instance, conductors highlighted the viola in bar 6 and bar 8 in Mozart (Example 2.9, p. 65), where the viola changes the bowing from repetitive short semiquavers to longer bows. Conductors also marked several important counter-melodies in bar 16 in Mozart (Example 2.10, p. 65), where the viola and cello imitate the melody and rhythm by the first and second violin in the previous bar (bar 15); in bar 31 in Mozart (Example 2.8, p. 64), where the cello's voice emerges when other instruments are having a crotchet rest at the end of this phrase; and also in bar 47 in Mozart (Example 2.11, p. 65), where the viola and cello play the counter-melody to the top two lines. Conductors expressed that they would 'help phrasing and bringing out the counter-melody' (C2) to ensure the counterpoint melody is 'well-balanced to the top part' (C2). While for some instances, conductors would not only focus on one single melody, but stressed the counterpoint structure between different instrumental sections, such as in bar 14 in Dvořák (Example 2.7, p. 63), and to 'make sure to support these melodies' (C3).

Example 2.9 Mozart, *Serenade in G major*, K.525, 1st movement, bars 1-13.

Example 2.10 Mozart, *Serenade in G major*, K.525, 1st movement, bars 14-27.

Example 2.11 Mozart, *Serenade in G major*, K.525, 1st movement, bars 42-48.

Phrasing

Conductors distinguished between 'active beat' and 'passive beat' in their conducting, and articulated this as the way in which they communicated phrases. As a conductor stated:

> *Active beat is when I intentionally communicate something with my beat. I would look at the players and make more motion, whereas passive beats can be smaller in physical size and just follow the beating pattern and tempo. (...) Through looking, facial expression and movement intensity, I give active beats. (C3)*

Conductors would conduct by active beat to mark the beginning of phrase, and keep passive beating patterns in the middle of phrase. They believed that through using these two types of beat alternatively, conductors' gesture would communicate the phrasing as well as 'the sense of direction toward the next phrase' (C3). They mentioned the phrasing in Mozart's and also in Bartók's excerpts. One conductor considered Bartók's excerpt as 'very complex in the phrasing' (C3), so it is very important for him to 'mark the phrases clearly' (C3).

In addition to cueing the beginning of a phrase, the end of a phrase is another issue to tackle for conductors. One conductor mentioned that 'breathing' is an essential concept connecting to phrasing. Using an example in bar 10 in Mozart (Example 2.9, p. 65), he stated that he would 'ensure the breath and the rest' (C1) at the end of this phrase. Another conductor mentioned the end of phrase in bar 31 in Mozart (Example 2.8, p. 64), and expressed that he would give a 'slight stress' (C5) on the downbeat and he hoped the musicians would play a diminuendo and have a lighter end of the phrase using their 'natural musicality' (C5).

2.3.2.4 Dynamic change

In music performance, dynamic marks in the score are translated into corresponding loudness articulated by instruments. Based on individual conductors' interpretations of music, there might be nuance differences in the level and also in the timing of loudness change, as well as in the way the dynamics transit from one level to another. All the six conductors provided comments on music dynamic change in interviews. They mainly focused on two types of dynamic change: 1) a sudden dynamic change of prominent accent (e.g., *sforzando* and *subito forte*); and 2) a longer process of presenting dynamic contrast (e.g., *crescendo* and *diminuendo*).

***Subito forte*, *sforzando*, and *marcato* accent**

One conductor described the difference between a *subito forte* and a *crescendo*, using examples of the *sforzando* in bars 18-19, and the following *crescendo* starting from bar 20 in Mozart (Example 2.10, p. 65). It appeared that the major differences were how fast the volume reaches the maximal loudness and whether the loudness returns to the original lower level afterward. The conductor (C1) reported: 'the accent of the *subito forte* should be shown in the previous beat [in the gesture], and returns to piano in a quite rigorous way', whereas a *forte* would 'come out quite naturally' and the conductor should 'notice the degree of the forte and hold the attack' in a *crescendo*.

Four other conductors (C2, C3, C4, C6) also gave comments on the *sforzando* in bar 18 in Mozart (Example 2.10, p. 65), with three of their comments in line with the aforementioned conductor's opinion. They described that the *sforzando* should 'back off very quickly' (C2) and the conductor should 'clean the energy' (C6) immediately after the *sforzando*, whereas only one conductor provided a different interpretation for bar 18 — even though he described the features of *sforzando* in similar ways to the other four conductors. He reported: '*sforzando* often just means the attack of the accent, so you would expect it coming back to piano on the next note' (C3). But in this particular musical occasion, he noted the *piano* mark on the third beat, and stated that 'I would do the *piano* later on the third beat rather than jump back straight away if I'm true to the text' (C3). Besides, the description of the *marcato* accent on the second violin in bar 37 in Bartók (Example 2.6, p. 62) revealed different character of *marcato* accent, which was described as being able to 'offer bounce' (C6) and 'it's heavy but still with the lift that keeps going forward' (C6).

***Diminuendo*, *crescendo*, and Romantic music build up**

Three conductors (C1, C5, C6) highlighted the dynamic aspect in Dvořák between bars 14-20 and referred to a long process of loudness change (Example 2.7, p. 63). One conductor felt that the *crescendo* and *diminuendo* in bar 14 should be framed carefully in conducting, since it starts from 'super light and super quiet' (C4) *pianissimo*. Another two conductors paid more attention to the prolonging crescendo coming later in bar 16 to bar 20 and expected the orchestra to have 'intensified and expansive sound' (C5). This expanding *crescendo* is also connected with the 'gluey' (C6) feature and the 'Romantic build up' (C6) of musical tension.

2.3.2.5 Instrumental configuration

Instrumental sections, textural change, and playing technique

Six comments from conductors concerned the instrumental configuration, including different ways to structure instrumental sections, and different techniques involved in sound production. Three conductors mentioned the contrast between *solo* and *tutti* in Bartók. They reported that they would give different types of gesture to the solo players and full orchestra respectively to mark the beginning of *solo* or *tutti* sections. One conductor specified the difference between *solo* and *tutti* sections and illustrated that he would expect 'the *forte* played by solo players is different from the *forte* played by the full orchestra'.

Conductors paid attention to sudden changes of compositional texture and different playing techniques. Two conductors marked textural changes in music. One comment (C1) described the musical textural reduction in bars 29-30 in Dvořák (Example 2.5, p. 62), where the single melody played by violas is left when the chord played by the other instruments ends. Another comment (C6) was marked in bar 82 in Bartók (Example 2.12, p. 68), where individual melodic lines by different instruments turn into union tutti together. Regarding techniques for sound production, one conductor (C5) stressed the *pizzicato* on double bass in bar 5 in Dvořák (Example 2.2, p. 60) to make musicians 'breath together and play with more precision and clarity'.

Example 2.12 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 69-94.

2.3.3 Conducting movements in relation to performance sound

2.3.3.1 Basic functions: Beating pattern and cuing gesture

Basic beating patterns and phrasing

As expected, all conductors reported that they would change their basic beating pattern according to time signature changes in Dvořák and Bartók. But they reported ways in which they understood basic beating pattern to do more than to indicate the time signature per musical bar. Conductors reported that they would switch between two-beat, three-beat and four-beat patterns in order to deliver higher level temporal structure such as phrase, particularly in Bartók. The tempo in Bartók is very fast that conductors tended to conduct in one-beat per bar, yet conductors stated that they would combine per two, three or four bars, depending on the musical context, as integrated units of beating pattern to communicate 'bigger phrases' (C2).

Cuing gesture

Conductors use their movement to highlight the expression of the top main melody, for instance, in bar 13 and bar 29 in Dvořák. In bar 13 (Example 2.7, p. 63), the conductor's left hand would 'really stay with them [the second violin]' to show 'the leading of the voices' (C3). In bar 29 (Example 2.5, p. 62), only the viola plays, so the conductor would encourage the viola by hand gesture and eye-contact. Conductors generally expected that with their cuing gesture, the instrumental sections could play with 'precision' (C1), and also 'confidence' (C3), thereby 'maintaining momentum' (C1); and the rest of the orchestra should 'realise the importance of this instrument group' and 'give space for them [this instrument group] to play' (C3).

In other occasions, conductors use their movement to bring out counter-melodies, for instance, in bar 6, bar 8 (Example 2.9, p. 65), bar 16 (Example 2.10, p. 65), bar 31 (Example 2.8, p. 64), and bar 47 (Example 2.11, p. 65) in Mozart. The cuing gesture for counter-melodies was described as an 'encouraging', 'palm-up' gesture (C1), and sometimes accompanied with extra attention from the conductor by eye-contact.

2.3.3.2 Kinematic features: Hand position and travel distance

It was found that conductors would use different hand positions, and the distance over which their gestures travel – sometimes being described as ‘movement amplitude’ by conductors – to deliver musical features including dynamic change, instrumental configuration, phrasing, melodic contour, and rhythmic features.

The contrast between dynamic levels and different instrumental configurations

According to conductors’ comments, hand positions, travel distance, and also the distance between different body parts could all be used to indicate dynamic changes in music, including sudden dynamic change of *sforzando* and gradual dynamic transitions such as *crescendo* and *diminuendo*. Three conductors described their gestures for the *sforzando* in bars 18-19 in Mozart (Example 2.10, p. 65). They would give a ‘big’ (C2), ‘strong’ (C2), ‘heavy’ (C6), ‘intense’ (C3) gesture, or a gesture ‘with big weight’ (C2) on the downbeat to indicate the *sforzando*. It is worth noting that except the word ‘big’, conductors used exactly the same adjectives – ‘strong’, ‘heavy’, ‘intense’, ‘with big weight’—to describe the sound they expected from the orchestra in this instance (C2, C3, C6). One conductor (C3) expressed that the *sforzando* gesture should have a ‘bounce’ and that it should ‘create the dynamics between the forte and piano’. The expanding travel distance of gesture also accompanies with outward moving directions, thus cause increasing distance between their hands and body. One conductor (C2) reported that he would use eye-contact to facilitate the *sforzando*. After the *sforzando*, the gesture should be ‘back off very quickly’, and the hands would return to the original lower position close to body till the next *sforzando*.

Similarly, gradual dynamic transition of *crescendo* was also associated with higher vertical position of hands, broader travel distance of gesture, and further distance between the two hands and the body. Three conductors used the *crescendo* in bars 13-20 in Dvořák (Example 2.7, p. 63) to illustrate their *crescendo* gesture as a ‘palm upward’ (C2), ‘intensifying’ gesture (C5). They noted the usage of different body parts when differentiating *sforzando* from *crescendo*. They would move their upper arms more ‘to create the sense of space’ (C2) when building a bigger *crescendo*, whereas they tended to use hands and forearms more when creating a *sforzando*. Conversely, they would have the opposite gesture for *diminuendo* and turn their palms downward to dictate the following *diminuendo* in bar 21 (Example 2.7, p. 63) in Dvořák. Two conductors (C2, C4) reported that they would use ‘small’ and ‘light’ gestures corresponding to the *pianissimo* in bar 1 and bar 13 in Dvořák (Example 2.7, p. 63) and their hands would ‘stay low’ and ‘very close to the chest’ in these two occasions, which are contrary features compared to the *crescendo* gesture.

Conductors would also vary their movement size to instruct different instrumental configurations, particularly the contrast between *tutti* and *solo* in Bartók. Three conductors (C1, C3, C5) associated the full ensemble *tutti* with 'bigger movement', movement with 'more weight' and 'more intensity', and they would 'open up [their] body and up [their] face', whereas instruments' *solo* was tended to be connected with 'enclosed', 'compact' movement. One conductor mentioned that he would use eye-contact to 'draw everyone's attention' and 'give them confidence to play' when the music switches from *solo* to *tutti*.

Phrase structure and rhythmic pattern

Conductors also use different travel distance of movement to deliver phrase structure. Two conductors mentioned that they would use 'bigger' and 'more active' movement to mark the beginning of a new phrase, while one conductor noted that he would 'give stronger downbeat' at the beginning of a phrase but it might 'not be physically so big' (C3).

Three comments were about communicating fast, short semiquaver rhythm using resembling features of 'small', 'short' and 'light' gestures. Two conductors (C1, C4) stated that the gesture in bar 5 in Mozart (Example 2.9, p. 65) should have 'light' and 'fluid' characters to help musicians play the semiquaver precisely, whereas in bars 7-8 in Dvořák (Example 2.2, p. 60), the conductor should give 'smaller and shorter gesture' corresponding to the 'shorter bowing' and 'help the bounce' of music (C2).

2.3.3.3 Kinematic features: Movement smoothness and trajectory shape

Smooth movement with less verticality

Four conductors talked about the smoothness of their conducting movement and that this feature directly corresponds with the character of performance sound, particularly in Dvořák. In Dvořák, smooth gesture was connected with moving directions and shapes, such as movement with less verticality. Conductors explained: 'the gesture with less verticality is more fluid, because the verticality on the beat stops the flow' (C4). It was described that their gestures would be very 'smooth', 'legato', 'fluid', 'lyrical', and 'lush' when they conduct Dvořák, and they also used very similar vocabulary to describe the sound character they expected from the orchestra (C1, C4). Conductors would pay more attention to the 'line growing' and 'harmony prominent' and 'focus more on the energy flow rather than dividing space into four beats' (C3). One conductor specifically mentioned the opening of this excerpt and described the beginning upbeat gesture as a 'slight, smooth, and open-palm gesture', which would make the performance sound have 'singing quality' (C1).

Smooth movements were also used to indicate *legato*. It was reported that a smooth gesture would be used to dictate the cello's melody with *legato* in bar 31 in Mozart (Example 2.8, p. 64) and thus to make the contrast to the *staccato* in the previous few bars.

The shape of movement trajectory

Conductors might change the shape of movement trajectory to indicate 1) performance sound features such as bounce; 2) instrumental configuration such as union *tutti*, and also 3) specific playing techniques including *glissando* and *pizzicato*. Based on conductors' opinions, the movement shape of a large circle was sometime associated with 'bounce' (C2, C6) of performance sound, especially on the *marcato* accent in bar 37 in Bartók (Example 2.6, p. 62). It is reported that conductors would give a 'large circle' 'like a yo-yo gesture' to offer the bounce of the sound (C6). Large, round shape of movement was also associated with instrumental configuration such as loud union *tutti*. One conductor (C6) would 'make a better circle' by his movement in bars 82-92 in Bartók (Example 2.12, p. 68). His movement would 'change from vertical to more horizontal' and make a 'more rounded gesture,' because he thought that this gesture may offer the 'bounce' of performance sound.

A large circle gesture was also used to instruct specific playing techniques such as *glissando*, for instance, in bar 45 and bar 63 in Bartók (Example 2.6, p. 62). Conductors reported that they would use 'large circle gesture' 'with rebound' to dictate the single bowing for playing glissando, and the performance sound should have 'bounce' (C2). Yet one conductor (C2) noted that his movement would have a slightly different shape in bar 45 compared to bar 63, since he would conduct the four bars proceeding to bar 45 as four-beat beating pattern, whereas the six bars before bar 63 would be conducted as six-beat beating pattern. According to different beating patterns leading to the *glissando*, his movement would have 'sharper shape' 'like a big letter J' in bar 63, when his movement would be more round in bar 45.

In addition to *glissando*, the conducting movement shape might also change to indicate *pizzicato*. One conductor (C5) drew attention to bar 5 in Dvořák (Example 2.2, p. 60), when the double bass joins in by *pizzicato*. He reported that he would give a 'more pointed upbeat' to double bass at this moment, so that they can 'breathe together' and play the *pizzicato* with 'more precision and clarity'.

2.3.3.4 Other factors related to conducting movement

The connection between movement features and the performed sound

It was found that conductors tended to expect that the sound performed by the orchestra imitates the features of their conducting movement, they stated: ‘there is a mirroring between my body gesture and what the orchestra does’ (C1), and ‘the ensemble should attach to my physicality and have the same kind of gestures in the playing as well as what I’m doing in my hand motions’ (C2). Their movement therefore would have different features according to the character of each musical excerpt. In Mozart, forte corresponded to the ‘weight of beating’ movement, and ‘detached’, ‘quick’ gesture was preferable to deliver ‘detached’, ‘short’ notes (C1). In Dvořák, ‘gluey’ movement was related to the ‘emotional’ ‘romantic build up’ (C6), whereas in Bartók, ‘sharp and aggressive’ gesture ‘with energy’ was connected with ‘vigorous’, ‘impulsive and energetic’ performance sound (C4).

Palm gesture

It appeared that combined with their conducting movement, conductors use different palm gestures to communicate their interpretational intentions to musicians. Upward and opened palm gestures usually connect with volume increasing and ‘inviting’, ‘encouraging’ musicians, whereas downward palms indicate volume decreasing and ‘holding’, ‘slowing’ (C2).

Breathing, facial expression and eye-contact

According to conductors’ opinions, breathing serves as a very important cue at several points: at the beginning of a performance; when a specific instrumental section enters; when the tempo changes; and at the moments after a phrase ends. On occasions when a performance begins, or a new voice enters, conductors may use breathing together with eye-contact, and they expect musicians to breathe together before they start playing. When the tempo fluctuates, for instance, with the *ritardando* in bar 13 in Bartók (Example 2.1, p. 59), conductors would subdivide the beat and also breathe in such a way as to ‘give enough space between beats’ (C4). At the moment after a phrase ends, particularly with an upward melodic contour in bar 10 in Mozart (Example 2.9, p. 65), conductors mentioned not only purely breathing, but also the ‘breathing gesture’. They described that they would ‘have a breathing gesture with whole body’ and have ‘relaxed beating in right hand’, and also use facial expression to draw the attention of the musicians (C1). They hoped that the breathing gesture could ‘give the music some space, but not only a pause of music’ (C4).

Performance context

Conductors mentioned that they would use different conducting strategies according to different performance contexts, such as in a rehearsal or in a concert, as well as different types of orchestra which they work with, such a professional or an amateur orchestra. They would use 'strict or more gestures' in a rehearsal, whereas in a concert, they tended to be more flexible in their movement. Regarding the orchestra which they are working with, they stated that 'conductors need to be aware of what the orchestra needs', 'react to what they need', and 'give them proper support'. When conductors work with an amateur orchestra, they tended to spend more time on 'generating sound' and 'working on the balance, the articulation, the structure and get through all of those', whereas when they conduct a professional orchestra, the orchestra would have more freedom to play and the conductor would just 'look for something to create the interest' of music (C4).

2.4. Summary and discussion of findings

The main findings from the conductors' interviews are summarised based on three topics: 1) conductors' general thoughts of conducting; 2) conductors' interpretations on musical compositions; and 3) conducting movement they intended to use to communicate such compositional structures.

2.4.1 Conductors' general ideas of orchestral conducting

Regarding research question 2.1, it was found that conductors think that as a conductor, they should play several main roles in the orchestra: 1) to reveal musical compositional structures, and 2) to provide their insight and interpretations on compositional structures. To achieve these two tasks, conductors should 3) have good connection and communication with musicians. Regarding the music compositional structure, conductors should have insight into the deeper structure of the composition. Instead of considering the composition as an isolated item, conductors are expected to be well-informed of historical and cultural knowledge about the composition. In addition, it was stated that conductors should add their own interpretations to the composition, and keep the balance between structural and expressive aspects of the composition. In terms of conductor's interpersonal relationship with musicians, the conductor should act as a director, a co-operator, and also a supporter/ facilitator in an orchestra.

As for the criteria by which to judge the quality of conducting and to achieve a good conducting, the knowledge of music, clarity of conducting movement, and good communication with musicians are considered to be essential. These criteria echo the roles a conductor should play in the orchestra. Conductors generally think that they possess strengths in several of these aspects and these strengths construct their own distinctive conducting qualities. In order to examine and improve the quality of their conducting, conductors tend to review their own conducting using video/audio recording, feedback from musicians/ the audience/ peers/ experienced conductors, and their own self-review and analysis.

2.4.2 Conductors' interpretational intentions

Regarding research question 2.2, it was found that conductors intend to communicate their understandings and interpretations of musical compositions in aspects of temporal, melodic, phrasing, dynamic, and instrumental features. The preparation for the first beat of a music performance is considered to be fundamental to set up the overall character of performance, including the tempo and the dynamic level. In the aspect of temporal structure, conductors choose different strategies to communicate tempo fluctuation, metrical change and local rhythmic pattern according to different musical context. In melodic aspect, conductors highlight melodic features more in Mozart's and Dvořák's compositions compared to Bartók's. Prominent melodic features including *mordent* and *glissando* would be instructed in conducting. The melodic contour is usually considered together with other musical aspects, including dynamic change and harmonic structures (e.g., cadence), as well as the relationship between counterpoint melodic lines by different instrumental sections. Elaborating phrase structure is considered to be an important task in conducting. Conductors use the configuration of active/ passive beating or different beating patterns to communicate phrase structure, and the end of a phrase is associated with breathing. In terms of dynamic aspects, conductors emphasise sudden dynamic change (e.g., *sforzando*) or gradual dynamic change (e.g., *crescendo* and *diminuendo*) in their conducting. In instrumental aspect, conductors deal with the interchange between *tutti* and *solo*, musical textual change (e.g., textual reduction), and also different techniques for playing instruments (e.g., *arco*/ *pizzicato*).

2.4.3 Conducting movement and performance sound

Regarding research question 2.3, it was found that in conducting, conductors intended to use cuing movements and kinematics of movement to communicate their musical interpretations. The cuing movement is a basic conducting technique to stress emphasis. Conductors generally cue a particular instrumental section when it enters, has main melody with intensified expressiveness (e.g., *crescendo*), or has a counter-melody with prominent features. The cuing gesture was described as a palm-up, encouraging gesture with eye-contact.

In addition, conducting kinematics— including hand position, movement size, speed, smoothness, and trajectory— are considered to communicate subtle nuance of musical variations and interpretations. It appears that a higher vertical position of the conductor's hand, a further distance between two hands, a bigger size and a faster speed of movement often, but not always, correspond to louder dynamic levels, *tutti* (in contrast to *solo*), or the beginning of a phrase. Conductors may also use different body parts to express different dynamic configuration. For instance, they use hands and forearms to indicate sudden dynamic change of *sforzando*, whilst they use upper arms to instruct prolonging *crescendo*. On the contrary, a lower vertical position of conductor's hand, a narrower distance between two hands, a smaller size and slower speed of movement often, but not always, correspond to quieter dynamic levels or *solo* (in contrast to *tutti*). Smaller size of movement is sometimes used to mimic and instruct short rhythm such as fast semiquavers. The smoothness of movement also communicates important information in conducting. Smooth movement with less verticality and round trajectory shape are used to communicate musical character of *legato*. Movement trajectory of large round circles may associate with *glissando*, loud union *tutti*, or the bounce character of performance sound. On the other hand, sharp movement trajectory may associate with specific techniques for playing instruments such as *pizzicato*.

Conductors use their movements to dictate the performance sound they expect, and they suppose that the sound produced by the orchestra should thus have similar qualities as their conducting movement if their interpretational intentions are successfully communicated. In conducting, body movement works together with different palm gestures, breathing, facial expression, and eye-contact to instruct musicians and to communicate musical interpretations. Conductors would also change their conducting strategies when they work with different orchestras (e.g., professional orchestras or amateur orchestras).

2.4.4 Discussion of findings

Several tendencies emerging from conductors' opinions about conducting can be observed:

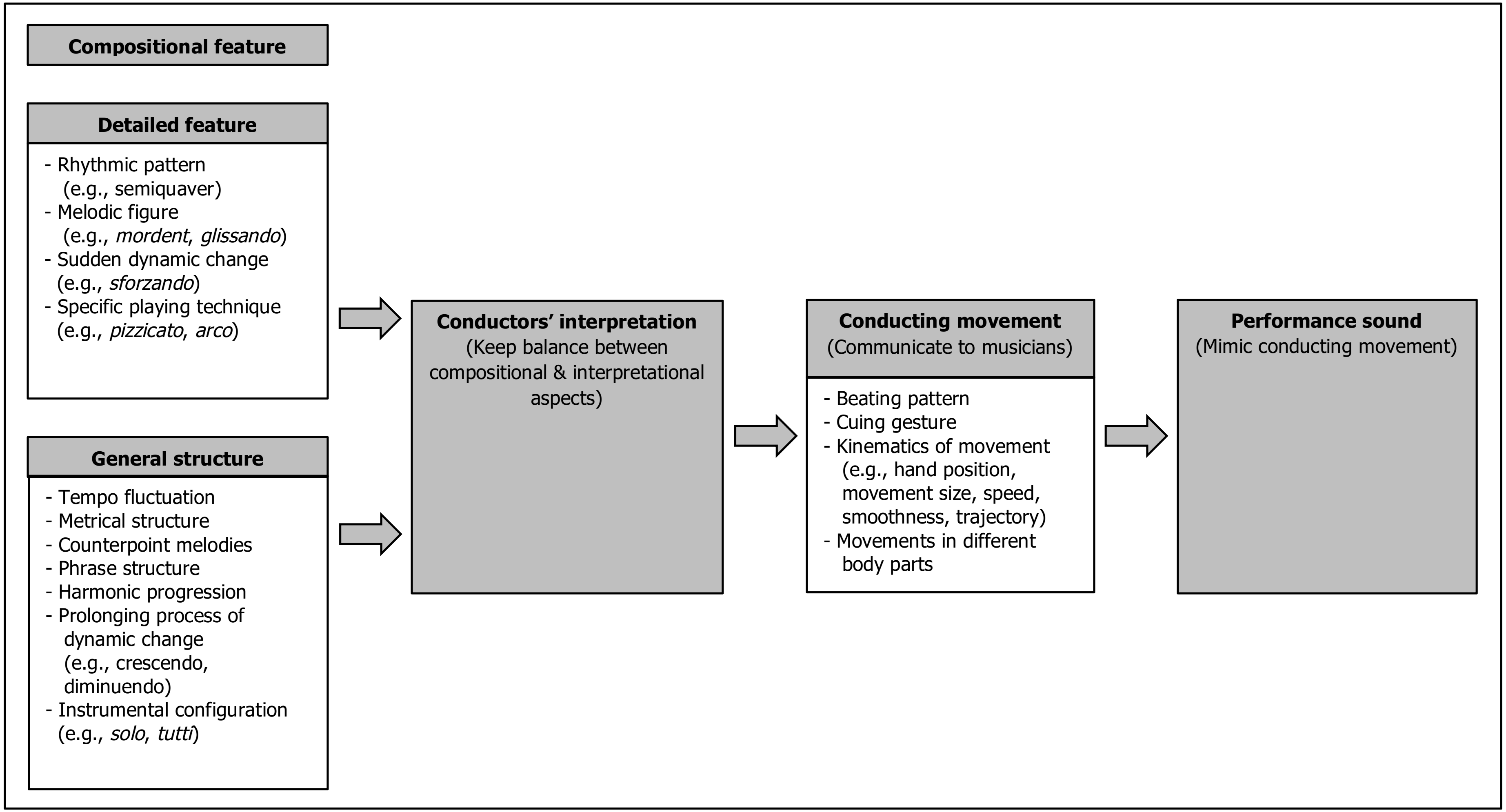
Diverse opinions on the relationship between the compositional structure and the conductor's interpretation

Conductors held different opinions on whether a conductor should focus on conveying compositional structures dictated by the score, or on providing their interpretations on the composition. Some conductors took a very strong position, stating that a conductor should be true to the indications in music score, whereas others were keener to communicate their personal musical interpretations. Conductors may favour either side, yet all of them agreed that conducting is about the balance between the two sides. The dictated notes in the score, the highlighted structures emphasised by conductors, and the balancing relationship between these two aspects accomplish the overall musical expressiveness in conducting.

Detailed features and general characters in composition together affect conductors' interpretation

Conductors may choose to emphasise detailed compositional features or general characters of music, yet in conductors' comments, obvious connections between these two aspects were found. Detailed compositional features included local rhythmic patterns (e.g., semiquaver), melodic figures (e.g., *mordent*, *glissando*), sudden dynamic changes (e.g., *sforzando*), and specific playing techniques (e.g., *pizzicato*, *arco*). These detailed features integrate together and construct general structural characters of the composition such as metrical structure, counterpoint melodies, phrase structure, harmonic progression, prolonging process of dynamic level change (e.g., *crescendo*, *diminuendo*), and instrumental configuration (e.g., *solo*, *tutti*). The interaction between the two aspects affects the allocation of conductors' attention. Conductors' selective attention reveals their musical interpretation. Such interpretation is communicated to musicians via conducting movement and thus affects the performed sound of music (Figure 2.1).

Figure 2.1 Compositional and interpretational factors in conducting



Direct connection between conducting movement and compositional features

Specific kinematic features of conducting movement (e.g., hand position, speed, smoothness, trajectory) directly correspond to particular compositional features selected by conductors in temporal, melodic, dynamic, and instrumental aspects. Conductors may also use different body parts to communicate subtle musical variations. For instance, conductors tend to use body parts closer to their torso, such as their upper arms, to communicate more general compositional structure (e.g., prolonging *crescendo* and *diminuendo*, instrumental configuration of *solo* and *tutti*), whereas peripheral movements in hands and forearms mostly relate to detailed compositional features (e.g., *sforzando*, semiquavers).

Correspondence between conducting movement and performance sound

According to the conductors' opinions, they expect musicians in the orchestra to resemble the conducting movement when playing instruments, and thus produce sound mimicking the qualities of such movement. The connection between conducting movement and performance sound reflects on both detailed compositional features (e.g., *sforzando* and the 'weight of beating'; short semiquavers and quick, small movement) and the general character of the composition (e.g., 'lush' character in Dvořák and 'gluey' movement; 'vigorous' character in Bartók and 'sharp and energetic' movement).

Overall, according to the conductors' opinions collected in this chapter, it is found that conductors intentionally use specific features of their conducting movement to communicate compositional elements they choose to highlight and their musical interpretations. Basic beating patterns, cuing gestures, and kinematic features of conducting movement all work together to communicate detailed compositional configurations, overall compositional structures, as well as the conductor's musical interpretational decisions. Conductors are also expected to keep the balance between compositional and interpretational aspects in their conducting. These findings confirmed that conductors purposely use movement variations in conducting to communicate important information regarding compositional and interpretational aspects of the musical work. In other words, 'what conductors *think* they do' is in accordance with 'what they are *told* to do' by educational manuals (see Table 1.1 in Chapter 1). Still, it is not clear whether this correspondence between conducting movement, compositional and interpretational elements can truly be observed in actual conducting performances. The following chapters (Chapter 3 and Chapter 4) will focus on the examination of kinematic features of performed conducting movement. Quantitative evidence collected by motion capture system will be compared with conductors' qualitative descriptions of conducting movement summarised in this chapter. Detailed connection between specific conducting kinematic features, compositional elements, and conductors' interpretational comments in actual conducting performance will be further explored.

Chapter 3: Conducting movement kinematics

3.1. Introduction

According to previous literature discussed in Chapter 1, kinematic features of extremities (hands or the baton tip) in conducting movement can affect respondents' movement synchronisation (e.g., Luck and Net 2008; Luck and Sloboda 2008; Luck and Toiviainen 2006) and perceived musical expressiveness (e.g., Luck, Toiviainen and Thompson 2010; Thompson 2012). Findings from these studies suggest that the conductor's baton tip movement kinematics are key elements to communicate important information to orchestral musicians. In Chapter 2, conductors' opinions in interviews indicated that they planned to use kinematic features in their conducting movement to communicate compositional elements they wanted to highlight in the music work. Yet it is still unknown how these planned movement kinematic variations reflect musical features in each composition in actual conducting performance.

The purpose of this chapter is to examine whether distinct kinematic features of baton tip movement can be found when conductors conduct each composition. Considering the exploratory nature of the current study, this chapter specifically focuses on basic linear kinematic variables of the baton tip movement. The emphasis on baton tip movement leads to a thorough investigation of how movement features of this single point communicate detailed compositional elements and conductors' specific interpretational locations in the composition. The present study examines two issues: 1) baton tip kinematic features attached to each compositional work, 2) the consistency of baton tip time-series kinematic patterns between repeated performance conducting the same composition. Specific research questions addressed in this current chapter are therefore:

3.1 Do conductors' baton tip movements have particular linear kinematic features corresponding to each musical composition?

3.2 Are the linear kinematic time-series patterns of conductors' baton tip movement similar across performances when they conduct the same musical composition?

3.3 Comparing three musical compositions, is the extent of similarity in the linear kinematic time-series patterns of conductors' baton tip movement across performances significantly different?

3.4 When conducting the same musical composition, are the linear kinematic time-series patterns of conductors' baton tip movement more consistent to performances conducted by themselves, than performances conducted by the other conductors?

To investigate these research questions, four linear kinematic variables including baton tip distance, speed, acceleration, and jerk were examined using several analysis procedures. Two-way ANOVAs (Music × Trial number) on the means of kinematic variables were employed to investigate Question 3.1. Since time-series patterns of conducting kinematics were the main focus for Question 3.2, 3.3, and 3.4, time-series analysis of cross-correlation was applied to examine the pattern similarities between each trial pair conducting the same composition (Question 3.2). Then one-way ANOVAs (Music) and t-tests (Within-conductor coefficients and Between-conductor coefficients) were conducted on cross-correlation coefficients to investigate Question 3.3 and Question 3.4 respectively. Although the aforementioned analyses only focuses on baton tip movement, movement data collected from conductors' other body segments were uploaded to DataShare open access data repository, University of Edinburgh for further analysis in future research.

3.2. Methods

3.2.1 Exploratory motion capture sessions

3.2.1.1 Participants

To test the experimental design and procedure, two conductors participated in a pilot study. They were recruited from the Reid School of Music, University of Edinburgh. Both participants were right-handed males, with conducting experience of 7 and 10 years respectively.

3.2.1.2 Material

The material selected for the pilot study was Elgar's *Pomp and Circumstance March*, Op. 39, No. 1, for the reason that the two main themes in this musical composition possess diverse musical characters, yet both have regular forms of phrase per eight musical bars. The two themes repeat several times respectively within this composition. These features make this composition particularly suitable for offering both within-theme and between-theme comparisons of conducting movement.

3.2.1.3 Design

Data were collected in a 12 m × 12 m × 5 m biomechanical laboratory in the University of Edinburgh. The captured volume was calibrated using Qualisys 300 mm wand kit with all cameras' average residuals being lower than 2 mm. A motion capture system (Qualisys, Pro-Reflex, Sweden) with nine cameras was used to record the movement at a sample frequency of 120 Hz. Three additional video cameras (Panasonic HC-V100) were set facing the conductor from front, side, and rear viewpoints respectively to record the conductors in digital video format.

3.2.1.4 Procedure

Each participant completed consent forms, having been fully informed about the nature of the study, what data would be recorded and in what format, and the intended use of these data. Each conductor participated one data collection session, and the researcher gave a short explanation of the experiment procedure to participants before data collection. Twenty-five 12mm reflective markers were then attached to conductors' upper body based on the marker set instruction of Upper Body Model in Visual 3D's documentation (see Table 3.1). Two additional markers were attached to the baton tip and baton shaft with the baton passing through the centre of the markers. The baton was counterweighted to ensure its balance point was unaffected. Calibration axes and markers captured from participants are presented in Figure 3.1.

Table 3.1 Locations of twenty-seven reflective makers in motion capture data collection

Body part	Marker	Location	Description
Head	RFHD	Right front head	Located approximately over the right temple
	LFHD	Left front head	Located approximately over the left temple
	RBHD	Right back head	Placed on the back of the head, in the horizontal plane of the front head markers
	LBHD	Left back head	Placed on the back of the head, in the horizontal plane of the front head markers
Trunk	CLAV	Jugular Notch	Placed on the point where the clavicle meets the sternum
	STRN	Xiphoid process of the Sternum	
	C7	Spinous process of the 7th cervical vertebrae	
	T10	Spinous process of the 10th thoracic vertebrae	
	RBAK	Mid scapula	Acts as an anti-symmetry maker
Pelvis	RASI	Right Anterior Superior Iliac Spine	
	LASI	Left Anterior Superior Iliac Spine	
	RPSI	Right Posterior Superior Iliac Spine	
	LPSI	Left Posterior Superior Iliac Spine	
Arm	RSHO	Right shoulder	Placed on top of the right Acromio-clavicular joint
	RUPA	Right upper arm	Between the elbow and the shoulder markers
	RELB	Right elbow	Placed on lateral epicondyle approximating the elbow joint axis
	RWRA	Right wrist thumb side	
	RWRB	Right wrist pinkie side	
	RFIN	Right finger	Placed on the dorsum of the hand just below the head of the second metacarpal of the right forefinger
	LSHO	Left shoulder	Placed on top of left Acromio-clavicular joint
	LUPA	Left upper arm	Between the elbow and the shoulder markers
	LELB	Left elbow	Placed on lateral epicondyle approximating the elbow joint axis
	LWRA	Left wrist thumb side	
	LWRB	Left wrist pinkie side	
	LFIN	Left finger	Placed on the dorsum of the hand just below the head of the second metacarpal of the left forefinger
Baton	Baton tip		
	Baton shaft		

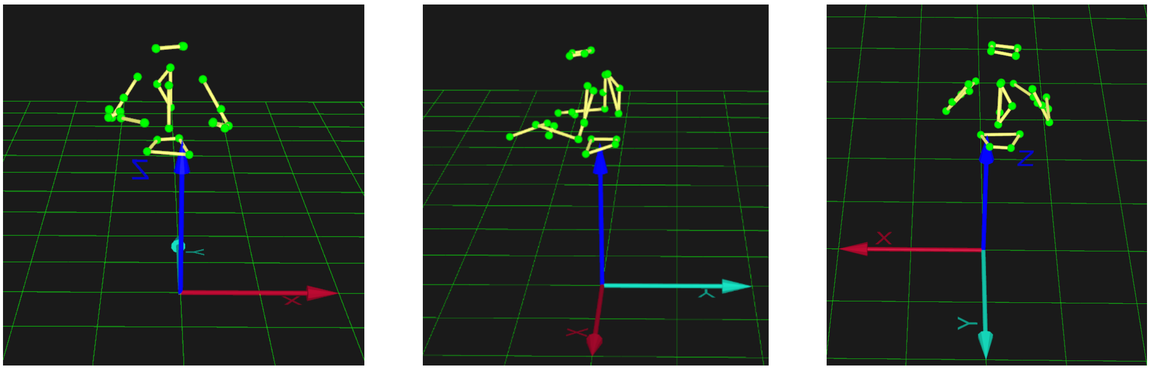


Figure 3.1 Calibration axes and twenty-seven markers captured from the participant's upper body from frontal (left figure), lateral (middle figure), and posterior (right figure) view

Conductors were instructed to perform their conducting gestures along with a recording of Elgar's *Pomp and Circumstance March*, Op.39, No.1 (London Philharmonic Orchestra and Georg Solti, Decca, 1997) played using computer laptop connected to speakers. Each participant conducted excerpts of two themes three times respectively. Data of 12 trials were collected in total (2 Conductors × 2 Themes × 3 Trials).

3.2.1.5 Preliminary data analysis

Preliminary observations were used to establish broad tendencies in the conductors' movement in this particular scenario of data collection, and to develop best methods for handling and analysing such data. Data recorded from pilot sessions were exported from Qualisys Tracker Manager (version 2.7, Pro-Reflex, Sweden), and smoothed using a fourth-order lowpass Butterworth filter with a cutoff frequency of 10 Hz using Visual 3D (standard version 4.93, C-motion, USA). Sample data of baton tip position in X (lateral axis, positive= left), Y (antero-posterior axis, positive=posterior), Z (longitudinal axis, positive=up) directions and the magnitude of position change are presented in Figure 3.2.

It appeared that the conductors tended to show different patterns of baton tip position change in the first two phrases in theme A (Example 3.1) and theme B (Example 3.2). For instance, from a preliminary observation, the displacements per beat were more even in theme A, whereas in theme B, the displacement for the first beat per bar tended to be greater than the second beat. Different movement patterns reflected musical characters in the two themes. In theme A, the music possesses rhythmic and fiery characters with the instruction of *con molto fuoco*, intensive musical accents and *staccato*, whereas theme B possesses a *legato e cantabile* character and smooth melodic contours. The displacement differentiation between the first and second beats within per musical bar may also suggest that when conducting theme B, conductors tended to focus more on higher level metrical structure, rather than emphasising each local beat. This could also be a strategy for conductors to create longer melodic phrases rather than stress short rhythmic fragments.

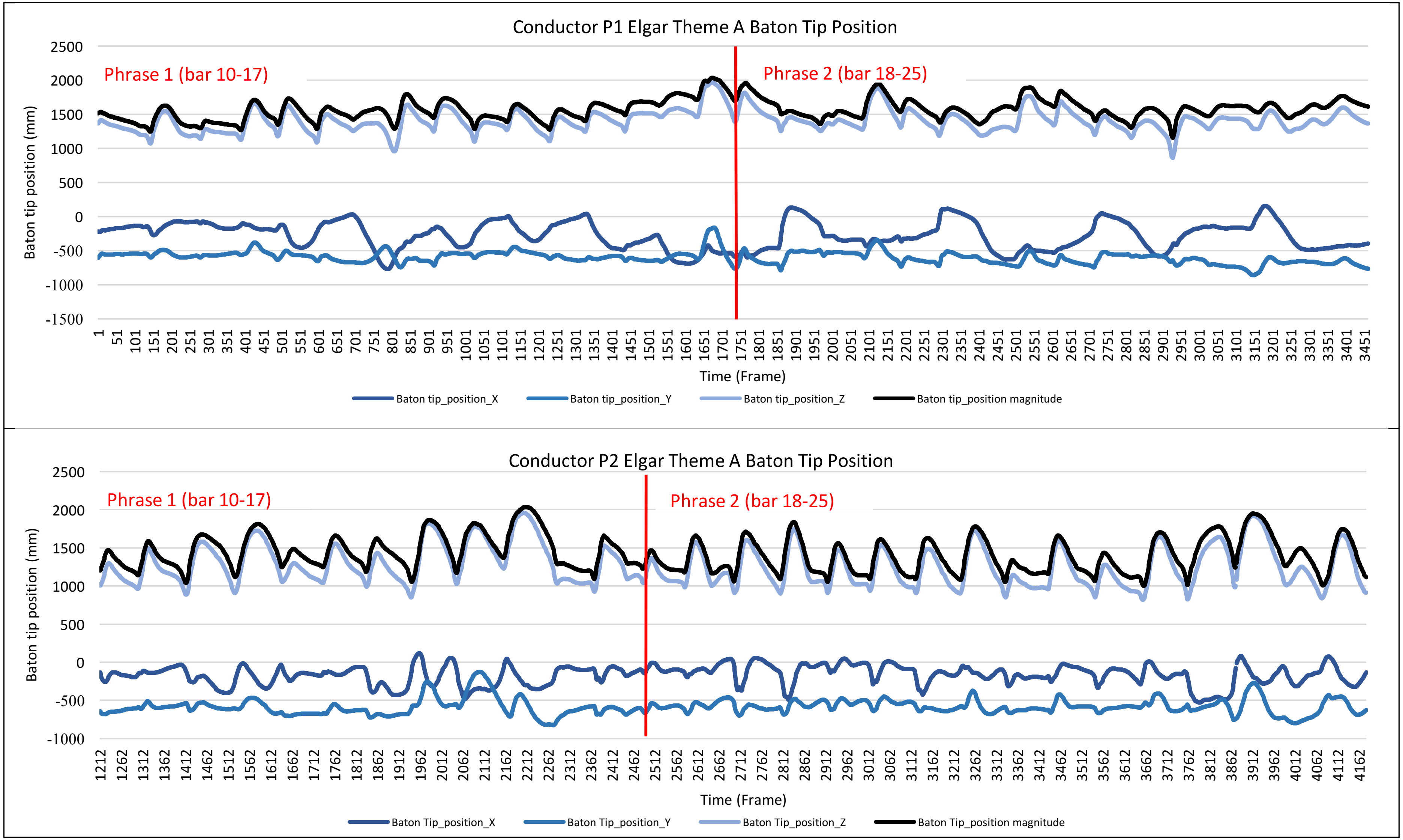


Figure 3.2 Sample data of baton tip position on *x*-, *y*-, *z*- axes and the magnitude of position change for two conductors in pilot study

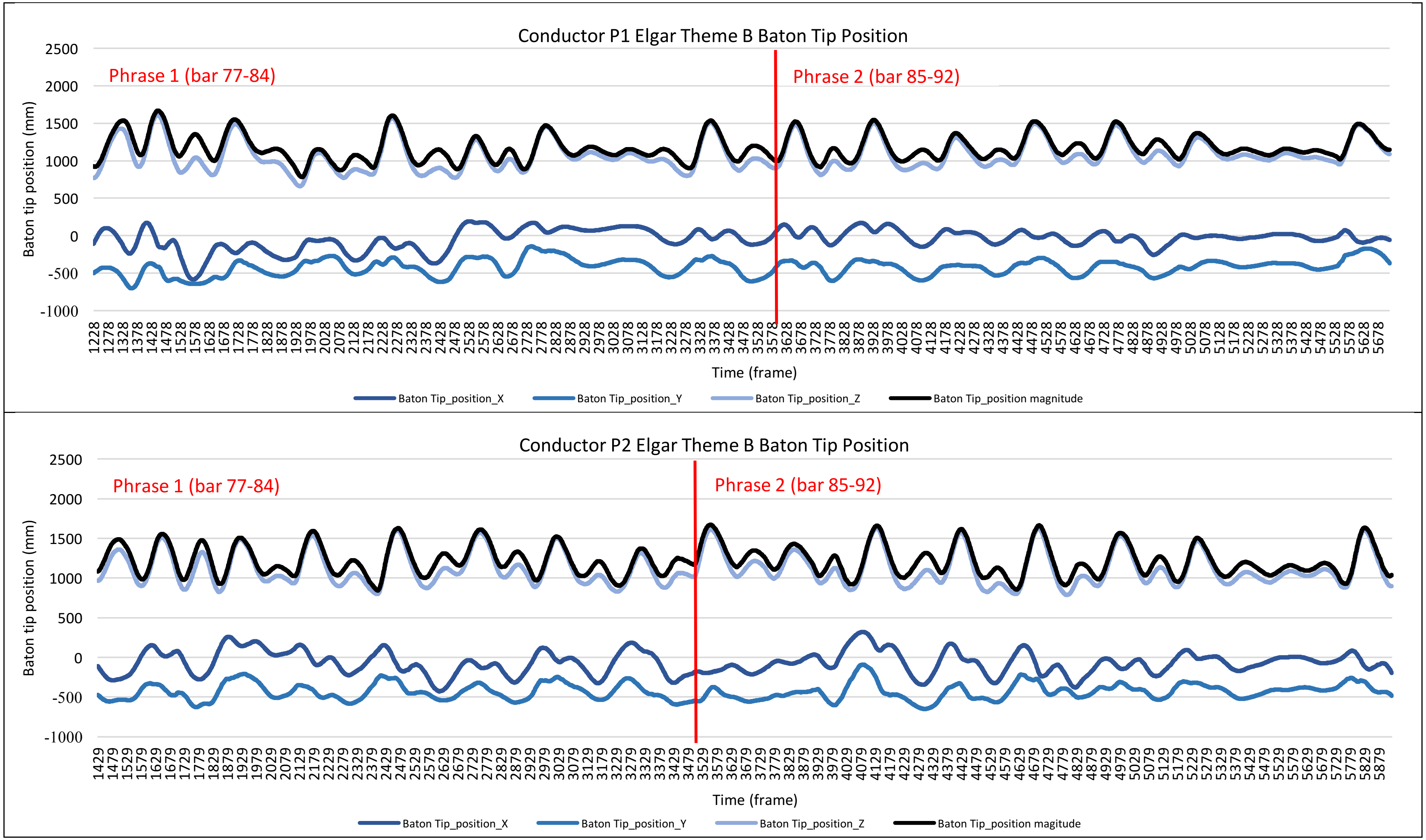
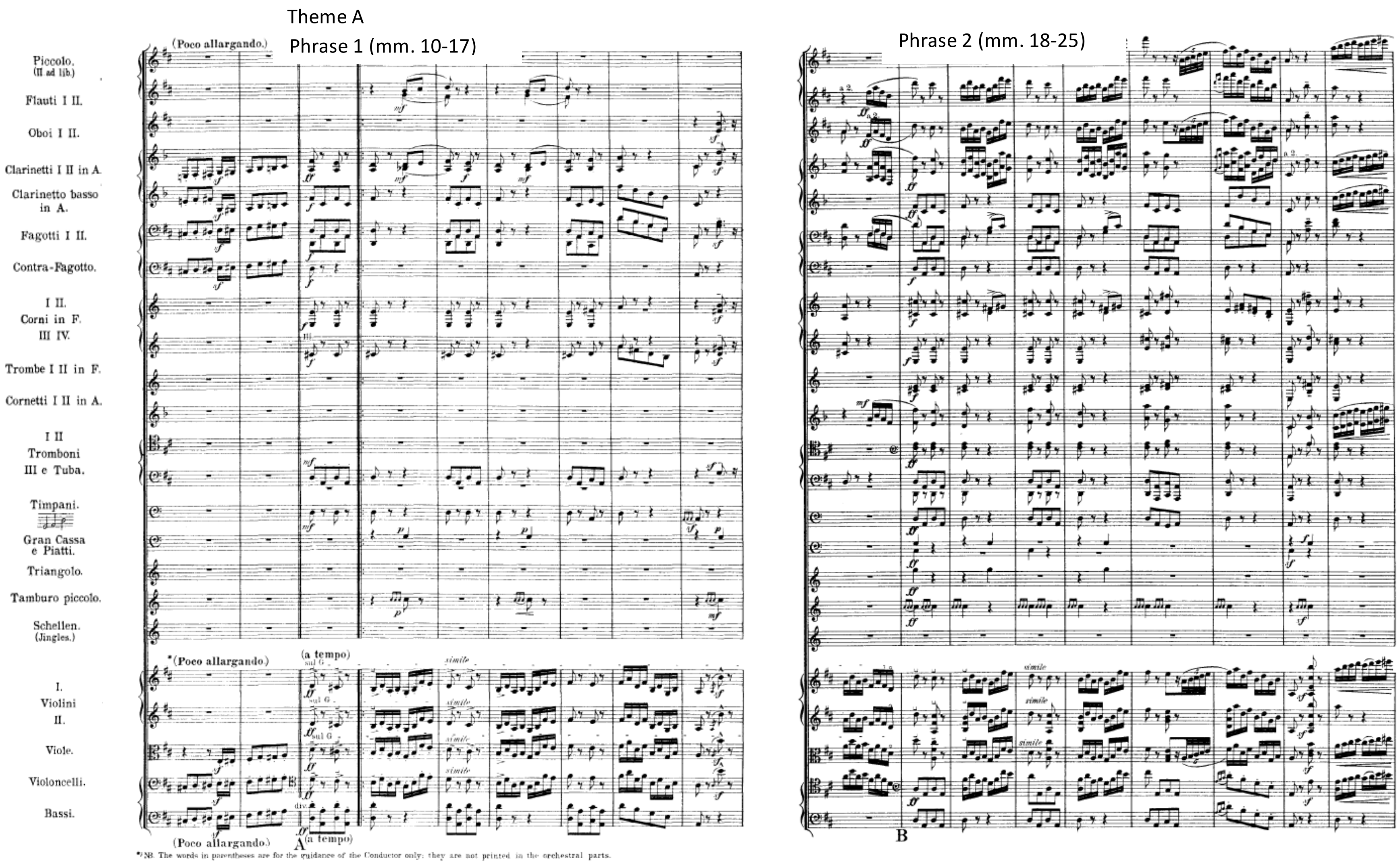


Figure 3.2-2 Sample data of baton tip position on *x*-, *y*-, *z*- axes and the magnitude of position change for two conductors in pilot study (continued)

Example 3.1 Elgar, *Pomp and Circumstance March*, Op.39, No.1, bars 8-25 (theme A).



Example 3.2 Elgar, *Pomp and Circumstance March*, Op.39, No.1, bars 77-91 (theme B).

The preliminary observations of pilot study data demonstrated the connection between conducting movement kinematics and compositional features, in such a way that the patterns of baton tip displacement reflected: 1) general characters of music themes which the composer dictated in the score (i.e. *con molto fuoco* and *legato e cantabile*); 2) compositional features in melodic, rhythmic, and articulation aspects; 3) different levels of metrical structure which the conductor intended to emphasise (i.e. at per beat level, and per bar level).

These preliminary findings thus informed the main experimental design and data analysis in the following ways:

1) Musical compositions with contrasting characteristics would be selected as experimental materials.

2) In order to examine continuous kinematic patterns of movement, which cannot be observed in discrete data analysis methods, time-series analysis methods, specifically, cross-correlation would be applied to data analysis.

3) To examine the potential connection between conducting movement and higher hierarchical musical metrical levels, in addition to analysis for time-warped data, kinematic variable means per musical bar would also be calculated for analysis.

4) To clarify how conducting movement reflects detailed compositional structures and also conductors' musical interpretational intentions, movement kinematic features would be matched with compositional structures as well as conductors' musical interpretations.

3.2.2 Experimental design

Musical excerpts from three string music compositions including Mozart's *Serenade in G major*, K.525 (first movement, bars 1-55), Dvořák's *Serenade in E Major*, Op.22 (first movement, bars 1-53), and Bartók's *Divertimento for String Orchestra*, Sz. 133 (third movement, bars 1-183) were selected as materials for the experiment. Using compositions for string ensembles had the advantage in the laboratory of mitigating potential technical problems that light reflections from brass or metal-keyed instruments may interfere with marker tracking. Each excerpt of music was approximately one-minute long, which is a duration that meets the limitation of motion capture recording equipment. As informed by the pilot study, musical excerpts with contrasting characters were known to be likely to produce clearer results. The three musical excerpts selected therefore represent diverse musical styles in different musical periods as commonly acknowledged in Western classical music history (Grout, Burkholder and Palisca 2006). Based on conductors' opinions in interviews (see Chapter 2), the three selected excerpts have distinctive characters. For instance, Mozart's excerpt was considered to be 'energetic,' whereas Dvořák was described as having 'lyrical' style. Bartók's excerpt was considered to have 'aggressive' and 'impulsive' characteristics. Yet these three musical excerpts share common basic features, such as dichotomous metrical structure, which make the conducting movements more comparable.

Data were collected in a 12 m × 12 m × 5 m biomechanical laboratory at the University of Edinburgh. The equipment and the setup are presented in Figure 3.3 and Figure 3.4. A nine-camera optical motion capture system (Qualisys, Pro-Reflex, Sweden) was used to record conductors' and musicians' movement data at a sample frequency of 120 frames per second. All cameras were adjusted to optimal positions to capture all markers by at least two cameras. A sample frequency over 100 Hz was considered to be adequate for musical movement according to previous studies (e.g., Burger et al. 2013; Desmet et al. 2012; Keller and Appel 2010; Leman and Naveda 2010). The captured volume was calibrated using the Qualisys 300 mm wand kit with all cameras' average residuals being lower than 2 mm. An audio recorder, Zoom H6 (Zoom, USA), connected to one pair of Neumann KM184 microphones (Sennheiser, Germany) was set 1 metre behind the conductor (approximately three metres away from musicians) to collect audio recordings. In order to synchronise movement and audio recordings, the audio recorder was connected to the motion capture system and recorded the synchronisation pulse generated by Qualisys system as the time code. Three additional video cameras , Panasonic HC-V100 (Panasonic, Japan), were set facing the conductor from front, side, and rear viewpoints respectively to record conductors in digital video format. Sitting and standing positions for conductors and musicians were marked on the floor to keep their positions constant across recording sessions. The conductor stood in the centre of the arc formed by the five musicians. The conductor was approximately 2 metres away from the musicians, and the musicians were approximately 1 metre away from the musician next to them.

Figure 3.3 Equipment set up for motion capture data collection

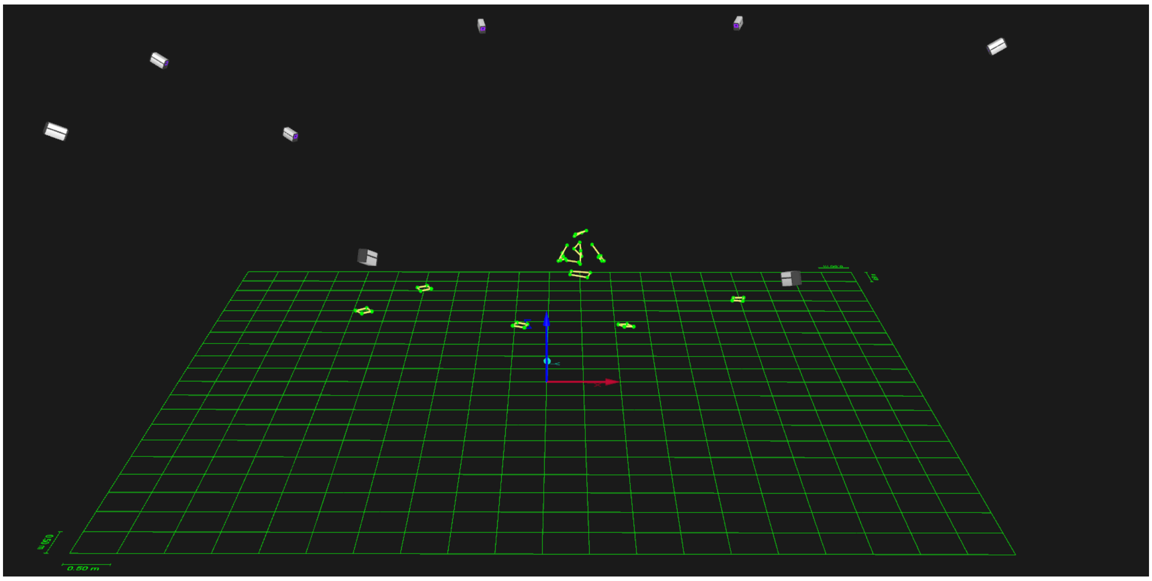


Figure 3.4 Camera set up and makers captured by cameras in motion capture data collection

3.2.3 Ethics

The same ethical clearance procedures were followed as described in section 2.2.3 in Chapter 2.

3.2.4 Recruitment

The same recruitment procedures for conductors were followed as described in section 2.2.4 in Chapter 2.

Musicians were recruited using email lists, including the weekly bulletin list comprising professional musicians, maintained by the Connect Director for the Scottish Chamber Orchestra; the Reid School of Music email list at the University of Edinburgh comprising student musicians; and also email lists for seven music societies at the University of Edinburgh comprising amateur musicians across the University including Chamber Orchestra, Composer's Orchestra, Edinburgh Contemporary Music Ensemble, Film Music Orchestra, Music Society Orchestra, Music Society Sinfonia Orchestra, and String Orchestra. The recruitment email contained basic information about this study and indicated an honorarium of £ 120 for attending all three recording sessions (9 hours in total).

3.2.5 Participants

See 2.2.5 in Chapter 2 for detailed information of the six participating conductors.

Participating musicians were selected from email respondents based on their experience as a performing musician, taking into account the extent of their experience as an orchestral player. The details of the five musicians participating in the experiment are presented in Table 3.2. Four musicians are female and one musician is male; all are right-handed. They have mean experience of playing their instrument of 15.6 years (SD=2.30), and mean experience of orchestral playing for 12.2 years (SD=3.11). Two musicians described their status as 'professional performer'; three musicians considered themselves as 'advanced student'.

Table 3.2 Participating musicians

Instrument	**Gender**	**Status**	**Experience playing this instrument (year)**	**Experience playing in orchestra (year)**
Violin 1	Female	Advanced student	17	10
Violin 2	Female	Advanced student	15	9
Viola	Female	Advanced student	12	11
Cello	Male	Professional performer	18	16
Bass	Female	Professional performer	16	15

3.2.6 Procedure

Participating conductors were provided with details of the selected musical excerpts, together with copies of specific score editions one month before motion capture sessions. All conductors wore black clothing when attending motion capture sessions as requested, in order to reduce the light reflections recorded by the motion capture system. In each session, data from two conductors were collected. Three data collection sessions took place within one month, and data from six conductors were collected in total.

Motion capture data collection was conducted in the same day after each conductor' interview. Each conductor rehearsed with musicians for 30 minutes, then undertook a recording session for approximately 1 hour. Documents including consent forms and permission for data usage forms completed during interviews were checked by the researcher and participants were given the opportunity to ask questions. Following this, a short instruction on the motion capture procedure was given to conductors. During the rehearsal and recording session, conductors could choose to use their own baton or the baton prepared in the laboratory, and could also use their own annotated versions of scores or those scores prepared in the laboratory. They could communicate verbally with musicians and could assign the time for rehearsing three musical excerpts at liberty within the rehearsal sessions within a 30-minute time limit.

After a rehearsal, twenty-five 12mm reflective markers were attached to the conductor's upper body and two markers were placed on the baton following the Upper Body Model and procedure used in the pilot study (see Table 3.1 and Figure 3.1 in Section 3.2.1.4). In addition, since musicians' head movements were considered to carry important communicative information in performance (Badino et al. 2014; Glowinski et al. 2013), four markers were put on each musicians' head using an elastic head band. The final result of participant preparation of the conductor is presented in Figure 3.5. Each conductor conducted the three musical excerpts in random order generated by the researcher and recorded each musical excerpt three times successively. Fifty-four conducting trials were recorded in total (3 Trials × 3 Musical excerpts × 6 Conductors).

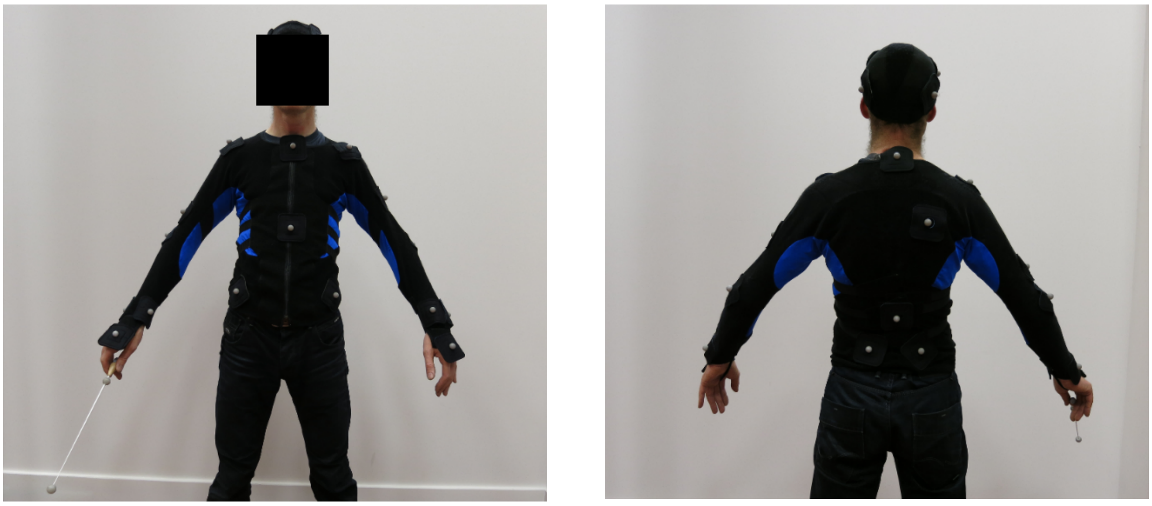


Figure 3.5 Final result of participating conductor preparation

3.2.7 Data processing

The definition of linear kinematic variables

Collected data were exported from Qualisys Track Manager (version 2.7, Pro-Reflex, Sweden) as C3D files and imported to Visual 3D (standard version 4.93, C-motion, USA). The linear kinematic variables of the baton tip were considered as variables of interest because they carry key information for musicians (Luck and Nte 2007; Wöllner et al. 2012). The following analysis would focus on the baton tip marker only, whereas data collected from all twenty-seven markers were uploaded to

DataShare open access data repository, University of Edinburgh as C3D format. The format of C3D is an accessible and reusable format commonly used for motion capture research projects (e.g., IEMP project at Durham University, UK). The shared source helps developing further analysis and research based on this data corpus.

The original signals of baton tip were smoothed using a fourth-order low-pass Butterworth filter with a cut-off frequency of 10 Hz, which was chosen by visual inspection of markers' power spectra. Scalar linear kinematic variables of conductor's baton tip including **speed** ($m.s^{-1}$), scalar **acceleration** ($m.s^{-2}$), and scalar **jerk** ($m.s^{-3}$) were computed using Visual 3D pipeline commands. Scalar variables were variables of interest because they contain values of variables without directional information. Since the high flexibility of conducting movement and also the exploratory nature of this study, it would be beneficial to only focus on kinematic scalar variables regardless of the directions of movement trajectory.

Pipeline commands for computing baton tip linear kinematic variables using Visual 3D are shown in Appendix 3. Displacements along the *x*-, *y*-, *z*- axes was calculated from the change in baton tip position on the *x*-, *y*-, *z*- axes in each two consecutive frames of data; velocity on *x*-, *y*-, *z*- axes was computed as these displacements divided by the data time interval (1/120 s); acceleration and jerk were computed as the first derivative and the second derivative of velocity respectively. Speed, scalar acceleration and scalar jerk combining values along three axes were then calculated using 'signal magnitude' function in pipeline based on Equation 3.1.

$$(x^2 + y^2 + z^2)^{\frac{1}{2}}$$

(Equation 3.1)

where x. y, z are the variable values on X, Y, Z axes respectively.

The definition of musical beat and musical bar

For comparing conducting movement across different trials, all data were time-warped based on the reference of musical beats. Time-warping is an adjustment for the temporal continuum of data to eliminate tempo differences between different performance trials, as well as to remove uneven time intervals between beats within each trial caused by performance tempo fluctuations. Since the delay between the conductor's movement and musicians' reaction is changeable and affected by various factors (Luck and Nte 2007; Luck and Toiviainen 2006), it was challenging to estimate the beat timing from audio recordings. The timing for musical beats were thus estimated using conductors' movement in this study. The beat– or tactus– timing for conducting movement was defined as the time when the lowest position of baton tip on the *z*-axis (vertical axis) occurred within a beat period identified by Visual 3D. The initiation of a musical bar was defined as the onset of the first beat in the given bar. The interval of a musical bar was defined as the time span from the onset of the first beat in the given bar until the onset of the first beat in the next bar. All movement data were then resampled by interpolation as 1000 data points per musical bar using Matlab (version 8.5). Through this procedure, the number of movement data points can be considered as the reference to match in relation to specific musical bars for further analysis.

Kinematic variables at musical bar level

The time-warped data contained local kinematic fluctuations for regular beating movement per musical beat, which restrained the broader outline of any kinematic trend. In order to gain the overview of kinematic changes in reference to compositional structures, it is beneficial to explore kinematic trends at a higher metrical level corresponding to musical bars. For this reason, in addition to time-warped data, kinematic curves based on the sum of distance per musical bar, as well as means of speed, acceleration, and jerk per musical bar were also taken for cross-correlations. The mean was selected as the index to represent kinematic features including speed, acceleration, and jerk for a musical bar instead of the maximum, considering the fact that individual conductors sometimes applied different conducting beating patterns, and also switched between different beating patterns (e.g., one beat, two beats, or four beats per bar) when conducting the same musical composition. The time spans between adjacent beats in beating movement, that is the periods to accelerate to reach kinematic maxima within per beat in movement, were thus different according to the selected beating pattern. For example, when conducting a composition of the same tempo, the time span between adjacent beat in beating movement is twice the length when conducting by the two-beat pattern, compared to conducting by the four-beat pattern. The difference in kinematic maxima thus may be the consequence of different beating patterns in conducting, rather than different features in kinematics. On the other hand, kinematic means represent averaged features within per musical beat, which are less affected by different beating patterns in conducting. The sum of distance was selected as the index instead of the mean of distance within per musical bar, considering the fact that the mean of instant movement distance showed identical patterns as the mean of speed –which was calculated as the distance divided by the fixed time interval (1/120 s). The analysis of mean distance thus did not supplement any further information than mean speed. On the other hand, the distance sum within a musical bar was based on non-time-warped data, and thus offered knowledge related to the movement size within a musical bar, and presented different patterns than speed mean data owing to different time spans across musical bars.

In addition, in time-warped data analysis, distance data were omitted because they showed identical patterns as speed data (for the same reason stated above). The term **distance** is used to refer to the distance sum within per musical bar henceforth in this thesis. Therefore, the kinematic variables at two metrical levels analysed and discussed in this thesis are defined and summarised in Table 3.3:

Table 3.3 Definition of kinematic variables

Variable	**Definition**
1. Time-warped data	Data resampled by interpolation as 1000 data points per musical bar
1.1 **Speed**	The scalar value of the first derivative of baton tip position, divided by 1/ sample frequency (120 Hz)
1.2 **Acceleration**	The scalar value of the first derivative of baton tip resultant velocity
1.3 **Jerk**	The scalar value of the second derivative of baton tip resultant velocity
2. Bar data	The sum or the mean value of a variable within the time span from the onset of the first beat in a given bar until the onset of the first beat in the next bar
2.1 **Distance** (sum)	The sum of distance within the time span of a given bar (based on non-time-warped data)
2.2 **Speed** (mean)	The mean of speed within the time span of a given bar
2.3 **Acceleration** (mean)	The mean of acceleration within the time span of a given bar
2.4 **Jerk** (mean)	The mean of jerk within the time span of a given bar

3.2.8 Data analysis

Processed kinematic variables were investigated using various statistical analysis methods to explore different aspects of data. Two-way ANOVAs (Music × Trial number) and non-parametric Friedman's Tests on four kinematic variables (bar data of baton tip distance, speed, acceleration, and jerk in Table 3.3) were performed to examine whether conducting movement had particular kinematic features corresponding to each musical excerpt (Question 1). Time-series analysis of cross-correlations were conducted at two metrical levels (time-warped data and bar data in Table 3.3) to investigate whether kinematic patterns of conductors' movement were similar across trials when they conduct the same excerpt of music (Question 2). Then one-way ANOVAs (Music) and non-parametric Friedman's Tests were performed on cross-correlation coefficients of trial pairs (maximal coefficients for time-warped data, and coefficients on lag 0 for bar data) to examine whether conductors' movement kinematic patterns had different extent of similarity comparing the three musical excerpts (Question 3). Student *t*-tests (Within-conductor coefficients and Between-conductor coefficients) and non-parametric Mann Whitney U Tests were conducted on cross-correlation coefficients (maximal coefficients for time-warped data, and coefficients on lag 0 for bar data) to investigate whether conductors' movement kinematic patterns were more consistent to trials conducted by themselves, compared to trials conducted by the other conductors (Question 4). Descriptive analyses, ANOVAs, *t*-tests, non-parametric Friedman's Tests, and non-parametric Mann

Whitney U Tests were performed using Statistical Package for Social Sciences (SPSS, version 19.0, IBM, USA); cross-correlations were conducted using Matlab (version 8.5, MathWorks, USA); all figures were produced using Microsoft Office Excel (2016, Microsoft, USA).

Kinematic differences between musical excerpts and trial number: ANOVAs

Descriptive analyses provided an overview of conducting kinematic features of four variables (baton tip distance, speed, acceleration, and jerk) in different musical excerpts, trial number, and also conductors.

The kinematic differences of distance, speed, acceleration, and jerk between Musical excerpts (Mozart, Dvořák, Bartók), Trial number (Trial 1, Trial 2, Trial 3), as well as the interactions between those two factors were examined using two-way ANOVAs with repeated measures (Music × Trial) according to the fact that each conductor conducted three trials for each musical excerpt. The α-level of 0.05 was applied to determine whether kinematic variables showed significant differences when conducting different musical excerpts and in a different trial number. Where the assumption of normality was violated in Shapiro-Wilk's tests, non-parametric Friedman's Tests were performed instead of ANOVAs. Since three levels were employed to both repeated measures—Music and Trial, the homogeneity of covariance (the sphericity for repeated measure) must be met. Where the criterion of sphericity was violated in Mauchly's Tests, Greenhouse-Geisser corrections were applied. Where the main effect reaches significance, Tukey's tests were applied to conduct post-hoc pairwise comparisons. Where the interactions between Music and Trial factors reached significance, simple main effect analyse were conducted on Music factor and Trial factor respectively at each level using one-way ANOVAs according to Howell's (1992) recommendation. In two-way ANOVAs and simple main effect analyses, effect sizes were estimated based on Hopkins's (2006) suggestions.

It should be noted that a different statistical procedure was employed for distance because the nature of distance data is different from other kinematic variables. Distance data is based on the distance sum within each musical bar, and the value of distance sum is thus affected by the time span of each musical bar. The distance differences across different musical excerpts might therefore originate from different compositional structures, i.e. how many beats within a bar and the tempo setting of the composition, rather than from different features of the conductors' movement. For this reason, the examination of Music factor for distance data was omitted in analysis. Since the experiment design contained two repeated-measures (Music and Trial), one-way ANOVAs with repeated measure (Trial) were conducted at each level of Music (Mozart, Dvořák, and Bartók) for distance data. Where Shapiro-Wilk's tests of normality failed, non-parametric Friedman's Tests were applied instead of ANOVAs. Where Mauchly's Tests of homogeneity of covariance was violated, Greenhouse-Geisser corrections were applied. Where the main effect reaches significance, Tukey's tests were applied to conduct post-hoc pairwise comparisons. Effect sizes were estimated according to Hopkins's (2006).

This thesis contains intensive discussion around Music, Trial, and Conductor. For clarity, in this thesis, the term **Music** refers to the Music factor, with **Mozart, Dvořák, and Bartók** referring to musical excerpts by these three composers respectively;
Trial refers to the Trial factor, with **Trial 1, Trial 2, Trial 3** referring to each trial number;
Regarding **Conductor**, **C1, C2, C3, C4, C5, C6** refers to the six participants respectively henceforward in this thesis.

Kinematic time-series similarities: Cross-correlations

Cross-correlation is a standard procedure to investigate the similarity between two sets of time-series data. The cross-correlation coefficient is an indicator for the similarity of data patterns, with strong correlation indicated by a value approaching one. This correlation will be positive if the data sets are in phase and negative if they are correlated but out of phase. Values approaching zero indicate weak correlations. Cross-correlation can also produce a series of coefficients with different time lags between two sets of time-series data, by sliding the two data sets by different time intervals (Stergiou 2004). Conducting movement data is highly time-dependent, and cross-correlation is thus an appropriate analysis method to apply to this study, because this method treats kinematic variables as continuous time-series data rather than discrete data points. Owing to diverse conducting styles across conductors, individual conductors' movement may tend to show different patterns in conducting movement curves. Cross-correlation is advantageous to search and estimate the best match between two data sets with different time lags.

To examine the similarity in kinematic patterns between trials, cross-correlations were performed on each pair of trials conducting the same musical excerpt (3 trials × 6 conductors= 18 trials per musical excerpt; [18 × (18-1)]/ 2= 153 trial pairs per musical excerpt). This procedure was repeated for three kinematic measures of time-warped data, as well as four kinematic variables at bar level data in three musical excerpts respectively. It should be noted that cross-correlation produces one coefficient for each possible time lag between two data sets. For time-warped data, only the maximal cross-correlation coefficient of each trial pair were discussed in this study, regardless of the time lag where the maxima appeared. For bar data, maximal coefficients for all pairs showed on lag 0, thus only the coefficients on lag 0 were taken for further analysis. No cross-correlation analysis was conducted on trial pairs across different musical excerpts because 1) conducting movements were expected to be different across musical excerpts in the reference of diverse musical compositional structures; 2) the number of data points varied for each different musical excerpt, and was therefore not suitable for cross-correlation analysis, and 3) the preliminary descriptive analyses had already shown observable differences across different musical excerpts. This cross-correlation procedure produced 3213 coefficients in total (153 pairs × 7 variables × 3 musical excerpts= 3213).

To further examine whether conducting movement kinematic patterns had different extents of similarity comparing three musical excerpts, one-way ANOVAs with repeated measure (Music) were conducted to determine whether significant differences were shown between cross-correlation coefficients in different musical excerpts. Where the assumption of normality was violated in Shapiro-Wilk's Tests, non-parametric Friedman's Tests were employed instead of ANOVAs. Where the homogeneity of covariance was violated in Mauchly's Tests of Sphericity for the three levels (Mozart, Dvořák, and Bartók) of the repeated measure (Music), Greenhouse-Geisser corrections were applied. Where the music effect reaches significance, Tukey's tests were applied to conduct post-hoc pairwise comparisons. Effect sizes for ANOVAs were estimated using Hopkins's (2006) criterion. This procedure was performed on cross-correlation coefficients for 7 kinematic variables (time-warped data and bar data) respectively.

In addition, to determine whether conductors' movement kinematic patterns were more consistent with trials conducted by themselves than trials conducted by the other conductors, *t*-tests with independent groups (Within-conductor coefficients versus Between-conductors coefficients) were performed to examine whether significant differences exist between 18 coefficients of trial pairs by the same conductor (trial 1-2, 1-3, 2-3 for each conductor), and 135 coefficients of trial pairs by different conductors conducting the same musical excerpt. Where Shapiro-Wilk's Test of Normality failed, non-parametric Mann Whitney U Tests were conducted instead of *t*-tests. Where the homogeneity of variance was compromised as indicated by Levene's Test being below 0.05, adjustments to the degrees of freedom were applied. Effect sizes for *t*-tests were estimated according to Hopkins (2006). This procedure was performed on 7 variables in 3 musical excerpts respectively (7 variables × 3 musical excerpts= 21).

The types of cross-correlation coefficient discussed in this thesis therefore include:

Coefficient (time-warped): the maximal cross-correlation coefficient of a trial pair based on time-warped data;

Coefficient (bar data): the cross-correlation coefficient on lag 0 of a trial pair based on the sum or mean per musical bar;

Within-conductor coefficient: the cross-correlation coefficient on a trial pair conducted by the same conductor;

Between-conductor coefficient: the cross-correlation coefficient on a trial pair conducted by

different conductors.
All types of coefficient above were based on trial pairs conducting the same musical excerpt.

3.3. Results

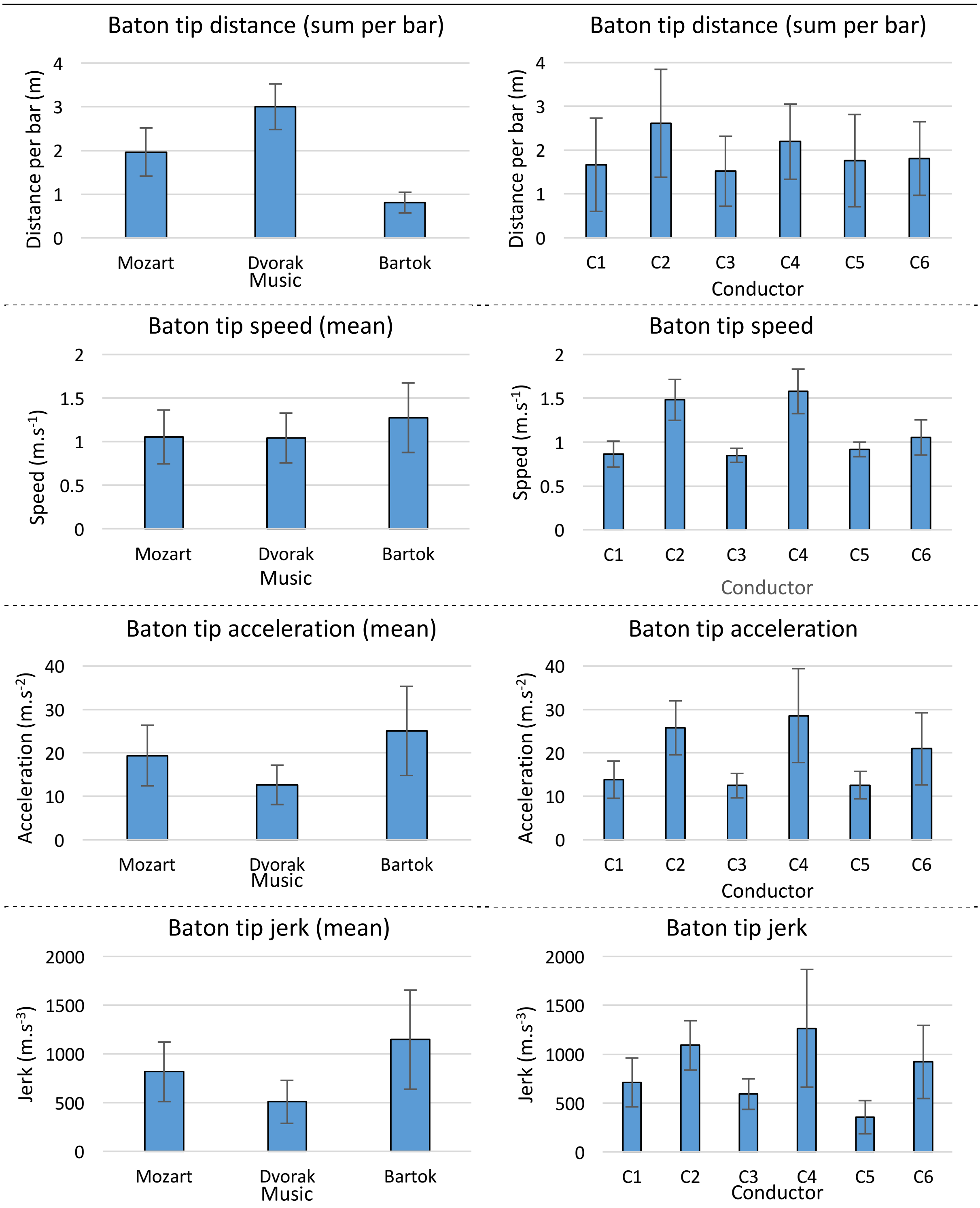
3.3.1 Linear kinematic differences of baton tip movement

3.3.1.1 Kinematic differences between musical excerpts and conductors: descriptive analyses

Descriptive statistics of the baton tip's four linear kinematic variables (distance, speed, acceleration, and jerk) are summarised in Table 3.4. Preliminary observations of three musical excerpts can be made in Figure 3.6. On average, conductors' baton tip moved for the greatest distance in Dvořák and the shortest distance in Bartók– which might be the consequence of the longer time spans and the shorter time spans within musical bars in those two musical excerpts respectively. As for other kinematic variables, conductors' baton tip moved with the highest mean speed, acceleration and jerk in Bartók, followed by Mozart, and with the lowest mean speed, acceleration and jerk in Dvořák. Regarding different conductors, the general tendency can be seen that baton tip movements by C2 and C4 showed greater distance and higher speed, acceleration and jerk, while C1, C3, and C5 showed lower values for these kinematic variables; C6 showed values between these two groups.

Table 3.4 Descriptive statistics for musical excerpts and conductors

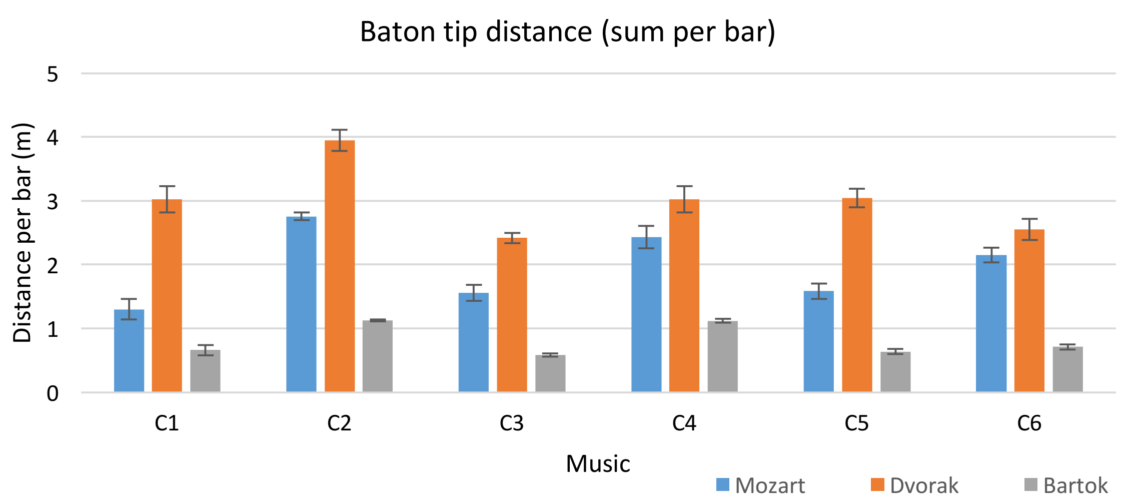
Variable	Music	Conductor	Mean	Standard Deviation	95% Confidence Intervals	
					Lower	Upper
Distance (m)	Mozart	All	1.964	0.547	1.348	2.395
	Dvořák		3.001	0.523	2.606	3.652
	Bartók		0.807	0.236	0.592	0.988
	All	C1	1.662	1.068	0.841	2.484
		C2	2.609	1.229	1.664	3.553
		C3	1.520	0.797	0.907	2.133
		C4	2.192	0.855	1.534	2.849
		C5	1.756	1.053	0.946	2.565
		C6	1.805	0.845	1.156	2.455
Speed ($m.s^{-1}$)	Mozart	All	1.056	0.307	1.023	1.088
	Dvořák		1.041	0.284	1.008	1.065
	Bartók		1.275	0.400	1.254	1.297
	All	C1	0.861	0.148	0.891	0.941
		C2	1.482	0.235	1.568	1.650
		C3	0.849	0.081	0.863	0.920
		C4	1.579	0.254	1.673	1.747
		C5	0.916	0.084	0.904	0.964
		C6	1.054	0.199	1.080	1.133
Acceleration ($m.s^{-2}$)	Mozart	All	19.383	6.957	18.383	20.135
	Dvořák		12.661	4.546	12.126	12.984
	Bartók		25.047	10.255	24.590	25.529
	All	C1	13.852	4.286	15.772	16.829
		C2	25.791	6.213	27.905	29.521
		C3	12.468	2.823	12.910	13.734
		C4	28.545	10.796	34.058	36.188
		C5	12.562	3.145	13.720	14.707
		C6	20.962	8.291	23.056	24.572
Jerk ($m.s^{-3}$)	Mozart	All	816.917	306.713	782.000	851.834
	Dvořák		507.913	221.313	480.878	522.307
	Bartók		1146.434	506.758	1123.438	1170.381
	All	C1	714.178	249.368	824.801	881.258
		C2	1091.875	251.005	1180.153	1257.354
		C3	592.971	154.529	615.143	658.160
		C4	1264.453	602.091	1574.505	1691.901
		C5	356.908	167.973	435.090	470.624
		C6	922.143	373.975	1035.463	1107.773

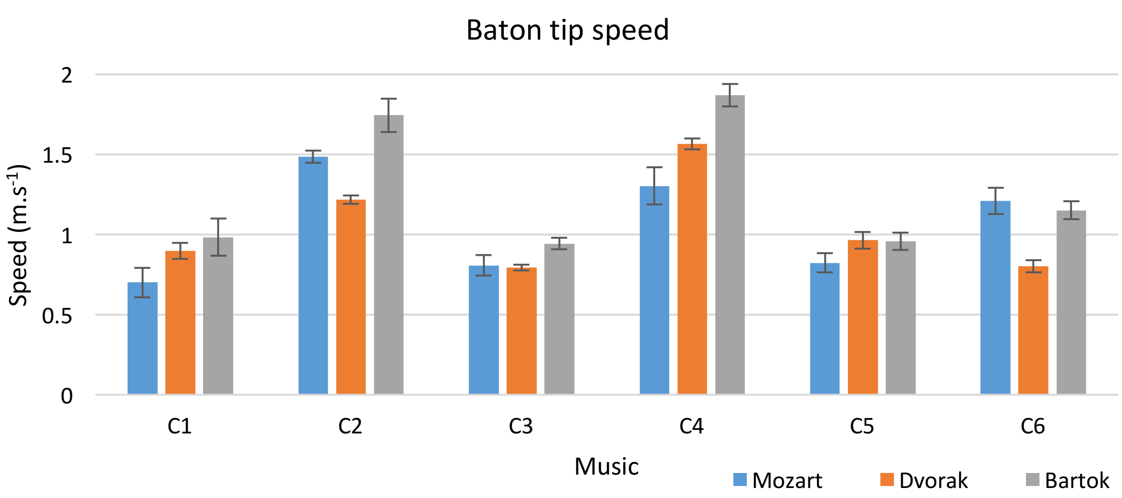


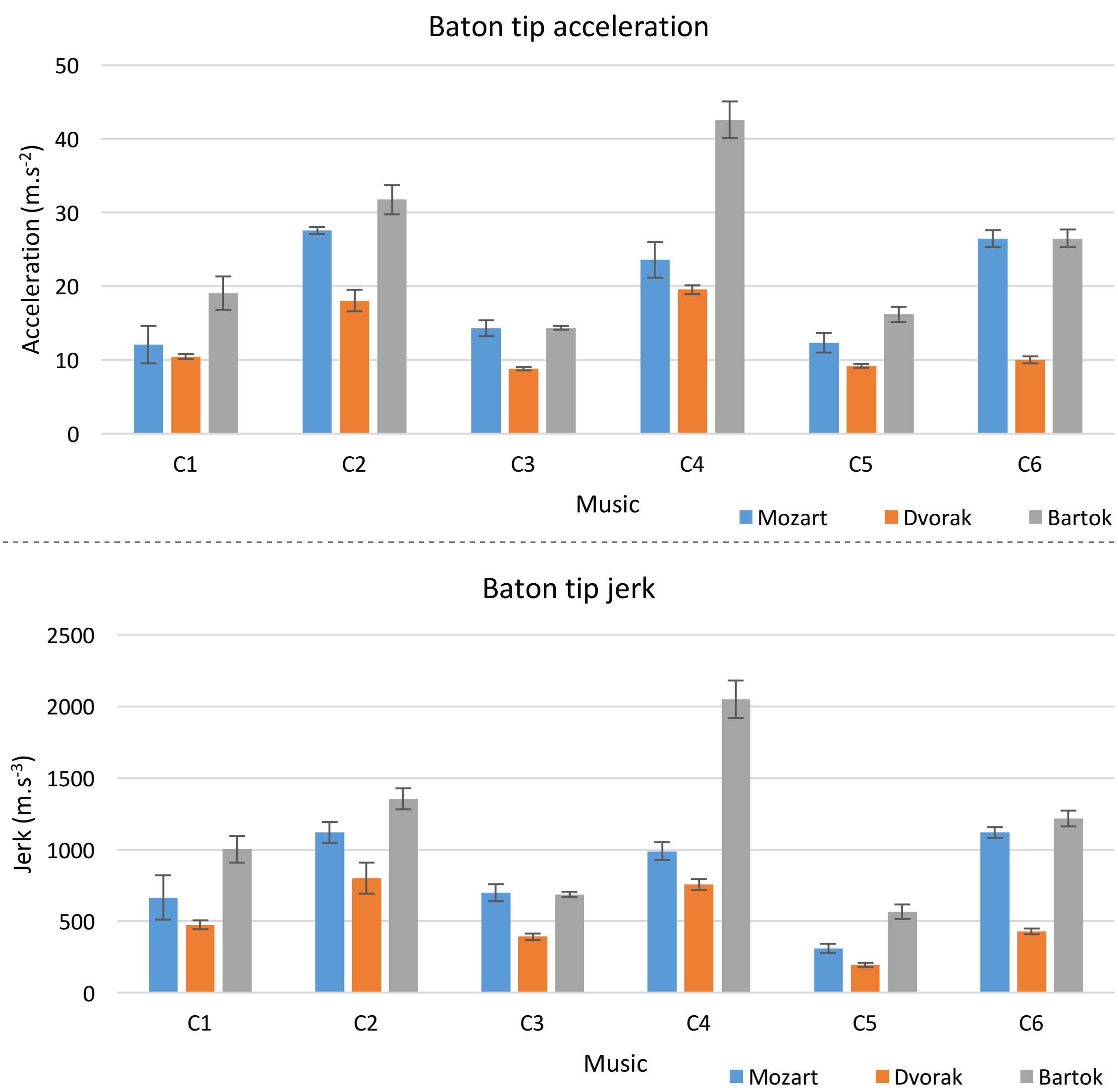
Note: Error bars indicate standard deviations

Figure 3.6 Kinematic variable means and SDs in three musical excerpts and for six conductors

Detailed analyses in Figure 3.7 reveal differences across musical excerpts in each conductor's conducting (full results are given in Appendix 4). While conducting movement tended to show the highest values for speed, acceleration and jerk in Bartók, followed by Mozart and Dvořák, several conductors deviated from this general trend. For baton tip speed, C1 and C4 had higher speed in Dvořák than in Mozart, and C5 had the highest speed in Dvořák of the three musical excerpts. For baton tip jerk, C3 had slightly higher jerk in Mozart than in Bartók. For acceleration, all conductors followed the general trend, with Mozart and Bartók having very similar values of acceleration within C3's and C6's conducting. For movement distance, all conductors showed the same tendency that their movement had the greatest distance in Dvořák and the shortest distance in Bartók.







Note: Error bars indicate standard deviations

Figure 3.7 Kinematic variable means and SDs in three musical excerpts and for six conductors

3.3.1.2 Kinematic differences between musical excerpts and trial number: descriptive analyses and ANOVAs

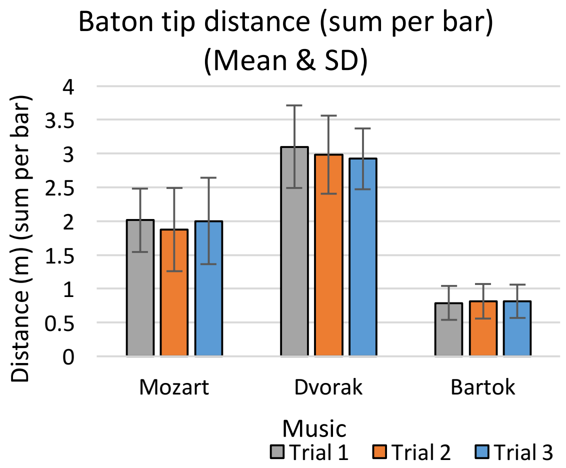
Descriptive analyses for musical excerpts and trial number are summarised in Table 3.5. As is evident in Figure 3.8, Dvořák had the greatest movement distance, followed by Mozart and Bartók regardless of trial number. Bartók had the highest values for speed, acceleration, and jerk, followed by Mozart and Dvořák regardless of trial number. No obvious difference was observed between trials.

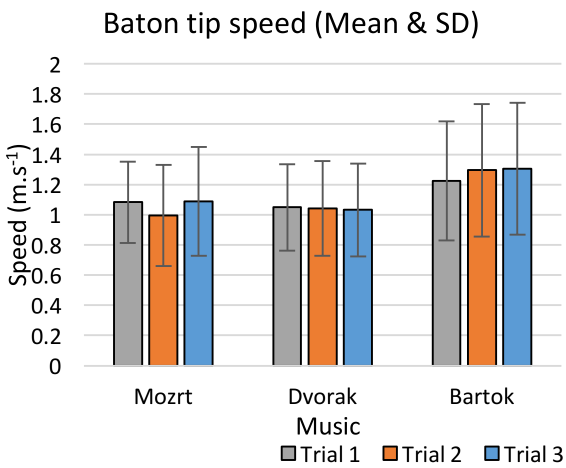
Table 3.5 Descriptive statistics for musical excerpts and trials

Variable	Music	Trial	n	Mean	Standard Deviation	95% Confidence Intervals		Test of normality (Shapiro-Wilk)
						Lower	Upper	
Distance (m) (sum per bar)	Mozart	1	6	2.015	0.470	1.521	2.509	0.611
		2	6	1.873	0.614	1.229	2.517	0.803
		3	6	2.003	0.637	1.335	2.671	0.322
	Dvořák	1	6	3.101	0.612	2.459	3.743	0.429
		2	6	2.981	0.579	2.373	3.589	0.118
		3	6	2.923	0.448	2.453	3.392	0.176
	Bartók	1	6	0.789	0.248	0.528	1.050	0.065
		2	6	0.814	0.256	0.545	1.083	0.036
		3	6	0.817	0.248	0.556	1.078	0.047
Speed ($m.s^{-1}$)	Mozart	1	6	1.082	0.271	0.798	1.367	0.267
		2	6	0.995	0.334	0.645	1.345	0.687
		3	6	1.087	0.361	0.708	1.466	0.191
	Dvořák	1	6	1.049	0.286	0.749	1.350	0.400
		2	6	1.041	0.314	0.711	1.370	0.173
		3	6	1.032	0.306	0.711	1.354	0.074
	Bartók	1	6	1.225	0.395	0.810	1.640	0.203
		2	6	1.295	0.438	0.835	1.755	0.048
		3	6	1.304	0.437	0.846	1.763	0.042
Acceleration ($m.s^{-2}$)	Mozart	1	6	20.053	6.321	13.420	26.686	0.122
		2	6	18.354	7.867	10.098	26.610	0.276
		3	6	19.707	7.824	11.497	27.917	0.026
	Dvořák	1	6	12.965	5.090	7.623	18.307	0.011
		2	6	12.718	4.990	7.481	17.9550	0.042
		3	6	12.288	4.390	7.682	16.895	0.078
	Bartók	1	6	23.950	10.078	13.373	34.527	0.292
		2	6	25.786	11.183	14.050	37.522	0.584
		3	6	25.360	11.396	13.401	37.319	0.773
Jerk ($m.s^{-3}$)	Mozart	1	6	862.802	301.335	546.571	1179.034	0.419
		2	6	778.475	352.111	408.957	1147.992	0.785
		3	6	806.983	318.147	473.108	1140.857	0.298
	Dvořák	1	6	528.883	265.120	250.657	807.109	0.755
		2	6	514.704	235.393	267.674	761.733	0.354
		3	6	479.103	199.984	269.233	688.974	0.505
	Bartók	1	6	1109.162	487.504	597.558	1620.766	0.481
		2	6	1185.728	572.194	585.247	1786.209	0.554
		3	6	1142.495	554.898	560.166	1724.825	0.801

Note: Data sets violating the assumption of normality are highlighted.

Figure 3.8-1 Means and standard deviations of four kinematic variables





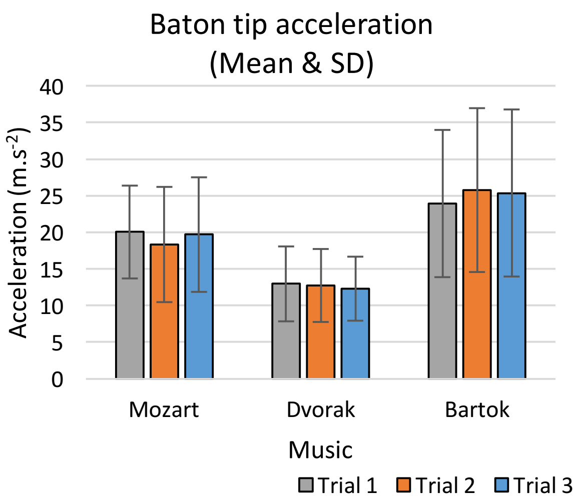
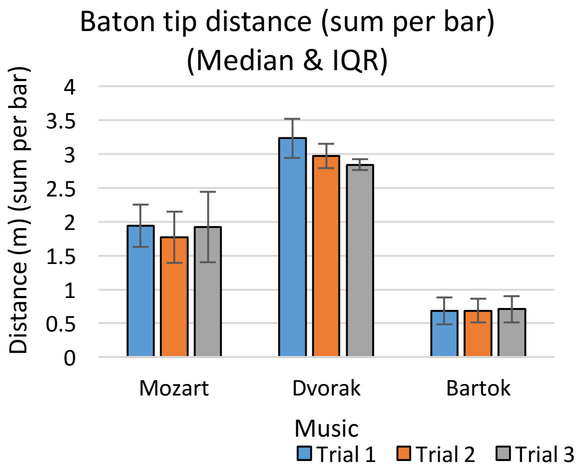
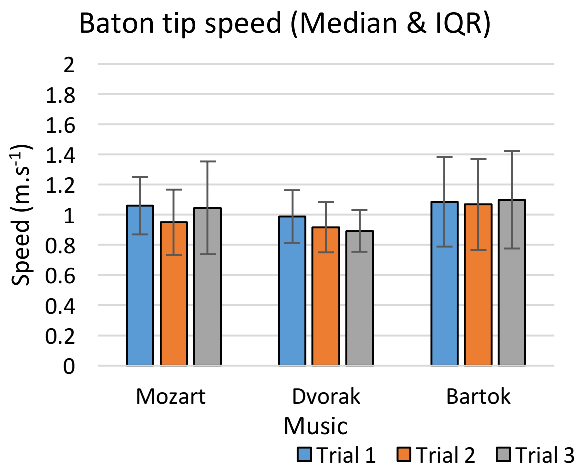
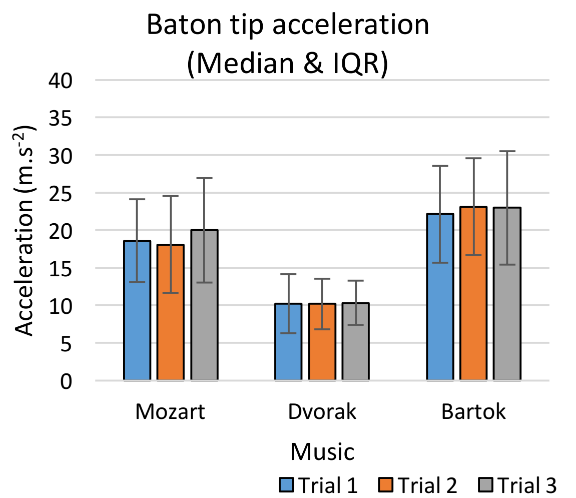
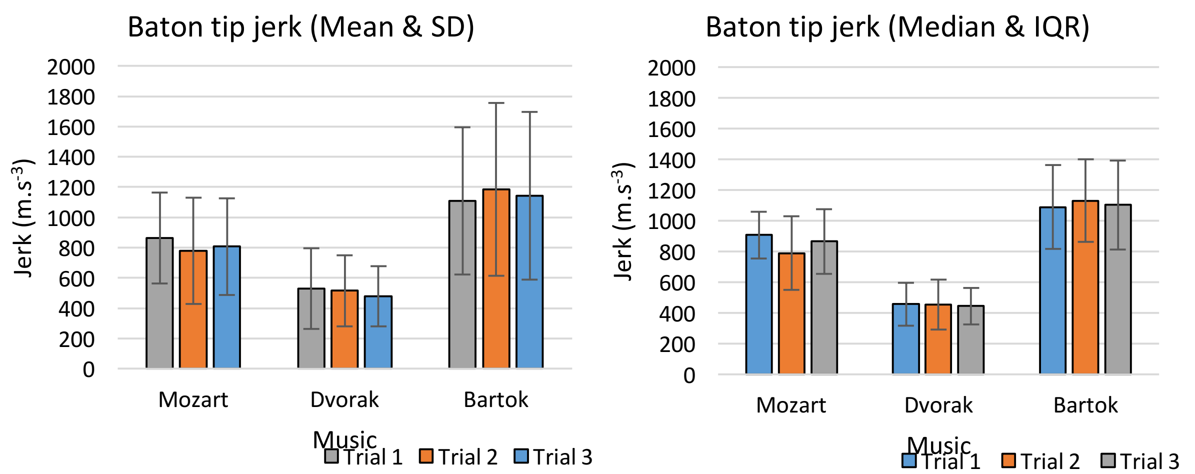


Figure 3.8-2 Medians and inter-quartile ranges of four kinematic variables









Note: Error bars indicate standard deviations	Note: Error bars indicate inter-quartile ranges

Figure 3.8 Kinematic variable means, medians, SDs and IQRs in three musical excerpts and for three trials

Statistical analysis results using two-way repeated measure ANOVAs (Music × Trial) for baton tip jerk are presented in Table 3.6. Distance, speed, and acceleration data violated the assumption of normality in Shapiro-Wilk's Tests, and non-parametric tests were performed instead. For jerk data, significant Music effects were found in ANOVA, supported by moderate effect size. Post-hoc tests indicated significant differences between Mozart and Dvořák, as well as between Dvořák and Bartók, but no significant difference was found between Mozart and Bartók. No significant Trial effect and interaction was found. Results of non-parametric Friedman's Tests for kinematic variables of distance, speed and acceleration are presented in Table 3.7. Significant Music main effects were shown in two trials for speed and all trials for acceleration. For speed data, no significant difference was found between the conducting for Mozart and Dvořák. All Trial main effects were rejected in Friedman's Tests.

Table 3.6 Results of two-way repeated measure ANOVAs (music × trial)

Variable	Effect	Sphericity (Mauchly's)	Tests of within-subjects effects						Post hoc
			df	F	Sig.	Partial Eta Squared	Effect size	Power	
Distance	N/A								
Speed	N/A								
Acceleration	N/A								
Jerk (df error= 10)	Music	0.383	2	11.597	0.002**	0.699	0.836 (moderate)	0.964	1-2 (p= 0.040*) 1-3 (p= 0.258) 2-3 (p= 0.023*)
	Trial	0.691	2	0.852	0.455	0.146	0.382 (small)	0.157	
	Music x trial	0.077	4	2.073	0.123	0.293	0.541 (small)	0.512	

Note: 1) Distance, speed, and acceleration data violated the assumption of normality and were tested using Friedman's Tests as in Table 3.7; 2) * = P<0.05; ** = P<0.01; *** = P<0.001

Table 3.7 Results of non-parametric Friedman's Tests (music, trial)

Variable	Main Effect	Music/trial	Friedman's Test	Post hoc	
			Sig.	Pair	Sig.
Distance	Music	N/A			
	Trial	Mozart	0.135	N/A	
		Dvořák	0.311	N/A	
		Bartók	0.513	N/A	
Speed	Music	1	0.311	N/A	
		2	0.042*	Mozart- Dvořák	0.600
				Dvořák- Bartók	0.046*
				Mozart- Bartók	0.028*
		3	0.042*	Mozart- Dvořák	0.917
				Dvořák- Bartók	0.075
				Mozart- Bartók	0.028*
	Trial	Mozart	0.115	N/A	
		Dvořák	0.846	N/A	
		Bartók	0.223	N/A	
Acceleration	Music	1	0.006**	Mozart- Dvořák	0.028*
				Dvořák- Bartók	0.075
				Mozart- Bartók	0.028*
		2	0.006**	Mozart- Dvořák	0.046*
				Dvořák- Bartók	0.028*
				Mozart- Bartók	0.028*
		3	0.006**	Mozart- Dvořák	0.028*
				Dvořák- Bartók	0.046*
				Mozart- Bartók	0.028*
	Trial	Mozart	0.223	N/A	
		Dvořák	0.115	N/A	
		Bartók	0.311	N/A	
Jerk	N/A				

Note: 1) For distance data, comparisons between musical excerpts were omitted as reasons stated in section 3.2.8; 2) jerk data were tested using ANOVA as in Table 3.6; 3) * = P<0.05; ** = P<0.01; *** = P<0.001

Unsurprisingly, using descriptive analyses, ANOVAs, and Friedman's Tests, it was found that conductors' baton tip linear kinematic features— including speed, acceleration and jerk— showed significant differences when they conducted different musical excerpts, with the exceptions of the speed between Mozart and Dvořák, and the jerk between Mozart and Bartók. By contrast, trial number did not affect these kinematic features. These results offered information related to overall kinematic features of entire trials. It is still unknown, however, how the kinematics vary during the course of trials, and whether these kinematic variations, i.e. time-series kinematic patterns, of different conductors' conducting would show similar or different curves in reference to compositional structure. Therefore, in the next section, time-series analyses, specifically cross-correlations, would be applied to compare conductor's movement kinematic patterns.

3.3.2 Linear kinematic time-series similarities of baton tip movement

In this section, similarities of conductors' movement kinematic time-series patterns were examined using cross-correlational analysis. To further investigate whether the extent of similarity in conductors' movement kinematic patterns is different when comparing the three musical excerpts, one-way ANOVAs (Music) were applied to investigate the cross-correlation coefficients in three musical excerpts. To explore whether conductors' movement were more consistent to trials conducted by themselves compared to trials conducted by the other conductors, *t*-tests (Within-conductor coefficient versus Between-conductor coefficient) were performed to compare cross-correlation coefficients from trial pairs conducted by the same conductor, and coefficients from trial pairs conducted by different conductors. All cross-correlation analyses were based on trial pairs conducting the same musical excerpt. Trial pairs conducting different musical excerpts were not included in the discussion because conducting movement tends to connect with specific compositional structures in each musical excerpt, as well as that differences of kinematic variables between musical excerpts have already been observed in previous analyses.

3.3.2.1 Kinematic time-series similarities: descriptive analyses of cross-correlation coefficients

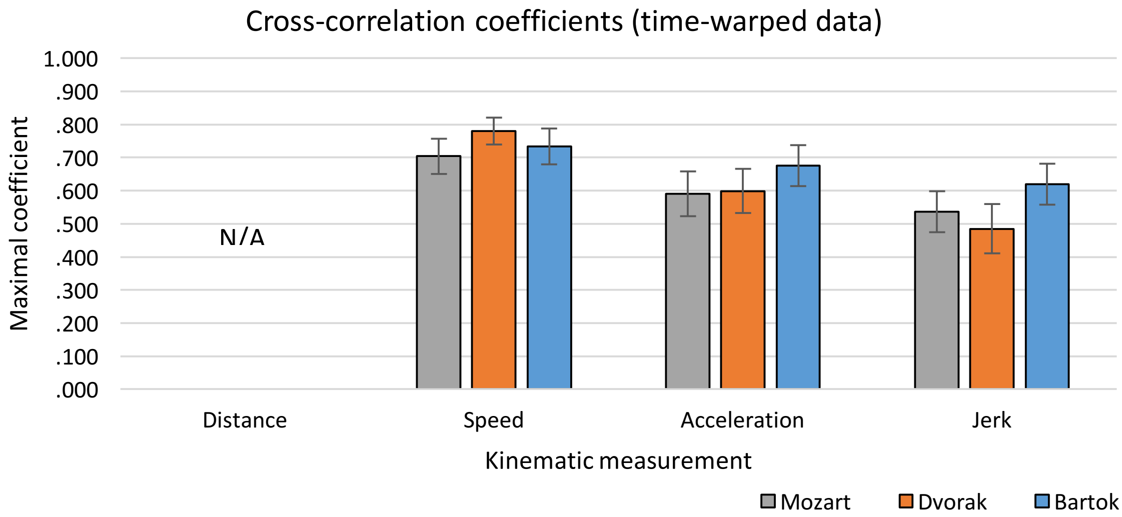
Appendix 5 shows the full results of cross-correlational analysis based on 3213 trial pairs within the same musical excerpt, including the maximal coefficient of each trial pair and its time lag[2]. Descriptive analyses of these maximal coefficients are summarised in Table 3.8. As can be observed in Figure 3.9, for time-warped data, Dvořák had highest coefficients for speed in three musical excerpts— in other words, taken as a group across all conductors and trials, movement speed patterns showed the greatest similarity when conducting Dvořák. Meanwhile, Bartók showed the greatest similarity for acceleration and jerk. For coefficients on bar data, all kinematic curves for Dvořák displayed the greatest similarity compared to Mozart and Bartók. It should be noted that bar data tended to show higher coefficients than time-warped data, which can be explained by smoother curves resulting from data averaging at bar data level.

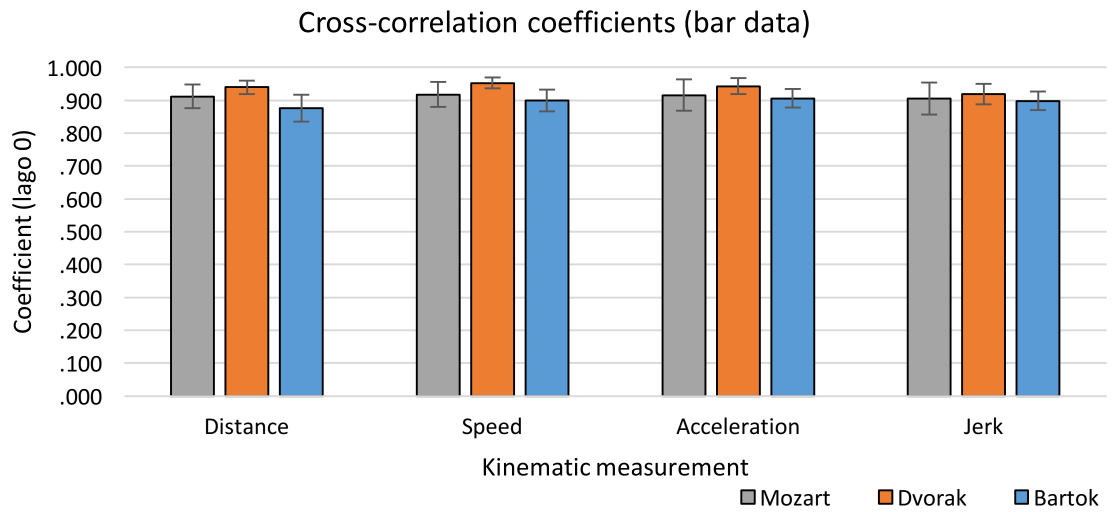
Table 3.8 Descriptive statistics of cross-correlation coefficients

Coefficient		music	N	Mean	Standard Deviation	95% Confidence Intervals		Test of Normality (Shapiro-Wilk)
						Lower	Upper	
Time-Warped	Distance	N/A						
	Speed	Mozart	153	0.704	0.053	0.696	0.712	0.060
		Dvořák	153	0.780	0.040	0.774	0.786	0.063
		Bartók	153	0.733	0.055	0.725	0.742	0.004
	Acceleration	Mozart	153	0.591	0.068	0.580	0.602	0.009
		Dvořák	153	0.598	0.067	0.588	0.609	0.082
		Bartók	153	0.676	0.062	0.666	0.686	0.090
	Jerk	Mozart	153	0.536	0.062	0.526	0.546	0.699
		Dvořák	153	0.485	0.074	0.473	0.497	0.773
		Bartók	153	0.620	0.062	0.610	0.630	0.173
Bar data	Distance	Mozart	153	0.912	0.037	0.906	0.918	0.008
		Dvořák	153	0.940	0.020	0.937	0.943	0.010
		Bartók	153	0.876	0.041	0.870	0.883	0.127
	Speed	Mozart	153	0.918	0.038	0.912	0.924	0.006
		Dvořák	153	0.953	0.017	0.950	0.955	<0.001
		Bartók	153	0.900	0.034	0.894	0.905	0.388
	Acceleration	Mozart	153	0.916	0.048	0.908	0.924	<0.001
		Dvořák	153	0.943	0.024	0.939	0.947	<0.001
		Bartók	153	0.906	0.029	0.902	0.911	0.291
	Jerk	Mozart	153	0.905	0.048	0.898	0.913	<0.001
		Dvořák	153	0.919	0.032	0.914	0.924	0.001
		Bartók	153	0.899	0.028	0.894	0.903	0.329

Note: 1) For time-warped data, analyses of distance data were omitted as reasons stated in section 3.2.7 and 3.2.8; 2) Data sets violating the assumption of normality are highlighted.

[2] For bar data, all maximal cross-correlation coefficients showed on lag 0, as explained in section 3.2.8.





Note: 1) For time-warped data, analyses of distance data were omitted as reasons stated in section 3.2.7 and 3.2.8; 2) Error bars indicate standard deviations

Figure 3.9 Cross-correlation coefficient means and SDs in three musical excerpts

3.3.2.2 Kinematic time-series similarities in different musical excerpts: ANOVAs on cross-correlation coefficients

Statistical analyses results of one-way ANOVAs with repeated measures (Music) on trial pair cross-correlation coefficients are presented in Table 3.9. Significant Music effect was shown in time-warped jerk data, supported by moderate effect sizes. The post-hoc tests indicated that all pairwise comparisons between music excerpts reach significance. The assumption of normality was violated in other data sets, and thus non-parametric Friedman's Tests were conducted. The results in Table 3.10

presented significant Music effects for all kinematic variables, both at time-warped data and at bar data, with the exceptions of the time-warped acceleration between Mozart and Dvořák, and bar jerk between Mozart and Bartók. These results suggested that the extent of movement kinematic pattern similarity mostly shows significant difference between three musical excerpts.

Table 3.9 Results of one-way repeated measure ANOVAs (Music) on cross-correlation coefficients

Coefficient		Group	Sphericity (Mauchly's)	Tests of within-subjects effects					Post hoc
				df	F	Sig.	Effect size	Power	
Time-warped	Distance	N/A							
	Speed	N/A							
	Acceleration	N/A							
	Jerk	Mozart	<0.001	1.4	192.554	<0.001***	0.748 (moderate)	1.000	All pairs: p<0.001***
		Dvořák							
		Bartók							
Bar data	Distance	N/A							
	Speed	N/A							
	Acceleration	N/A							
	Jerk	N/A							

Note: 1) The analysis for time-warped distance data was omitted as reasons stated in section 3.2.7 and 3.2.8; 2) Time-warped speed and acceleration data, and all bar data violated the assumption of normality, and thus non-parametric tests were performed as in Table 3.10; 3) * = P<0.05; ** = P<0.01; *** = P<0.001

Table 3.10 Results of non-parametric Friedman's Tests (Music) on cross-correlation coefficients

Coefficient		Friedman's Test		Post hoc	
		Group	Sig.	Pair	Sig.
Time-warped	Distance	N/A			
	Speed	Mozart, Dvořák, Bartók	<0.001***	Mozart- Dvořák	<0.001***
				Dvořák- Bartók	<0.001***
				Mozart- Bartók	<0.001***
	Acceleration	Mozart, Dvořák, Bartók	<0.001***	Mozart- Dvořák	0.138
				Dvořák- Bartók	<0.001***
				Mozart- Bartók	<0.001***
	Jerk	N/A			
Bar data	Distance	Mozart, Dvořák, Bartók	<0.001***	Mozart- Dvořák	<0.001***
				Dvořák- Bartók	<0.001***
				Mozart- Bartók	<0.001***
	Speed	Mozart, Dvořák, Bartók	<0.001***	Mozart- Dvořák	<0.001***
				Dvořák- Bartók	<0.001***
				Mozart- Bartók	<0.001***
	Acceleration	Mozart, Dvořák, Bartók	<0.001***	Mozart- Dvořák	<0.001***
				Dvořák- Bartók	<0.001***
				Mozart- Bartók	0.004**
	Jerk	Mozart, Dvořák, Bartók	<0.001***	Mozart- Dvořák	0.014*
				Dvořák- Bartók	<0.001***
				Mozart- Bartók	0.064

Note: The analysis for time-warped distance data was omitted as reasons stated in section 3.2.7 and 3.2.8; 2) * = P<0.05; ** = P<0.01; *** = P<0.001

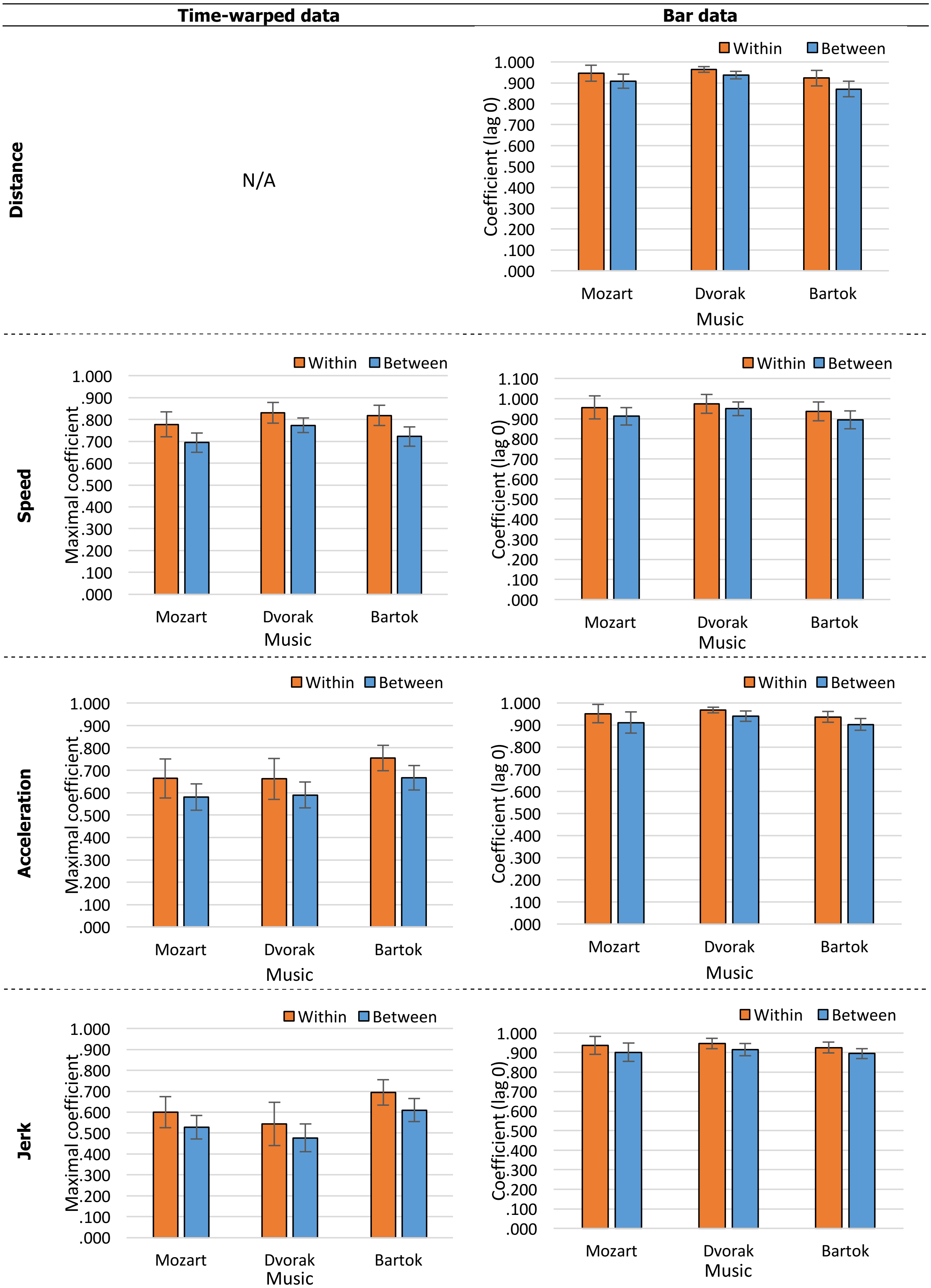
3.3.2.3 Kinematic time-series similarities within-conductor and between-conductors: *t*-tests on cross-correlation coefficients

Descriptive analyses of cross-correlation coefficients on trial pairs by the same conductor (Within-conductor coefficients) and trial pairs by different conductors (Between-conductor coefficients) are reported in Table 3.11. As revealed in Figure 3.10, on average, trials by the same conductor had higher coefficients than trials by different conductors for all variables in all musical excerpts in both time-warped data and bar data.

Table 3.11 Descriptive analyses of within-conductor and between-conductors cross-correlation coefficients

Variable		music	Coefficient	N	Mean	Standard Deviation	95% Confidence Intervals		Test of Normality (Shapiro-Wilk)
							Lower	Upper	
Time-warped	Distance	N/A							
	Speed	Mozart	Within	18	0.778	0.058	0.749	0.807	0.507
			Between	135	0.694	0.044	0.687	0.702	0.002
		Dvořák	Within	18	0.831	0.047	0.808	0.855	0.030
			Between	135	0.773	0.034	0.767	0.779	<0.001
		Bartók	Within	18	0.818	0.046	0.796	0.841	0.127
			Between	135	0.722	0.045	0.714	0.730	0.036
	Acceleration	Mozart	Within	18	0.664	0.087	0.621	0.707	0.129
			Between	135	0.581	0.059	0.571	0.591	0.123
		Dvořák	Within	18	0.662	0.091	0.617	0.707	0.930
			Between	135	0.590	0.058	0.580	0.600	0.540
		Bartók	Within	18	0.755	0.056	0.727	0.783	0.398
			Between	135	0.666	0.055	0.656	0.675	0.249
	Jerk	Mozart	Within	18	0.600	0.073	0.563	0.636	0.060
			Between	135	0.528	0.056	0.518	0.537	0.449
		Dvořák	Within	18	0.544	0.104	0.492	0.595	0.102
			Between	135	0.477	0.066	0.466	0.488	0.814
		Bartók	Within	18	0.694	0.061	0.664	0.725	0.324
			Between	135	0.610	0.055	0.601	0.619	0.645
Bar data	Distance	Mozart	Within	18	0.947	0.038	0.928	0.965	<0.001
			Between	135	0.908	0.034	0.902	0.914	0.002
		Dvořák	Within	18	0.964	0.013	0.957	0.971	0.042
			Between	135	0.937	0.019	0.934	0.940	<0.001
		Bartók	Within	18	0.923	0.038	0.904	0.942	0.180
			Between	135	0.870	0.037	0.864	0.876	0.220
	Speed	Mozart	Within	18	0.956	0.034	0.939	0.973	0.001
			Between	135	0.913	0.035	0.907	0.919	0.001
		Dvořák	Within	18	0.973	0.008	0.969	0.978	0.358
			Between	135	0.950	0.015	0.947	0.952	<0.001
		Bartók	Within	18	0.937	0.027	0.923	0.950	0.297
			Between	135	0.895	0.031	0.889	0.900	0.218
	Acceleration	Mozart	Within	18	0.951	0.042	0.931	0.972	<0.001
			Between	135	0.911	0.047	0.903	0.919	<0.001
		Dvořák	Within	18	0.967	0.013	0.961	0.973	0.007
			Between	135	0.939	0.024	0.935	0.943	<0.001
		Bartók	Within	18	0.936	0.024	0.924	0.949	0.224
			Between	135	0.902	0.027	0.898	0.907	0.151
	Jerk	Mozart	Within	18	0.937	0.045	0.914	0.959	0.001
			Between	135	0.901	0.047	0.893	0.909	<0.001
		Dvořák	Within	18	0.945	0.026	0.932	0.959	0.133
			Between	135	0.916	0.031	0.910	0.921	<0.001
		Bartók	Within	18	0.926	0.028	0.912	0.940	0.056
			Between	135	0.895	0.026	0.891	0.899	0.029

Note: 1) For time-warped data, analyses of distance data were omitted as reasons stated in section 3.2.7 and 3.2.8; 2) Data sets violating the assumption of normality are highlighted.



Note: 1) For time-warped data, analyses of distance data were omitted as reasons stated in section 3.2.7 and 3.2.8; 2) Error bars indicate standard deviations

Figure 3.10 Within-conductor and Between-conductors cross-correlation coefficient means and SDs

Results of *t*-tests with independent groups (Within-conductor coefficients versus Between-conductor coefficients) are presented in Table 3.12. It was evident that there were significant differences between within-conductor coefficients and Between-conductor coefficients for acceleration and jerk in the time-warped data, and distance, speed, acceleration in the bar data in Bartók, supported by moderate to large effect sizes. Other variables violated the assumption of normality and non-parametric Mann-Whitney U Tests were performed. The results in Table 3.13 showed significant differences between Within-conductor coefficients and Between-conductor coefficients for all variables at both time-warped data and bar data in all musical excerpts. This evidence suggested that conductors' movement kinematic patterns were more similar to trials conducted by themselves, compared to trials conducted by the other conductors.

Table 3.12 Results of t-tests (Within-conductor coefficients and Between-conductors coefficients)

Coefficient			**Test for Equality (Levene's)**	**T-test for equality of means**			
				df	**T**	**Sig.**	**Effect size**
Time-warped	Distance	N/A					
	Speed	Mozart	N/A				
		Dvořák	N/A				
		Bartók	N/A				
	Acceleration	Mozart	0.037	19.2	3.936	0.001**	1.135 (moderate)
		Dvořák	0.006	18.9	3.269	0.004**	0.964 (moderate)
		Bartók	0.616	151	6.481	<0.001***	1.610 (large)
	Jerk	Mozart	0.024	19.7	4.015	0.001**	1.118 (moderate)
		Dvořák	0.001	18.9	2.669	0.015*	0.825 (moderate)
		Bartók	0.290	151	6.049	<0.001***	1.458 (large)
Bar data	Distance	Mozart	N/A				
		Dvořák	N/A				
		Bartók	0.965	151	5.636	<0.001***	1.395 (large)
	Speed	Mozart	N/A				
		Dvořák	N/A				
		Bartók	0.343	151	5.406	<0.001***	1.445 (large)
	Acceleration	Mozart	N/A				
		Dvořák	N/A				
		Bartók	0.621	151	5.056	<0.001***	1.322 (large)
	Jerk	Mozart	N/A				
		Dvořák	N/A				
		Bartók	N/A				

Note: 1) Analyses for time-warped distance data were omitted as reasons stated in section 3.2.8; 2) data sets violating the assumption of normality were tested using non-parametric tests as in Table 3.13; 3) data sets failing the test of equality are highlighted; 4) * = P<0.05; ** = P<0.01; *** = P<0.001

Table 3.13 Results of non-parametric Mann-Whitney Tests (Within-conductor coefficients and Between-conductors coefficients)

Coefficient			**Group**	**Mann-Whitney Test Sig.**
Time-warped	Distance	N/A		
	Speed	Mozart	Within-conductor Between-conductors	<.001***
		Dvořák	Within-conductor Between-conductors	<.001***
		Bartók	Within-conductor Between-conductors	<.001***
	Acceleration	Mozart	N/A	
		Dvořák	N/A	
		Bartók	N/A	
	Jerk	Mozart	N/A	
		Dvořák	N/A	
		Bartók	N/A	
Bar mean	Distance	Mozart	Within-conductor Between-conductors	<.001***
		Dvořák	Within-conductor Between-conductors	<.001***
		Bartók	N/A	
	Speed	Mozart	Within-conductor Between-conductors	<.001***
		Dvořák	Within-conductor Between-conductors	<.001***
		Bartók	N/A	
	Acceleration	Mozart	Within-conductor Between-conductors	<.001***
		Dvořák	Within-conductor Between-conductors	<.001***
		Bartók	N/A	
	Jerk	Mozart	Within-conductor Between-conductors	<.001***
		Dvořák	Within-conductor Between-conductors	<.001***
		Bartók	Within-conductor Between-conductors	<.001***

Note: 1) Analyses for time-warped distance data were omitted as reasons stated in section 3.2.8; 2) * = P<0.05; ** = P<0.01; *** = P<0.001

It was shown from cross-correlation coefficients that conductors' movement kinematic patterns were more similar when they were conducting Dvořák, compared to when conducting Mozart and Bartók. Conductors' movement kinematic patterns were also more consistent to trials conducted by themselves, compared to trials conducted by the other conductor. The mean cross-correlation coefficient was 0.636 for time-warped data, and 0.916 for bar data. The high cross-correlation coefficients suggested a high similarity of conducting movement kinematic patterns within musical composition. It appeared that conducting kinematics may bond with musical compositional structure. In a musical performance context, conductors organise their conducting movement in order to communicate specific musical compositional features and interpretations. To further understand how specific kinematic features connect with particular compositional structures, in the next chapter, deviation points of kinematic variables, i.e. time points when movement showed prominent kinematic features, were identified and then matched with compositional features in temporal, melodic, and dynamic aspects.

3.4. Summary of findings

The main findings of baton tip kinematic analyses are summarised in the order of four research questions concerning kinematic features in three musical excerpts, and similarities of kinematic time-series patterns.

3.4.1 Conducting movement's kinematic features in three musical excerpts

Regarding research question 3.1, it was found that conductors' baton tip movements possess particular linear kinematic features corresponding to each musical composition. Results in descriptive analyses and ANOVAs showed that: 1) Conductors' baton tip moved the greatest distance per musical bar when conducting Dvořák, and the shortest distance when conducting Bartók, which could be explained by diverse time spans within musical bars when conducting different musical excerpts. 2) Conductors' baton tip moved in highest speed, acceleration and jerk when conducting Bartók, whereas the three kinematic values were medium in Mozart and lowest in Dvořák respectively. 3) Significant differences were found for all kinematic variables between Musical excerpts using ANOVAs and Friedman Tests, supported by moderate effect sizes. In all pairwise comparisons, only the speed data between Mozart and Dvořák, and the jerk data between Mozart and Bartók were not significantly different. These results are in accordance with the selection of diverse styles of three music compositions. 4) No significant effect of Trial number was found for all kinematic variables using ANOVAs, which indicated that conductors' conducting kinematics were consistent across trials within the same excerpt of music.

3.4.2 Conducting movement's kinematic time-series similarities

Regarding research question 3.2, it was found that linear kinematic time-series patterns of conductors' baton tip movement were highly similar across performances of the same musical composition. Results of cross-correlations showed that for time-warped data, conductors' baton tip kinematic patterns had moderate coefficients ranging from 0.485 to 0.780 in cross-correlations, whereas for bar data, kinematic patterns had fairly high coefficients between 0.876 and 0.953. Higher coefficients for bar data are the results of smoother curves of bar means, which eliminated local fluctuations in time-warped data curves.

Regarding research question 3.3, it was found that when comparing three musical compositions, linear kinematic time-series patterns of conductors' baton tip movement showed different extents of similarity. Results of descriptive analyses and ANOVA of cross-correlation coefficients showed that: 1) for time-warped data, conductors' baton tip had the most similar speed patterns when conducting Dvořák, whereas their baton tip had the most similar acceleration and jerk curves when conducting Bartók. For bar data, Dvořák possessed the highest similarity for all kinematic time-series patterns in three musical excerpts. 2) One-way ANOVA (Music) and Friedman's Tests revealed that conductors' movement similarity (i.e. cross-correlation coefficients) had significant differences in all kinematic patterns for the three Musical excerpts, for both time-warped data and bar data, supported by moderate effect sizes.

Regarding research question 3.4, it was found that when conducting the same musical composition, linear kinematic time-series patterns of conductors' baton tip movement are more consistent with repeated performances conducted by themselves, compared to performances conducted by the other conductors. Results of descriptive analyses and *t*-tests on cross-correlation coefficients showed that: 1) coefficients for trial pairs conducted by the same conductor were higher than coefficients for trial pairs conducted by different conductors. 2) *t*-tests (Within-conductor coefficient versus Between-conductor coefficient) and Mann-Whitney *U* Tests revealed that within-conductor coefficients were significantly different from between-conductor coefficients, for all kinematic patterns, for both time-warped data and bar data, in all musical excerpts, supported by moderate to large effect sizes.

Overall, evidence presented in this chapter demonstrates that conductors' baton tip movements showed particular linear kinematic features corresponding to each musical composition. The time-series patterns of these linear kinematic features were highly consistent across repeated performances of the same musical composition, particularly for performances conducted by the same conductor. These findings supported conductors' statements in interviews and findings in Chapter 2 that conducting movement is highly dependent on compositional structure. To understand how detailed movement features attach to particular compositional elements, kinematic variations in conducting movement will be explored in the next chapter. Movement kinematic deviations found in conducting performances will then be connected with compositional elements and conductors' interpretational opinions.

Chapter 4: Connecting conducting movement kinematic variability to compositional features

4.1. Introduction

The previous chapter examined conducting movements across musical compositions and between individual conductors. It was found that baton tip movements showed distinct kinematic features corresponding to each musical composition, and kinematic patterns of baton tip movement were highly consistent when conducting the same composition. These findings suggested that conducting movement is clearly dependent on musical composition in real performances, which is in accordance with the dominant ideology of conducting movement stated in conducting educational manuals (see Table 1.1 in Chapter 1). As supported by the conducting movement emblem collections in conducting educational manuals and the study conducted by Benge (1996), prominent conducting movement should carry important information regarding compositional features and the conductors' musical interpretations. From this viewpoint, movement variability appears to be an important aspect to be investigated in conducting.

Conducting movement shows repetitive and cyclical beating patterns corresponding to the metrical structure of the composition. However, according to conductors' opinions in interviews (Chapter 2), they intentionally employ particular movements, which are different from the regular beating movement, to communicate prominent compositional features they would like to emphasise in performance. The aim of this chapter is to investigate how it is that conducting movement variations deviating from regular beating movement to reflect specific compositional elements and interpretational locations in performed musical works in actual conducting performance.

In order to discuss conducting movement with reference to specific musical instances, time-points when conducting kinematic deviations occur (i.e. when movements show prominent kinematic features and deviate from the regular repetitive movement pattern) have to be identified. Since no existing method is available in current musical movement literature to identify movement kinematic deviations, this study developed a new and original analysis approach according to statistical principles— described as Deviation Point Analysis (DPA) in this thesis. In DPA, thresholds are set based on the data's standard deviation, and kinematic deviation points (DPs) can thus be identified. In this study, DPA was employed to detect deviations in conductors' movement, as well as time-points when high movement variability shows between individual conductors. Main research questions in this chapter are therefore:

4.1 Do conductors' movement kinematic deviations correspond to specific compositional features in three musical excerpts?

4.2 Do more stable and less stable kinematic deviations in conducting movement reflect different compositional features?

4.3 Do time-points when conductors' movements have higher variability correspond to specific compositional features?

To detect DPs having prominent kinematic features and associate these with compositional features, DPA for each conducting trial was performed to examine Question 4.1. In order to examine whether these DPs were stable within the same conductor's conducting, DPA for the mean curve of three trials conducted by the same conductor were performed, and then compared with the results from each trial to examine Question 4.2. DPs showing high kinematic variability between conductors were identified using DPA to examine Question 4.3.

4.2. Methods

See Chapter 3, section 3.2.2 for experimental design, section 3.2.3 for ethics, section 3.2.4 for recruitment, section 3.2.5 for participants, section 3.2.6 for data collection procedure, section 3.2.7 for data processing.

4.2.1 Statistical analysis

4.2.1.1 Data preprocessing

To make kinematic data comparable across trials, all data were transferred into standard scores prior to DPA. *Z*-scores of the data for each conducting trial were taken by the trial's mean and standard deviation using Equation 4.1, Equation 4.2, and Equation 4.3.

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad \text{Equation 4.1}$$

$$SD = \left(\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n-1}\right)^{\frac{1}{2}} \qquad \text{Equation 4.2}$$

$$x_{norm} = \frac{(x_i - \bar{x})}{SD} \qquad \text{Equation 4.3}$$

where $\bar{x}$ is the mean for i samples in the trial, SD is the standard deviation for i samples in the trial, and x_{norm} is the standardised value for the ith sample.

4.2.1.2 Deviation Point Analysis (DPA)

In movement analysis, continuous methods can reveal movement patterns through time, which cannot be seen in discrete analysis methods (Hamill et al. 2000; Stergiou 2004). Considering that conducting movement is highly time-dependent, it is advantageous to employ continuous methods to explore conducting movement, and thus to identify time-points when movement kinematics show prominent features, which can be matched with compositional features in the musical score. **Deviation Point Analysis (DPA)** in this thesis applied a series of continuous methods to detect kinematic **Deviation Points (DPs)** in three types of data: 1) each conducting trial; 2) each conductors' average curves (of the three trials conducted by the same conductor); 3) between-conductor variability, i.e. kinematic standard deviations between conductors.

In continuous analysis of movement, curve-average method and point-by-point method are the two main methods to compute standard deviation. The curve-average method (Equation 4.4). computes the standard deviation across all samples in each trial, which produces one single value to represent the trial's within-trial variability, whereas the point-by-point method (Equation 4.5 and Equation 4.6) computes the standard deviation across different trials at each time-point, which produces a continuous series of standard deviation to represent the between-trial variability at each time-point (Stergiou 2004). This thesis applied both methods to identify kinematic DPs. For the first and second types of data— analyses of each trial, and analyses of each conductor's average curve— the single value of standard deviation produced by the curve-average method for each trial/ conductor was used to set up the threshold for identifying DPs, whereas for the third type of data— analyses of between-conductor variability— the point-by-point method was used to produce between-conductor standard deviation, and the curve-average method was then used to compute the standard deviation of movement variability to set up the threshold for identifying DPs when conductors' movement had high between-conductor variability.

$$SD_{avg} = \left[\frac{\sum_{i=1}^{k} SD_i^2}{k}\right]^{\frac{1}{2}}$$ Equation 4.4

$$M_i = \frac{\sum_{j=1}^{n} x_{ij}}{n}$$ Equation 4.5

$$SD_i = \left[\frac{\sum_{j=1}^{n} (x_{ij} - M_i)^2}{n-1}\right]^{\frac{1}{2}}$$ Equation 4.6

where SD_{avg} is the average of standard deviation across all k samples, SD_i is the standard deviation value for the ith sample, M_i is the mean for ith sample, x_{ij} is the data value for the ith sample in jth trial, and n is the number of trials.

It should be noted that in this study, continuous methods were applied to examine bar data instead of time-warped data (see Table 3.3 in Chapter 3). This had the virtue of avoiding local kinematic fluctuations and exploring kinematic deviations at a higher musical metrical level (musical bar), which could then be matched with compositional features identified in the score. Even though the continuous kinematic data set was transformed into discrete data points representing movement features within per musical bar in this case, bar data still possess the characteristics of time-series data[3], which are suitable for applying continuous methods.

In the analyses for the first and second types of data— analyses of each trial, and analyses of each conductor's average curve, the upper and lower thresholds of the mean ± [1.96 × standard deviations (curve-averaged)] were set to identify DPs, based on the fact that 95% of data points should be included in this range and 5% of data points will be identified if the data are normally distributed. All data taken for analysis were *z*-scores of the original data set, which indicated that means were 0 and thresholds were ±1.96 in all cases. This procedure yielded 72 figures for trial analyses [6 conductors × 4 kinematic variables (distance, speed, acceleration, jerk) × 3 musical excerpts; 3 trials in each figure, see Figure 4.1 as an example], and 12 figures for the conductor's average curve analyses (4 kinematic variables × 3 musical excerpts; 6 conductors in each figure, see Figure 4.2 as an example). For the third type of data— analyses of between-conductor variability, standard deviations between conductors were computed using the point-by-point method. The continuous movement variability was then plotted using the mean curve of all conductors ± [1.96 × standard deviations (point-by-point)], which produced 12 figures in total (4 kinematic variables × 3 musical excerpts, see Figure 4.3 as an example). DPs of between-conductor variability were identified using the threshold of mean standard deviation (curve-averaged) ± [1.96 × standard deviations (curve-

[3] Taking into account the temporal trait of the bar data, bar data can be considered as time-series data with a larger time window (per musical bar), compared to time-warped data.

averaged) of between-conductor standard deviations (point-by-point)], which produced 12 figures in total (4 kinematic variables × 3 musical excerpts, see Figure 4.4 as an example).

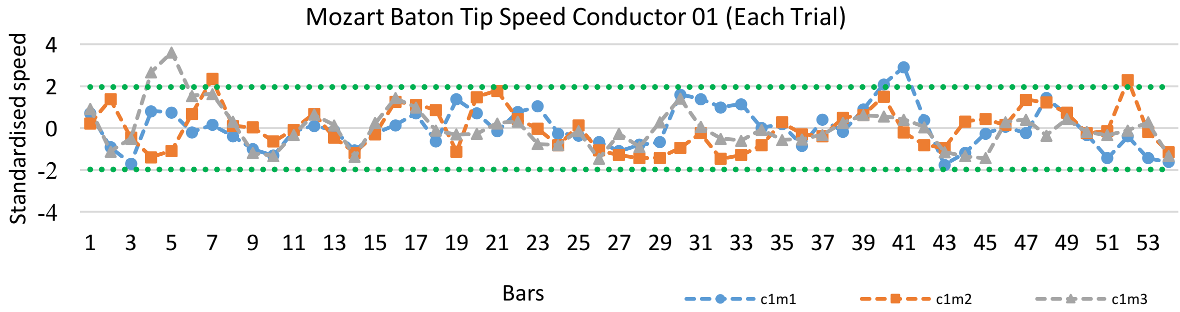


Figure 4.1 Example of deviation point analysis of individual trials

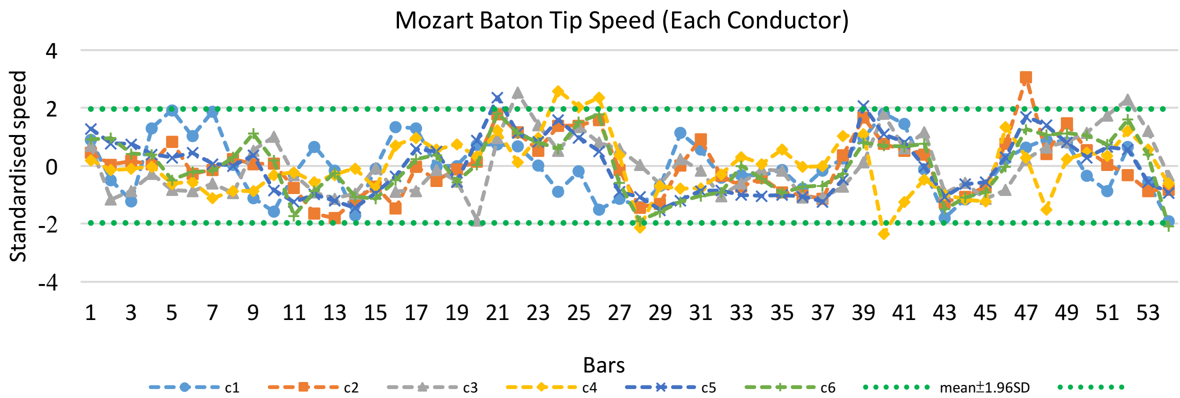


Figure 4.2 Example of deviation point analysis of individual conductors' average curve

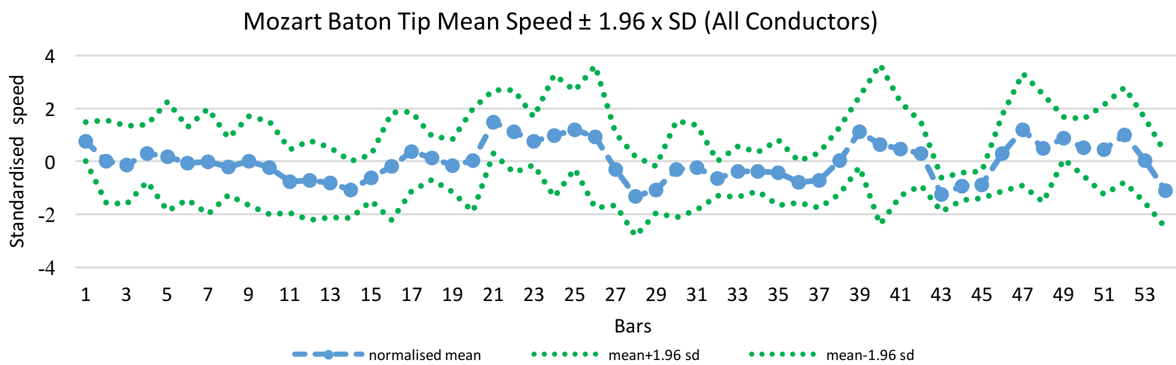


Figure 4.3 Example of between-conductor variability

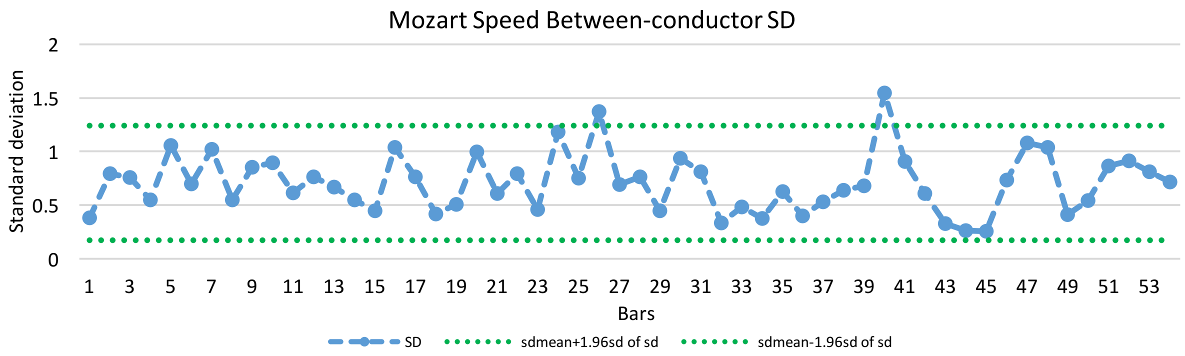


Figure 4.4 Example of deviation point analysis of between-conductor variability

Following DPA of these three types of data, musical bar numbers identified as DPs were summarised (see Figure 4.5 as an example) and were compared with compositional structures.

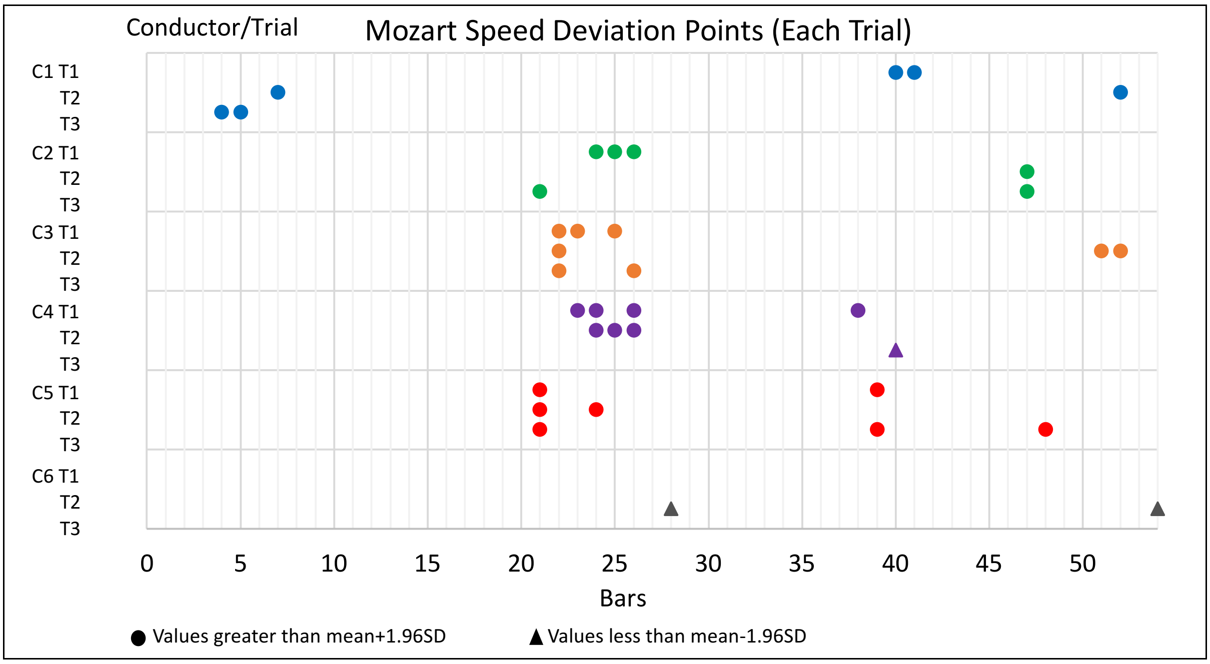


Figure 4.5 Example of deviation point summary

In the first and second types of analysis—analyses of each trial and analyses of each conductor's average curve, two types of kinematic DP identified using DPA were discussed:

Upper Deviation Point (UDP): a kinematic data point passing the upper threshold of the data mean + [1.96 × standard deviations (curve-average)];

Lower Deviation Point (LDP): a kinematic data point passing the lower threshold of the data mean − [1.96 × standard deviations (curve-average)].

In the third type of analysis— analyses of between-conductor variability, a DP with **High movement variability** was defined as: a data point when conductors' kinematic variability, i.e. between-conductor standard deviation (point-by-point), passing the upper threshold of [the mean between-conductor standard deviation (point-by-point)] + [1.96 × standard deviation (curve-average) of between-conductor standard deviation (point-by-point)]. There was no data point passing the lower threshold of movement variability and being identified as DP with low movement variability for all kinematic variables in all musical excerpts.

All identified kinematic DPs found in conducting movements were then compared with conductors' stated interpretational locations in interviews. The discussion in this chapter followed the convention established in Chapter 3 regarding kinematic variables (section 3.2.7), the definition of musical bar (section 3.2.7), and the manner with which to refer to musical excerpts and participants (section 3.2.8).

4.3. Results

On account of the fact that the three musical excerpts by Mozart, Dvořák and Bartók are of different time length and have different numbers of musical bars, the DPs were identified from different sample sizes, and the results for different musical excerpts are thus not directly comparable. For this reason, the results of DPA are discussed in the order of musical excerpts. For each musical excerpt, results are presented for three types of analysis: 1) analyses of each trial; 2) analyses of each conductor's mean curve (of three trials); and 3) analyses of between-conductor variability. These results from DPA were then matched with conductors' intended interpretational locations reported in interviews. The results of each musical excerpt are then followed by a general discussion of findings from the three musical excerpts.

For the first type of analysis— analyses of each trial— Upper Deviation Points (UDPs) and Lower Deviation Points (LDPs) for four kinematic variables were compared and discussed. To further explore the connection between these Deviation Points (DPs) and compositional features, the statistics of UDPs and LDPs are then presented by temporal order, together with corresponding compositional features.

To examine whether these kinematic DPs identified from each trial were consistent across trials, and thus could be considered as typical kinematic features of each participant's conducting, the second type of analysis was performed—analyses of each conductor's mean curve (of three trials). Identified UDPs and LDPs from each conductor's mean curve were compared with the results in each trial, and were discussed together with compositional features. By comparing kinematic DPs identified from these two analysis methods, it was possible to examine whether more stable DPs correspond to higher level or more important compositional features, which are indicated by musical score analysis or conductors' interpretational comments, whereas less stable DPs reflect lower level or less important musical structures. DPs identified from each trial represented distinctive kinematic features in each trial, whereas DPs identified from each conductor's average curve were more consistent across trials. DPs consistently identified from both methods were the most stable ones, and thus were regarded as typical kinematic features of each conductor's conducting; DPs identified from trial only or from conductor's mean curve only were considered as less stable deviations; DPs with opposite deviation types (UDP and LDP) in two analysis methods or in different conductors' conducting were considered as the most unstable kinematic deviations.

The second type of analysis aimed to examine whether kinematic DPs were consistent within each conductor's conducting, whereas the third type of analysis explored the variability across different conductors' conducting, by examining between-conductor point-by-point standard deviations. DPs which showed high kinematic variability between conductors (there was no data points passing the lower threshold of variability in all musical excerpts) were presented and compared with the results in the first and second types of analysis. High variability between conductors indicates that individual conductors tended to employ different conducting strategies compared to one another to communicate compositional features, no matter whether each conductor's kinematic features were consistent within their own conducting or not.

The results from three types of DPA were then compared with conductors' opinions collected from interviews. In interviews, conductors specified interpretational locations they intended to highlight when conducting three musical compositions (section 2.3.2), and described the body movements they used to communicate these musical interpretations (section 2.3.3). Prominent baton tip movements (kinematic DPs), which were different from regular beating patterns, were identified from their conducting using DPA. These kinematic DPs shown in conducting movement are compared with conductors' stated interpretational intentions reported in interviews.

It should be noted that according to conducting principles (e.g., Green, Gibson and Malko 2004; Rudolf 1995) and conductors' opinions in interviews (Chapter 2), features of compositional structure should be instructed by conducting movement prior to the time-point when the compositional feature occurs. Therefore, in the discussion, bar numbers of compositional features include the bar before the compositional feature occurs.

4.3.1 Deviation Point Analyses in Mozart

4.3.1.1 Kinematic deviation points in relation to compositional features: Deviation Point Analyses of individual trials in Mozart

DPs of four kinematic variables— distance, speed, acceleration, and jerk— identified from trials conducting Mozart are summarised in Figure 4.6, with complete analyses presented in Appendix 6. The statistics of UDP and LDP are showed in Figure 4.7. As can be observed from Figure 4.7, comparing the four kinematic variables, conductors tended to possess more UDPs for speed and jerk, and fewer UDPs for distance and acceleration in Mozart. Comparing six conductors, C6 had the least UDPs, with only a few deviations for acceleration and jerk. As for LDPs, only a few deviations for distance and speed were shown in Mozart.

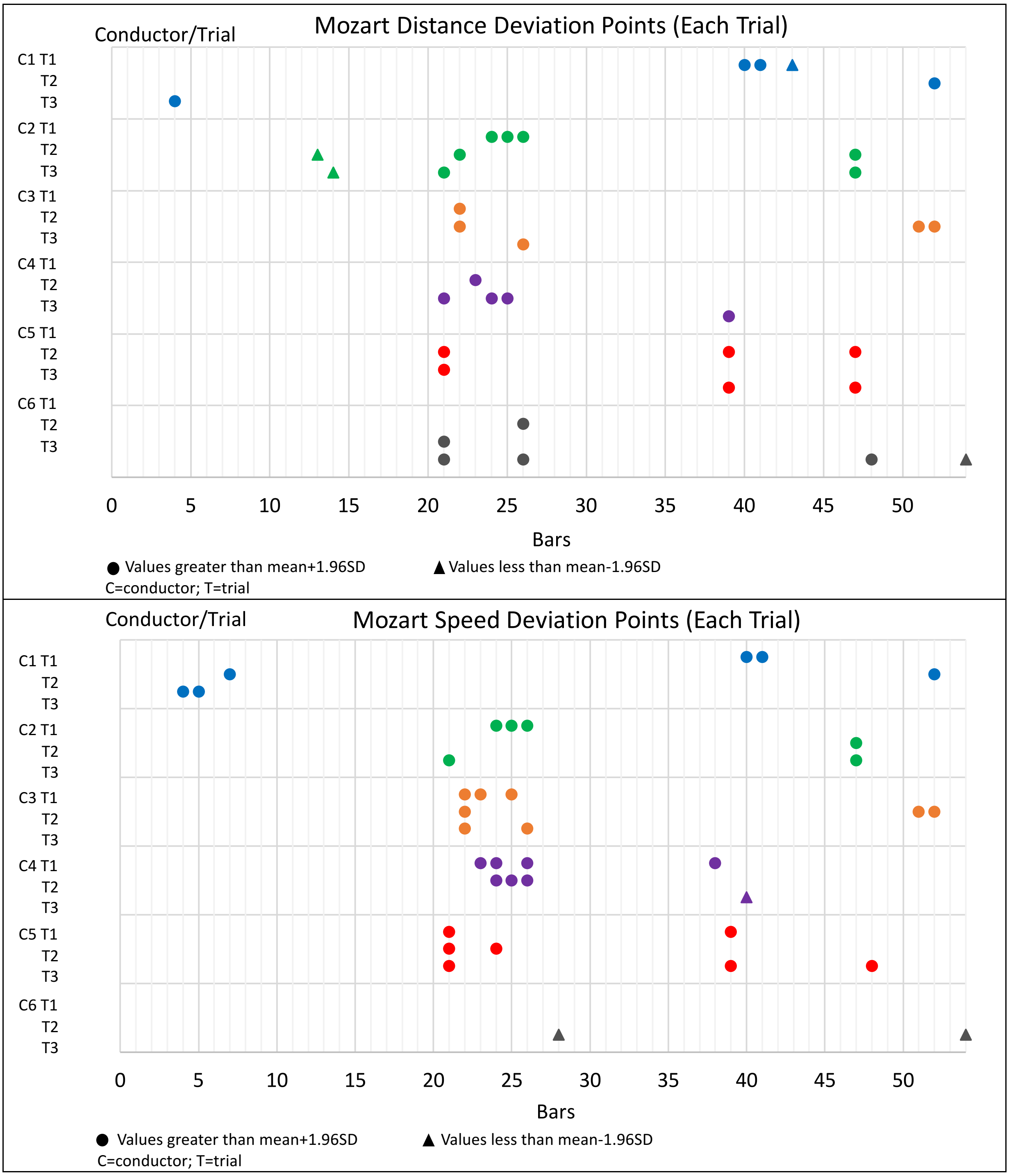


Figure 4.6 Deviation points of each trial for four kinematic variables in Mozart

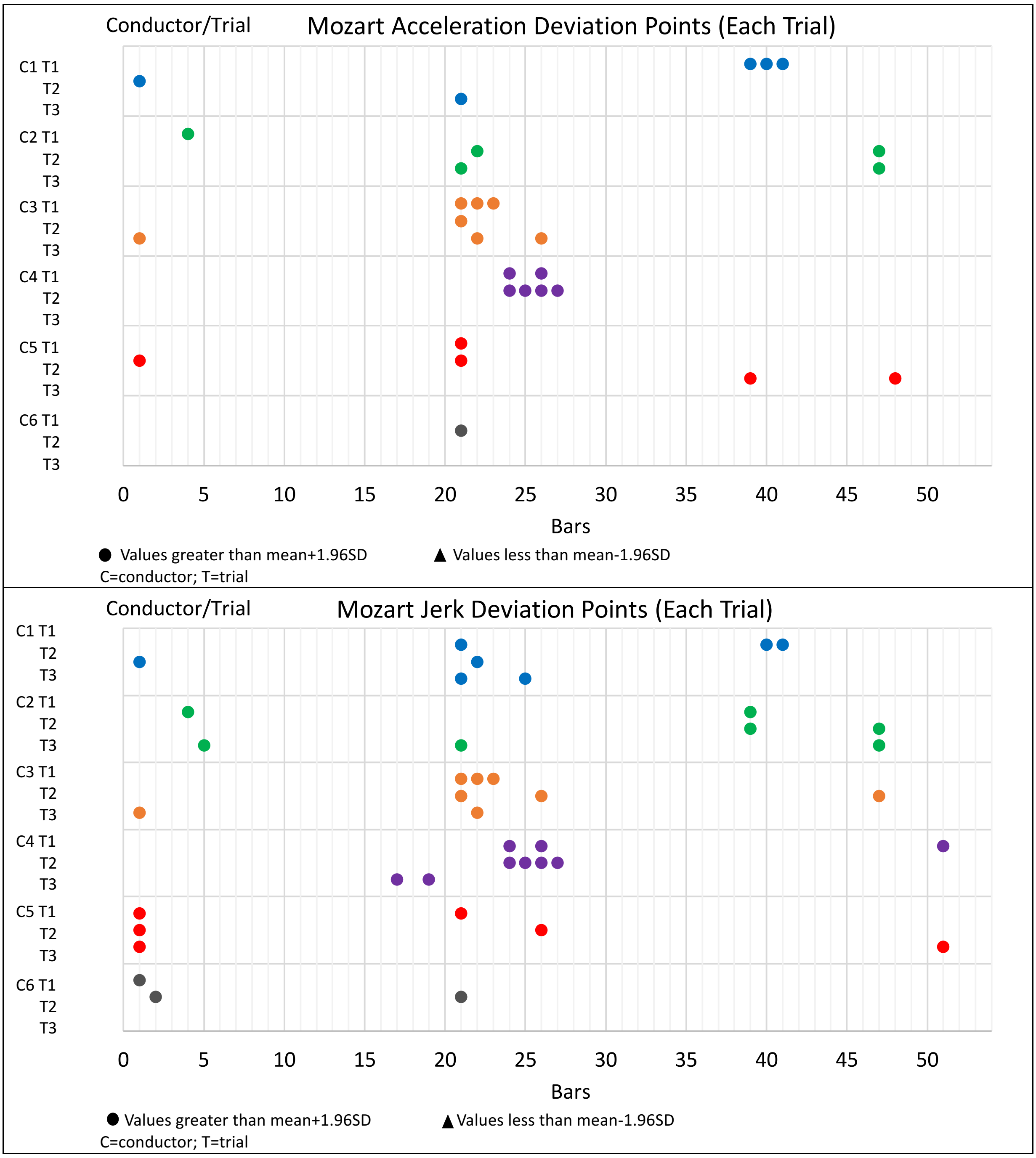


Figure 4.6-2 Deviation points of each trial for four kinematic variables in Mozart (continued)

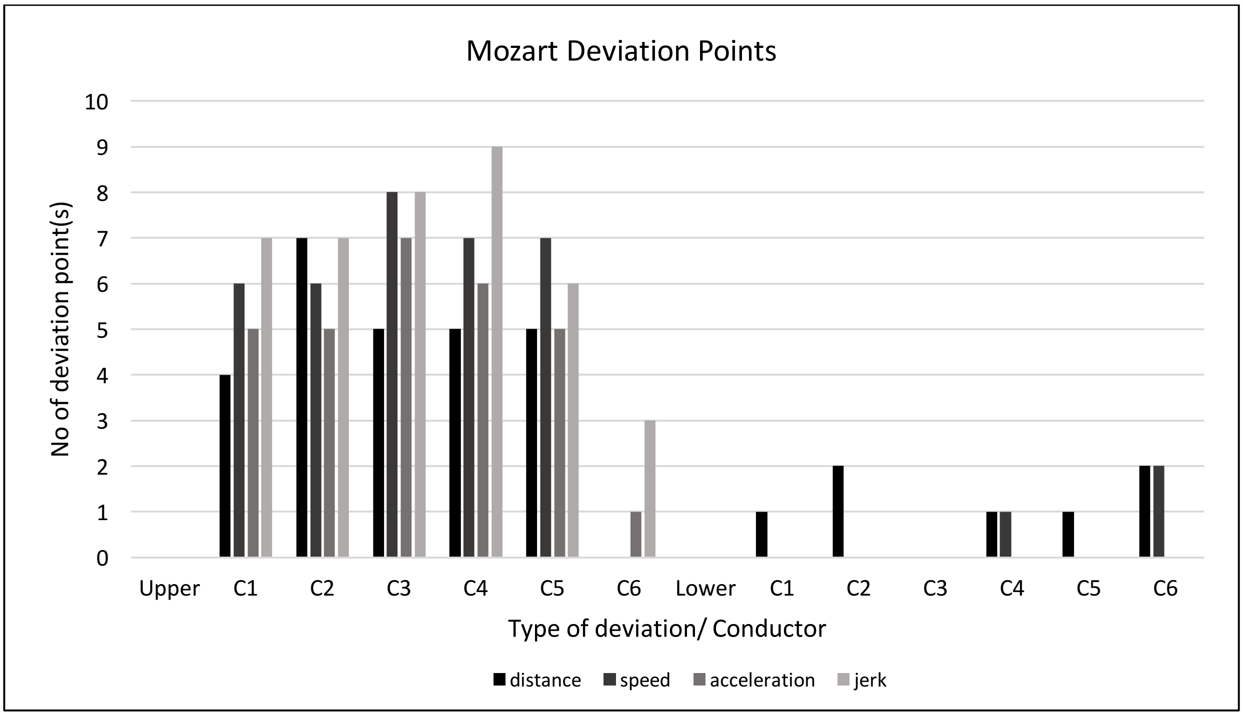
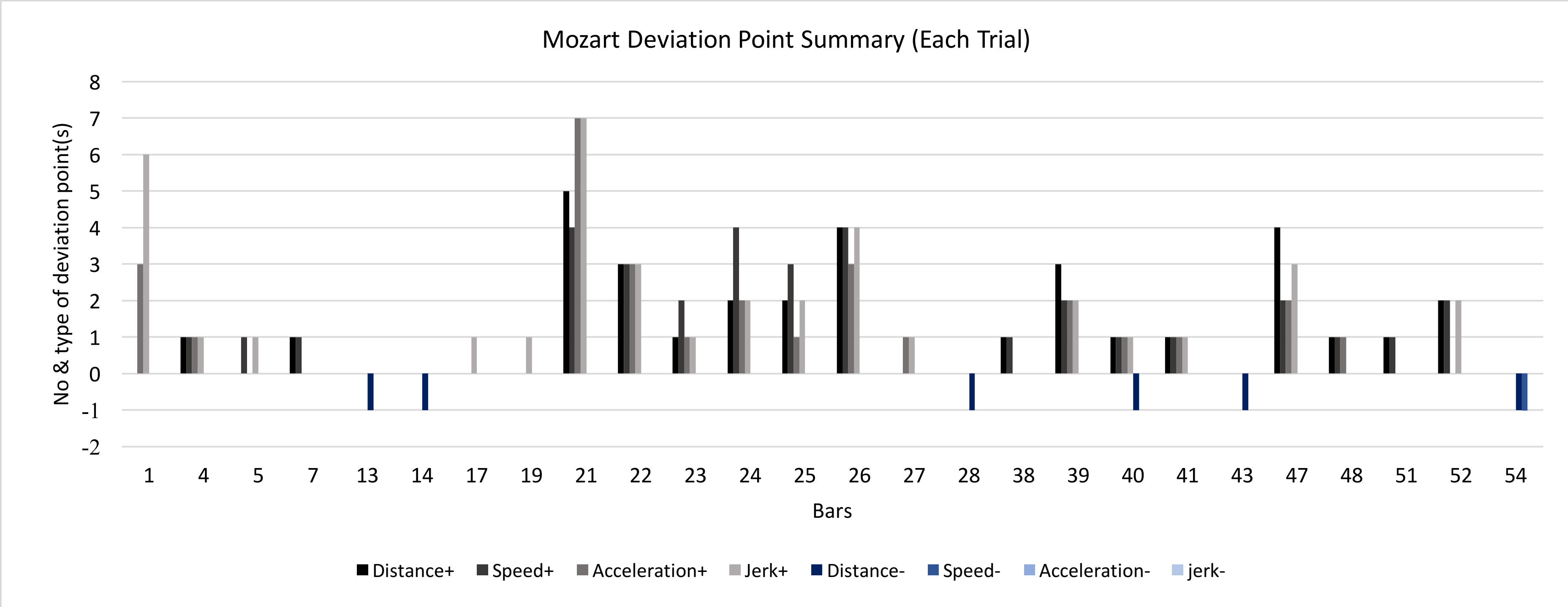


Figure 4.7 Statistics of upper deviation points and lower deviation points in Mozart

The statistics of UDPs and LDPs are presented by temporal order in Figure 4.8, together with the summary of compositional structures. The tendency can be seen from Figure 4.6 that identified UDPs concentrated between bars 21-27, which can be confirmed in Figure 4.8. All six conductors had UDPs between bars 21-27 (Example 4.1). The concentration of UDPs coincided with the combination of melodic, rhythmic and dynamic features in music. The upward melodic line starting from bar 20 leads to the melodic climax in bar 22, companied with *crescendo* from *piano* to *forte*. Syncopation in bars 24-25 sustains the melodic peak till the melody goes downward in bar 27.



Bar	1	4-5	7	17, 19	21-27	28	38-41	47-48	51-52	54
Conductor	1,3,5,6	1,2	1	4	1,2,3,4,5,6	6	1,2,4,5	2,3,5	1,3,4,5	6
Music feature	beginning	rhythmic change	(accent)	(preparation of) sf	upward melody melodic climax syncopation crescendo dynamic climax	new theme f→ p	counterpoint melody p→ f	counterpoint melody p→ f	trill	f→ p

Figure 4.8 Kinematic deviation points and summary of musical features in Mozart

Example 4.1 Mozart, *Serenade in G major*, K. 525, 1st movement, bars 14-27.

In general, it can be observed from the summary of Figure 4.8 that UDPs of movement kinematics often corresponded with compositional features including the beginning of new rhythmic pattern in bar 5 (Example 4.2), upward melodic line and melodic climax in bars 21-27, counterpoint melodies by viola and cello in bars 39-41 and bars 47-48 (Example 4.3), special technique such as *trill* in bars 51-52 (Example 4.3), special rhythm such as syncopation in bars 24-25 (Example 4.1), dynamic change such as *crescendo* in bar 21 (Example 4.1) and the switch from *piano* to *forte* in bar 39 and bar 47 (Example 4.3). Conversely, the dynamic switch from *forte* to *piano* in bar 28 (Example 4.4) and bar 54 (Example 4.3) coincided with LDPs of movement.

Example 4.2 Mozart, *Serenade in G major*, K. 525, 1st movement, bars 1-6.

Example 4.3 Mozart, *Serenade in G major*, K. 525, 1st movement, bars 35-55.

Example 4.4 Mozart, *Serenade in G major*, K. 525, 1st movement, bars 28-34.

4.3.1.2 Within-conductor stability of kinematic deviation points: Deviation Point Analyses of individual conductor's mean curves in Mozart

To examine whether these kinematic DPs identified from each trial are stable across trials, and thus could be considered as stable deviations in each conductors' conducting, DPA were performed on each conductor's averaged curve of three trials conducting Mozart. Analyses of each conductor's mean curve are presented in Figure 4.9, with DPs identified from each conductor's mean curve summarised in Figure 4.10. The statistics of UDPs and LDPs in conductor's mean curves are presented by temporal order in Figure 4.11.

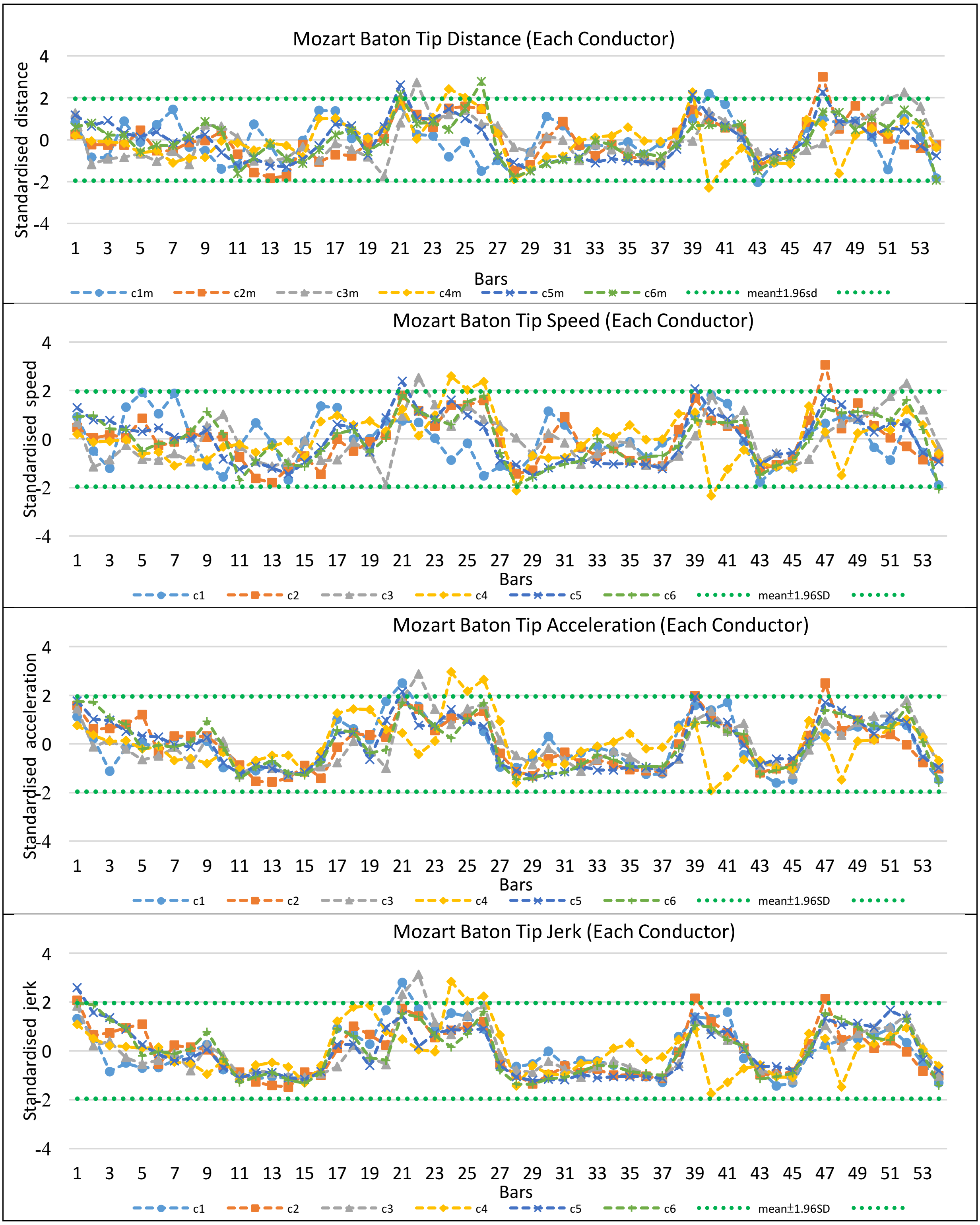


Figure 4.9 Deviation point analyses of each conductor's mean curve of three trials conducting Mozart

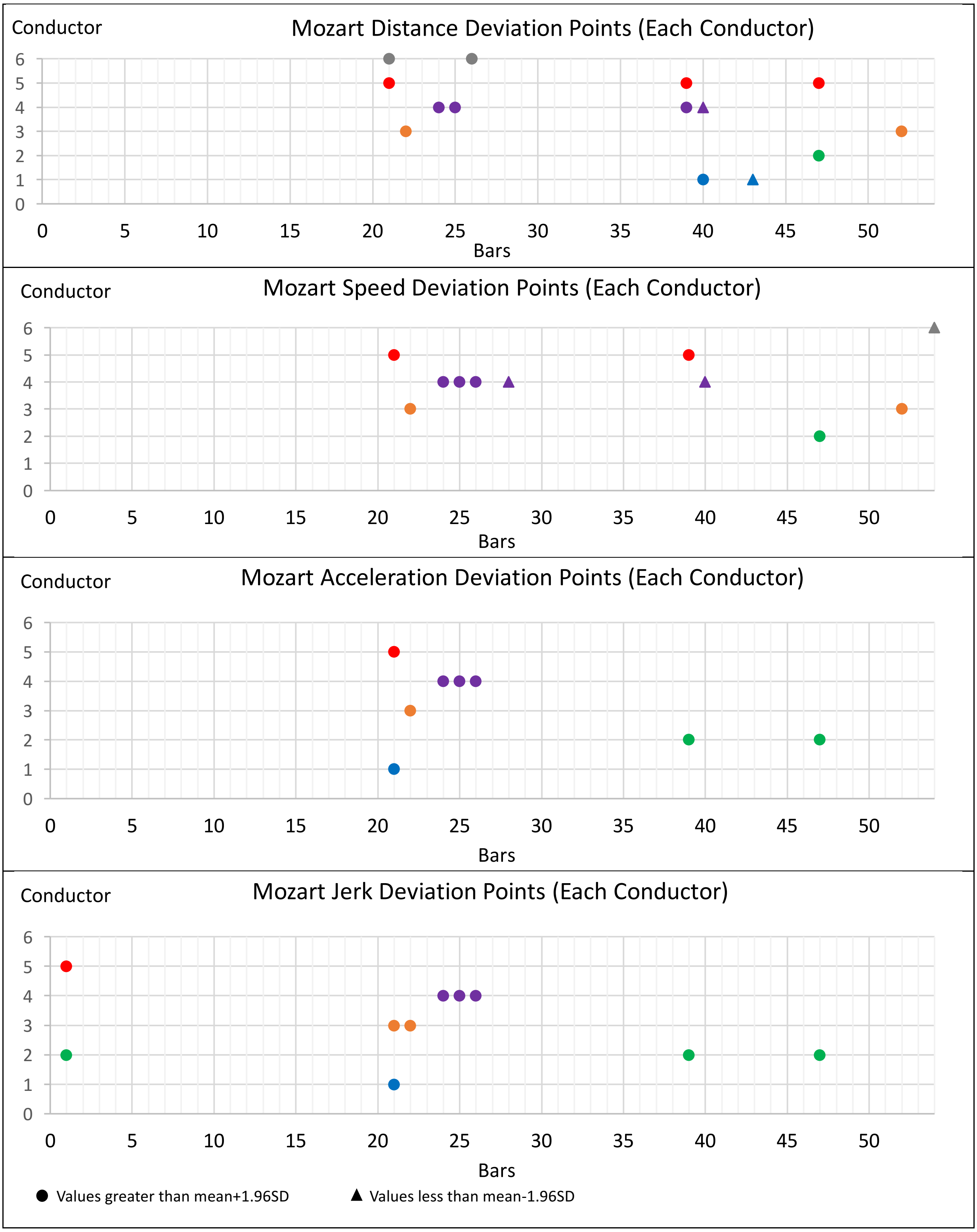
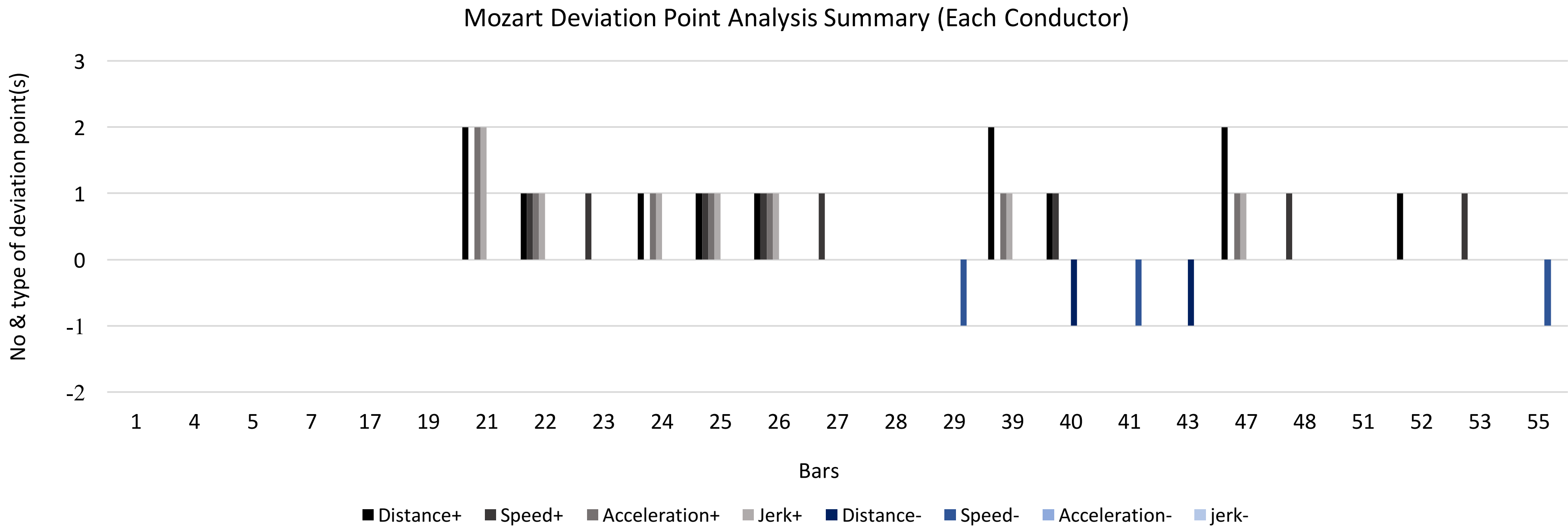


Figure 4.10 Deviation points of each conductor's mean curve for four kinematic variables in Mozart



Bar	1	4-5	7	17, 19	21-27	28	38-41	47-48	51-52	54
Conductor	1,3,5,6	1,2	1	4	1,2,3,4,5,6	6	1,2,4,5	2,3,5	1,3,4,5	6
Music feature	beginning	rhythmic change	(accent)	(preparation of) sf	upward melody melodic climax syncopation crescendo dynamic climax	new theme f→ p	counterpoint melody p→ f	counterpoint melody p→ f	trill	f→ p

Figure 4.11 Statistics of deviation points of conductor's mean curves in Mozart

The comparison can be made between DPs in each trial (Figure 4.8) and DPs in each conductor's mean curve (Figure 4.11), and the similarities and differences are summarised in Figure 4.12. It appeared that the most stable DPs, i.e. DPs identified from both individual trials and conductors' averaged curves (the first row 'Agree' in Figure 4.12), tended to agree with compositional events that conductors explicitly intended to highlight most, according to the number of comments they gave in interviews. In interviews, conductors emphasised the upward melody reaching the climax, combined with *crescendo* and syncopation in bars 21-26 (Example 4.1). The dynamic contrasts from *piano* to *forte* in bar 39 and bar 47 (Example 4.3) were also considered as important features in Mozart's excerpt. Less stable deviation points identified from conductor's mean curves only or from trials only (the second row 'Conductor only' and third row 'Trial only' in Figure 4.12) tended to reflect more local compositional features including the introduction of new rhythm (e.g., bar 5, Example 4.2) and musical accent (e.g., bar 19, Example 4.1). There was only one unstable point having opposite deviation types (UDP and LDP) in two analysis methods or between conductors (the fourth row 'Disagree' in Figure 4.12).

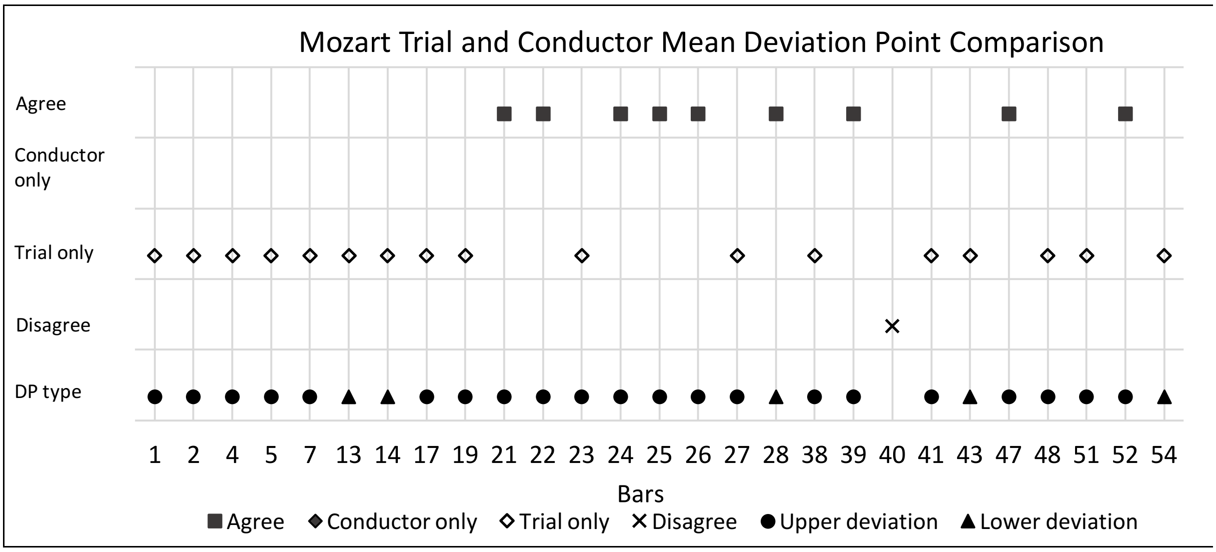


Figure 4.12 The comparison of deviation points in trials and in conductor's mean curves in Mozart

4.3.1.3 Between-conductor kinematic variability: Deviation Point Analyses of between-conductor standard deviation in Mozart

DPA on trials and on conductor's mean curves were used to examine the within-conductor consistency of movement kinematics, whereas the DPA on between-conductor kinematic standard deviation were used to investigate the movement variability between conductors.

Analyses of between-conductor kinematic variability are presented in Figure 4.13, with DPs with high between-conductor variability were identified in Figure 4.14. These DPs with high between-conductor variability (from Figure 4.14) were compared with DPs from trials and conductor's mean curve analyses (Figure 4.12) and are summarised in Figure 4.15.

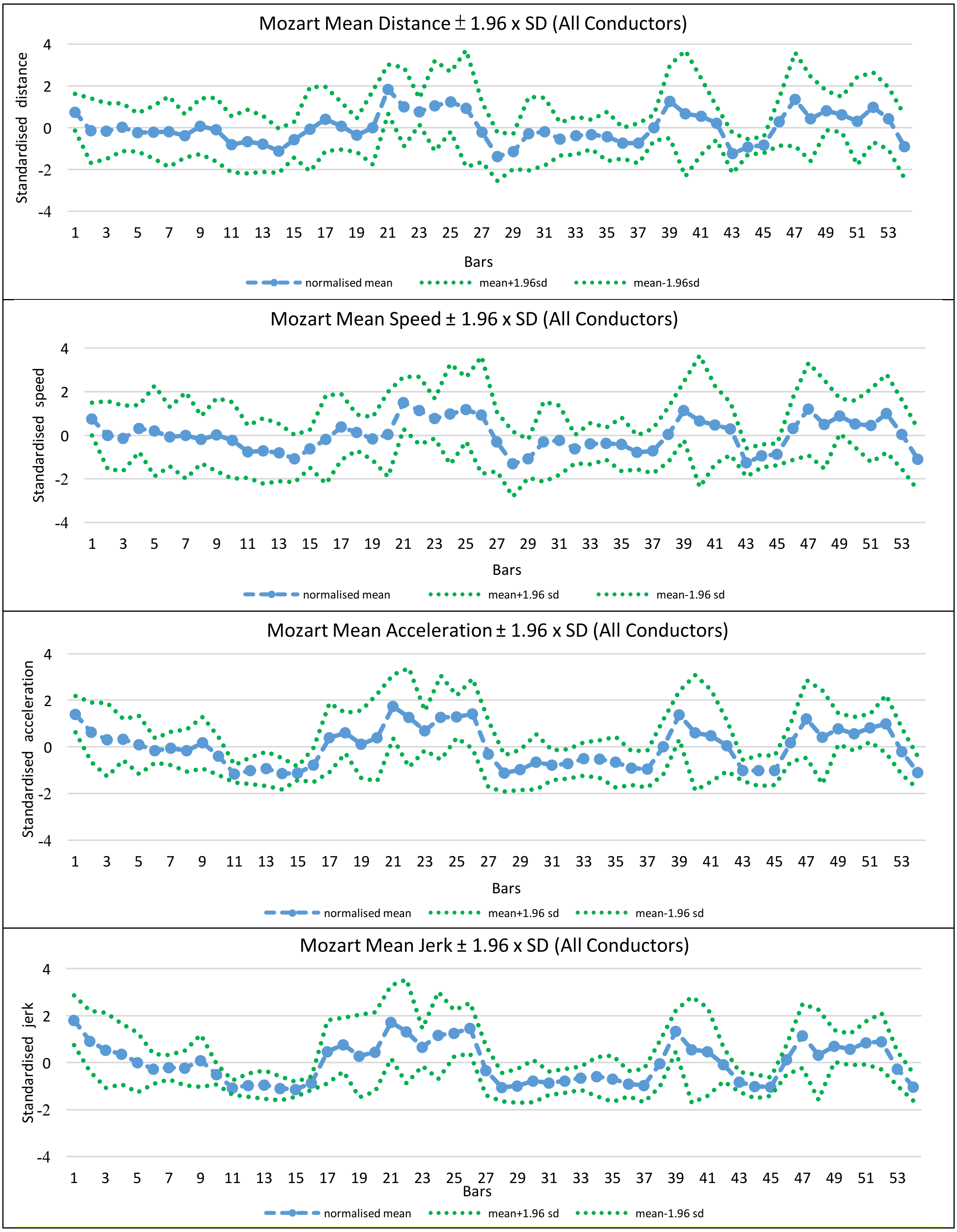


Figure 4.13 Between-conductor kinematic variability in Mozart

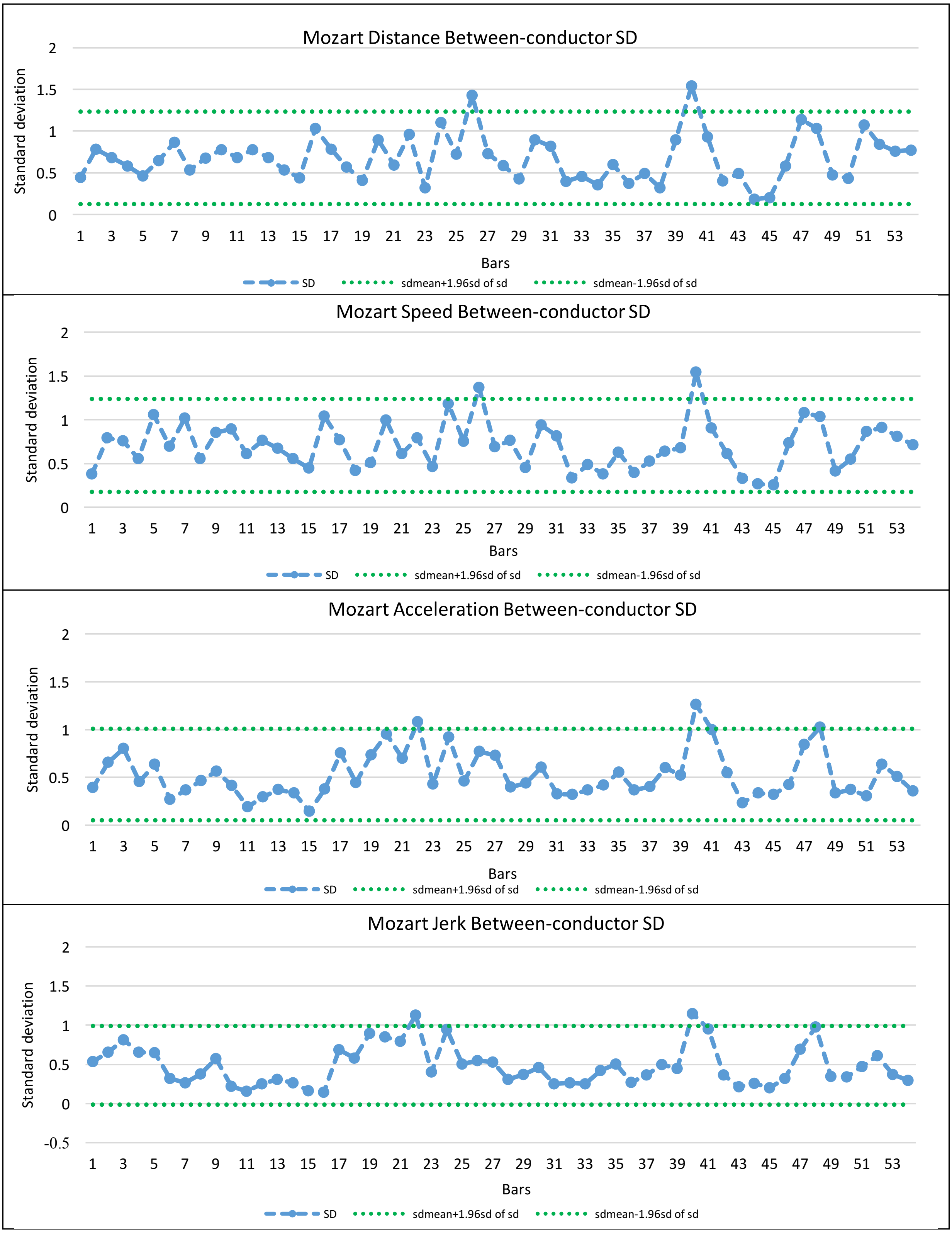


Figure 4.14 Deviation point analysis of between-conductor kinematic variability in Mozart

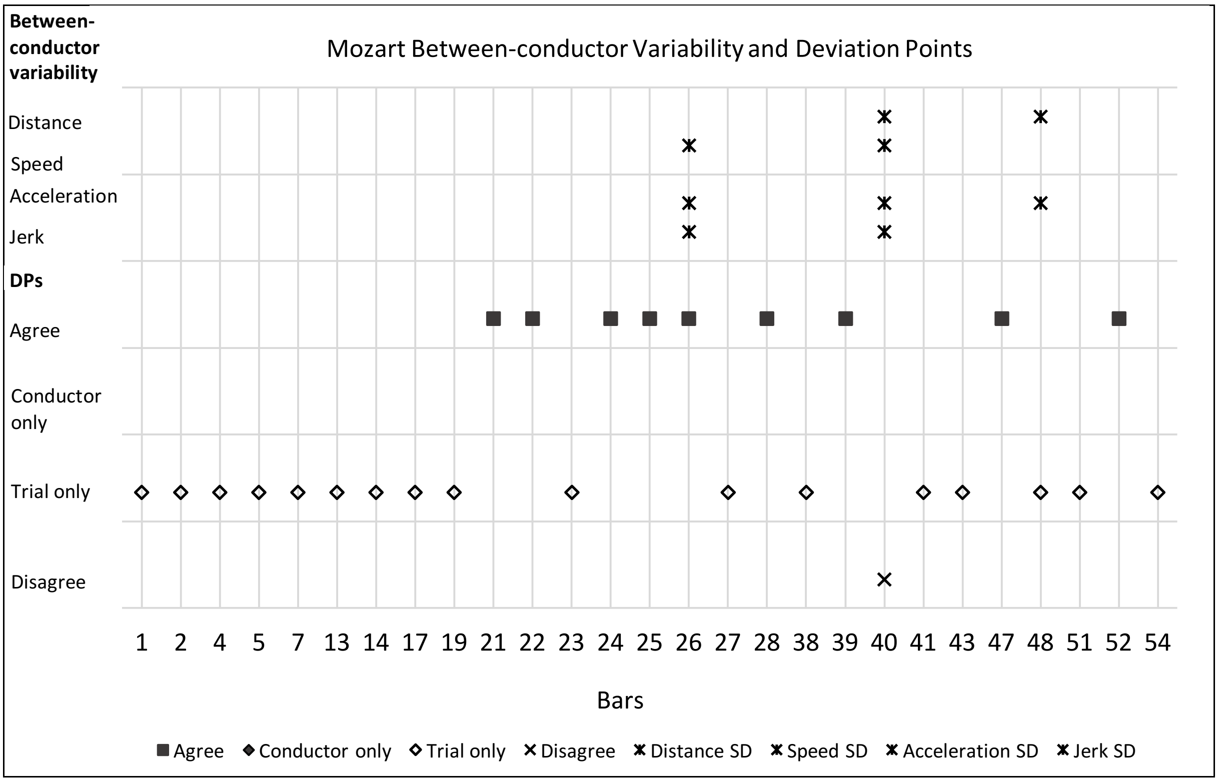


Figure 4.15 The comparison of between-conductor variability deviation points and within-conductor deviation points in Mozart

High variability indicates that conductors tended to have different movements compared to one another, no matter whether their own movements possess distinctive kinematic deviations at those time-points. It appeared that conductors' movements tended to be more flexible after highlighted musical events, For instance, in bar 26 (Example 4.1) after the melodic climax and syncopation, and in bar 40 and bar 48 (Example 4.3), which are the bars after the music switches from *piano* to *forte*. The observation can be made that conductors employed more similar movement to communicate targeted compositional structures and the variability of movement tended to increase after these musical events.

4.3.1.4 Conducting kinematic deviations in relation to interpretational locations in Mozart

These kinematic DPs found in conducting movement were compared with conductors' stated interpretational intentions reported in interviews and summarised in Table 4.1 and Figure 4.16 (based on results in Table 2.9 in Chapter 2; Figure 4.8, Figure 4.11, and Figure 4.15 in Chapter 4). It can be observed from Table 4.1 that main clusters of UDPs agreed with conductors' interpretational locations in bars 1-5, 20-27, and 47-48. On occasions where identified kinematic DPs in conducting movement coincided with conductors' interpretational opinions, UDPs reflected conductors' movement descriptions such as 'big', 'strong', 'heavy' movement for *sforzando*, *crescendo*, and the switch from *piano* to *forte* (bars 18-19, 20-27, 39, 47); 'small', 'short', 'light' movements for semiquavers (bar 5). The movement for communicating short rhythms showed speed, acceleration, and jerk UDPs without distance UDP, which suggested that this movement was not a large movement, but was fast, jerky, and possessed high acceleration.

Table 4.1 Conductors' interpretational intentions and kinematic deviations in Mozart

	Score analysis	**Interview**	**Conducting kinematics**	
Bar	**Compositional feature**	**No. of comment**	**Kinematic deviation**	**High kinematic variability**
20-27	melodic climax, syncopation, dynamic change (*crescendo*)	4	conductor & trial	speed, acceleration, jerk
47-48	counterpoint melodies, dynamic change (*p*-*f*),	2	conductor & trial	distance, acceleration
39-40	counterpoint melodies, dynamic change (*p*-*f*)	(bars 47-48)	conductor & trial (UDP & LDP)	distance, speed, acceleration, jerk
41	start of new phrase	-	conductor & trial	
51-55	upward melody, *trill*, dynamic change (*f*-*p*)	-	conductor & trial	-
18-19	dynamic change (*sf*)	6	trial only	-
1	beginning of piece	4	trial only	-
5	semiquaver rhythm	3	trial only	-
4	start of new phrase	-	trial only	-
7	(accent)	-	trial only	-
28	*f*- *p*	-	conductor & trial (LDP)	-
43	*f*- *p*	-	conductor & trial (LDP)	
11	dynamic change (*f*-*p*)	4	-	-
31	direction of music, cadence, counterpoint melodies,	4	-	-
10	rest	2	-	-
6	counterpoint melodies	1	-	-
15-16	rhythmic imitation between instrumental parts	1	-	-

Note: 1) Kinematic deviations without special mark are UDPs; 2) bars 39-40 shared similar compositional structures as in bars 47-48.

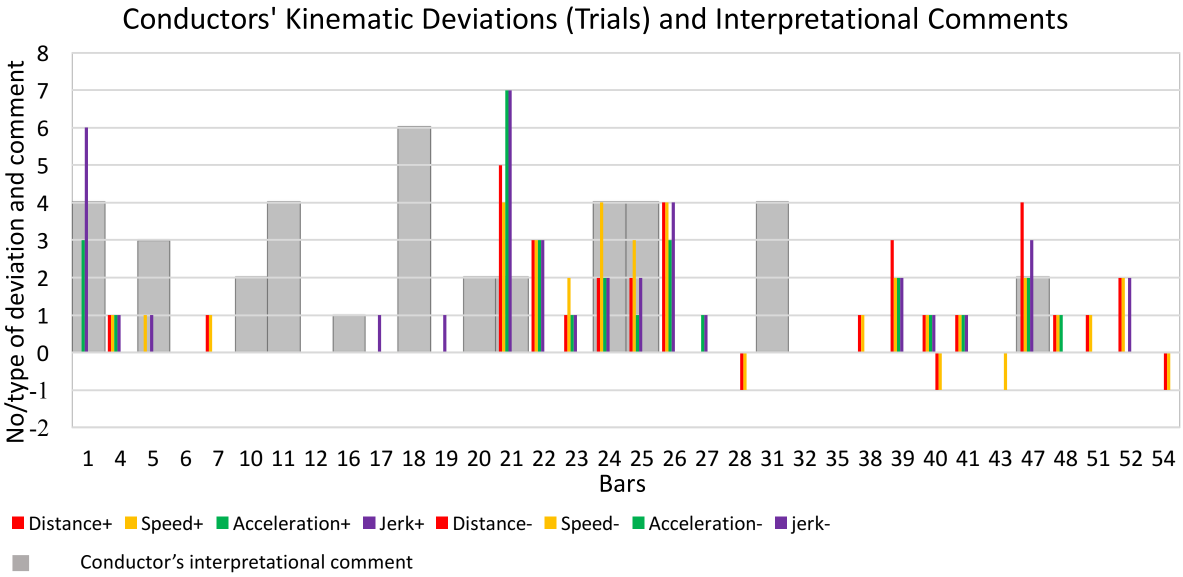


Figure 4.16 Conductors' interpretational intentions and kinematic deviations in Mozart

However, conductors' interpretational comments and kinematic deviations in their conducting sometimes did not match up with one another in Mozart. On several occasions, DPs showed in conducting without conductors' interpretational comment. These occasions included local detailed compositional features, such as the start of new phrase (bars 4, 41), local accent (bar 7), and playing technique of *trill* (bars 51-52). It should be noted that locations with dynamic change from *forte* to *piano* (bars 28, 43) were identified as LDPs. Even though conductors did not put comments on these two locations, in interviews, they did use other examples to illustrate that their conducting movement for communicating piano is very 'small', 'light', and their hands 'stay low' and are 'very close to the chest'. In other instances, DP was absent at conductors' interpretational locations. These instances contained counterpoint melodies (bars 15-16, 31), a rest (bar 10), and dynamic change from *forte* to *piano* (bar 11). Conductors described their cuing gesture for bringing out counterpoint melodies as an 'encouraging', 'palm-up' gesture. These gestures may sometimes be too gentle and subtle to be detected as movement DPs in kinematic analysis.

In summary, when conducting Mozart, conductors' intentions to communicate *sforzando*, *crescendo*, *forte*, and special rhythmic patterns were confirmed by salient clusters of kinematic UDPs in their conducting movements. Conductors' intentions to communicate *piano* were manifest in kinematic LDPs, even though conductors did not specifically mark these locations for *piano* in interviews. Conductors' intentions to communicate detailed compositional features such as local accent and *trill*, and cuing gestures for counterpoint melodies and new phrases were subtle and were not detected as DPs in their conducting movements.

4.3.2 Deviation Point Analyses in Dvořák

4.3.2.1 Kinematic deviation points in relation to compositional features: Deviation Point Analyses of individual trials in Dvořák

UDP and LDP of baton tip kinematics in Dvořák are summarised in Figure 4.17, with full analyses given in Appendix 6. The statistics of kinematic DPs are presented in Figure 4.18. Comparing UDPs of four kinematic variables in Figure 4.18, C3 possessed prominent figures of jerk UDPs compared to the other kinematic variables, whereas C6 had more numbers of UDPs for acceleration and jerk than for distance and speed. In this musical excerpt, only the baton tip distance, speed and acceleration showed few LDPs in C1, C3, C4, and C5's conducting.

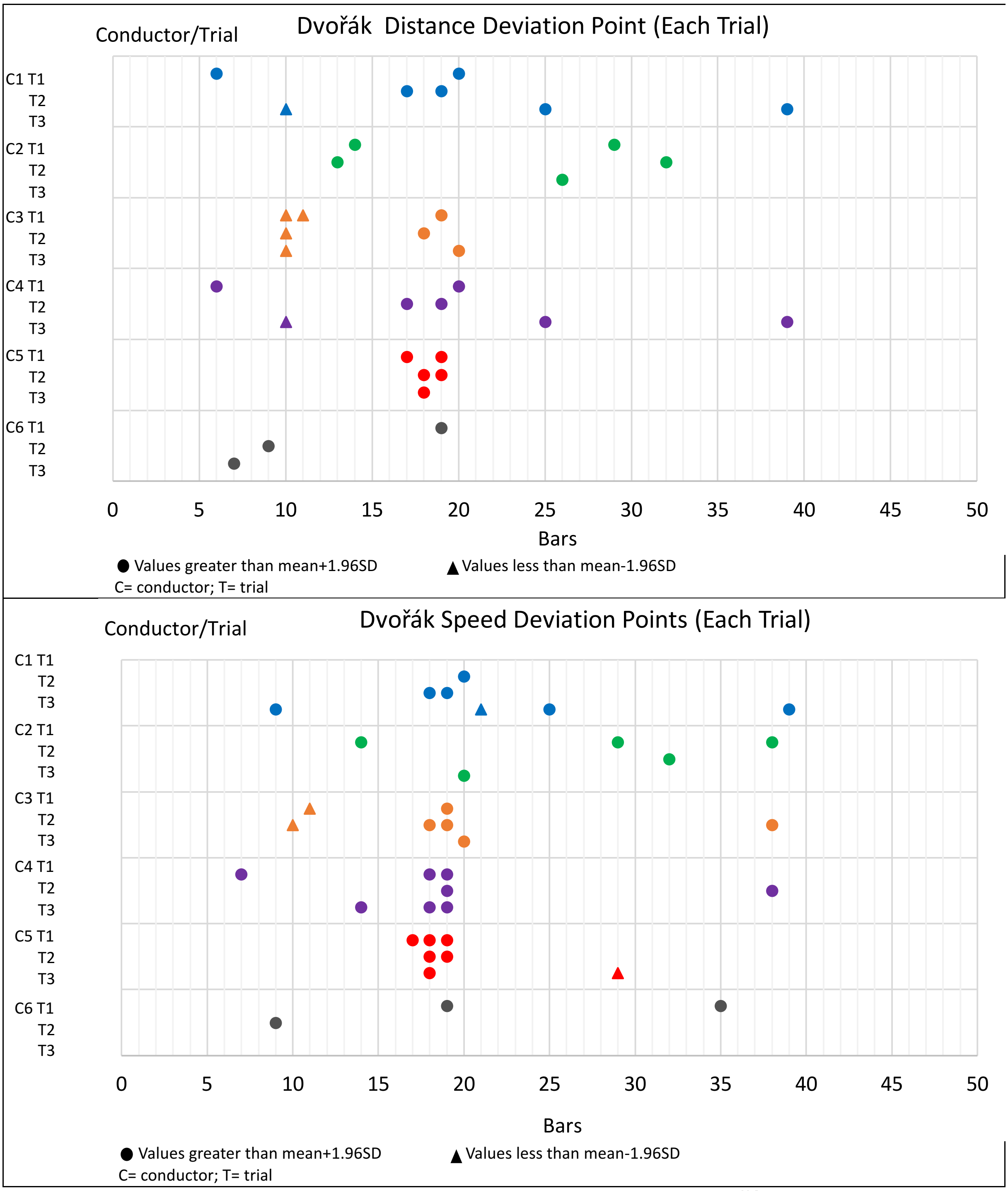


Figure 4.17 Deviation points of each trial for four kinematic variables in Dvořák

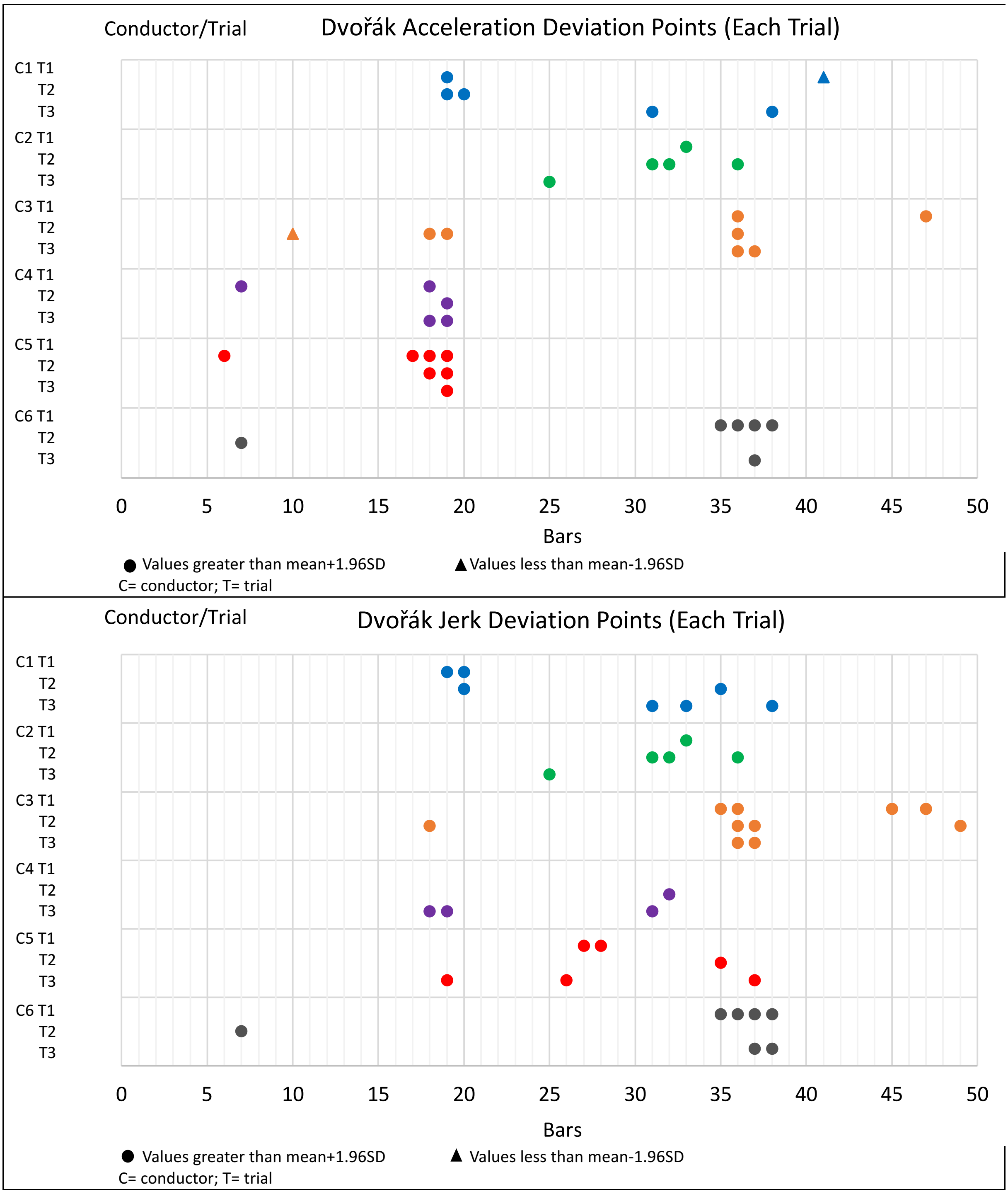


Figure 4.17-2 Deviation points of each trial for four kinematic variables in Dvořák (continued)

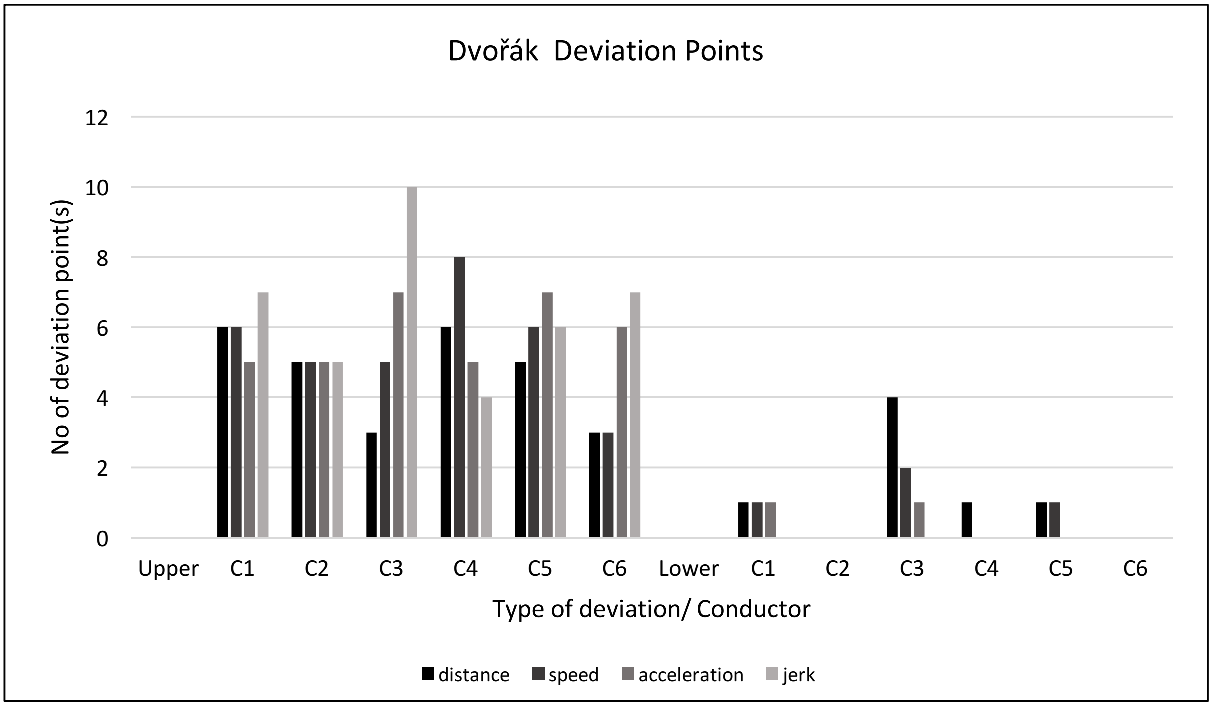
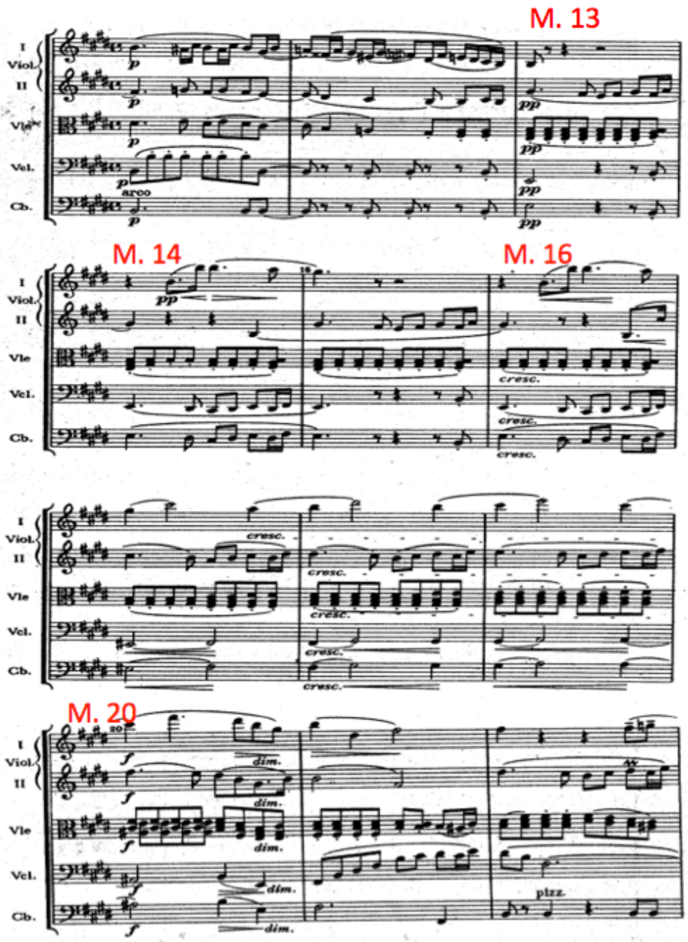


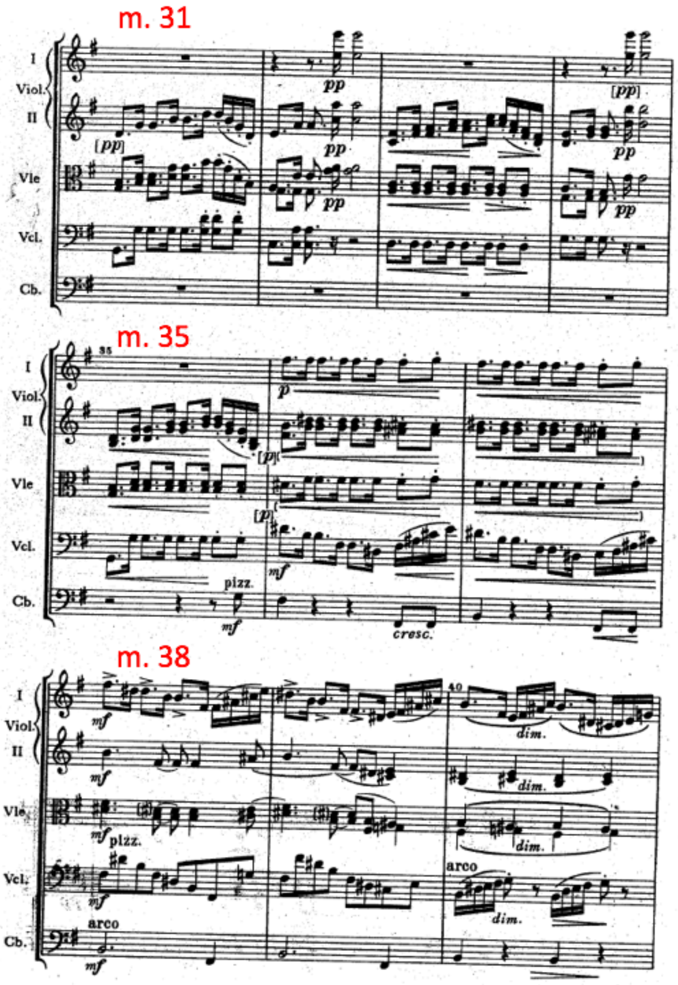
Figure 4.18 Statistics of upper deviation points and lower deviation points in Dvořák

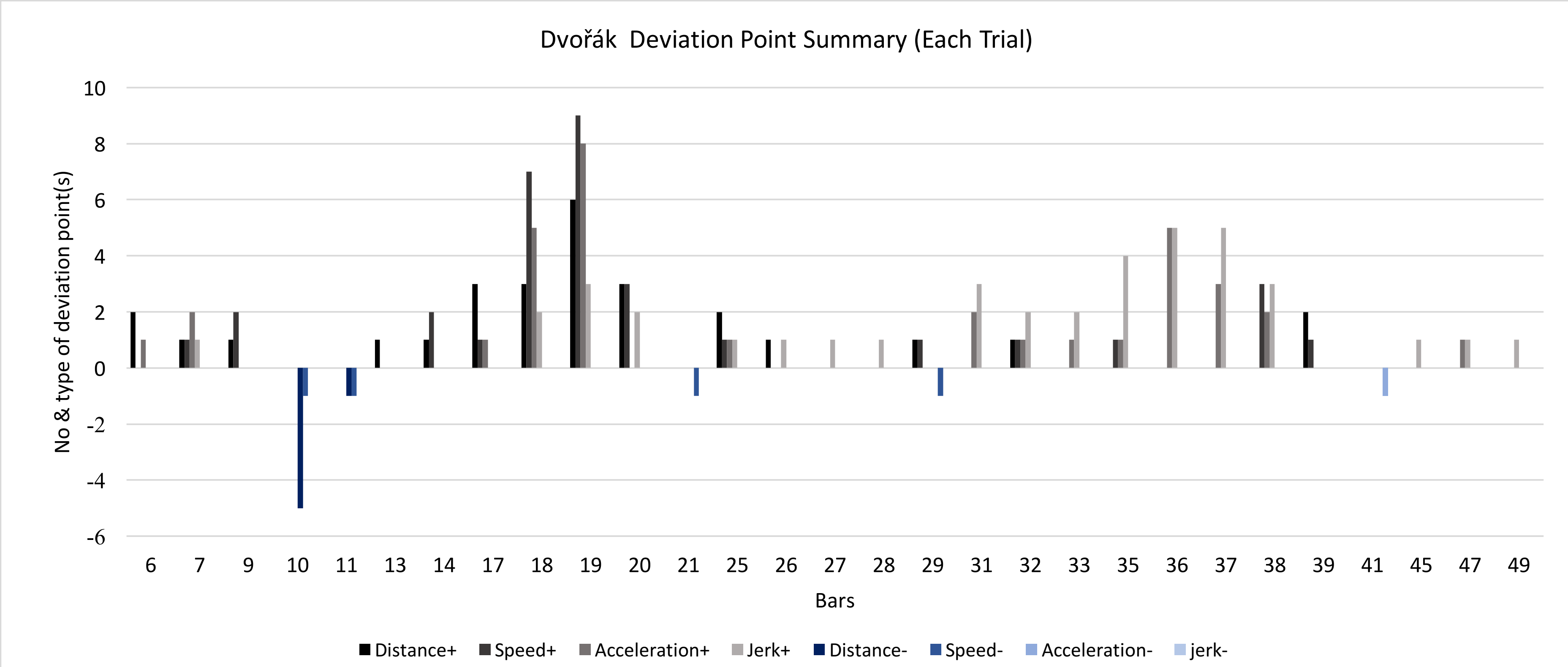
A preliminary observation can be made from Figure 4.17 that UDPs mostly gathered between bars 17-20 (Example 4.5) and bars 35-39 (Example 4.6). It can be further clarified in Figure 4.19 that comparing those two clusters, bars 17-20 showed more distance and speed UDPs than acceleration and jerk, whereas bars 35-39 showed the opposite tendency. Both deviation clusters matched with upward melodic line and continuous *crescendo*, yet those two music passages possess different rhythmic features. Music in bars 17-20 presents upward *legato* melodic line toward the melodic climax in bar 20, which construct the 'romantic build up' of music according to conductors' opinions, whereas in bars 35-39, dotted notes with *staccato* coupled with accents starting from bar 38 compose short rhythmic fragments.

Example 4.5 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 11-22.



Example 4.6 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 31-40.





Bar	6-7	9	10-11	14	17-20	21	25-26	27-29	31-33	35-39	41	45,47	49
Conductor	4,5,6	1,6	3	2,4	1,2,3,4,5,6	1	1,2,5	1,5	1,2,4	1,2,3,4,5,6	1	3	3
Music feature	rhythmic change cresc.	cresc.	metrical change dim.	counterpoint melody cresc. & dim.	Upward melody melodic climax cresc. dynamic climax	dim.	downward melody rhythmic change cresc.	rhythmic change dim. instrumental reduction	rhythmic change cresc. & dim.	cresc. p→mf accent	dim.	cresc.	downward melody

Figure 4.19 Kinematic deviation points and summary of musical features in Dvořák

The whole excerpt of Dvořák showed the tendency for more jerk UDPs to match up with short segments of rhythmic pattern, whereas distance, speed, and acceleration UDPs tended to associate with long continuous melodic lines. This tendency was consistent with the observation of two major deviation clusters stated above. The section developed around the lyric melodic theme (Example 4.7) from bar 1 to bar 25 contained more UDPs in distance, speed, acceleration, and less UDPs in jerk. But after the short rhythmic pattern is introduced in bar 25, particularly in the section developed around the dotted note theme (Example 4.6) from bar 31 to bar 49,[4] conductors tended to have more jerk UDPs rather than other kinematic UDPs.

Example 4.7 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 1-10.

Overall, UDPs matched up with upward melodic contour and melodic climax in bars 17-20 (Example 4.5), counterpoint melodies between the first and second violin, viola and cello in bar 14

[4] The section for the dotted note theme is from bar 31 to bar 53. But due to the limitation of motion capture equipment, movement data after bar 43 were not fully recorded for every trial. No movement data from any trial was recorded after bar 49. For this reason, for trial analyses, compositional structures after bar 49 were excluded in the discussion; for conductor's mean curve analyses, data after bar 43 were excluded in the analysis.

(Example 4.5), *crescendo* in bars 6-7, bar 9 (Example 4.7), bars 17-19 (Example 4.5), bar 25 (Example 4.8), bars 35-37 (Example 4.6), bar 45 and bar 47 (Example 4.9). While LDPs tended to be in line with dynamic change of *diminuendo* in bar 10 (Example 4.7), bar 21 (Example 4.5), bar 41 (Example 4.9). The prominent number of distance LDPs in bar 10 can be explained as the result of shorter time-span within this bar (there are only 2 beats in this bar) rather than because of the sudden change of conductors' movement kinematics. The exception in bars 27-28 (Example 4.8) should be noted. Even the music exhibits *diminuendo* and instrumental reduction from bar 27, conductors still showed jerk UDPs, which may be the movement feature they employed to express *trill* and short rhythmic patterns.

Example 4.8 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 23-30

Example 4.9 Dvořák, *Serenade in E major*, Op.22, 1st movement, bars 41-50.

4.3.2.2 Within-conductor stability of kinematic deviation points: Deviation Point Analyses of individual conductor's mean curves in Dvořák

The analyses of each conductor's mean curve of three trials conducting Dvořák are presented in Figure 4.20, with identified DPs in each conductor's mean curve summarised in Figure 4.21. Those UDPs and LDPs in conductor's mean curves are shown by temporal order in Figure 4.22.

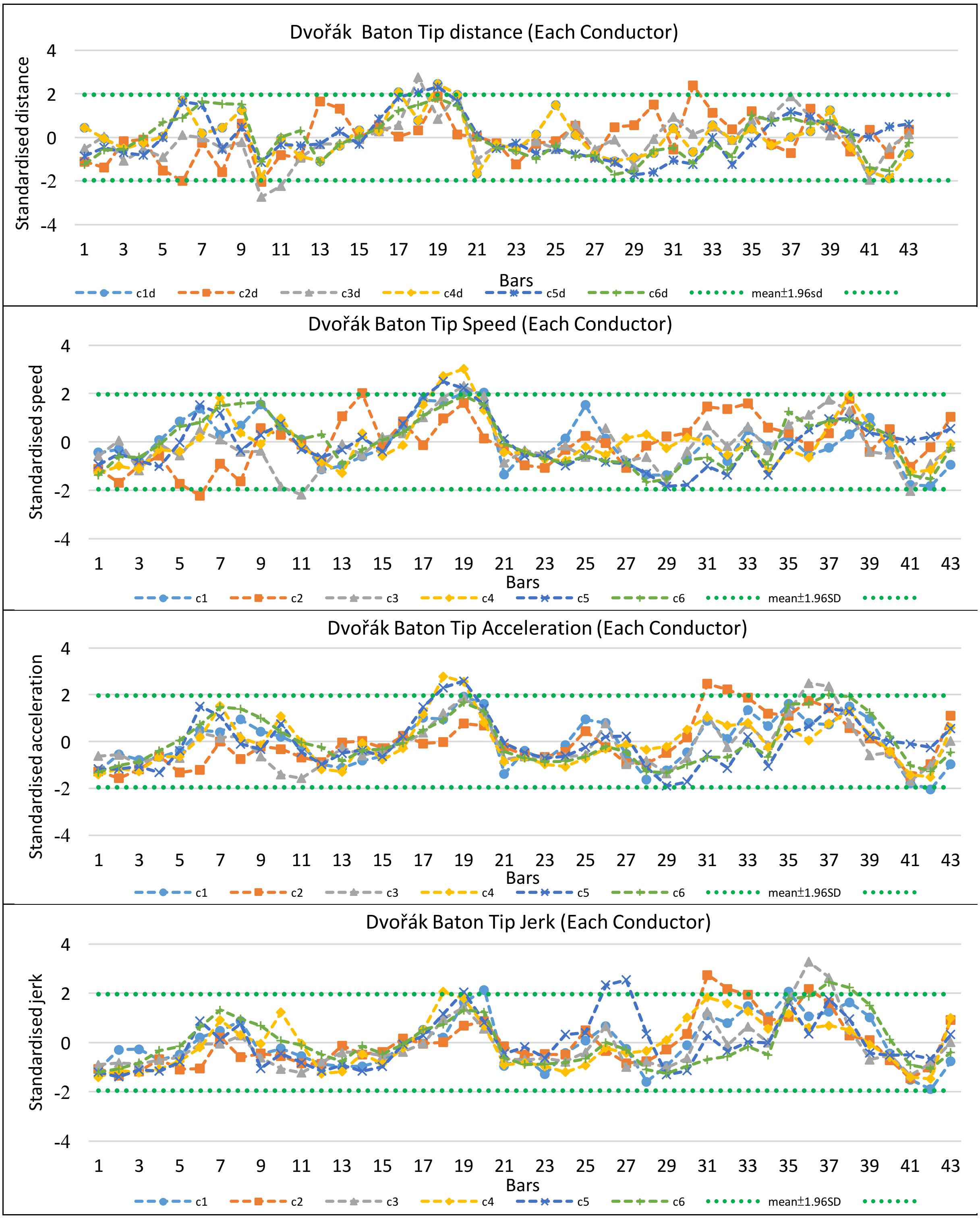


Figure 4.20 Deviation point analyses of each conductor's mean curve of three trials conducting Dvořák

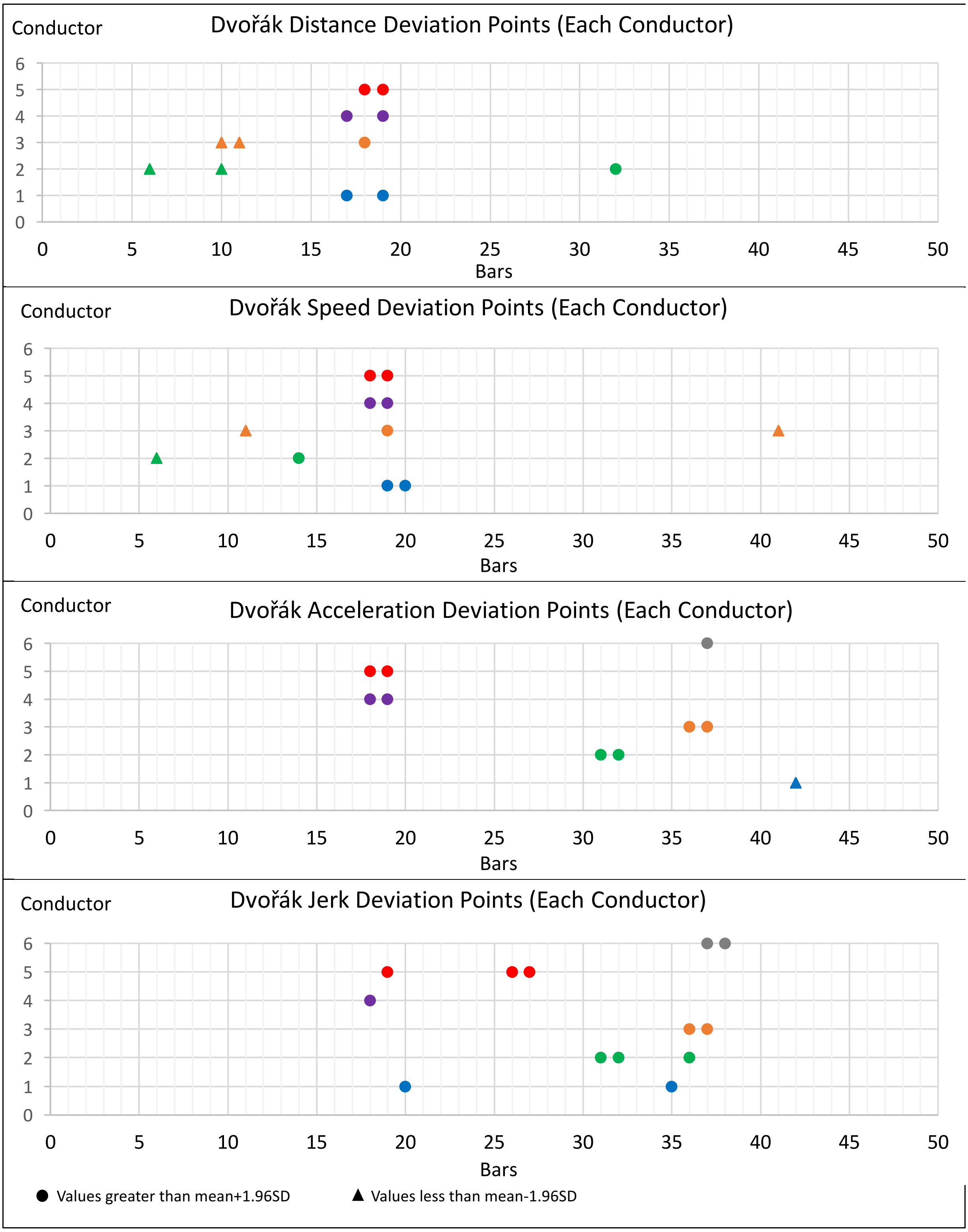
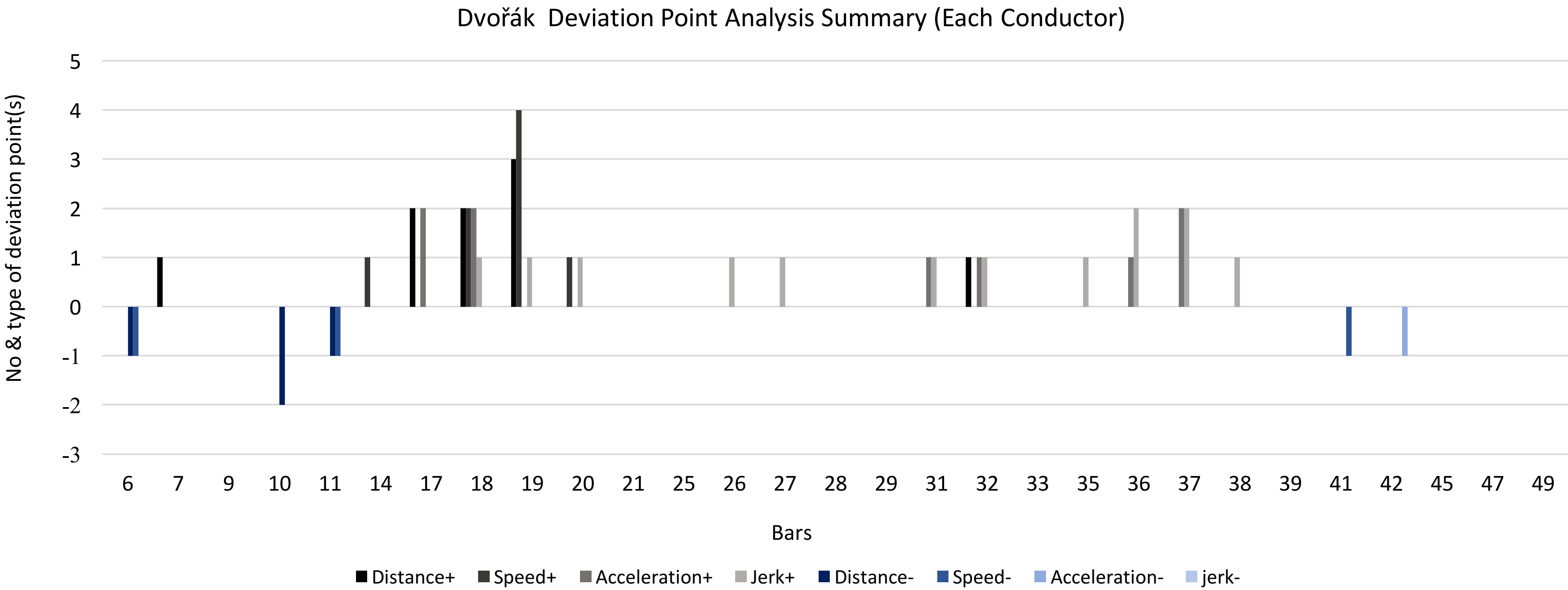


Figure 4.21 Deviation points of each conductor's mean curve for four kinematic variables in Dvořák



Bar	6-7	9	10-11	14	17-20	21	25-26	27-29	31-33	35-39	41	45,47	49
Conductor	4,5,6	1,6	3	2,4	1,2,3,4,5,6	1	1,2,5	1,5	1,2,4	1,2,3,4,5,6	1	3	3
Music feature	rhythmic change cresc.	cresc.	metrical change dim.	counterpoint melody cresc. & dim.	Upward melody melodic climax cresc. dynamic climax	dim.	downward melody rhythmic change cresc.	rhythmic change dim. instrumental reduction	rhythmic change cresc. & dim.	cresc. p→mf accent	dim.	cresc.	downward melody

Figure 4.22 Statistics of deviation points of each conductor’s mean curve in Dvořák

The comparison between DPs in trials (Figure 4.19) and in conductor's mean curves (Figure 4.22) are summarised in Figure 4.23. It appeared that the most stable DPs reaching agreement in both analyses (the first row 'Agree' in Figure 4.23) reflected the 'romantic build up' combining upward melody and *crescendo* in bars 17-20 (Example 4.5), as well as the introduction of short rhythmic pattern in bars 26-27 (Example 4.8), and the short rhythm combined with *crescendo* and accent in bars 35-38 (Example 4.6). Less stable DPs identified from conductor's mean curves only or from trials only (the second row 'Conductor only' and the third row 'Trial only' in Figure 4.23) tended to connect with smaller scale dynamic changes (e.g., bar 7, bar 9, bar 25, bar 33; Example 4.7, Example 4.8, Example 4.6). There were only two unstable DPs showing opposite deviation types (UDP and LDP) between two analysis methods or between different conductors (the fourth row 'Disagree' in Figure 4.23).

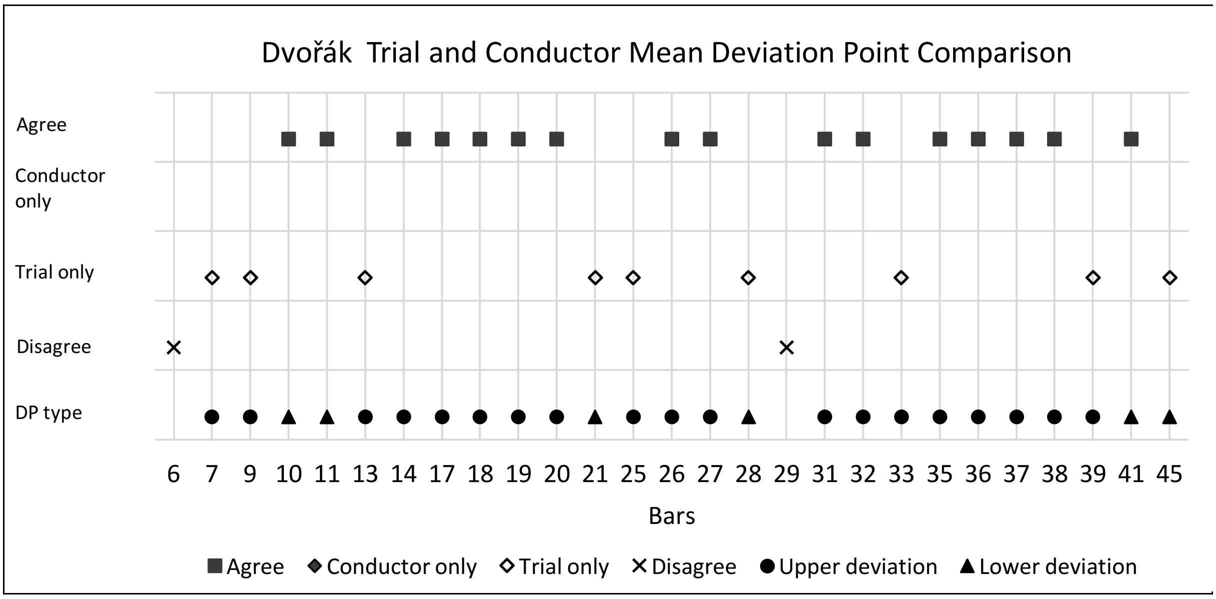


Figure 4.23 The comparison of deviation points in trials and in conductor's mean curves in Dvořák

An interesting observation can be made when comparing Dvořák with Mozart. In Mozart, rhythmic features tended to be considered as secondary and showed connections to less stable DPs (DPs identified from trials only or from conductor's mean curves only). On the other hand, in Dvořák, rhythmic features were more likely to be considered as primary, not only based on conductor's opinions given in interviews, but also according to the fact that the whole second section of Dvořák's excerpt (bars 31-53, see Example 4.6) is developed based on short rhythmic patterns, which show the contrast to long, lyric melodic lines in the first section (bars 1-30, see Example 4.7). Rhythmic features thus could be regarded as one of the main features to distinguish those two structural sections, and are also more likely to be connected to more stable DPs that identified from both analysis methods in Dvořák, particularly jerk DPs in bars 31-41.

4.3.2.3 Between-conductor kinematic variability: Deviation Point Analyses of between-conductor standard deviation in Dvořák

Analyses of between-conductor kinematic variability are presented in Figure 4.24, with DPs with high between-conductor variability shown in Figure 4.25. DPs with high between-conductor variability (from Figure 4.25) were compared with the stability of DPs (from Figure 4.23) and summarised in Figure 4.26. The observation can be made that high between-conductor kinematic variability tended to occur during or after target musical events which conductors intended to deliver. Bar 6 (Example 4.7), for instance, is the bar after the introducing of main melody and the *pizzicato* by double bass, but the *crescendo* starting from bar 5 is still proceeding. Bar 27 (Example 4.8) showed high kinematic variability after the introducing of short rhythmic pattern in bar 26. Yet in bars 31-32 (Example 4.6), conducting movement showed high variability in and after the bar when the new rhythmic theme is presented. This observed tendency was similar yet slightly different from the findings in Mozart, which high kinematic variability occurred only after target musical events.

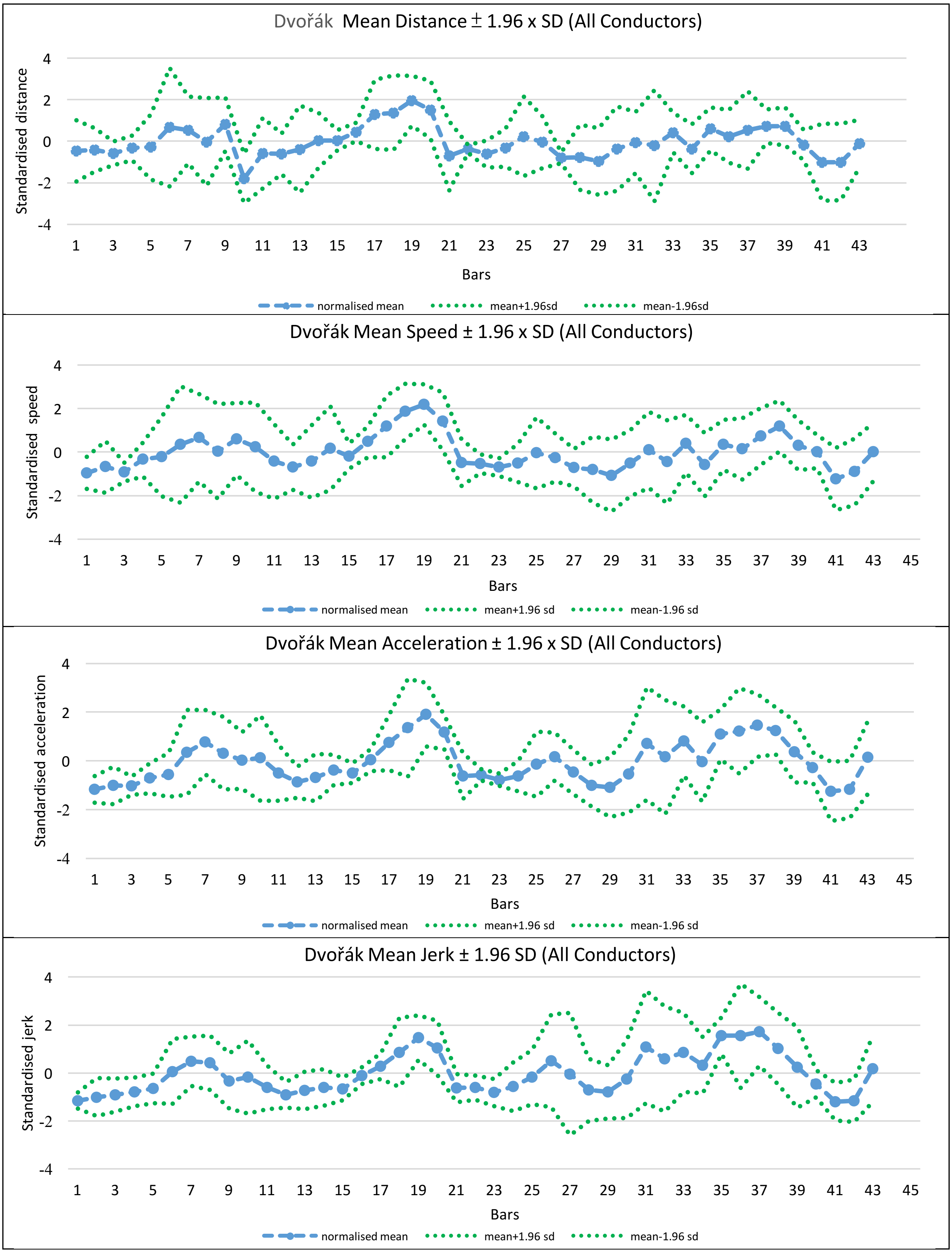


Figure 4.24 Between-conductor kinematic variability in Dvořák

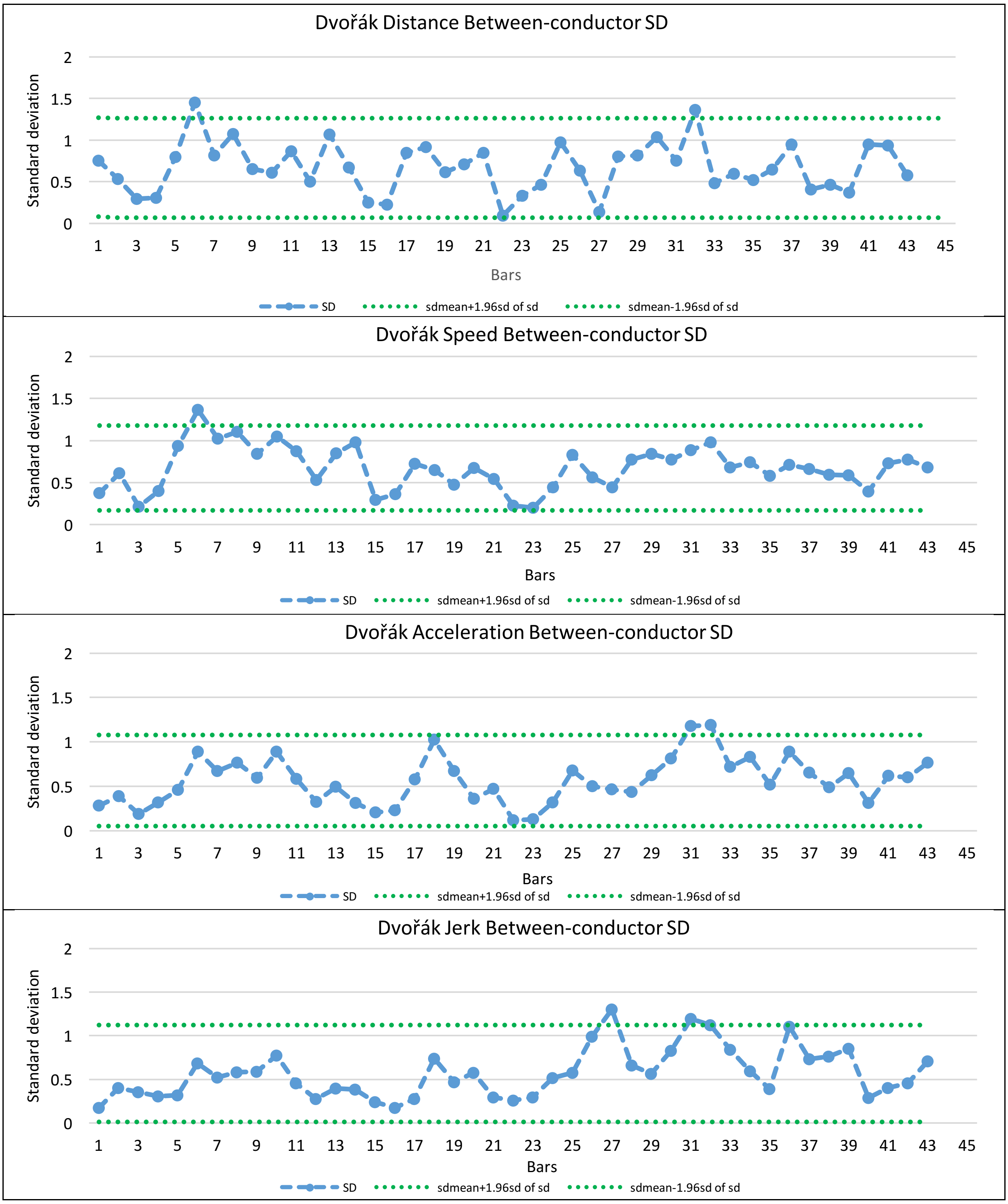


Figure 4.25 Deviation point analysis of between-conductor kinematic variability in Dvořák

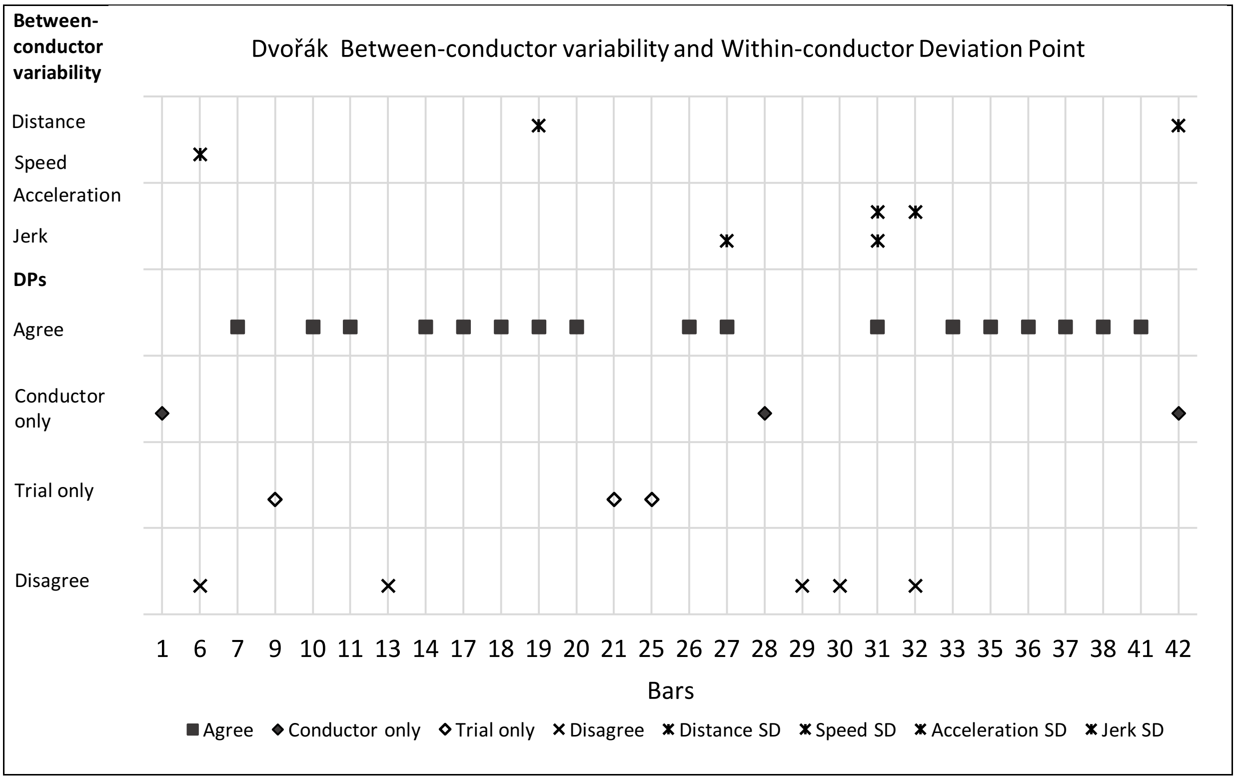


Figure 4.26 The comparison of between-conductor variability deviation points and within-conductor deviation points in Dvořák

4.3.2.4 Conducting kinematic deviations in relation to interpretational locations in Dvořák

Conductors' interpretational comments provided in interviews (section 2.3.2) and kinematic DPs shown in their conducting of Dvořák (section 4.3.2) are compared in Table 4.2 and Figure 4.27 (based on results in Table 2.9 in Chapter 2; Figure 4.19, Figure 4.22, and Figure 4.26 in Chapter 4). As can be seen, major clusters of UDPs in Dvořák agreed with conductors' interpretational intentions, and showed similar tendencies as observed in Mozart. Kinematic UDPs corresponded with conductors' 'intensifying', 'palm upward' movement for *crescendo* (bars 6, 9, 14, 25), particularly for the prominent 'Romantic build up' (bars 16-20); 'smaller and shorter' movement for short rhythmic fragments (dotted notes and *mordente*; bars 7-8, 26-27), cuing gestures for instrumental entry (bars 13-14, 29). On the other hand, substantial drops of movement distance corresponded with the metrical change from four beats to two beats in bar 10. The shorter time span within this musical bar resulted in shorter distance for movement. Similar to the observations in Mozart, LDPs were found for the *diminuendo* in bar 21 without conductors' comments. Conductors' intentions to cue the entry of instrumental parts were not shown in movement kinematics (bars 1, 2, 5), probably because movements showed small sizes corresponding to *piano* and *pianissimo* in these three cases.

Generally speaking, the tendencies found in Dvořák are similar to Mozart. Conductors' 'big', 'intensifying' movements communicating *crescendo* were observed as kinematic UDPs in conducting movement. Despite small size of movement, conductors' 'short' movements for short rhythmic patterns were observed as jerk UDPs. Conductors' intentions to communicate *piano* were observed as LDPs in movement, whether or not this was indicated in the conductors' comments. Conductors' cuing gestures for instrumental entry sometimes were not observed because of small sizes of movement.

Table 4.2 Conductors' interpretational intentions and kinematic deviations in Dvořák

	Score analysis	**Interview**	**Conducting kinematics**	
Bar	**Compositional feature**	**No. of comment**	**Kinematic deviation**	**High kinematic variability**
16-20	*crescendo*, dynamic climax (bar 20), melodic climax (bar 20), romantic build up	4	conductor & trial	distance
6	*crescendo*	(bar 5)	conductor & trial	speed
26-27	rhythmic pattern (*mordent*)	(bar 24)	conductor & trial	jerk
7-8	new rhythmic pattern (dotted note)	2	conductor & trial	-
14	*crescendo* and then *diminuendo*	2	conductor & trial	-
9	irregular phrase, *crescendo*	2	trial only	-
13	entry of main melody	2	trial only	-
29	entry of melody, new theme	2	trial only	-
25	*crescendo*	1	trial only	-
10	metrical change (4/4→2/4)	4	conductor & trial (LDP)	-
11	recovery from metrical change (2/4→4/4)	(bar 10)	conductor & trial (LDP)	-
21	*diminuendo*	-	trial only (LDP)	-
1	beginning of piece, *pp*, lyric character, phrasing	5	-	-
5	entry of main melody, phrasing, *pizzicato*	4	-	-
2	counterpoint melodies	2	-	-
24	rhythmic pattern (*mordent*)	1	(bar 26-27)	-

Note: 1) Kinematic deviations without special mark are UDPs; 2) conductors tended to put their interpretational comments at the beginning when a compositional feature occurs, and kinematic DPs in their conducting movement may remain for longer periods. The *crescendo* commences at bar 5; the *mordents* commence at bar 24, and the metrical switch between 4/4 and 2/4 commences at bar 10.

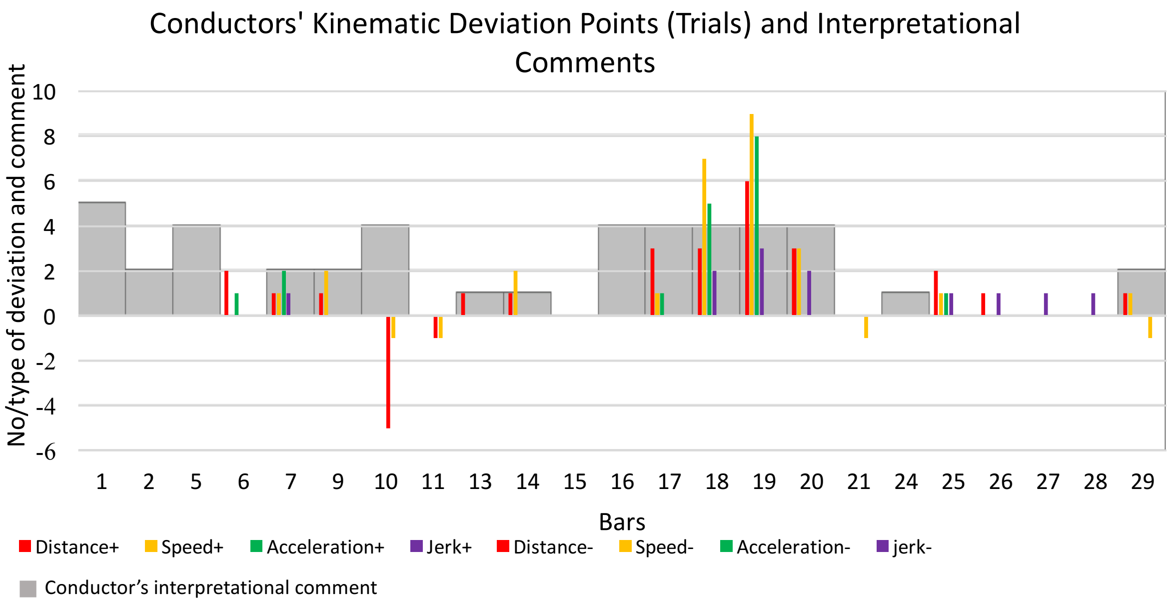


Figure 4.27 Conductors’ interpretational intentions and kinematic deviations in Dvořák

4.3.3 Deviation Point Analyses in Bartók

4.3.3.1 Kinematic deviation points in relation to compositional features: Deviation Point Analyses of individual trials in Bartók

Identified kinematic UDPs and LDPs in Bartók are summarised in Figure 4.28, with full analyses shown in Appendix 6. The statistics of UDPs and LDPs in four kinematic variables are presented in Figure 4.29. In total, conductors had more UDPs in jerk than in the other kinematic variables[5]. As for LDPs in Bartók, deviations in four kinematic variables were more even in C1’s conducting, whereas C4 showed more LDPs in distance and speed, C5 possessed more LDPs in acceleration and jerk, and C6 showed more LDPs in speed and acceleration.

[5] Conductors had 117 UDPs in distance, 115 in speed, 113 in acceleration, and 122 in jerk in total.

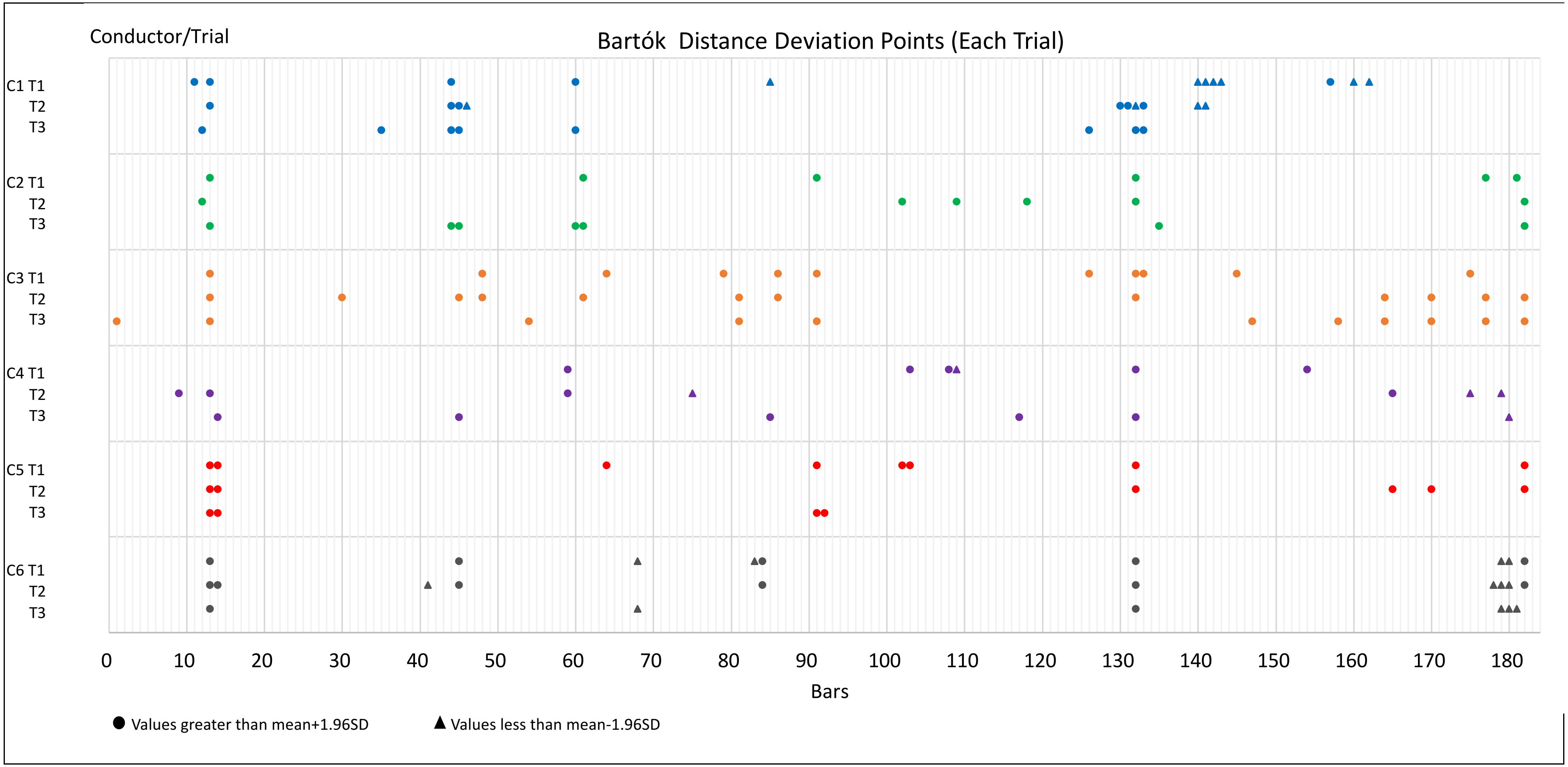


Figure 4.28 Deviation points of each trial for four kinematic variables in Bartók

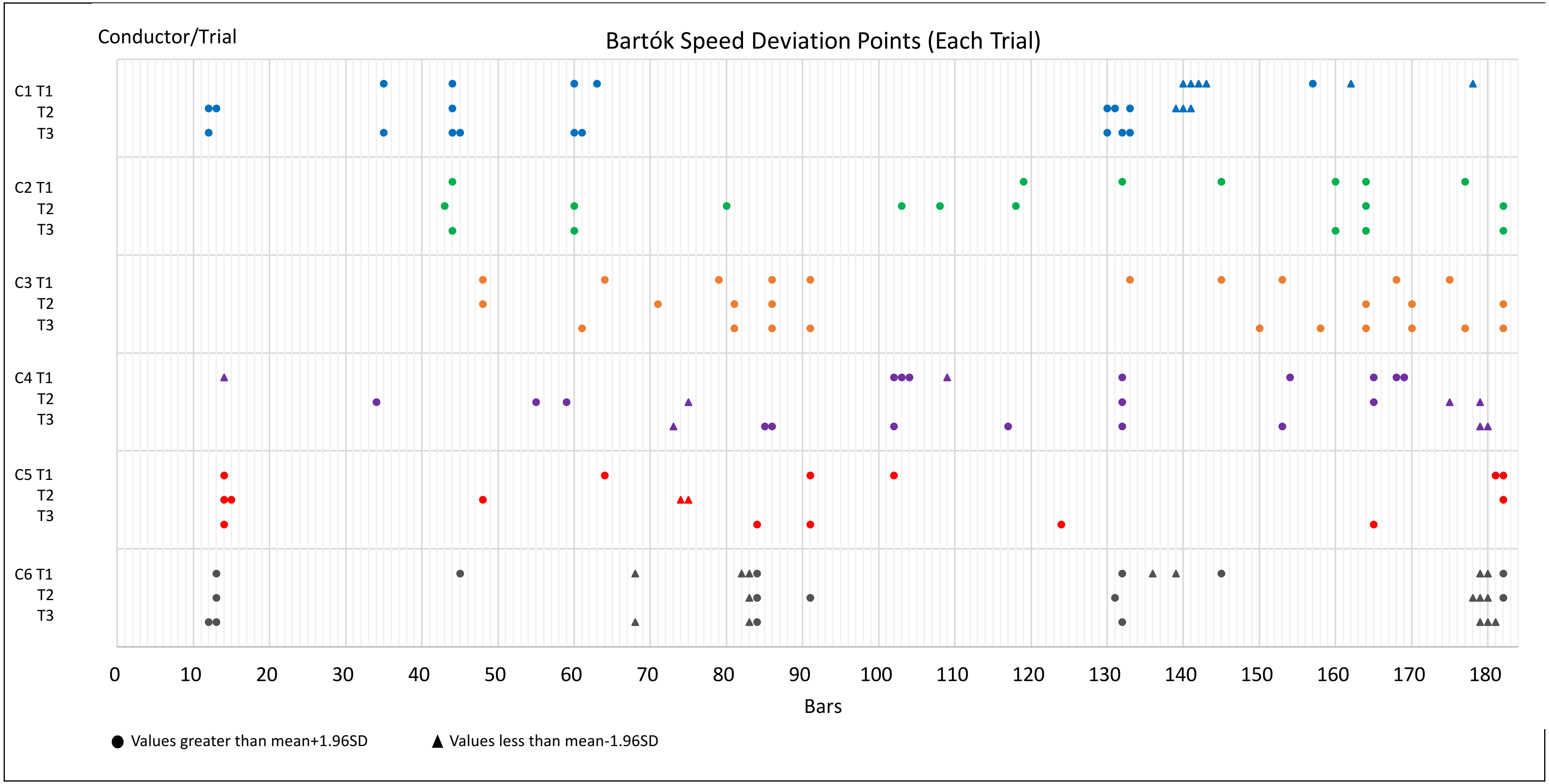


Figure 4.28-2 Deviation points of each trial for four kinematic variables in Bartók (continued)

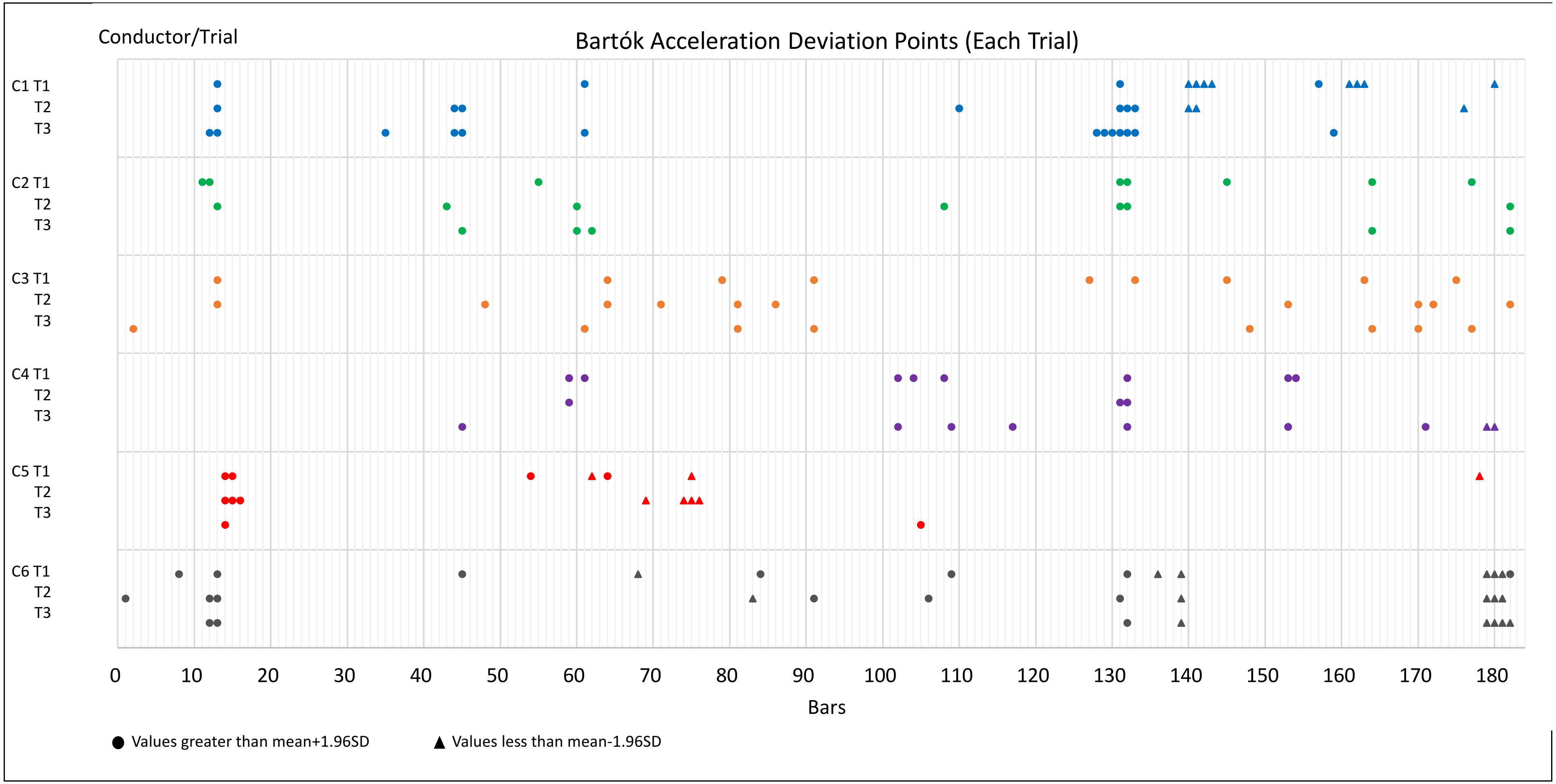


Figure 4.28-3 Deviation points of each trial for four kinematic variables in Bartók (continued)

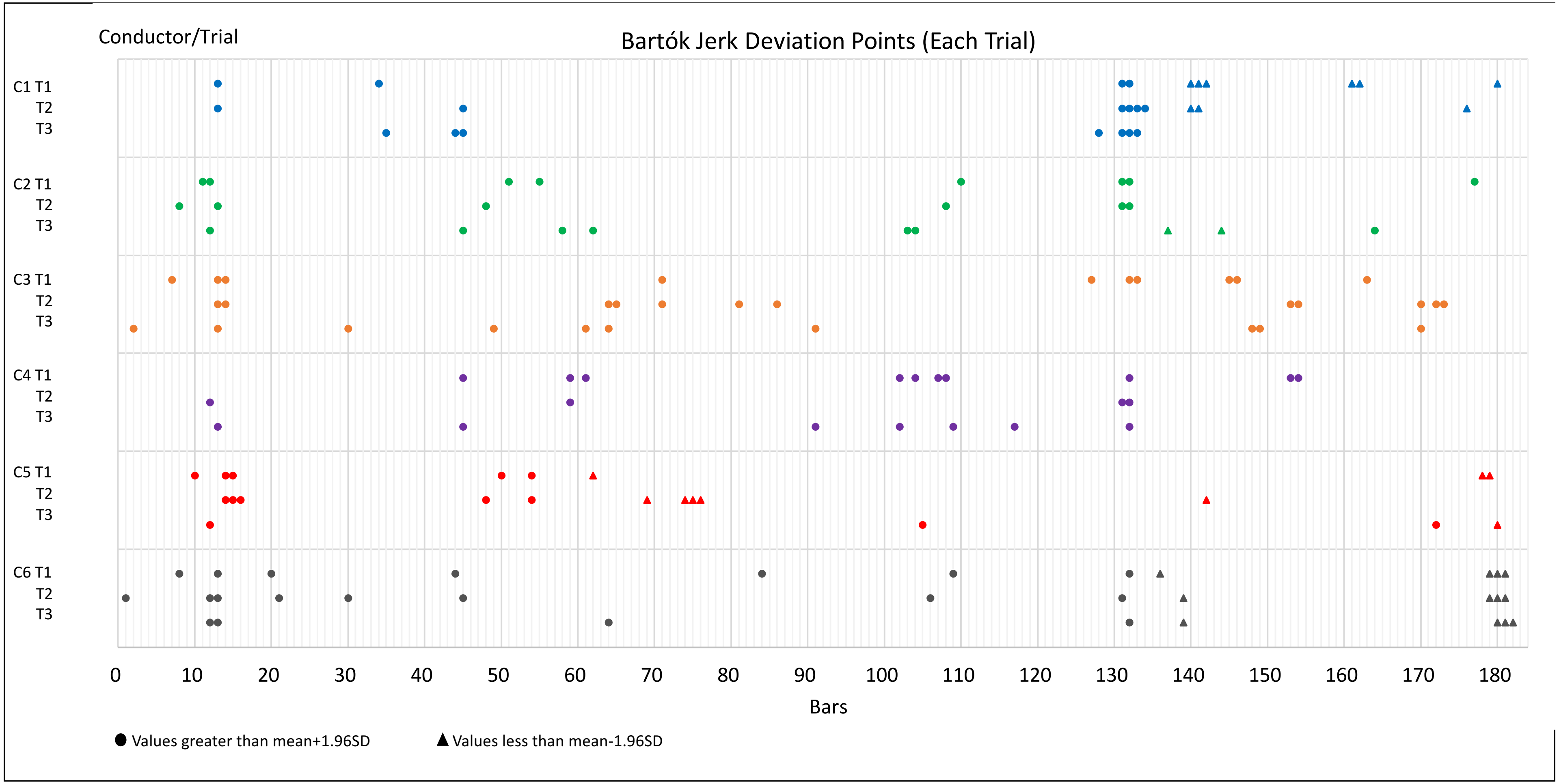


Figure 4.28-4 Deviation points of each trial for four kinematic variables in Bartók (continued)

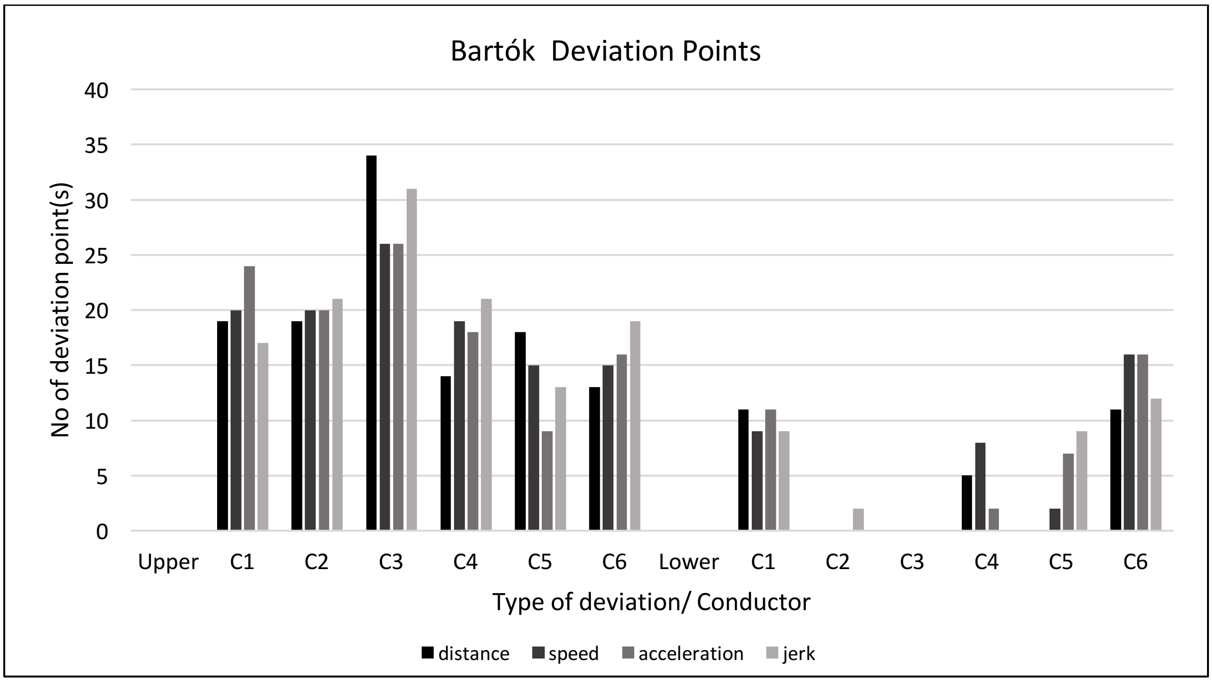


Figure 4.29 Statistics of upper deviation points and lower deviation points in Bartók

When comparing different conductors, C3 had the greatest number of UDPs in all variables, which was similar to the results in Mozart. C5 and C6 possessed the least number of UDPs compared to other conductors. Considering this finding together with Mozart and Dvořák, C6 tended to have the least number of kinematic UDPs of the six conductors. He showed the least UDPs in distance and speed when conducting Dvořák and Bartók, and also had the least UDPs in acceleration and jerk when conducting Mozart.

Several evident clusters of kinematic deviation points can be observed in Figure 4.28 and summarised in Figure 4.30. Kinematic UDPs concentrated in bars 12-14, bars 43-45, bars 59-61, bars 84-86, bars 130-133, bars 164-165, and bar 182, while LDPs clustered in bars 136-144, and bars 178-180. UDP clusters tended to respond to musical structural traits including tempo change in bars 12-14 (Example 4.10), metrical change in bars 131-133 (Example 4.11), and the end of excerpt in bar 182 (Example 4.12), as well as highlighted melodic characters including *glissando* in bar 45 (Example 4.13) and bar 61 (Example 4.14), and obvious upward melodic skip in bar 165 (Example 4.15). It is noteworthy that even though the music shows union instrumental texture in both bars 82-86 (Example 4.16) and bars 178-180 (Example 4.12), conducting movement tended to present different types of deviation in those two cases. In the case of bars 82-86, kinematic variables showed LDPs in bars 82-83, then switched to obvious UDPs from bar 84, which is just before the syncopation in bar 85. As for the latter case, the music maintains the same note throughout bars 178-180, which coincided with

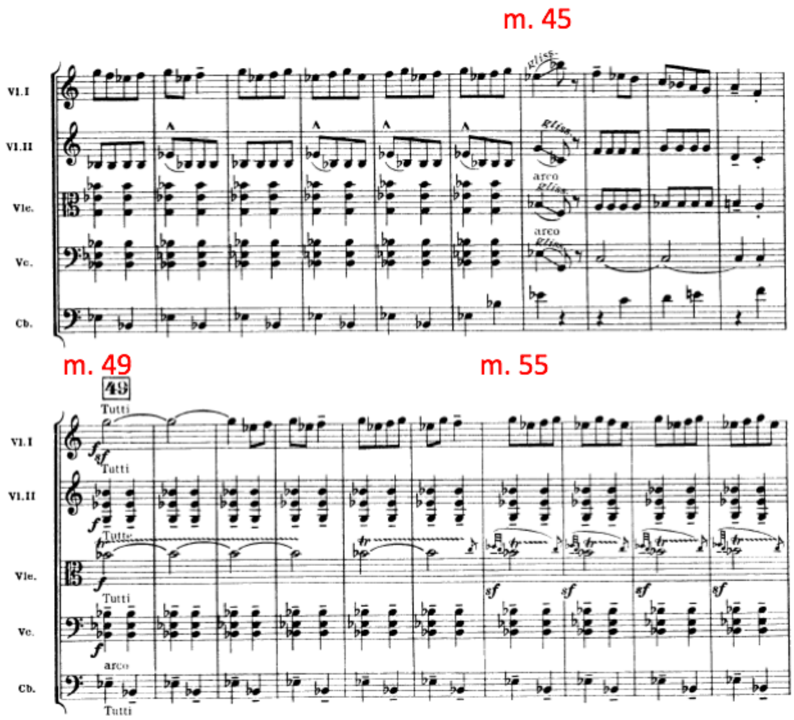
LDPs of kinematic variables. The LDP clusters might also reflect the instrumental reduction in music, for instance, in bars 139-144 (Example 4.17).

Example 4.10 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 1-18.

Example 4.11 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 118-137.

Example 4.12 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 169-183.

Example 4.13 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 39-58.

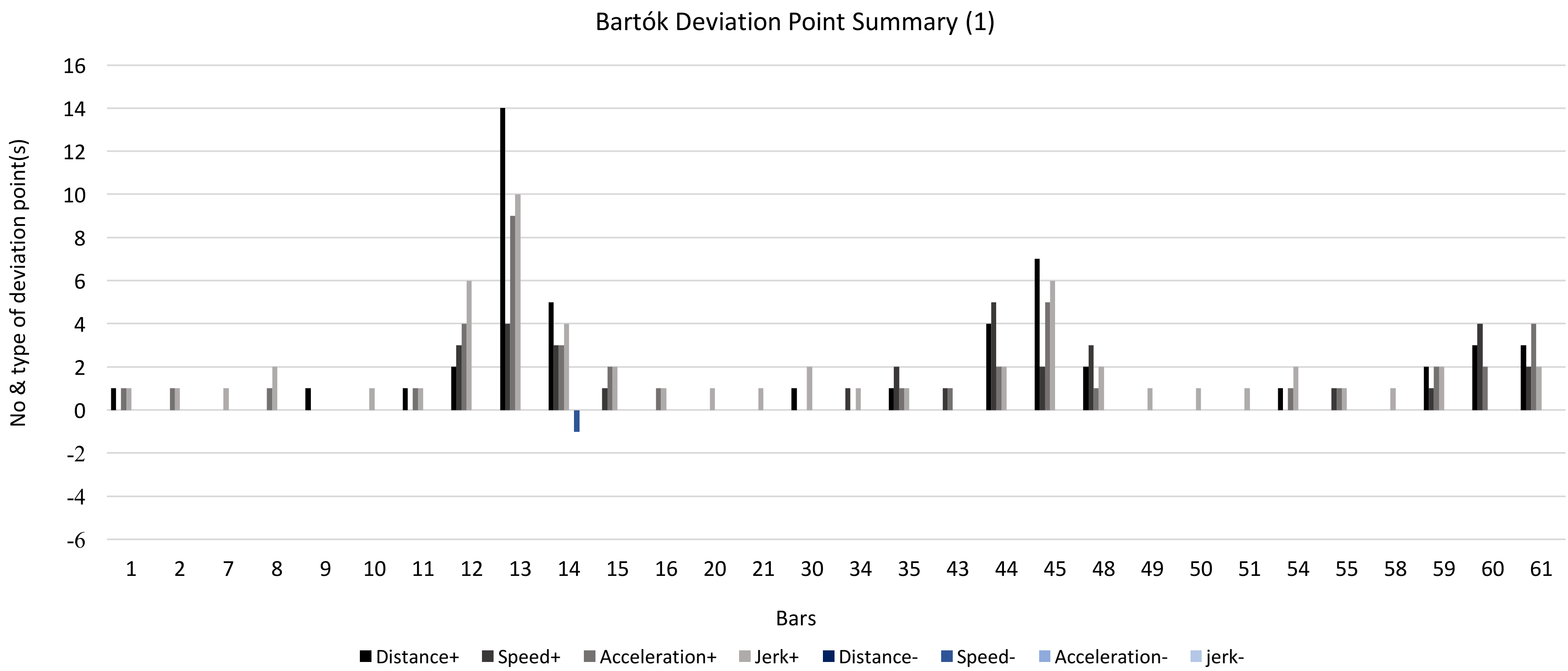


Example 4.14 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 59-79.

Example 4.15 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 158-168.

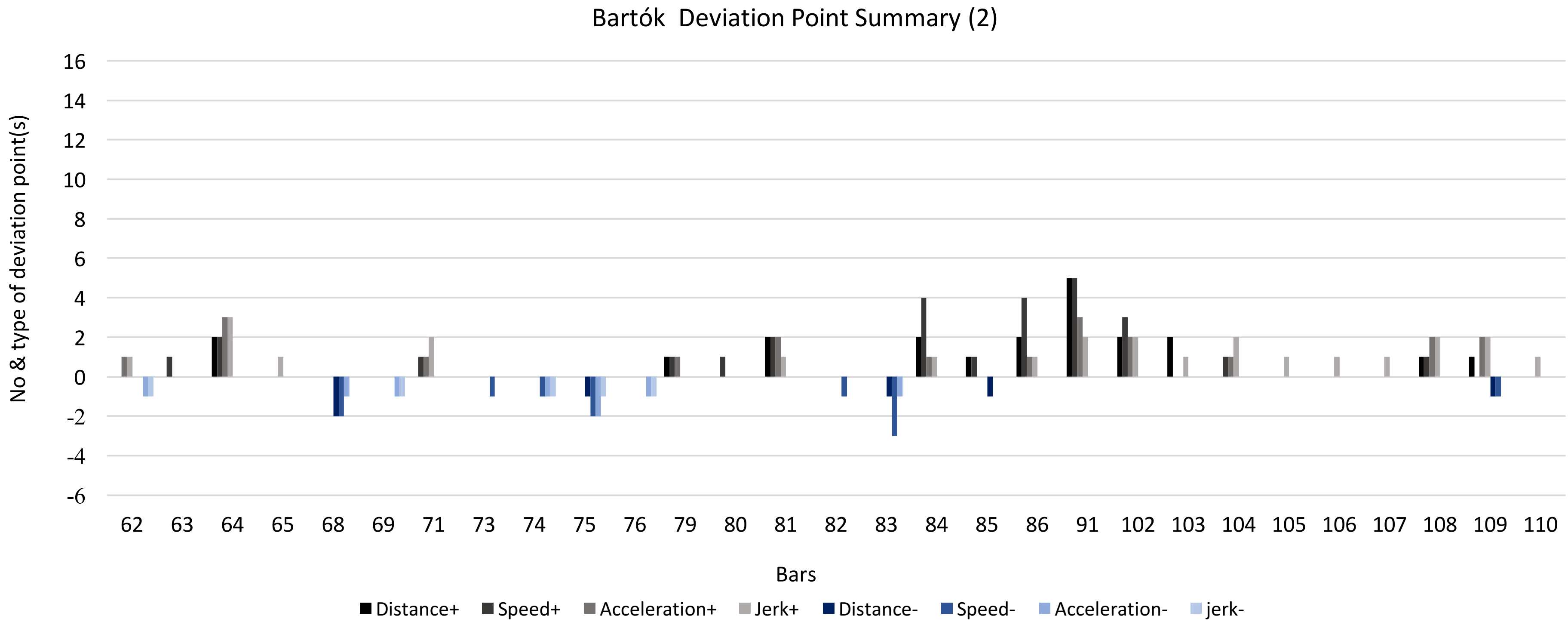
Example 4.16 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 80-93.

Example 4.17 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 138-147.



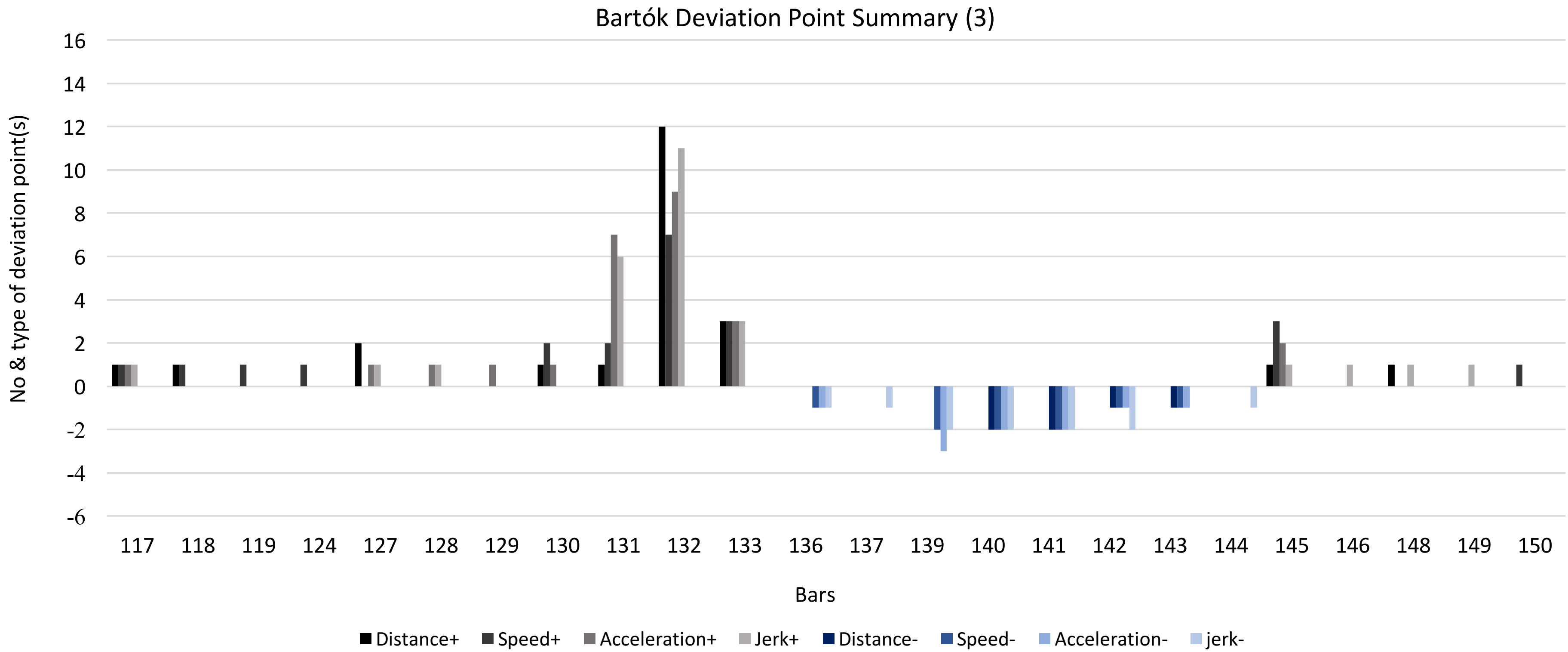
Bar	1-2	7-8; 10-11	12-14	15-16	20-21; 30	34-35	43-45	48-51; 54-55; 58-59	60-61
Conductor	3,6	2,3,5,6	1,2,3,4,5,6	5	3,6	1,4	1,2,4,6	2,3,4,5	1,2,3,4
Music feature	beginning upward melody f	accent	poco rall	f	solo→tutti	sf	accent gliss.	f sf accent	gliss.

Figure 4.30 Kinematic deviation points and summary of compositional features in Bartók



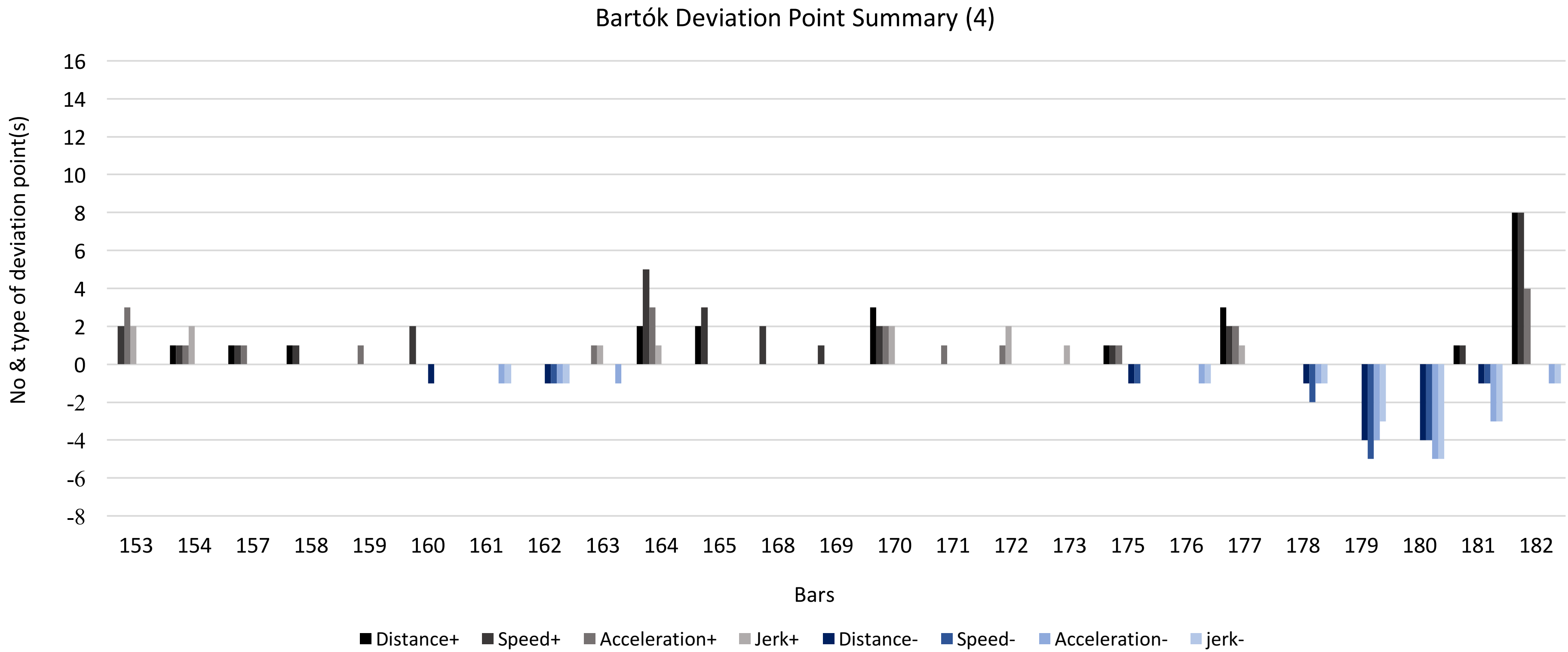
Bar	62-65	68-69	71	73-76	79-81	82-86	91	102-110
Conductor	1,2,3,5,6	5,6	3	4,5	2,3	3,4,5,6	3,4,5,6	2,4,5,6
Music feature	f instruments join in	p instruments join in	f instruments join in	p instruments join in	f instruments join in	f union	ff	f sf trill

Figure 4.30-2 Kinematic deviation points and summary of compositional features in Bartók (continued)



Bar	117-119; 124; 127-130	131-133	136-137; 139-144	145-146	148-150
Conductor	1,2,3,4,5	1,2,3,4,6	1,2,5,6	2,3,6	3
Music feature	strong rhythm f accent union	metrical change	p instrumental reduction	cresc. p→ f	syncopation f

Figure 4.30-3 Kinematic deviation points and summary of compositional features in Bartók (continued)

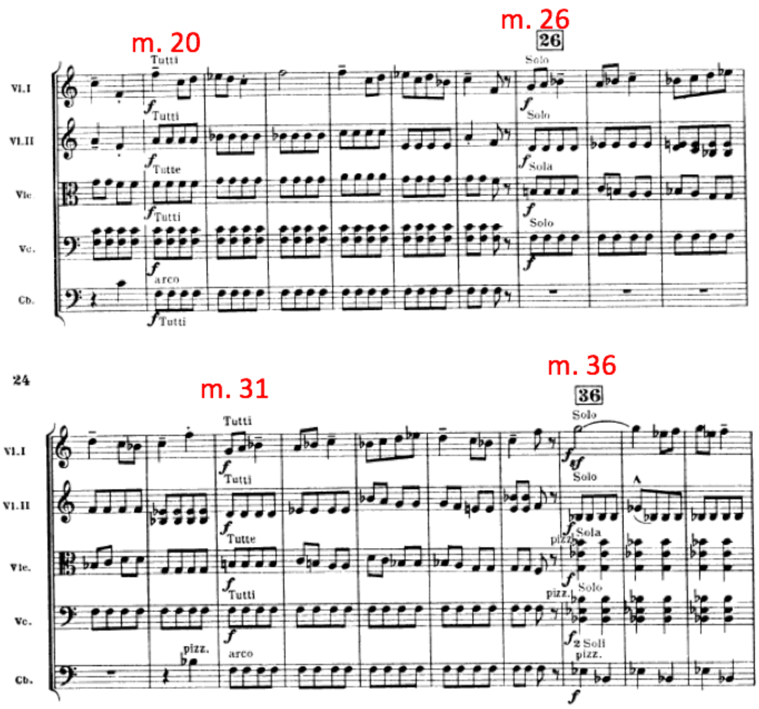


Bar	153-154	157-158	159-160	161-162	163-165	168-169	170-173	175-176	177-181	182
Conductor	3,4	1,3	1,2	1	1,2,3,4,5	3,4	3,4,5	1,3,4	1,2,3,4,5,6	2,3,5,6
Music feature	melodic skip p→ f	syncopation f	p	mf	melodic skip f	downward melody f	instruments join in f	cresc.	union f→ ff	section ends

Figure 4.30-4 Kinematic deviation points and summary of compositional features in Bartók (continued)

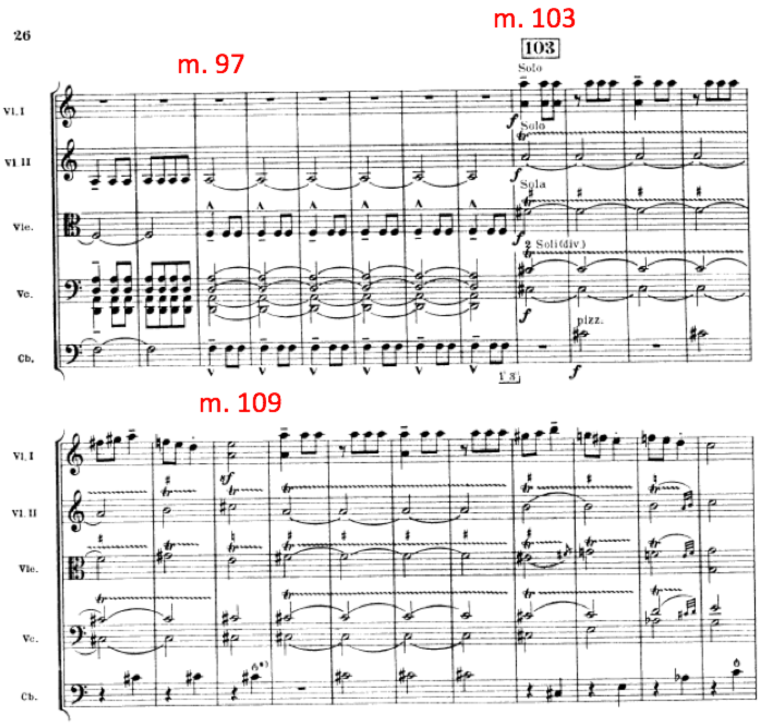
In general, kinematic UDPs matched up with major structural changes and melodic traits discussed above, as well as the switch of instrumental configuration from *solo* to *tutti* in bars 20-21, bar 30 (Example 4.18), major melodies for instruments to join in in bar 71, bar 79 (Example 4.14), bars 118-119, bars 127-128 (Example 4.11), bars 171-172 (Example 4.12), melodic upward skip in bar 154 (Example 4.19), special technique such as *trill* in bars 49-51, bars 54-55, bars 58-59 (Example 4.13), bars 103-110 (Example 4.20), bars 159-160 (Example 4.15), dynamic change such as musical accent in bar 8, bars 10-11 (Example 4.10), bars 54-55 (Example 4.13), and also *crescendo* in bar 145 (Example 4.17). It should be noted that the music has similar instrumental texture from bar 68 to bar 81 (Example 4.14) and that different instruments take turns to play the major melody, during which movement kinematics showed UDPs in bar 71, yet had LDPs in bars 68-69 and bars 73-76. The change of deviation types corresponded to the dynamic change between *forte* and *piano* in this case.

Example 4.18 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 19-38.



Example 4.19 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 148-157.

Example 4.20 Bartók, *Divertimento*, Sz. 113, 3rd movement, bars 95-117.



4.3.3.2 Within-conductor stability of kinematic deviation points: Deviation Point Analyses of individual conductor's mean curves in Bartók

The analyses of each conductor's mean curve of three trials conducting Bartók are presented in Figure 4.31, with identified DPs summarised in Figure 4.32. Statistics of UDPs and LDPs in conductor's mean curves are shown by temporal order in Figure 4.33.

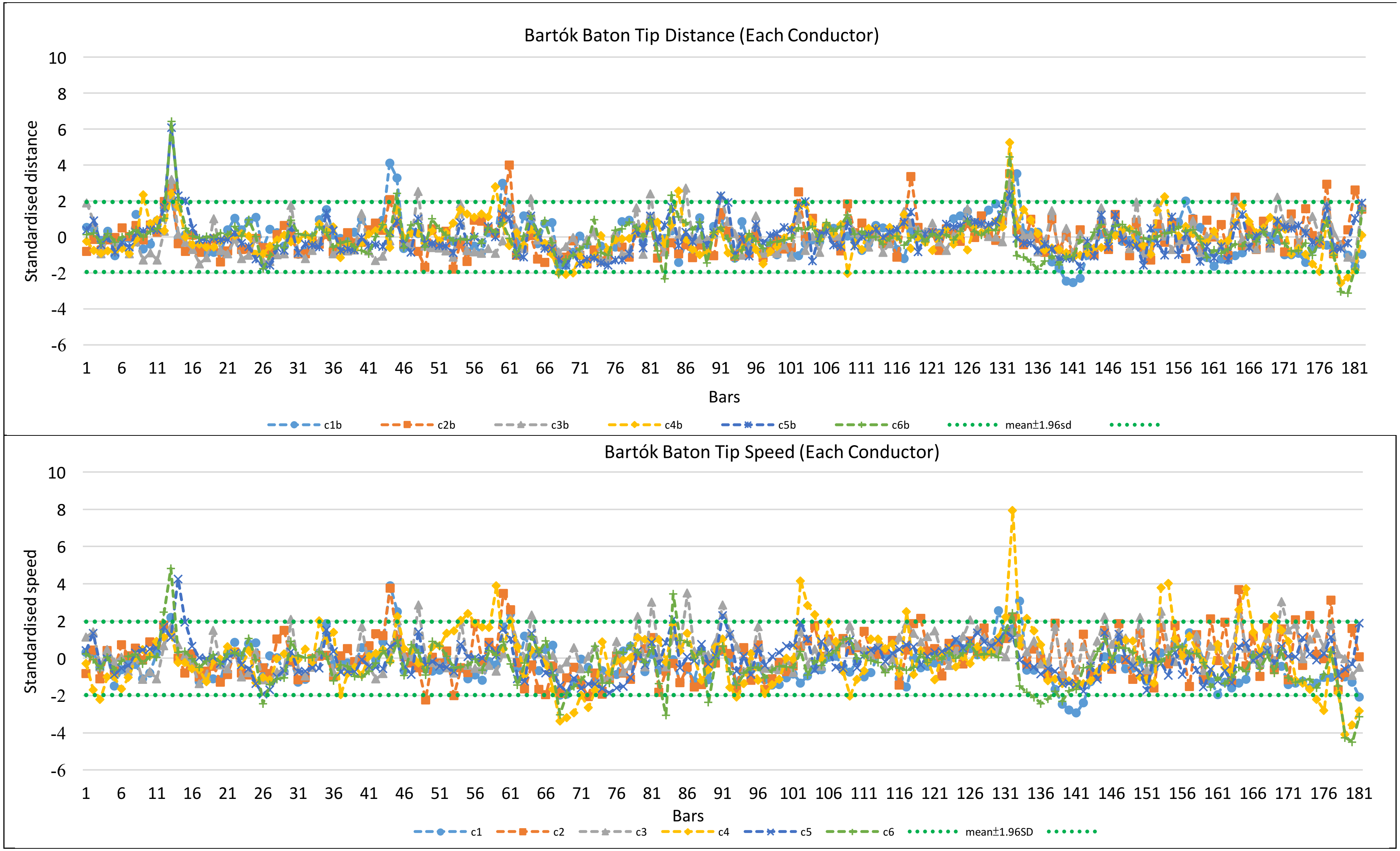


Figure 4.31 Deviation point analyses of each conductor’s mean curve of three trials conducting Bartók

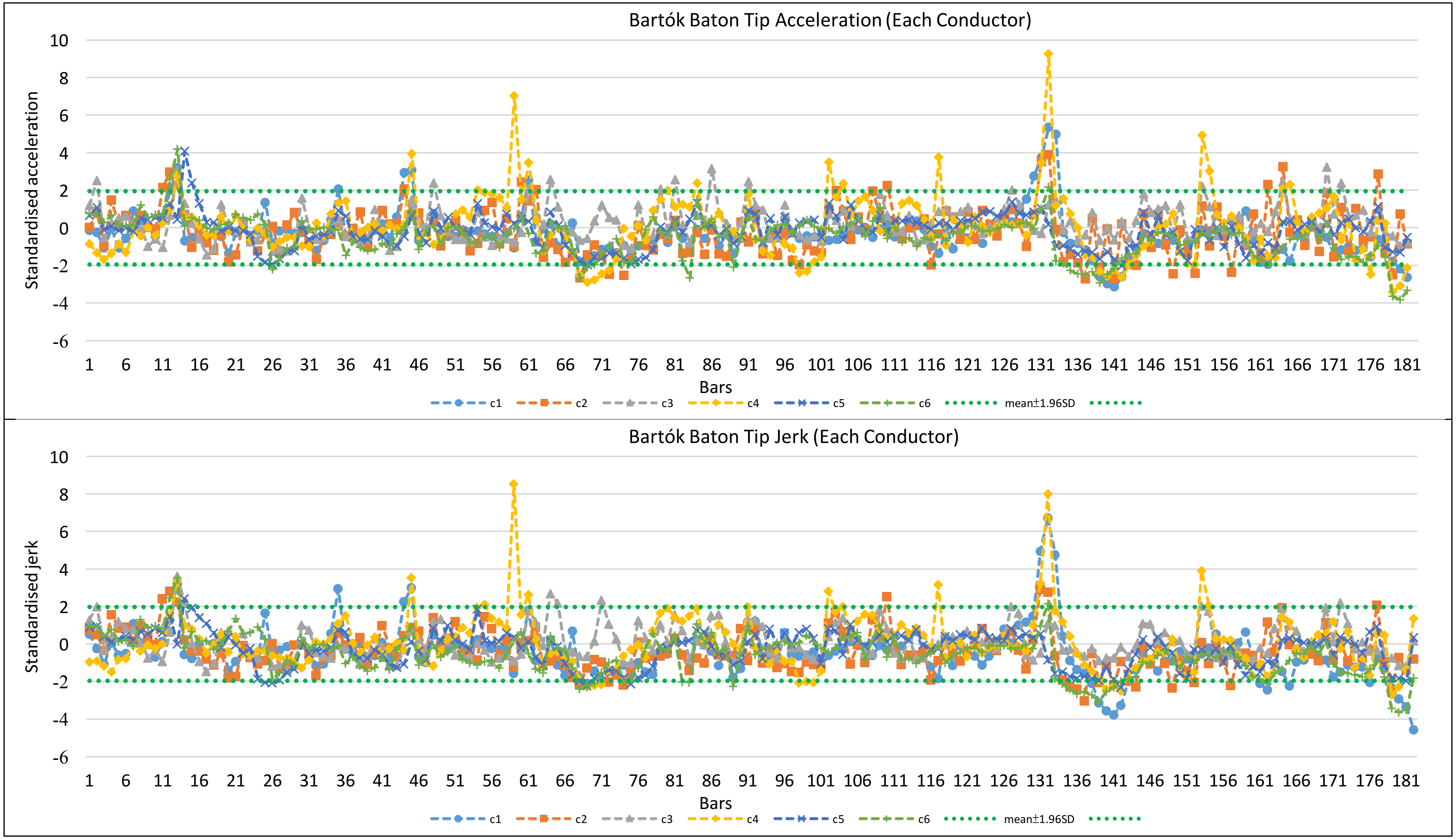


Figure 4.31-2 Deviation point analyses of each conductor's mean curve of three trials conducting Bartók's music (continued)

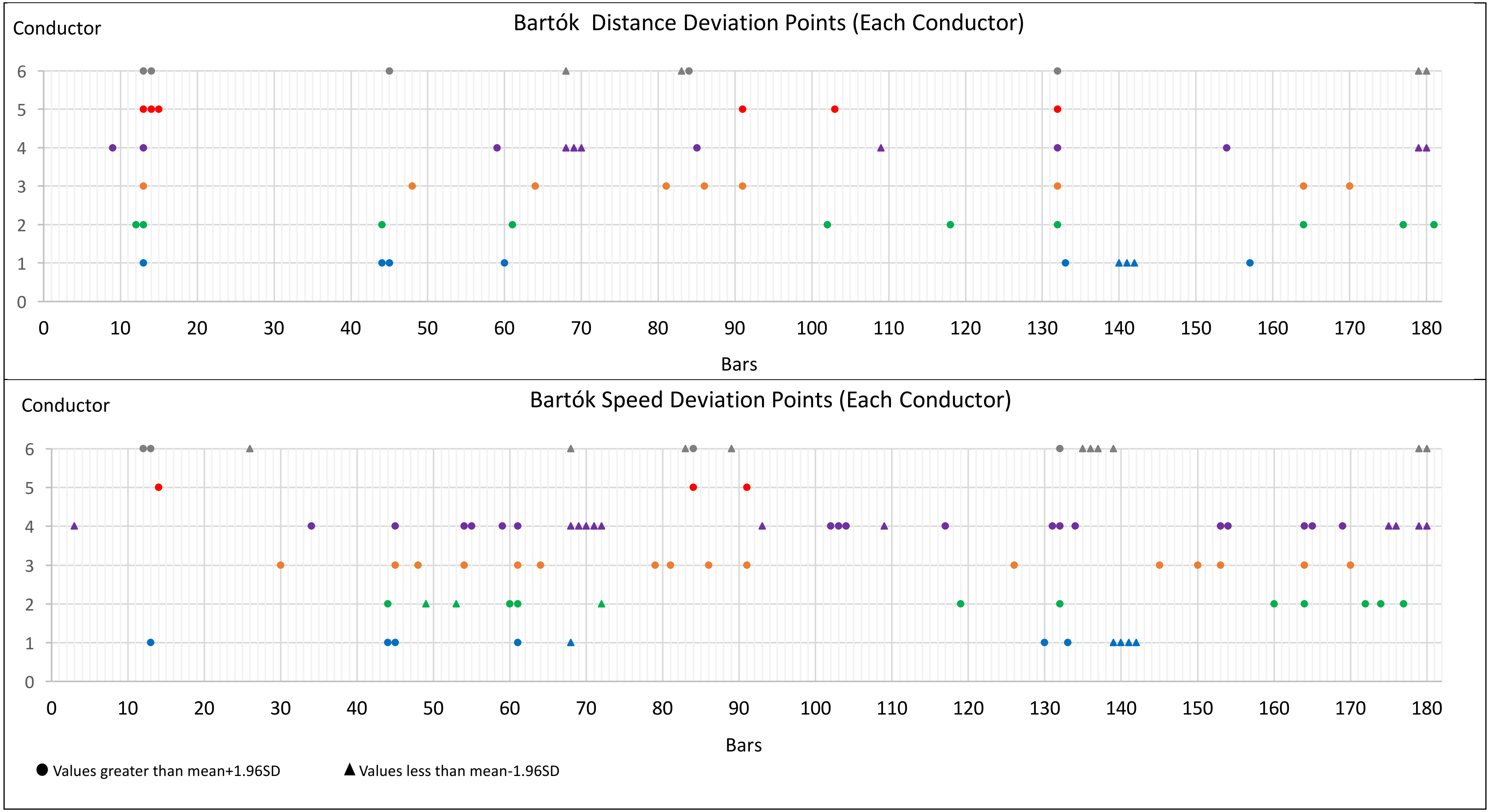


Figure 4.32 Deviation points of each conductor's mean curve for four kinematic variables in Bartók

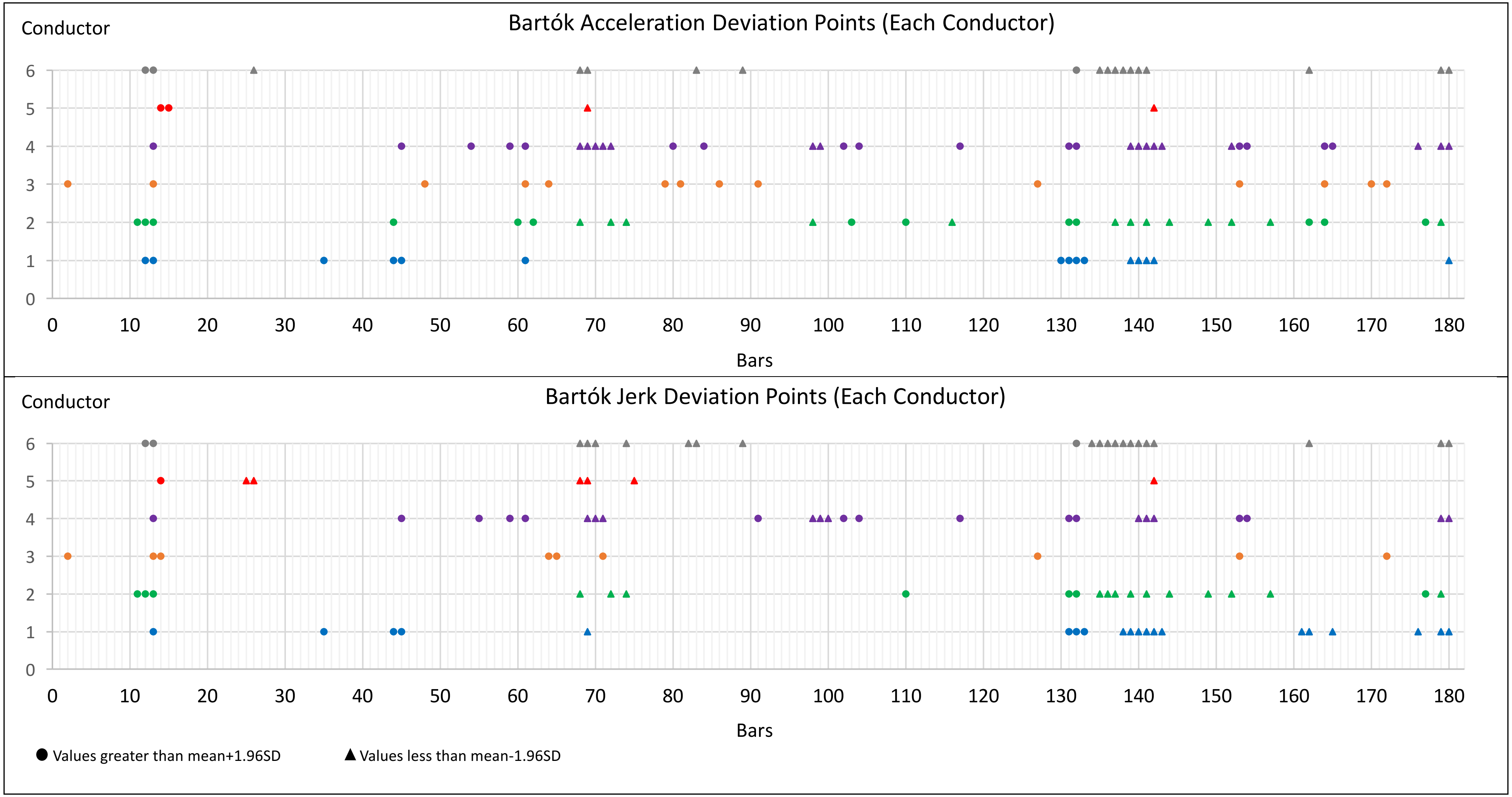


Figure 4.32-2 Deviation points of each conductor's mean curve for four kinematic variables in Bartók (continued)

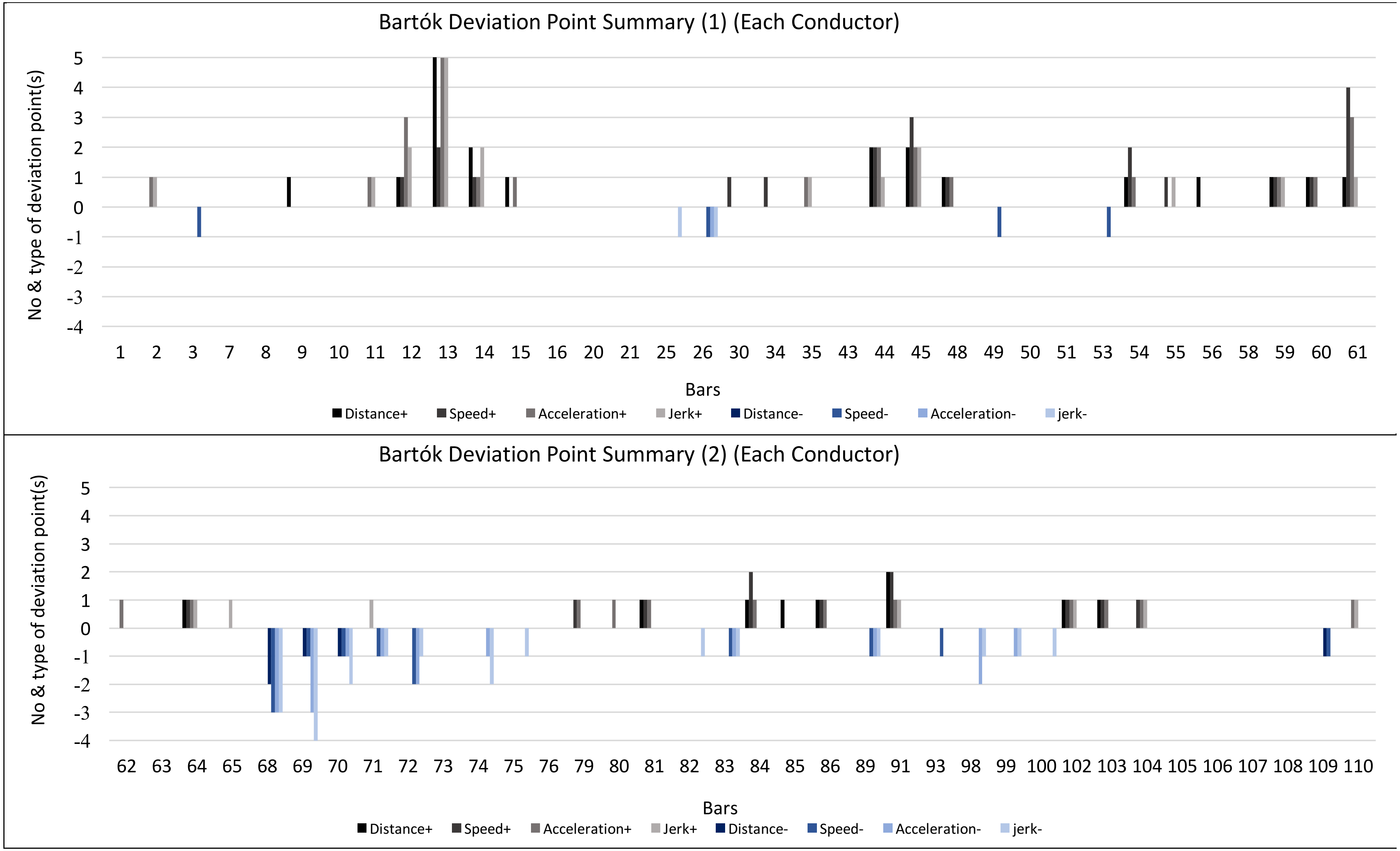
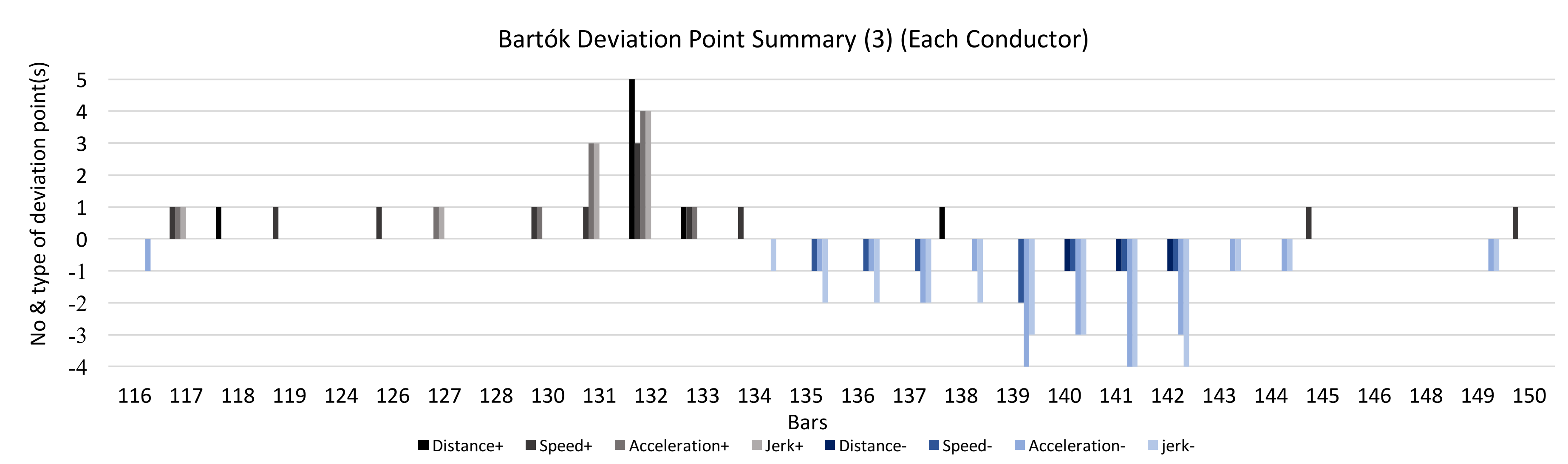


Figure 4.33 Statistics of deviation points of each conductor’s mean curve in Bartók



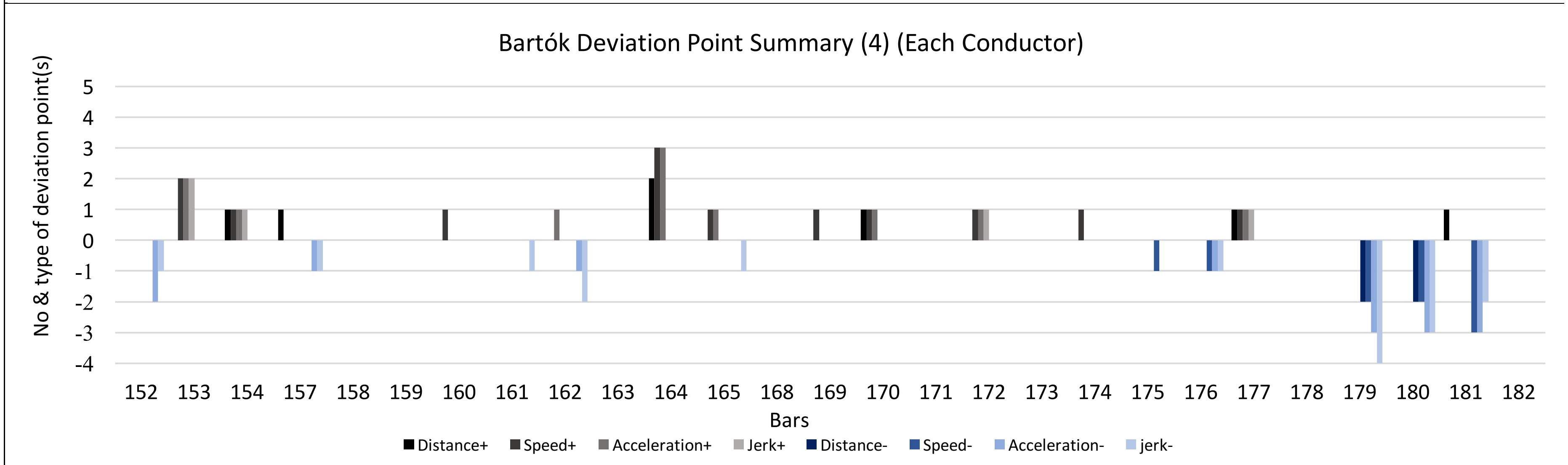


Figure 4.33-2 Statistics of deviation points of each conductor’s mean curve in Bartók (continued)

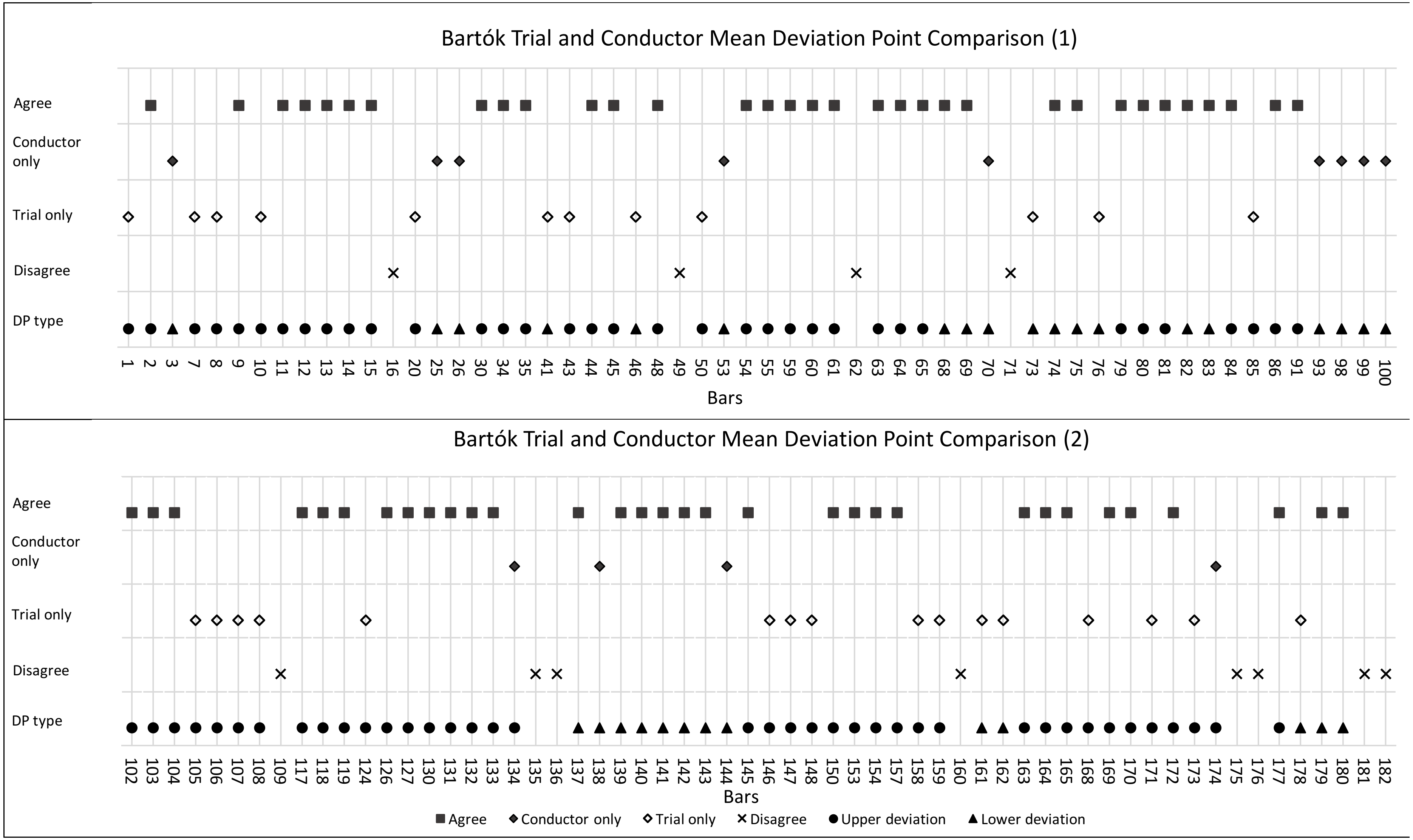


Figure 4.34 The comparison of deviation points in trials and in conductor's mean curves in Bartók

The comparison between DPs identified from each trial (Figure 4.30) and from each conductor's mean curve (Figure 4.33) are summarised in Figure 4.34. It appeared that the most constant DPs identified from both methods (the first row 'Agree' in Figure 4.34) matched with metrical change (bars 12-13, Example 4.10), *glissando* (bar 45, Example 4.13; bar 61, Example 4.14), and union instrumental texture (bars 82-84, Example 4.16), which were highlighted in conductors' interviews[6]. It should be noted that even though *glissando* generally tended to be considered as a detailed melodic feature at local level of compositional structure, in interviews, conductors recognised *glissando* as one of the distinctive features in Bartók, and they stated that they would intend to highlight *glissando* in their conducting.

Another interesting observation is that compared to the most stable deviation point clusters stated above, kinematic DPs tended to be less stable for compositional features including accented elements, introducing of main melodies, and the switch between *solo* and *tutti*. For instance, the music presents similar structures combining musical accents and *trill* throughout bars 49-55 (Example 4.13), and also bars 103-108 (Example 4.20), yet deviations did not remain stable throughout those two periods. Sometimes DPs were identified from both methods, but sometimes they were identified from only one of the two methods. Similar cases were found on the introducing of main melodies by individual instruments alternatively in bars 68-81 (Example 4.14), and also the switch between *solo* and *tutti* in bar 20 and bar 26 (Example 4.18). These cases might be evidence to indicate that conductors tended to use more flexible strategies to introduce new melodies, as well as to instruct accents and the switch between *solo* and *tutti* when these compositional traits occur more frequently.

4.3.3.3 Between-conductor kinematic variability: Deviation Point Analyses of between-conductor standard deviation in Bartók

Analyses of between-conductor kinematic variability are presented in Figure 4.35, and DPs with high between-conductor variability are shown in Figure 4.36. The comparison of DPs of between-conductor variability and the stability of within-conductor DPs are summarised in Figure 4.37. The tendency can be observed that high between-conductor kinematic variability inclined to occur before or during highlighted musical events, for instance, before *glissando* in bar 45 and bar 61 (Example 4.13 and Example 4.14), and before introducing main melodies in bar 118 (Example 4.11). Yet high movement variability occurred during the important metrical change in bars 131-133 (Example 4.11).

[6] Due to the limited time for interview, conductors only provided interpretational comments in bars 1-91 for Bartók's excerpt.

In cases of upward melodic leaps in bar 154 and bar 165 (Example 4.19 and Example 4.15), high variability was shown before and during the leaps. The only exception for this tendency was the instrumental union from bar 178 (Example 4.12). The increasing kinematic variability after the start of union might indicate that conductors tended to employ various conducting strategies to maintain the union chord and conclude this music except. Compared to Mozart and Dvořák, high kinematic variability tended to occur earlier than highlighted musical events in Bartók. The findings could connect to conductors' opinions in interviews that they inclined to conduct Bartók by one beat per bar, which suggested that any musical change which conductors intended to make should be presented in their movement in the bar prior to the musical event.

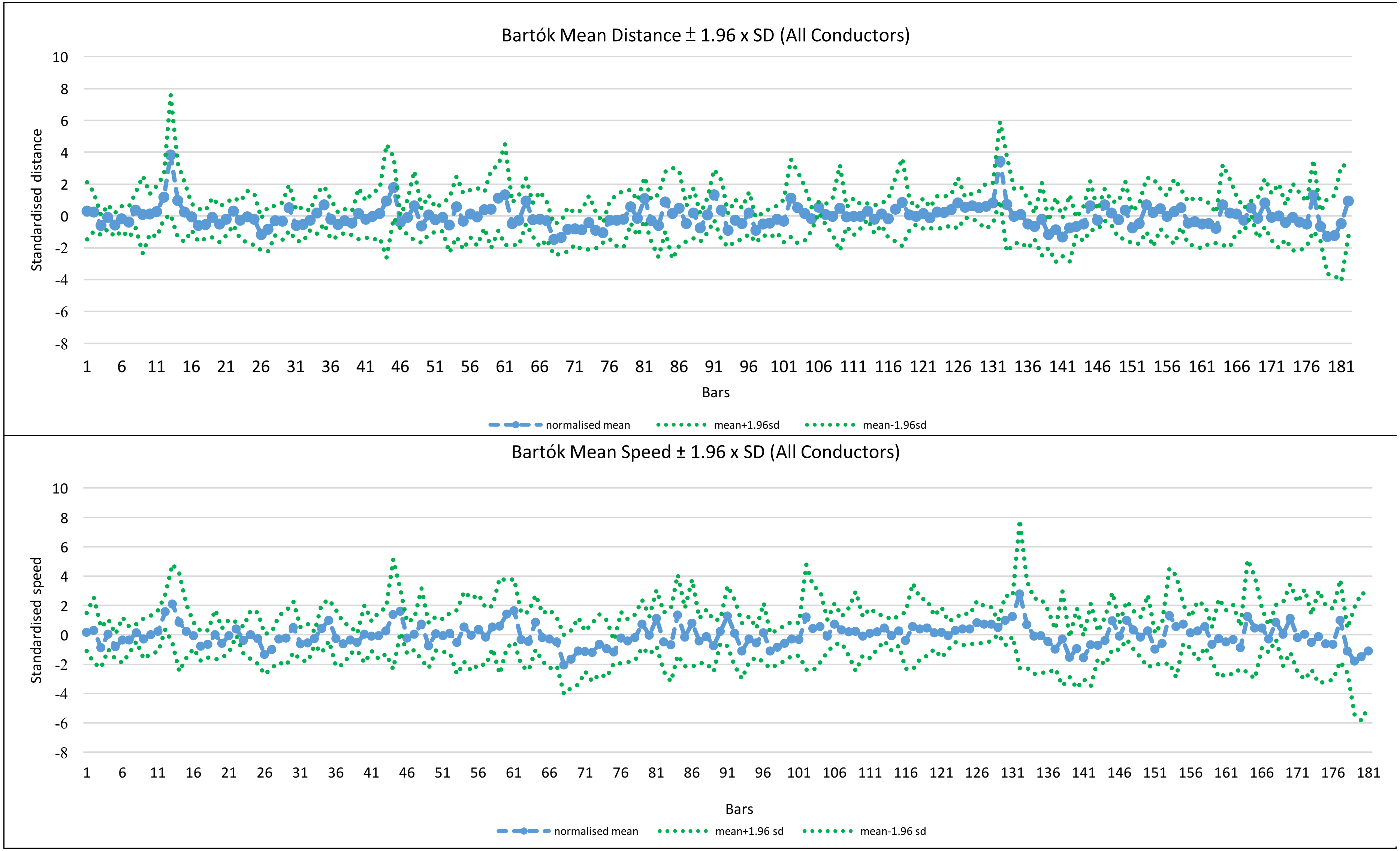


Figure 4.35 Between-conductor kinematic variability in Bartók

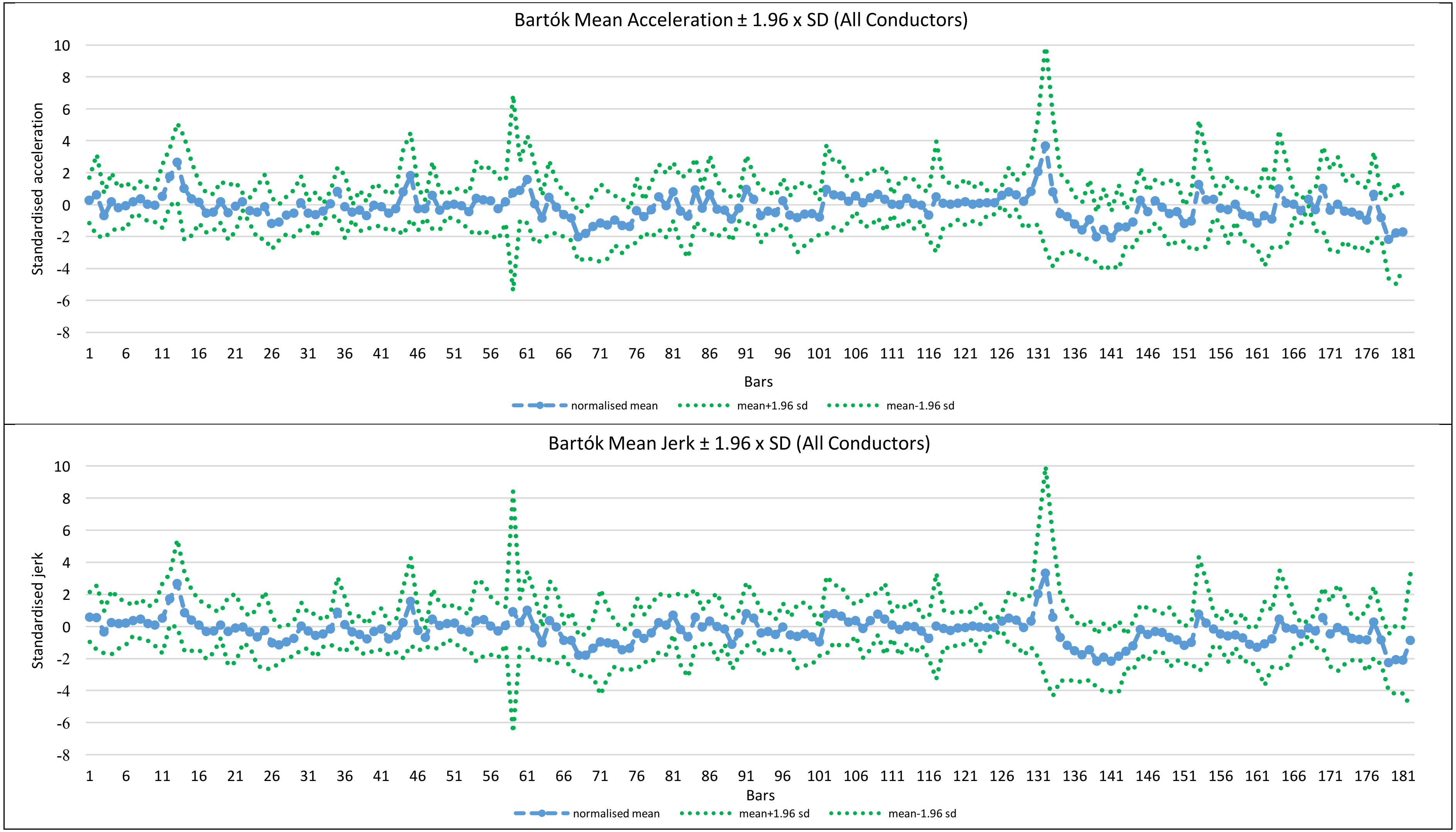


Figure 4.35-2 Between-conductor kinematic variability in Bartók (continued)

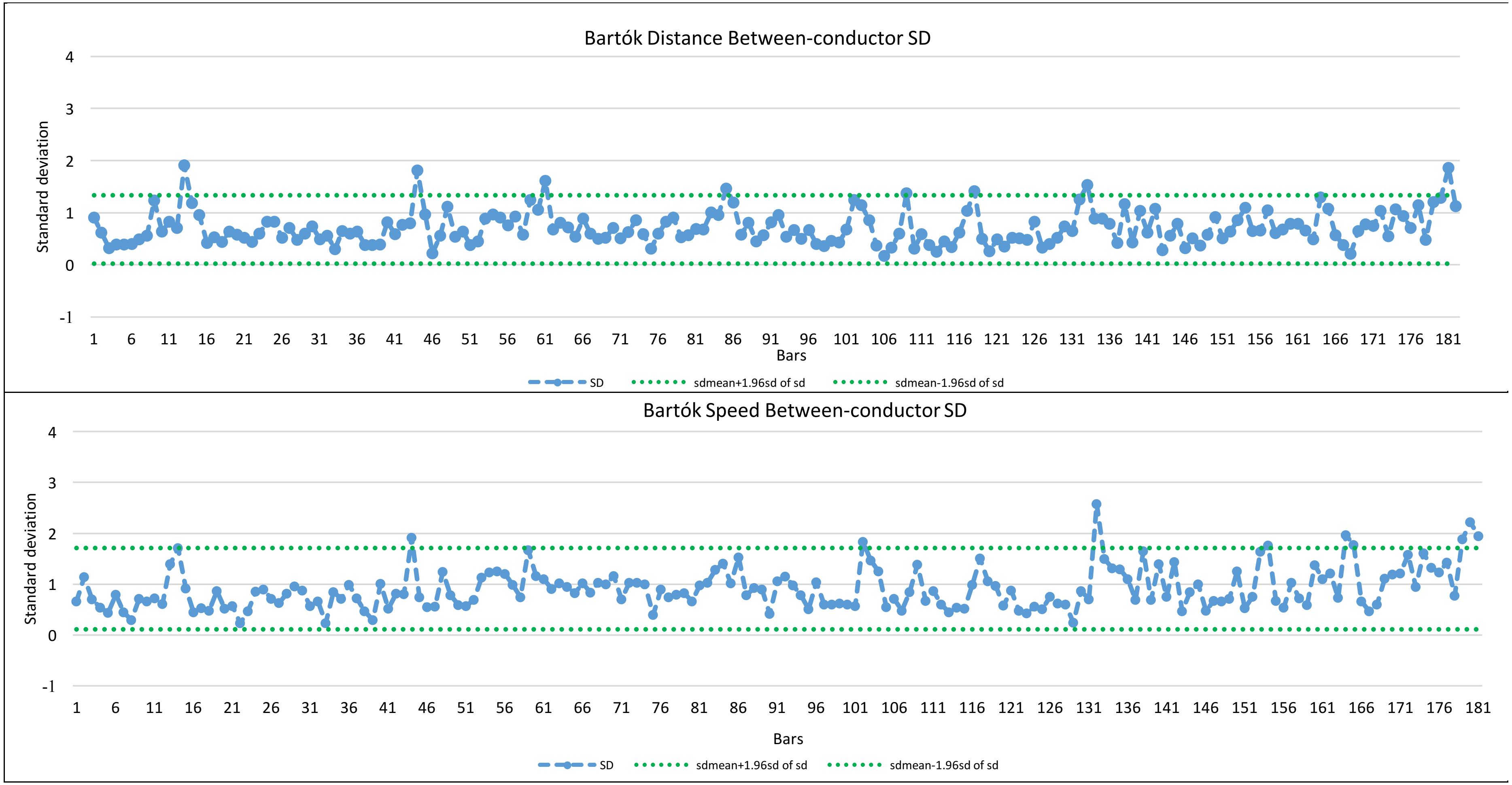


Figure 4.36 Deviation point analyses of between-conductor kinematic variability in Bartók

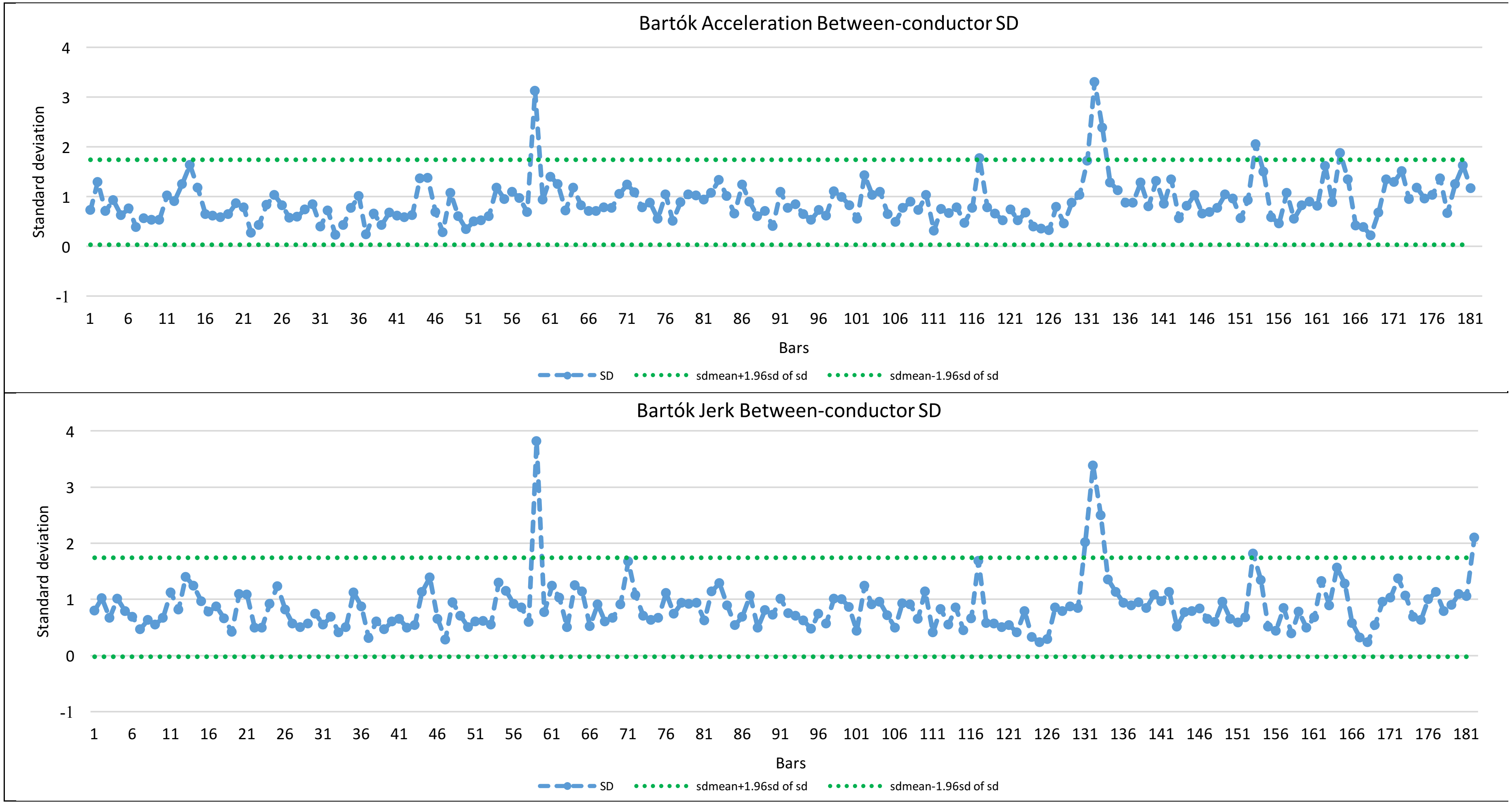


Figure 4.36-2 Deviation point analyses of between-conductor kinematic variability in Bartók (continued)

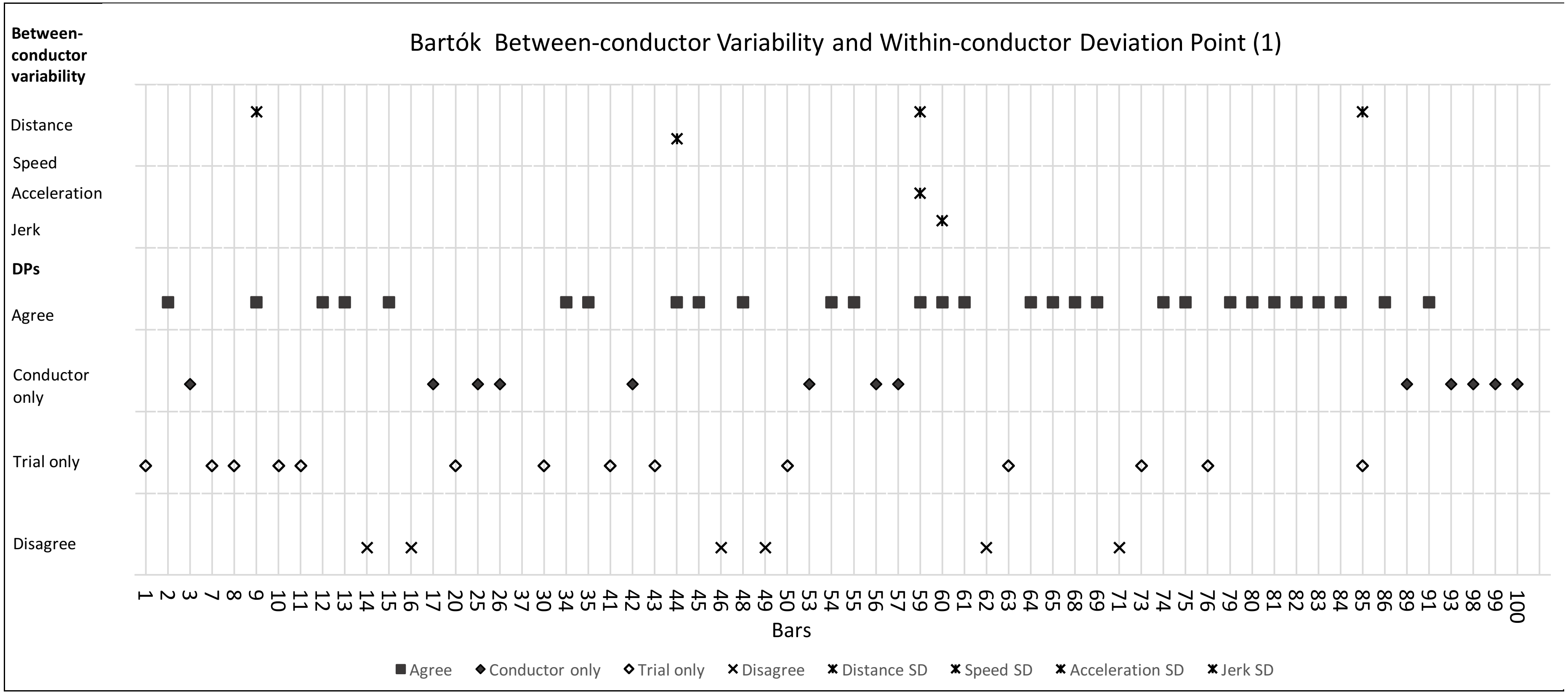


Figure 4.37 The comparison of between-conductor variability deviation points and within-conductor deviation points in Bartók

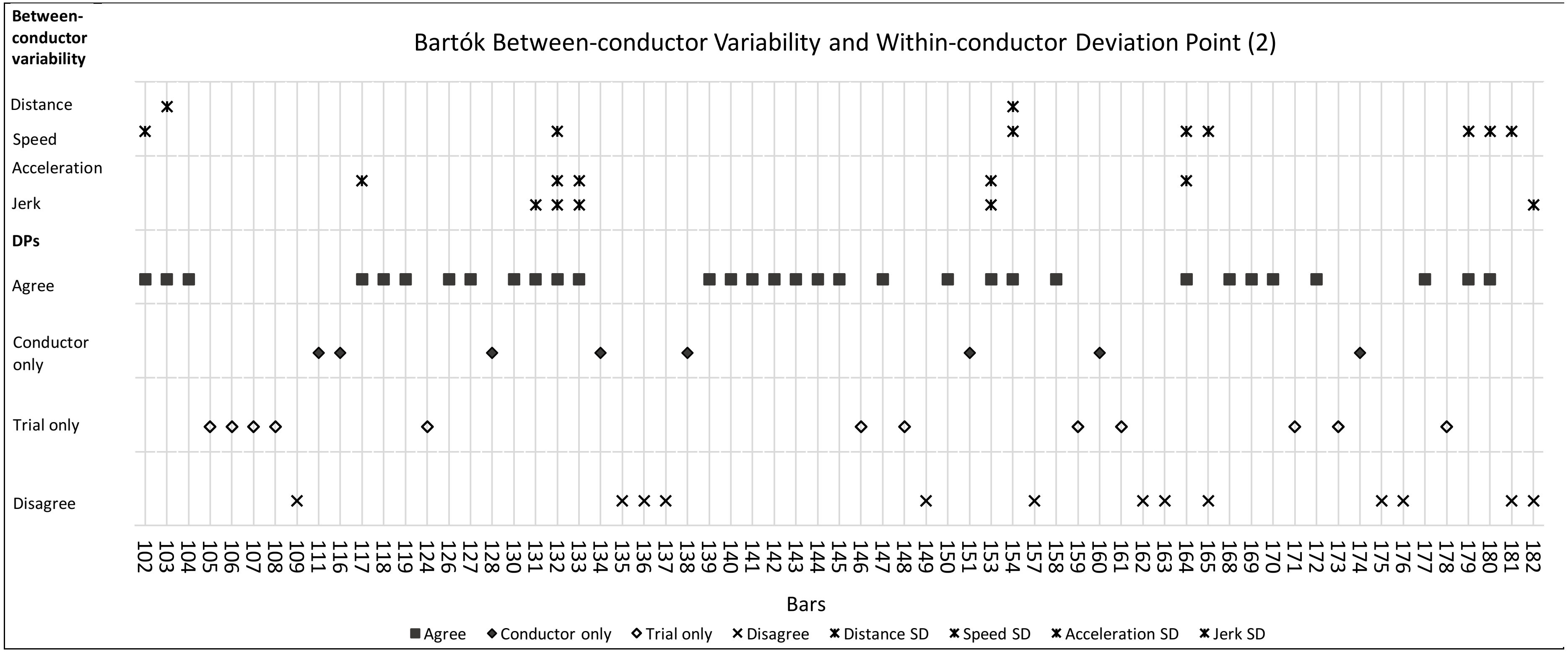


Figure 4.37-2 The comparison of between-conductor variability deviation points and within-conductor deviation points in Bartók (continued)

4.3.3.4 Kinematic deviation points in relation to interpretational locations in Bartók

Conductors' interpretational intentions stated in interviews (section 2.3.2) and kinematic DPs presented in their conducting of Bartók (section 4.3.3) are compared in Table 4.3 and Figure 4.38 (based on results in Table 2.9 in Chapter 2; Figure 4.30, Figure 4.33, and Figure 4.37 in Chapter 4). It can be observed that kinematic UDPs coincided with conductors' beat subdivision for *poco rall* and *a tempo* (bars 13-14), 'bigger movement' with 'more weight' and 'more intensity' for *tutti* (bars 20, 49), 'large circle' movement for *glissando* (bars 45, 61), 'more pointed upbeat' for *pizzicato* (bars 16-17), cuing movements for instrumental entry (bars 62, 65). Conversely, LDPs in conducting movement were associated with 'enclosed', 'compact' movement for *solo* (bars 26[7], 68). It should be noted that UDPs corresponded with musical accents and *trill* (bars 7-12, 34-35, 43-44, 50-60), even though conductors did not provide comments at these locations. This composition is full of intensive musical accents, and owing to limited time in interviews, conductors might only choose to mention several selective occasions rather than marked all accents in the composition.

[7] The LDP in bar 26 was based on conductor's mean curve analysis, which is not shown in the results for trial analysis in Figure 4.28.

Table 4.3 Conductors' interpretational intentions and kinematic deviations in Bartók

	Score analysis	Interview	Conducting kinematics	
Bar	**Compositional feature**	**No. of comment**	**Kinematic deviation**	**High kinematic variability**
82-92	instrumental union, syncopation	3	conductor & trial (UDP & LDP)	distance
45	*glissando*	1	conductor & trial	speed
7-12	accent	-	conductor & trial	distance
61	*glissando*	(bar 45)	conductor & trial	distance, acceleration, jerk
13-14	tempo change (*poco rall→ a tempo*)	6	conductor & trial	-
62, 65, 71, 77	*p→f*, entry of main melody	(bar 68)	conductor & trial	-
31	*solo→tutti*, *f*	1	conductor & trial	-
49	*solo→tutti*, *f*, *sf*, *trill*	1	conductor & trial	-
1-2	beginning of piece	-	conductor & trial	-
34-35	accent	-	conductor & trial	-
43-44	accent	-	conductor & trial	-
50-60	*sf*, *trill*	-	conductor & trial	-
20	*solo→tutti*, *f*	3	trial	-
16-17	*pizzicato*	1	trial	-
92	*ff*, entry of new melody	1	trial	-
68, 74	*p*, entry of main melody	1	conductor & trial (LDP)	-
26	*tutti→solo*, *f*	2	conductor (LDP)	-
37	accent	1	-	-

Note: 1) Kinematic deviations without special mark are UDPs; 2) the compositional structure in bar 61 is similar to bar 45; the compositional structures in bar 62 and 65 are similar to bar 68.

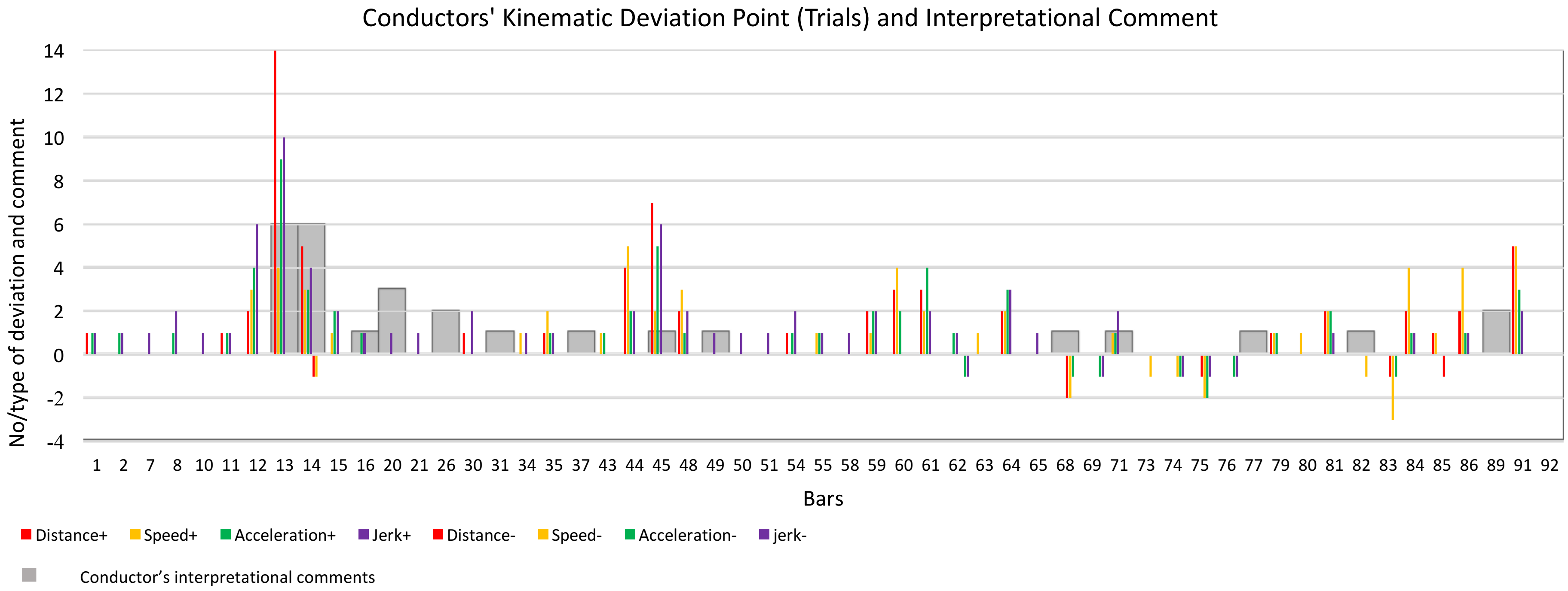


Figure 4.38 Conductors’ interpretational intentions and kinematic deviations in Bartók

4.3.4 Discussion of kinematic deviation points and movement variability in three musical excerpts

4.3.4.1 Kinematic deviation points in three musical excerpts

Even though deviation points identified from three musical excerpts were not comparable directly due to different sample sizes (different bar numbers and musical lengths), several common tendencies emerged from findings in three musical excerpts. In all musical excerpts, conductors tended to show the most number of UDPs in jerk compared to other variables. For instance, five of six conductors showed most UDPs for jerk in Mozart; three of six conductors possessed the highest number of UDPs for jerk in Dvořák and Bartók compared to other kinematic variables. This might be due to the fact that jerk is a higher derivative variable, which makes it more likely to be affected by sampling noise and therefore to pass thresholds and be identified as DPs compared to other variables.

Comparing between conductors, C3 tended to possess the most UDPs of the six conductors. C3 showed the most UDPs for all variables in Bartók, and also showed the most UDPs for distance, speed, acceleration in Mozart, and acceleration and jerk in Dvořák. Conversely, C6 had the lowest number of UDPs, which can be observed from all variables in Mozart, and also distance and speed in Dvořák and Bartók.

4.3.4.2 The connection between kinematic deviation points and compositional features

Compositional features and bar numbers showing corresponding kinematic UDPs, LDPs, and high variability to those compositional features in three musical excerpts are summarised in Table 4.4. This summary included all DPs identified from trials, from conductor's mean curves, from both of them, as well as from between-conductor variability. Overall, conductors' kinematic UDPs reflected distinctive musical features in individual musical excerpts. For instance, Bartók presents wider variety of structural change (e.g., metrical change) and the contrast of instrumental configurations (e.g., *solo* and *tutti*) compared to Mozart and Dvořák, and conductors thus tended to use kinematic UDPs to instruct tempo fluctuations, metrical changes, the switch between *solo* and *tutti*, and the introduction of instrumental parts. Contrasted with Dvořák's lyric melodic style, both Mozart and Bartók possess rhythmic character. Conductors' UDPs hence corresponded to irregular rhythm or short rhythmic fragments in these two musical excerpts accordingly. As for melodic features, conducting UDPs linked to counterpoint melodies, melodic climax, and upward melody in Mozart and Dvořák, whereas distinctive melodic features in Bartók such as *glissando* and *trill* were presented by kinematic deviations in conducting. The three musical excerpts have distinctive dynamic traits, which were clearly reflected on conducting movement deviations. Mozart contains a lot of dynamic contrast and conductors' UDPs tended to highlight the dynamic contrast from *piano* to *forte*. One of the most important features in Dvořák is its 'Romantic build up' according to conductors' opinions in interviews. Kinematic UDPs were thus used to instruct the *crescendo* and the dynamic climax in the music. Rhythmic patterns in Bartók contain intensive musical accents, which were associated with kinematic deviations in conductors' movement.

As for LDPs of movement, in Mozart, kinematic LDPs coincided with dynamic change including *diminuendo*, and the contrast from *forte* to *piano*, whereas in Bartók, lower deviations mainly reflected instrumental reduction and sustained note. It seems that in Bartók, conductors were keener to employ LDPs to highlight musical features which contrast with the 'aggressive' style of this musical excerpt.

Table 4.4 Summary of compositional features and bars showing corresponding kinematic Deviation Points in three musical excerpts

Kinematic feature	Upper Deviation Point (UDP)											
	-	High variability	-	-	-	-	-	High variability	High variability	High variability	High variability	High variability
Musical feature	**Structural/ Instrumental configuration**						**Melodic feature**					
	Tempo flactuation	Metrical change	End of excerpt	New theme	solo→tutti	Instrument(s) join in	Counterpoint melodies	Melodic climax	Upward skip	Upward melody	Glissando	Trill
Mozart				bar 28			bars 39-40 bars 47-48	bars 22-26		bar 21		bars 51-52
Dvořák							bar 14	bar 20*		bars 17-20*		
Bartók	bars 12-14	bars 131-133*	bar 182		bar 20 bar 31	bar 71 bar 79 bars 118-119 bars 127-128 bars 171-172			bar 154* bar 165*		bar 45* bar 61*	bars 49-59 bars 103-110* bars 159-160

Kineamtic feature	Upper Deviation Point (UDP)					
	High variability	High variability	High variability	-	High variability	-
Musical feature	**Rhythmic feature**		**Dynamic feature**			
	Syncopation	New rhythmic pattern	Crecendo	Dynamic climax	p→f	Accent
Mozart	bars 24-25*	bar 5	bar 21		bar 39* bar 47*	
Dvořák		Bar 31*	bars 6-7* bars 17-19* bar 25 bars 35-37 bar 45 bar 47	bar 21		bars 38-39
Bartók	bars 85-86*		bar 145			bar 8 bars 10-11 bars 54-55

Note: * indicates bars showing high kinematic variability

Table 4.4-2 Summary of compositional features and bars showing corresponding kinematic Deviation Points in three musical excerpts (continued)

Kineamtic feature	Lower deviation point (LDP)				
	-	High variability	-		
Musical feature	**Structural/ Instrumental configuration**	**Melodic feature**	**Dynamic feature**		
	Instrumental reduction	Sustained note	f→p	Diminuendo	Piano
Mozart			bar 28 bar 54	bars 10-11 bar 21 bar 41	
Dvořák					
Bartók	bars 139-144	bars 82-83 bars 178-180*			bars 68-69 bars 74-76

Note: * indicates bars showing high kinematic variability

Regarding between-conductor kinematic variability, high variability between conductors tended to connect with compositional traits in melodic, rhythmic and dynamic aspects. Conductors' movement kinematics appeared to be more diverse to one another when they intend to deliver structural features in composition.

As stated above, general tendencies can be observed that kinematic deviations tended to reflect specific compositional features. In reality, however, those compositional features usually combine together and interact with one another in a complicated manner in musical composition, and conducting movement might thus only reflect particular musical aspects selected by the conductor. It appeared that short rhythmic patterns tended to be highlighted using jerk UDPs regardless of musical features in melodic or instrumental aspects, particularly in Dvořák and Bartók. For instance, those short rhythmic patterns were still features selected by conductors to highlight using jerk UDPs, even when music shows instrumental reduction and *diminuendo* in Dvořák (bars 27-28, Example 4.8). As for Bartók, conductors seemed to emphasise rhythmic and dynamic features despite similar instrumental texture. In bars 85-86, irregular rhythmic pattern of syncopation was stressed by an obvious cluster of kinematic UDPs even though the instrumental texture remains as union. In case of bars 68-81, UDPs and LDPs responded to dynamic change of *forte* and *piano* respectively, in spite of similar music texture through this passage.

In summary, it was found that in actual conducting performances, kinematic DPs in conducting movement and high kinematic variability between conductors reflect the overall character of each musical excerpt, as well as featured compositional elements in the musical work. These results reflect the ideology evident in conducting textbooks such that special movements are used to instruct highlighted compositional elements in conducting (see Table 1.1). Various features in melodic, rhythmic, harmonic, dynamic, instrumental aspects interact in the composition, and it relies on conductors to provide their musical interpretations and to select musical elements they want to highlight in performances. In interviews (Chapter 2), conductors provided their interpretational annotations of three musical excerpts. The connection between 'What do conducting textbooks *tell* conductors to do?', 'What do conductors *say* they are doing?' and 'What do conductors *do* in the process of conducting?' will be further addressed in the next chapter.

4.4. Summary of findings

The findings in this chapter can be summarised surrounding three research questions concerning kinematic deviations in conducting movement, the stability of these deviations, and the kinematic variability in conducting.

Regarding research question 4.1, it was found that conductors' movement kinematic deviations corresponded to specific compositional elements in three musical excerpts. Results of trial analyses using DPA showed that:

1) In Mozart and Dvořák, kinematic UDPs connected with compositional elements including melodic features such as upward melodic line, melodic climax, counterpoint melodies; entry of new rhythmic pattern and special rhythm such as syncopation; dynamic change such as *crescendo*, and the switch from *piano* to *forte*; special playing technique such as *trill*. In Bartók, kinematic UDPs associated with compositional elements including structural change such as tempo change, metrical change, and the switch from *solo* to *tutti*; distinctive melodic features such as *glissando* and obvious upward melodic skip; dynamic features such as musical accent.
2) In contrast to kinematic UDPs, LDPs tended to coincide with the dynamic switch from *forte* to *piano*.
3) Comparing four kinematic variables, jerk UDPs tended to match with short segments of rhythmic pattern, particularly in Dvořák and Bartók, whereas distance, speed, and acceleration UDPs inclined to associate with continuous, prolonging melodic lines.
4) Comparing three musical excerpts, kinematic DPs clearly reflected each composition's characters in structural, melodic, rhythmic, and dynamic aspects. In structural aspect, Bartók presents wide variety of structural configuration, and conducting kinematic DPs thus corresponded to structural features including tempo fluctuation, metrical change, and instrumental contrast (e.g., *solo* and *tutti*). In melodic aspect, in Mozart and Dvořák, kinematic DPs linked to melodic climax, upward melodic line, and counter point melodies, whereas in Bartók, DPs connected to distinct features including *glissando* and *trill*. In rhythmic aspect, kinematic DPs, particularly jerk UDPs, showed strong connections with short rhythmic patterns in the second section in Dvořák, and also in Bartók. In dynamic aspect, kinematic DPs reflected different dynamic traits in three musical excerpts, that they bonded with dynamic contrast (i.e. *forte* and *piano*) in Mozart, dynamic climax of 'Romantic build up' in Dvořák, and also intensive accent in Bartók.
5) Complicated combinations of compositional elements may induce kinematic variations departing from the aforementioned tendencies. For instance, in Dvořák, conductors tended to highlight *trill*

and short rhythmic patterns using jerk UDPs, in spite of the *diminuendo* and instrumental reduction occurring at the same moment. Another example is that in Bartók, different kinematic deviation types of UDP and LDP reflected the dynamic change between *forte* and *piano* regardless the similar instrumental texture of music.

Regarding research question 4.2, it was found that more stable deviations and less stable deviations reflect different compositional elements respectively. Results of conductors' mean curve analyses using DPA showed that:

1) In Mozart, the most stable DPs (identified from both trials and from conductor's mean curves) connected to dynamic contrasts from *piano* to *forte*, as well as the combination of melodic climax, *crescendo* and syncopation; in Dvořák, the most stable DPs associated with the combination of short rhythm, *crescendo*, and accent, as well as the 'romantic build up' by upward melodic line and *crescendo*; in Bartók, the most stable DPs coincided with metrical change, *glissando*, and union instrumental texture.
2) In Mozart, less stable DPs (identified from trials only, or from conductor's mean curves only) connected to local compositional features including musical accent and *trill*; in Dvořák, less stable DPs associated with local smaller scale dynamic changes; in Bartók, less stable DPs coincided with musical accent and the switch between *solo* and *tutti*.
3) Comparing three musical excerpts, DPs showed different connections with compositional elements, which reflected the structural differences between musical compositions. In Mozart, rhythmic features tended to associate with less stable DPs, which may suggest that rhythmic features were not the most important features to highlight in this musical excerpt. In Dvořák, kinematic DPs connected with rhythmic features in a stable manner, which was in line with the fact that two different types of rhythmic pattern are the essential elements to consist of two musical themes and structural sections in Dvořák. Another example is that *glissando* connected with DPs in a stable manner in Bartók, even though *glissando* generally tended to be considered as secondary local feature in other compositions.

Regarding research question 4.3, it was found that high kinematic variability between conductors corresponded to important structural locations in the composition. Results of between-conductor variability analyses using DPA showed that high between-conductor kinematic variability tended to appear after the targeted musical events conductors intended to highlight in Mozart, whereas high variability was more likely to appear during or after target musical events in Dvořák, and appear before or during target events in Bartók. A possible explanation for this is that conductors mostly conducted by one beat per bar in Bartók, and thus the instruction for forthcoming musical events needed to be shown in the prior musical bar in their conducting. This finding suggested that each conductor tended to apply idiosyncratic strategies to approach target interpretational musical events.

In summary, findings in this chapter demonstrated particular connections between conducting kinematic deviations and compositional structures in conducting performance. Conducting movement kinematic deviation points closely associated with compositional elements in temporal, melodic, rhythmic, dynamic, instrumental aspects. Stable kinematic deviation points tended to connect with important structural features in the composition, whereas less stable kinematic deviation points reflected secondary detailed compositional elements. High movement variability between conductors coincided with important compositional structures, which suggested that individual conductors use diverse strategies to highlight these structural points. These findings provide empirical observations of actual conducting movement, which are in line with conducting movement ideology displayed in conducting educational manuals and conductors' self-reported intentions in conducting. In the next chapter, findings from this chapter will be discussed together with findings in conductors' interviews (Chapter 2) and kinematic analyses for conducting movement in Chapter 3. Conductors' ideas of conducting movement will be connected with observed movement features in conducting performances.

Chapter 5: General discussion

In previous chapters, orchestral conducting was examined via conductors' interviews and kinematic analyses of conducting movement. In Chapter 1, the instructional ideas of conducting movement were explored via conducting instructions in textbooks. It is believed that the conductor's movement kinematics communicate important information in conducting. There has been a growing body of research into music performers' and listeners' body movement, demonstrating that musical movements are closely attached to compositional elements and the performer's interpretational intentions. Since the variability of conducting movement rises from the interactive dynamical system of compositional, interpretational, and performance factors, empirical research is needed to investigate whether such variations in conducting movement kinematics indeed communicate compositional and interpretational aspects in actual conducting performances. In Chapter 2, conductors' ideas in performing their body movements and their interpretations of three performed compositions were explored. Detailed analyses of conductors' self-reports identified key events and key features in their conducting, and guided the subsequent analyses of observed movement kinematics. In Chapter 3 and Chapter 4, the actual movements in conducting performances of selected excerpts of works– chosen to be broadly representative of stylistically varied repertoire– were collected and empirically analysed, including an innovative method to explore the variability of conducting movement.

In this chapter, findings from conductors' interviews and kinematic analyses of conductors' performed conducting movement are joined together. In the complex interactive dynamical system of conducting performance, this thesis explored core issues such as 'What are conductors *told* to do?', 'What do conductors *say* they are doing?', and 'What do conductors *do* in the process of conducting? This chapter aims to link up these aspects of orchestral conducting. Section 5.3.1 examines the question of how the observed kinematic features in conducting movement (Chapter 3 and Chapter 4) follow conductors' ideas of their performing conducting (Chapter 2). Section 5.3.2 examines whether the observed kinematic features in conducting movement (Chapter 3 and Chapter 4) are in line with conventional emblems suggested by conducting pedagogical manuals (Chapter 1). The overall findings based on these aspects of conducting are then discussed together with previous findings from musical performance studies (section 5.3.3- section 5.3.5), and thus add evidence to our existing knowledge of body movement in musical performance, particularly for orchestral conducing.

5.1. Thesis summary

The underlying purpose of this thesis was to explore how the ideas of conducting movement– as portrayed in instructional manuals, and through conductors' own reported beliefs and intentions about conducting– are actually reflected in the practice of performance. Specific aims of the project were to examine 1) how kinematic variations in movement connect with compositional elements in conducting performances, and 2) how conductors' musical interpretations and conducting ideas are reflected in the kinematic variations in their conducting movement. Adopting a mixed-method approach, conductors' opinions collected from interviews and conducting movement collected using motion capture system gathered information regarding conductors' musical interpretation and conducting movement kinematics. Subsequent analyses of these data investigated the connection between movement kinematics, compositional features, and conductors' musical interpretations in conducting performances.

In structured interviews, six conductors reported their general beliefs of conducting, as well as their specific interpretational annotations of three musical excerpts by Mozart, Dvořák, and Bartók (Chapter 2). Conductors identified key musical instances they intended to highlight in their conducting, and described specific body movements they planed to use to emphasise these selected instances. Self-reported qualitative descriptions of conducting movement were thematically analysed, and the results guided the subsequent quantitative analyses of conducting kinematics. After interviews, the same group of conductors worked on the three selected musical excerpts with a small string ensemble, while the movement of twenty-seven markers in the conductor's upper body and baton were recorded using a motion capture system: Qualisys (Chapter 3). Linear kinematic features of their conducting movement were described by four dependent variables of baton tip– distance, speed, acceleration, and jerk. To explore whether conductors' baton tip kinematics were significantly different between repertoire, and between different trial order, the differences of conducting movement kinematics between music repertoire and trial number were investigated using two-way repeated measure ANOVAs (repertoire (3) x trial (3)). Within the same repertoire, the similarity of kinematic time-series patterns between two performances were examined by cross-correlations. To explore whether the time-series patterns of conductors' baton tip kinematics had different extent of similarity when conducting each repertoire, the differences in kinematic similarity between repertoire were examined using one-way ANOVAs (repertoire) on cross-correlation coefficients. To explore whether the time-series patterns of conductors' baton tip kinematics were more consistent to their own repeated performances, compared to the other conductors' conducting, the differences between within-conductor kinematic similarity (repeated performances by the same conductor) and between-conductor kinematic similarity (performances by different conductors) were explored using *t*-tests (comparing within-conductor coefficients and between-conductor coefficients) on cross-correlation coefficients. The connection between compositional elements, conductors' interpretations, and the kinematics of the executed conducting movements was then explored (Chapter 4). The analysis method of DPA (Deviation Point Analysis) was developed to identify time-points when conductors' movement showed distinctive kinematic features deviating from the regular beating movement. These kinematic deviation points (DPs) found in conducting movement were then matched up with compositional elements in score analysis.

5.2. Summary of key findings

5.2.1 Conductors' interpretational intentions and descriptions of conducting strategies

Conductors' general ideas about conducting and their interpretational intentions of three music compositions were explored in Chapter 2 and detailed findings in the conductors' interviews are presented in section 2.4. In general, it was found that **conductors believe that conducting kinematics are an important means for them to communicate their musical interpretations**. Key findings relating to this aspect of the study were:

1) Conductors emphasise different musical features in individual compositions. For instance, they highlighted the dynamic contrast between *forte* and *piano* in Mozart; the Romantic build up consisting of upward melodic contour and *crescendo* in Dvořák; the instrumental contrast between *solo* and *tutti*, and unique features of *trill* and *glissando* in Bartók.

2) Conductors believe that kinematic features in their conducting movement should communicate the compositional features they intended to emphasise. For instance, higher position of hands (on vertical axis), larger size and higher speed of movement, and further distance between two hands are usually associated with *forte*, *tutti*, and the beginning of phrases, whereas lower position of hands, smaller size and lower speed of movement, and narrow distance between hands usually indicate *piano*, *solo*, and short rhythm (e.g., semiquavers). Smooth movement with a rounded trajectory shape is used to express *legato* character in composition, whereas large round circles can sometimes communicate *glissando* or loud union *tutti* in the composition.

3) Conductors think that these communicative norms should be considered in the performance context. It was expected that conductors should have deep insight of compositional structure and

add their own interpretation to the composition. Conducting movement kinematics combine with the other conducting strategies such as palm gesture, breathing, facial expression, eye-contact, and they work together to communicate the conductor's musical interpretations. Playing multiple-roles in an orchestra as a director, co-operator, and supporter, conductors are expected to adjust their communicative strategies to achieve good communication with musicians, according to the performance context (e.g., in a concert or in a rehearsal) and the orchestra type they work with (e.g., professional or student orchestras).

These conductors' ideas and descriptions of their own conducting movements provide evidence for our understanding of what it is that conductors *think* they are doing. These reports collected from interviews were compared with motion capture data of performed conducting movement, offering detailed and objective evidence to account for conductors' actual movements and actions in biomechanical terms.

5.2.2 Linear kinematic features in conducting movement

Linear kinematic variables (distance, speed, acceleration and jerk) of conductors' baton tip movement were analysed in Chapter 3 and detailed findings are presented in section 3.4. Overall, it was found that **in conductors' executed conducting movements, movement kinematics reflect the musical character of each composition in systematic ways, such that kinematics remain consistent across repeated performances of the same composition**. Key findings relating to this aspect of the study were:

1) Conductors' baton tip movement showed distinctive kinematic features corresponding to each musical excerpt. Conductors' baton tip had highest speed, acceleration, and jerk when conducting Bartók, medium values for kinematic variables when conducting Mozart, and lowest values for kinematic variables when conducting Dvořák[8]. Using two-way repeated measure ANOVAs (repertoire x trial), it was found that conducting kinematics were significantly different between music repertoire.

2) Conductors' baton tip movement showed consistent kinematic features and time-series patterns when they conducted the same repertoire. Using two-way repeated measures ANOVAs (repertoire x trial), no significant kinematic difference was observed between trial numbers, which suggests that conductors' baton tip movements presented consistent kinematic features in repeated

[8] Baton tip movement distance per musical bar was not included in the discussion because it is affected by different time-spans of musical bars in three music compositions.

performance conducting the same musical excerpt. For time-series patterns of conducting kinematics, within the same repertoire, cross-correlations produced moderate coefficients ranging from 0.485 to 0.780 for time-warped data, and high coefficients ranging from 0.876 to 0.953 for bar data, which suggested that all conductors' baton tip movement presented similar kinematic time-series pattern when they conducted the same musical excerpt.

3) Considering the extent of similarity of conductors' baton tip kinematic time-series patterns, for the time-warped data within the same composition, conductors' baton tip had the most similar time-series patterns of speed when conducting Dvořák comparing the three compositions, and the most similar patterns of acceleration and jerk when conducting Bartók comparing the three compositions. For the bar data, conductors' baton tip had the most similar patterns of speed, acceleration, and jerk when conducting Dvořák comparing the three compositions. Using one-way ANOVAs (repertoire) on cross-correlation coefficients, significant differences between music repertoire were found for both time-warped data and bar data, which suggested that the extent of conducting movement kinematic similarity was significantly different between repertoire.

4) When conducting the same composition, conductors' baton tip movements had more consistent time-series kinematic patterns to repeated performances conducted by themselves, compared to performances conducted by the other conductors. Using *t*-tests (within-conductor coefficient and between-conductor coefficient) on cross-correlation coefficients, significant differences between within-conductor and between-conductor coefficients were confirmed for all kinematic variables.

5.2.3 Connection between conducting kinematic deviations and compositional features

Specific time-points when conductors' baton tip movement showed distinctive kinematic features were identified (described as kinematic deviation points, or DPs), and then were matched up with compositional elements in musical scores in Chapter 4. Detail findings are listed in section 4.4. In summary, it was found that **in conducting performances, movement kinematic deviations and high movement variability associated with featured compositional elements**. Key findings relating to this aspect of the study were:

1) Different types of DPs connected to respective compositional elements. Kinematic UDPs (Upper Deviation Points) in conductors' movements reflected compositional features including tempo fluctuation; melodic features of melodic climax; rhythmic features of syncopation and short rhythmic patterns (semiquavers and dotted notes); dynamic features of *forte*, *crescendo*,

sforzando, and accent; playing techniques of *glissando* and *trill*; instrumental configuration of *tutti* (in contrast to *solo*). On the other hand, kinematic LDPs (Lower Deviation Points) in conductors' movements reflected compositional features including metrical change from 4/4 to 2/4, dynamic features of *piano* and *diminuendo*, and instrumental configuration of *solo* (in contrast to *tutti*). However, complicated combinations of compositional features may induce conducting strategies departing from abovementioned tendencies. For instance, kinematic UDPs in conducting movement reflected *trill* in the composition regardless of *diminuendo* and instrumental reduction.

2) The stability of DPs reflects the importance of compositional elements. Stable kinematic DPs (identified from both individual trials and individual conductor's mean curves) in conducting movements reflected important compositional structures including the dynamic contrast from *piano* to *forte* in Mozart, the combination of melodic and dynamic climaxes in Mozart and Dvořák, and tempo fluctuation, metrical change, and *glissando* in Bartók. On the other hand, less stable kinematic DPs (identified from individual trials only or from individual conductor's mean curves only) in conducting movements reflected local detailed compositional elements including small scale *crescendo*, accent, and *trill*. Kinematic DPs in conducting also became less stable when the same compositional element occurs repeatedly in the excerpt (e.g., the switch between *solo* and *tutti* in Bartók).

3) High movement variability between conductors were found at locations with important structural musical events, which suggested that conductors employed idiosyncratic conducting strategies to communicate these highlighted compositional features.

5.3. Discussion

Conducting instructions from selected textbooks were examined as representative of conducting movement ideas (Chapter 1). In interviews, conductors stated that they use particular body movements to communicate their musical interpretations (Chapter 2). Conductors' performed conducting movements were explored using kinematic analyses in Chapter 3 and Chapter 4, demonstrating some systematic ways by which movement kinematics connected with both compositional structures and the conductors' interpretational intentions. Key findings from these chapters are summarised in the previous section. In the current discussion section, findings from the examination of existing literature, the investigation of conductors' self-reported statements about conducting, and the analyses of conductors' performed conducting movement kinematics are brought together.

In section 5.3.1, findings from conductors' interviews and observations of their conducting movement kinematics are discussed together. This discussion links the two aspects of orchestral conducting about 'What do conductors *say* they are doing?' and 'What do conductors *do* in the process of conducting?' to examine the issue of how conductors' ideas of conducting are revealed in their conducting movement kinematics (corresponding to thesis aim (2) in section 1.5.2 and section 5.1). In section 5.3.2, observed kinematic DPs in conductors' conducting performances are compared with the existing collection of conducting movement emblems suggested by conducting textbooks. This discussion links the two aspects of orchestral conducting about 'What are conductors *told* to do?' and 'What do conductors *do* in the process of conducting?' to investigate the issue how specific conducting movement emblems are observed in actual conducting performances (corresponding to thesis aim (1) in section 1.5.2 and section 5.1). In section 5.3.3 to section 5.3.5, findings in the current research are compared with results from previous musical performance studies, and thus aims to add empirical evidence about how conducting movements are affected by compositional and interpretational factors in the performance context. Section 5.3.3 addresses the relationship between musical movement kinematics and compositional structures; section 5.3.4 addressed the relationship between musical movement kinematics and the performer's interpretational intentions; and section 5.3.5 addresses the issue of kinematic variability in musical movements.

5.3.1 Linking conductors' interpretational intentions to conducting kinematics: evidence from interviews and kinematic analyses

5.3.1.1 Conductors' ideas of musical characters in relation to movement kinematic features in conducting performance

Conductors reported ideas of their own conducting movements and their opinions on the musical characters in three conducted musical excerpts in interviews (Chapter 2). Kinematic analyses in this thesis found that conductors' movements possessed distinctive kinematic features when conducting each composition (Chapter 3). It appeared that these kinematic features observed in their conducting performances reflected conductors' ideas of their own movements and their opinions on musical characters. For instance, regarding kinematic features in speed, acceleration, and jerk, it was found that conductors' baton tip moved with the highest speed, acceleration, and jerk when conducting Bartók, followed by Mozart, and moved with the lowest speed, acceleration, and jerk when conducting Dvořák (section 3.3.1). High values in kinematic variables when conducting Bartók corresponded with conductors' descriptions of 'impulsive', 'energetic', 'aggressive', 'rowdy' characters of this composition; medium kinematic values corresponded with the 'vigorous' character in Mozart, whereas low kinematic values corresponded with 'calm', 'lush', 'not too impulsive' characters in Dvořák (section 2.3.2.1). Low kinematic values shown in Dvořák, particularly low jerks, agreed with conductors' statements in interviews that they generally use 'smooth', 'legato', 'fluid', 'lyrical' movements when conducting Dvořák (section 2.3.3.3).

It should be noted that conductors' baton tip distance showed a different tendency than the other kinematic variables. It was found that conductors' baton tip moved the greatest distance per musical bar when conducting Dvořák, and moved the shortest distance when conducting Bartók (section 3.3.1). This is the consequence of different metrical and tempo configurations in individual musical compositions, which produced different time spans within musical bars. There are four beats within a musical bar in Mozart and Dvořák, and only two beats within a musical bar in Bartók. In addition, the tempo instruction in Dvořák is *Moderato*, which should be performed with a slower tempo than *Allegro* in Mozart and *Allegro assai* in Bartók. When taken together, these metrical and tempo factors result in the time spans within per musical bar being the longest when conducting Dvořák, which was more likely to allow conductors' baton tip to move in longest distance compared to the other two compositions.

Overall, conductors' baton tip movement showed distinctive kinematic features when conducting each composition. These kinematic features remained consistent across repeated performances of the same composition, and were significantly different from features shown in the other compositions (section 3.3.1 and section 3.3.2). These kinematic features were consistent with conductors' interpretational intentions of individual compositions, as well as their descriptions of intended conducting movement. Following this agreement between conductors' ideas of their own conducting and observed kinematic features in their actual conducting performances, the specific interpretational locations within compositions and prominent kinematic DPs observed in conductors' movement will be discussed in the following section.

5.3.1.2 Conductors' interpretational locations in relation to movement kinematic deviation points in conducting performance

In interviews, conductors provided annotations on interpretational locations they wanted to highlight when they conducted the three musical excerpts, and describe specific body movements they planned to use to communicate these interpretations (Chapter 2). In kinematic analyses, kinematic DPs shown in conductors' actual conducting movements were identified using DPA (Chapter 4). It appeared that kinematic DPs in conductors' body movements were mostly consistent with conductors' descriptions of their conducting movement. Within each composition, major clusters of kinematic UDPs found in conducting movement consistenly connected with conductors' interpretational locations, and signalled important compositional structures including tempo fluctuation; prominent 'Romantic build up' of melodic and dynamic climax; dynamic change of *sforzando*, *crescendo* and *forte*; instrumental configuration of *tutti*; distinctive melodic contour of *glissando*. These observed UDPs agreed with conductors' descriptions of their movement stated in interviews including 'clear gesture' for tempo fluctuation; 'bigger movement' and 'broader travel distance' for *sforzando*, *crescendo*, *forte* and *tutti*; 'clear and large circle' for *glissando*. Conductors' intentions to communicate short rhythmic patterns (semiquavers, dotted notes, and *mordente*) were observed as jerk UDPs despite that conductors stating that they would use 'smaller movement' to communicate these. On the contrary, kinematic LDPs signalled metrical change (reduction from 4/4 to 2/4), dynamic change of *piano*, and instrumental configuration of *solo*. These observed LDPs agreed with conductors' descriptions of their movement stated in interviews such that they would use 'smaller movement' to communicate these. Kinematic LDPs corresponding to *piano* were found in conducting movements, no matter if conductors put comments on these locations or not (based on findings in Chapter 2 and Chapter 4).

However, conductors' intentions to communicate detailed compositional feature of local musical accent sometimes were not shown in conducting movement DPs, especially when these accents occur frequently in a composition. Conductors' cuing gestures for instrumental entry were sometimes not found in conducting kinematics, especially when these instrumental parts play by *piano*. There are several imaginable reasons for the inconsistencies between conductors' interpretational intentions and kinematic DPs shown in their conducting: 1) conductors may use more flexible methods to deal with these local detailed compositional features in such a way that conductors may not necessarily emphasise these detailed features every time when they occur; 2) conductor's movement may present kinematic variations to instruct these detailed compositional features, but the extent of variations may not be obvious enough to reach the threshold in the analyses and to be identified as kinematic deviation points; 3) these detailed compositional features may occur in specific instrumental parts and the conductor may use either right hand or left hand to instruct them, which their special movement can not be detected by the analysis of baton tip kinematics alone; 4) conductors may apply other strategies (e.g., change movement trajectory, eye-contact etc.) rather than the kinematic variations analysed in this thesis to instruct these compositional features.

In brief, major clusters of kinematic DPs in conductors' movement indeed reflected conductors' interpretational intentions. Conductors' interpretational intentions sometimes were not observed in their conducting kinematics, particularly for detailed compositional features. This might be the result of the flexibility of conducting movement, and limitations of analysis method. These findings suggested that conductors' body movement did show corresponding kinematic features as their ideas and plans for performing conducting, especially for important structural features in compositions.

5.3.2 Conducting emblems and movement kinematic deviation points in conducting performance

As addressed in section 5.3.1, in the current study, specific kinematic features in conducting movements were found to be used to communicate conductors' self-stated musical interpretations. The connection between conducting kinematics, compositional elements, and the conductor's musical interpretations is embedded in conductors' education, which is based on the conventional conducting emblems compiled by conducting textbooks. In this section, the kinematic variations observed in actual conducting performances in the current study are discussed together with conducting instructions suggested by popular conducting pedagogical manuals.

Conducting movement emblems documented in educational manuals (summarised from Table 1.1 in Chapter 1), conductors' self-reports in interviews (Chapter 2) and kinematic deviation points found in conducting performances (Chapter 4) in the current study are compared in Table 5.1. Some observed kinematic deviations in the current study corresponded with, and also added empirical evidence for existing conducting movement emblems. The pedagogical instruction to employ larger movement for tempo fluctuation and dynamic changes (*forte*, *crescendo*, *sforzando*, *subito forte*, and accent) were confirmed by observed distance UDPs in conducting. Even though conducting pedagogical manuals did not mention changes in movement speed, acceleration, and jerk, in the current study, these kinematic deviations were detected for communicating tempo fluctuation and dynamic changes. Jerk UDPs particularly corresponded with instructions of sudden changes of movement (for *sforzando* and *subito forte*) and abrupt stops on counts (for *staccato*), compared to the other kinematic variables. On the contrary, the pedagogical instruction to employ smaller movement for dynamic changes of *piano* and *diminuendo* were supported by observed kinematic LDPs. The pedagogical instruction to cue the entry of instrumental part associated with observed distance, speed, acceleration, and jerk deviations in the current study. Even though these cuing movements were not detected as kinematic DPs every time when they occurred, particularly for entry played in *piano*.

Table 5.1 Pedagogical conducting emblems, conductors' descriptions of movement, identified kinematic Deviation Points and examples

Musical feature	Pedagogical conducting emblem	Conductors' description	Kinematic deviation	Example
Tempo fluctuation	- beat subdivision - slightly larger beat before *ritardando* and a slightly smaller beat before *accelerando*	clear gesture, beat subdivision	- obvious distance, speed, acceleration, jerk UDPs	Bartók: bars 13-14
Rhythmic feature				
Syncopation	- syncopation without accent: require no special gesture - syncopation with accent: staccato, sharp gesture	-	- distance, speed, acceleration, jerk UDPs - high distance, speed, acceleration, jerk variability	Mozart: bars 24-25 Bartók: bars 85-86
Dotted notes	-	smaller movement	- obvious jerk UDP - distance, speed, acceleration UDPs - high variability when switching to dotted note pattern	Dvořák: bars 7-8, 31-39
Short rhythmic pattern (e.g., semiquavers)	-	smaller movement	- distance, speed, acceleration, jerk UDPs	Mozart: bars 4-5
Melodic features				
Melodic climax	-	-	- distance, speed, acceleration, jerk UDPs - high distance, speed, acceleration, jerk variability	Mozart: bars 22-25 Dvořák: bar 20
Main melody entry	- eye-contact - direct baton or hand toward the instrumental part	eye-contact, cueing gesture, palm-up gesture, encouraging gesture	- distance, speed, acceleration, jerk UDPs (for *forte* entry) - distance, speed, acceleration, jerk LDPs (for *piano* entry)	Bartók: bars 62, 68-81, 92, 103, 165, 171-177
Counterpoint melodies	- eye-contact - direct baton or hand toward the instrumental part	eye-contact, cueing gesture, palm-up gesture, encouraging gesture	- distance, speed, acceleration, jerk UDPs	Mozart: bars 39, 47 Dvořák: bar 14
Phrasing	- smooth, sustained, supportive gesture - larger gesture at the beginning of a phrase; smaller gesture at the end of a phrase	larger and active movement at the beginning of a phrase	-	-

Musical feature	Pedagogical conducting emblem	Conductors' description	Kinematic deviation	Example
Dynamics				
Forte	- large size of gesture - left palm faces the conductor - can be intensified by slight shaking of forearm - supportive gesture in left hand to indicate a continuous *forte* level	-	- distance, speed, acceleration, jerk UDPs - high distance, speed, acceleration, jerk variability after switching to forte	Mozart: bars 39, 47 Bartók: bars 71, 79, 92, 103
Piano	- small size of gesture - left palm faces musicians	lower hand positions, narrower distance between hands and body	- distance, speed, acceleration, jerk LDPs	Mozart: bars 28, 54 Dvořák: bars 1-4 Bartók: bars 68, 69, 74, 136-144
Crescendo	- gesture gradually becomes larger lift the left hand, thumb up, upward palm	higher hand position, broader travel distance, further distance between 2 hands/ hands & body	- distance, speed, acceleration, jerk UDPs - more stable UDPs for bigger scale *crescendo* (compared to smaller scale *crescendo*)	Mozart: bars 20-21 Dvořák: bars 9, 17-20, 45, 47 Bartók: bar 145
Diminuendo	- gesture gradually becomes smaller - turn the left palm slowly toward the musicians or downward - lower left hand position	narrower travel distance, downward-palms	- distance, speed, jerk LDPs	Dvořák: bars 21, 41
Subito forte	- suddenly enlarge the size of gesture with a fist and rebound - move hand away from the body quickly	higher hand position, broader travel distance, back off very quickly	- jerk UDPs	Mozart: bars 18, 19
Subito piano	- suddenly compress the size of gesture - pull back hand closing to the body quickly - turn the left palm toward musicians quickly	-	-	-
Accent, *fp*	- strong, large gesture suddenly	offer bounce, heavy but with lift	- obvious jerk UDPs - distance, speed, acceleration UDPs	Mozart: bars 18, 19 Bartók: bars 7-12, 36, 43-44, 49-60, 103

Musical feature	Pedagogical conducting emblem	Conductors’ description	Kinematic deviation	Example
Articulation				
Staccato	- sudden motion of the hand followed by an abrupt stop - quick, straight motion with a stop on each count - bouncing on the down-beat - small gesture	-	- obvious jerk UDPs - distance, speed, acceleration UDPs	Dvořák: bars 7-8, 26-27, 31-39 Bartók: bar 153
Legato	- smooth, sustained, flowing, curved gesture small to very large gesture (depending on the emotional intensity of the music)	smooth movement, less verticality		Dvořák’s excerpt
Instrumental configuration				
Tutti	-	broader travel distance	- distance, speed, acceleration, jerk UDPs	Bartók: bars 20, 49
Solo	-	narrower travel distance	-	
Instrumental reduction	-	-	- distance, speed, acceleration, jerk LDPs	Bartók: bars 139-142
Technique				
Trill	-	-	- obvious jerk UDPs - distance, speed UDPs - high jerk variability	Mozart: bars 51-52 Dvořák: bars 25-27 Bartók: bars 49-60, 103-116, 159-164
Glissando	-	clear gesture, large circle	- obvious distance, speed, acceleration, jerk UDPs - high distance, speed, acceleration, jerk variability before *glissando*	Bartók: bars 45, 61
Pizzicato	-	more pointed upbeat	- obvious jerk UDPs - distance, speed, acceleration UDPs	Dvořák: bar 5 Bartók: bars 16, 36, 104, 106, 159

Observed conducting kinematics were found to be inconsistent with pedagogical conducting emblems for phrasing and syncopation. The conducting instruction to start phrases with larger movements was not supported by observed kinematic deviations. This, however, did not necessarily mean that the observation of conducting kinematics contradicted with proposed conducting strategies. According to previous literature, phrase structure tends to display in small-scale local maxima of movement profile rather than large-scale global maxima (MacRitchie et al. 2009; 2013). These local kinematic fluctuations in conducting movement might therefore not be obvious enough to be identified as kinematic deviations. Another inconsistency showed in syncopation. According to conducting education manuals, no special movement is required for instructing syncopation (Green, Gibson and Malko 2004; Hunsberger and Ernst 1992; Labuta 2003; Rudolf 1995). Still, UDPs in distance, speed, acceleration, and jerk were found in conducting movement for syncopation in the current study. A possible reason might be that syncopation contains irregular accent on upbeats, which tends to induce higher jerk, together with other kinematic changes in conducting movement.

In keeping with the scale of this doctoral project, kinematic analyses were restricted to linear kinematic variables of baton tip movement. Descriptions from conducting educational manuals regarding palm direction, hand position, and distance between hands and body thus cannot be observed in the current study. Nevertheless, conducting kinematics observed from thorough analyses of baton tip movement contribute original and detailed evidence to understand better how conducting kinematics communicate detailed compositional features. Conducting educational manuals do not suggest rigid emblems to instruct detailed features in rhythmic, melodic, instrumental, and technique aspects of composition, whereas in the current study, specific kinematic deviations were found on several occasions. In kinematic analyses of baton tip movement, UDPs were found to be used to instruct rhythmic features of dotted notes and semiquavers; melodic climax; instrumental configuration of *tutti*, and special techniques of *trill*, *glissando*, and *pizzicato*. Jerk UDPs particularly responded to short rhythmic patterns (dotted notes and semiquavers) compared to the other three variables. Kinematic LDPs were found with instrumental configurations of *solo* and instrumental reduction. Instructions for these musical features were absent in pedagogical literature probably because conducting strategies to instruct detailed musical features are more context dependent. Conductors may determine movements to instruct primary compositional structural features first, and then several possible movements can be applied to communicate secondary detailed features. Kinematic analyses in the current study added observations of conducting strategies for these detailed musical features in particular musical contexts.

The observed correspondence between conducting kinematics and compositional features in this thesis confirms and provides explanations for findings in previous research, in which musically-trained viewers can successfully identify specific emblems from conducting movement and comprehend the conductor's communicative intentions (Cofer 1998; Gallops 2005; Sousa 1988). These studies identified conducting emblems based on systematic observations and qualitative descriptions of conducting movement, whereas analyses in this thesis further specified quantitative kinematic features– particularly movement distance, speed, acceleration, and jerk DPs– connected with certain compositional and interpretational elements. The connections between compositional elements, conductors' stated interpretational intentions, and kinematic deviations in conducting movement found in the current study demonstrated specific instances in which conductors use such conducting emblems to communicate with musicians in actual conducting performances.

5.3.3 Compositional structure and movement kinematics in musical performance

The current study of conducting movement provided evidence to support the theory that, in actual conducting performance, kinematics of conducting movement reflect compositional structures in aspects of metre, rhythm, phrasing, and dynamic configuration. These results can be discussed together with previous findings in music listeners' and performers' body movement. Previous research has suggested that the hierarchical structure of musical metre is encoded in music listeners' body movement. (Leman and Naveda 2010; Naveda and Leman 2010; Toiviainen et al. 2010). In conducting, it is a basic technique for conductors to use repetitive beating patterns (e.g., two-beat, three-beat, or four-beat patterns) to instruct metrical cycles (Green, Gibson and Malko 2004; Rudolf, 1995). In addition, in the current study, conductors used these beating patterns to communicate higher-level temporal segmentation in music, i.e. musical phrase, particularly in Bartók's music. Most conductors conducted in one beat per musical bar in Bartók, and in order to shape musical phrase structure across musical bars, they combined two, three, four, or five bars together to conduct in two-, three-, four-, or five-beat pattern. The switch between these beating patterns is thus not for instructing basic metre within musical bar, but for communicating higher-level phrase structure across multiple bars. According to conductors' opinions, irregular phrase structure is an important feature in Bartók, and they believed that switching beating patterns is an efficient conducting strategy to communicate musical phrases.

It has been found in previous research that local maxima of musicians' body movements correspond to phrase structure in music. Periodic movements in musicians' body segments including head nodding, body swaying, knee bending tend to match up with phrasing segmentations (Davidson 2012; MacRitchie, Buck and Bailey 2009; 2013; Thompson and Luck 2008, Wanderley et al. 2005). In the current study, conductors reported that, in order to instruct musical phrases, they distinguish active beats and passive beats in their conducting, in such a way that they conduct by active beats (e.g., larger movement) to instruct the beginning of musical phrase, and then switch to passive beats (e.g., smaller movement) during a phrase. They also employ smooth movement to lead the melodic direction within a musical phrase. However, kinematic DPs in the current study were not found to match up with phrases. A possible reason is that musical phrase is an underlying structure consistently exists in musical composition. Conductors thus may choose to use more prominent movements to instruct uncommon salient compositional features (e.g., dynamic or harmonic climax), and use less prominent movements to instruct the beginning of phrases that regularly occur. Even though corresponding kinematic DP in conducting movement was not found to substantiate conductors' statements, conductors' opinions are supported by previous findings that the periodicity of musical movement is bonded to musical phrases. In previous studies, similar curves of movement profile were found across musical phrases (MacRitchie, Buck and Bailey 2009; 2013). This finding strengthens conductors' own stated strategy, as reported in Chapter 2, to communicate phrases using active and passive beating movements.

Previous studies have suggested that rhythmic acoustic features of music significantly affect listeners' body movement kinematics, in such a way that music with higher pulse clarity and percussiveness induces movements with higher value of kinematic variables (speed, angular velocity, amount of movement etc.) on listeners' movements (Burger et al. 2012; 2013). These findings agree with observations of conducting movement in the current study. Comparing the three musical excerpts, conductors' movement showed highest speed, acceleration and jerk when conducting Bartók, which was considered to have 'impulsive' and 'energetic' characters for conductors, whereas conducting movements presented lowest speed, acceleration and jerk in Dvořák, which was considered to be a 'calm', 'not too impulsive' musical work for conductors. In addition to these overall musical characters, this correspondence also showed in specific music instances and identified kinematic DPs in conducting movement. Conductors' movements tended to show more kinematic UDPs, particularly jerk UDPs when instructing *staccato* and short rhythmic patterns (semiquavers and dotted notes). Linear kinematic analyses of baton tip movement in the current study yielded similar results as previous research investigating angular kinematic and the other variables (Burger et al. 2012; 2013). Burger et al. (2012; 2013) investigated rhythmic acoustic features, whereas the current study added evidence for the connection between conducting movement kinematics and rhythmic features in composition revealed in score analysis. All these findings together provide further evidence that rhythmic features in musical composition influence linear and angular kinematics of musical movement in predictable ways.

For dynamic configuration, previous studies found that percussionists' drumsticks play from higher position, and with higher velocity for louder music (Dahl 2004; 2006). In the current study, a similar tendency was found in conducting movement that conductors moved in bigger movement, higher velocity and acceleration for *forte*, *crescendo*, musical accent, and *tutti*. As conductors stated, they express their intended performance sound by the 'physicality' of their body movement. This parallel displays the mirroring between conducting movement and the acoustic sound performed by musicians' instrumental movements. The leader-follower relationship in the orchestra is demonstrated by the fact that conductors use their body movement to affect musicians' movement of playing instruments, and thus to achieve their intended performance sound. This relationship is also supported by previous findings for inter-personal dynamics in string quartet ensemble, that the leader' body movement communicates more information than the other members in the ensemble (Badino et al. 2014; Glowinski et al. 2013).

Overall, the current study found that in conducting performances, movement kinematics correspond to compositional features including high-level temporal structure of phrase, rhythmic features, and dynamic characters. The size of conducting movement communicates musical phrases and dynamic variations. Movement jerk particularly responds to short rhythmic patterns and *staccato*. These results agreed with previous findings in music listeners' and musicians' body movement, and added observations in conductors' baton tip movement. The leader-follower relationship between the conductor and musicians in the orchestra is manifest in the conducting strategy that conductors utilise their body movement to affect musicians' sound producing movement. All these discoveries provide specific evidence regarding the ways in which body movements in musical performances– including music listeners' musicians, and conductors' movements– strongly relate to musical compositional structure.

5.3.4 Interpretational intentions and movement kinematics in musical performance

In music performances, body movements not only reflect musical compositional structure, but also the musician's or the conductor's interpretational intentions of the composition. It is found in previous research that musicians' body movements reveal their different musical expressive intention (Camurri et al. 2000; 2005; Castellano et al. 2008). Similar results were found in conductor's baton tip movements in the current study. Different kinematic features (i.e. high value or low value of linear kinematic variables) were observed to correspond with individual musical characters in the three excerpts of compositions by Mozart, Dvořák, and Bartók discussed here. Analyses in previous research were based on repeated performances of the same composition when musicians intended to convey different types of emotion (e.g., happiness, sadness, anger, fear) (Camurri et al. 2000; 2005;

Castellano et al. 2008), whereas the movement kinematic difference observed in the current study is from conductors' interpretational intentions of inherent musical characters in different compositions (as conductors stated in interviews). In previous research, movement features were found to be different between performances in kinematic variables, as well as categorical analysis based on Laban Movement Analysis (Castellano et al. 2008). Findings in the current study demonstrated that linear kinematics of conducting movements vary according to the conductor's interpretational intentions, which is supported by previous findings.

Musical body movements reflect musicians' and conductors' overall expressive intentions, as well as specific interpretational locations they intend to highlight within a composition. Previous studies found that musicians' ancillary movement in body segments including head nodding and shaking, body swaying, wrist rotation, hand and arm lift for pianist, and circular movements of woodwind instruments often, but not always, associated the musicians' musical interpretational targets in the composition (Davidson 1994; 2007; Desmet et al. 2012). A similar tendency was observed from conducting movement in the current study. Specifically, prominent clusters of conducting kinematic DPs shown in baton tip distance, speed, acceleration, and jerk matched up with interpretational locations stated by conductors, whereas minor cluster of kinematic deviations are not necessarily connected to interpretational locations.

5.3.5 Conducting kinematic variability

In the complex interactive dynamical system of musical performance, conducting movements are affected by various compositional, interpretational and performance factors. Individual conductors may add different musical interpretations when conducting the same composition, and this can be observed from the diversity between individual conductors' body movements. In a previous study of musicians' body movement, it was demonstrated that individual musicians possess their own idiosyncratic ancillary movement, which are distinguishable from the other musicians' movements when playing instruments (Mitchell and MacDonald 2012). In the current study, observations of conductors' baton tip movements were in line with previous findings in musicians' movement. Cross-correlation coefficients for performances conducted by the same conductor were significantly higher than performances conducted by different conductors, which suggests that conductors' movement kinematics were more consistent with their own conducting, compared to the other conductors' conducting. This result also indicates that individual conductors possess unique movement patterns, which are different from the other conductors' conducting of the same composition. In particular, it was revealed in DPA that conductors' movement tended to be more different (showed high between-conductor variability) at key musical events they intended to emphasise. This observation agreed with previous findings that musicians' body movements are more divergent across performances at important structural events in the composition (Thompson and Luck 2011). Previous findings were based on the comparison of repeated performances by the same musician when they had different expressive intentions (e.g., expressive, deadpan), whereas the current study compared the movement from different conductors. These findings demonstrate that musicians' and conductors' movement displays idiosyncratic kinematic features, especially, in the use of different strategies to highlight important musical events in the composition.

Previous studies have found that string players' bowing movements present distinctive features corresponding to compositions by different composers, even though these compositions possess similar note configurations (Winold, Thelen and Ulrich 1994). The current study found significant differences in conducting movement speed, acceleration, and jerk between three compositions, with no significant effect from trial order. This suggests that conductors' movement possessed consistent kinematic features when they conducted the same composition, which are distinguishable from their conducting of the other compositions.

As noted in previous research, musical movements are highly context dependent (Hargreaves, MacDonald and Miell 2005; Moran 2014), such that music performers show different body movements in rehearsal and in concert (Moelant et al. 2012). In conducting, it has also been noted that musicians who observe the conductor from different visual angles may react to conducting movement differently (Price and Mann 2011; Silver 2013; Wöllner and Auhagen 2008). These considerations were reflected in conductors' opinions in interviews in the present study. Conductors stated that flexibility is an important aspect to achieve desirable outcome of performance, such that they apply different conducting strategies when working with different types of orchestra (e.g., professional or student orchestra), and use multiple approaches including body movement, palm gesture, eye-contact, facial expression, and breathing to effectively communicate with musicians in their conducting. To this end, the discussion of conducting movement should be contemplated within a broader framework of a dynamical system (see Figure 1.3 in Chapter 1), which consists of complex interactions between the composition, the conductor's musical interpretations, musicians' reactions, and the performance context.

The movement variability between different conductors' conducting, and between the conducting of different compositions found in the current study demonstrated musical performance models proposed by previous research. The KTH rule system (Friberg, Bresin and Sundberg 2006; Sundberg, Frydén and Friberg 1995) and the GERM model (Juslin, Friberg and Bresin 2001) have been used to analyse how the factors from the composition, from the music performer's expressive intentions, and from the performer's body movement jointly affect the performance execution of music. In the KTH rule system and the GERM model, musical expressions are associated with systematic timing and dynamic deviations in performance, and these deviations are in relation to biological movement in performance execution. In the current study, conducting movements were found to be diverse depending on structures in different compositions. When conducting the same composition, individual conductors employed idiosyncratic movements, and the high variability of movement coincided with interpretational locations stated by conductors. These findings clarified the influences from compositional and interpretational aspects, and how they interact with each other in actual conducting performance. Similar to the findings in previous research that the timing and dynamic deviations in performing acoustics are used for performers to highlight compositional features, in the current study, the kinematic deviations in conducting movement serve as important cues to communicate the conductor's interpretational intentions. Yet individual conductors may apply diverse movement to instruct such interpretational locations, which lead to high movement variability at key musical events in conducting. These findings provide important indications of how the influences from compositional and interpretational aspects cooperate together and shape conducting movements in orchestral performance.

In summary, this thesis found that kinematic features in conducting movements are mostly consistent with conductors' interpretational intentions and their ideas of performing conducting. This finding demonstrated that the use of conventional conducting emblems can indeed be observed from the actual practice of conducting performance using empirical methods. Observed kinematic variations in conducting movement reflected compositional and interpretational elements. However, it was found that individual conductors tended to apply diverse movements at key interpretational locations, and this finding highlighted the influence from individual conductors' interpretational decisions and conducting style. Kinematic variations in conducting movements were sometimes less consistent with conductors' interpretational intentions for detailed musical elements, and this demonstrated that principal compositional elements and the conductor's interpretational focus lead to more stable and consistent kinematic variations across repeated performances. These observations of the convergence and divergence of conducting movement add to our knowledge of how factors from compositional, interpretational, and performance aspects interact with each other in the dynamical system of orchestral conducting.

Chapter 6: Conclusions and future directions

To conclude, based on evidence collected from interviews and kinematic analyses of motion capture data, this thesis demonstrated and provided detailed kinematic evidence for the ways in which a general ideology of conducting movement, suggested by conducting pedagogical manuals and conductors' stated ideas of their own conducting, are fulfilled in the actual practice of conducting performance. The mixed-method design provided an appropriate approach to explore different aspects of orchestral conducting such as what conductors *say* they are doing and what conductors actually do in conducting, and to investigate how compositional and interpretational factors influence the kinematics of conducting movement within the dynamical system of conducting performance. Within this thesis it has been demonstrated that in conducting performances, compositional elements and conductors' interpretational intentions affect and contribute to the variability of conducting movement. Movement deviations in conducting, which are different from the regular beating movement, were observed to function as key gestural emblems for communicating structural features in music compositions, and highlighting the conductor's musical interpretations. These results are supported by previous findings in music listeners' and musicians' body movement. This thesis confirmed that connections between conducting movement, compositional elements, and the conductor's musical interpretations can be systematically observed within the dynamical system of conducting performance.

6.1. Strengths and limitations

The main strength of this thesis is that, by the mixed-method approach, various quantitative kinematic analyses of conducting movement were guided by conductors' qualitative descriptions of their own conducting. Consulting conductors' self-reported intentions in interviews, the subsequent exploration of their conducting movement focused on key musical events identified by conductors, and thus led to specific links between conducting movement emblems, compositional elements, and interpretational locations.

Previous musical movement research has mostly described the overall characters of movement (e.g., Burger et al. 2013; Leman and Naveda, 2010; Toiviainen, Luck and Thompson 2010), whereas the novel analysis method of DPA developed in this study provided a valuable tool to identify prominent movements occurring at specific moments during conducting performance. Using DPA, this thesis contributed empirical observations of how these particular conducting movements communicate conductors' interpretational intentions. These findings based on systematic kinematic analyses refined and replenished the existing collection of conducting movement emblems.

Some limitations, however, arose from the experimental design and analysis methods of this thesis. Regarding the experimental design, conductors trained in different conducting traditions (e.g., American, European, Russian traditions) tend to have different conducting styles and apply diverse conducting strategies (Holden 2003). The small group of six participating conductors were all recruited from Britain, and their opinions and conducting strategies might thus be biased by their shared musical educational background and conducting training tradition. Movements corresponding to various pieces of music show different features (Winold, Thelen and Ulrich 1994), but the observation of this particular group of conductors was limited to three specific musical excerpts. Due to restricted rehearsal time period before experiments, conductors might also not be able to fully achieve what they perceive as satisfactory performance, especially considering the constraints of student musicians' ability. In music performances, musical performers' body movement may also change according to the performance context and environment (Keller 2014; King and Ginsborg 2011; Moelants et al. 2012). According to conductors' opinions in interviews, they do apply different conducting strategies to the different types of orchestra with which they work (professional or amateur orchestra), and also to different performance context (concert or rehearsal). During conducting, conductors also constantly adjust their conducting movement according to the performed sound produced by the musicians. In the current study, the observed behaviour of conductors in the controlled environment in experiments may differ from their behaviour and natural manner in a real-world context.

Regarding limitations arising from analysis methods, one consideration for this thesis is that the motion analyses focused on the linear kinematic variable of one single point of baton tip movement. This decision comes from the constraints of the scale of this doctoral project. The decision was made in relation to evidence from previous studies that conductors' movements in end-effectors communicate important information in musical conducting (Luck 2011; Luck and Net 2008; Luck and Sloboda 2009; Luck and Toiviainen 2006). The concentration of analyses in baton tip movement allowed comprehensive analyses to match up specific kinematic deviations with particular critical compositional and interpretational elements, and thus to identify crucial key events in conducting. This provided valuable information about orchestral conducting. The focused analyses are the result of the limitations in time and thesis length of PhD study. However, as suggested by biomechanical studies, different movement features in combinative body parts (e.g., angle and angular velocity of joints) jointly accomplish the execution of movement (e.g., Buldt et al. 2013; Button et al. 2003; Coleman and Rankin 2005; Connaboy et al. 2016; Kelly 2007; Koblbauer et al. 2014). Some features of conducting movement such as angular kinematics and movement trajectory of different body segments were not able to be explored in this thesis. To develop further investigations into more kinematic variables and movements in different body parts in orchestral conducting, the motion capture data corpus collected from twenty-seven markers in conductors' upper body in the current study were uploaded to DataShare open access data repository, University of Edinburgh. Another limitation of analysis methods is that a statistically-based threshold was determined to identify kinematic deviation points according to statistic principles in DPA. This means that only movement variations reaching a certain level were included in the discussion. Subtle movement variations which did not reach the threshold and were excluded from the discussion may sometimes carry important musical information as well.

6.2. Implications for future research

Despite the aforementioned limitations, this thesis demonstrates a novel analysis approach which links conductors' interpretational intentions to specific observed movement kinematic features in their conducting. As suggested by conductors' opinions in interviews, conducting movements are divergent across different conductors' conducting styles, different musical compositions, and different performance contexts. More observations from a larger group of conductors from diverse musical educational backgrounds and extended repertoire would add more thorough information about conducting. Comparisons among multiple contexts (e.g., working with orchestras with different levels of expertise, studying conducting performances in both rehearsals and concerts) (Moelants et al. 2012) would help understand how conductors behave differently in these individual social contexts. In particular, novice and professional conductors tend to apply different conducting strategies (Bergee 2005). The comparison between conductors with different levels of expertise would provide practical suggestions for conductors' training.

To generate more comprehensive understanding of the overall conducting movement, the analysis method of DPA could be further applied to analyse other kinematic variables, as well as movements in conductor's other body segments. These detailed movement analyses of individual variables and body segments could also be related to general movement indexes (e.g., Camurri et al. 2000; 2005 Castellano et al. 2008). The comparisons of results from bottom-up approaches of detailed analyses and top-down approaches of general indexes may yield further knowledge about conducting movement.

Due to the limitation in data collection, it was not possible to explore some important aspects of conducting mentioned by conductors in interviews. The eye-contact and interaction between the conductor and musicians could be further explored using the comparison of multiple data sources such as motion capture data, eye-tracking technology, and systematic observations of digital video footage (e.g., Clayton 2007; Davidson 2007; 2012; Moelants et al 2012; Moran 2011; 2013). Further detailed study of musicians' perceptions of conducting movements, and their reactions, that is the acoustic features of performed sound (e.g., Gabrielsson 2000; 2003; Langner and Goebl 2003; Repp 1995; 1998), could shed more light on the ways in which conducting movement variability actually affects the outcome of the performance. All these findings regarding conducting performance could provide evidence for educational research, and ultimately be applied for the benefit of orchestral conductors, musicians, and concert audience.

6.3. Concluding remarks

This thesis presents a mixed-method examination of ensemble conductors' movement. In interviews (Chapter 2), conductors' ideas and beliefs regarding orchestral conducting and musical interpretation were explored, and the findings guided the subsequent analysis of conducting movement. In kinematic analyses of conducting movement (Chapter 3 and Chapter 4), conductors' body movements were recorded using motion capture system and kinematic features of conducting movement were described as four linear kinematic variables— distance, speed, acceleration, and jerk— of baton tip movement. Their movement kinematic differences and similarities were examined using ANOVAs, *t*-test, and cross-correlations. Movement deviations and variability were analysed using an original method developed in this study— Deviation Point Analysis (DPA). Findings from these analyses suggest that conductors' baton tip movements showed a certain level of similarity when conducting the same composition, yet each conductor's own movement patterns were still distinguishable from the other conductors' conducting. In particular, their movements tended to be idiosyncratic at the time-points at which they intended to communicate particular interpretational information. Conducting movement deviations in distance, speed, acceleration, and jerk communicated specific compositional elements in temporal, rhythmic, melodic, dynamic, instrumental aspects, as well as the conductor's interpretational intentions added to the composition.

The findings of this thesis demonstrate an agreement between the general ideology of conducting movement revealed in conducting pedagogical manuals, with conductors' ideas of their own conducting and their specific interpretations of musical compositions, and with the performed movement kinematic variations in actual performances. This thesis provides a framework to merge qualitative and quantitative observations of orchestral conducting, and to consider orchestral conducting movement as a dynamical system consisting of multiple factors in the context of music performance. The innovative analysis method developed in this thesis— Deviation Point Analysis (DPA) — contributes to identify key movements in conducting using quantitative approach, which is much more specific than obscure, subjective descriptions of conducting movement in previous literature.

The findings in this thesis could help to inform conductors' education and training. Kinematic variations deviating from regular beating movement are an important means to communicate musical interpretations. Regardless of the shape of movement trajectory and the other communicative vehicles (e.g., movements in different body parts, eye-contact, breathing), specific compositional elements in temporal, rhythmic, melodic, dynamic, instrumental aspects can be accurately communicated via deliberate manipulations of baton tip's movement size, speed, acceleration, and smoothness. Given the idiosyncrasy of conducting movement, individual conductors' movements shared an underlying similarity when they conducted the same composition. The qualitative descriptions of common conducting movement emblems can be observed and monitored using empirical methods such as quantitative analysis based on motion capture data. These empirical observations of conducting movement can provide feedback for conductors, facilitating detailed reflection and thus enhance the precision and efficacy of conducting movements.

Appendix 1: Original quotations of conducting movement descriptions in four conducting educational manuals

Musical element	Conducting movement description
Articulation (conducting style)	"Your conducting must 'look like' the music" (Labuta, 2003: p. 26)
Neutral	"The neutral or passive style lacks expressive quality and intensity. Conduct short, straight, connected lines…" (Labuta, 2003: p. 27)
Staccato	"The staccato gestures are characterized by the momentary stop of all motion in the stick, hand, arm…. The flick is performed by the sudden motion of the hand in the wrist joint, finishing in an abrupt stop." (Green et al., 2004: pp. 43-44) Light-staccato: "The light-staccato beat is a quick, straight motion with a stop on each count. The gestures are small." (Rudolf, 1995: p. 16) Full-staccato: "The full-staccato beat is a quick, slightly curved motion with a stop on each count. It is snappy and energetic, with a characteristic "bouncing" on the down-beat. The size may vary from small to large." (Rudolf, 1995: p. 19)
Legato	"Legato is a smooth, sustained, connected style… with flowing, curved gestures." (Labuta, 2003: p. 26) "The espressivo-legato beat is a curved, continuous motion. … The intensity and degree of curve vary with the emotional quality of the music. The size may be anywhere from fairly small to very large." (Rudolf, 1995: p. 24)
Marcato	"The marcato beat is heavy motion with a stop on each count. It is forceful, sometimes aggressive in character and medium to large in size; they are either straight or curved depending on the music." (Rudolf, 1995: p. 91)
Tenuto	"These gestures might also be called the very heavy legato gestures." (Green et al., 2004: p. 45) "The tenuto beat is a smooth motion with a stop on each count. It resembles the marcato, but lacks the aggressive impetus of that beat. Each beat is sustained with or without intensity, depending on the music. The size varies from small to large." (Rudolf, 1995: p. 158)
Dynamics	"When the palm faces the players it is usually read as a caution to soften; when it faces the conductor, the musicians read it as a command for more power." (Green et al., 2004: p. 68) "Dynamic levels are indicated are indicated primarily by the size of the beat pattern or by special motions of the left hand." (Hunsberger & Ernst, 1992: p. 35) "The dynamic s of the music can be expressed by the size of the gesture." (Rudolf, 1995: p. 52)
Forte	"Use the left hand to indicate a continuing forte level, especially for final tones or holds, which tend to diminuendo if not supported." (Labuta, 2003: p. 40) "[Forte] can be intensified by a slight shaking of the forearm." (Rudolf, 1995: p. 27)
Crescendo	By the size of movement "As the dynamics gradually increase or decrease, your gesture changes its size." (Rudolf, 1995: p. 58) By left hand: "Indicate the crescendo by lifting the left hand, thumb up, palm at an upward angle, with increasing tension in the forearm." (Labuta, 2003: p. 40) "Lifting the left hand, palm facing upward, …held up as long as you want to maintain *f*." (Rudolf, 1995: p. 60)
Diminuendo	By the size of movement: "As the dynamics gradually increase or decrease, your gesture changes its size." (Rudolf, 1995: p. 58) By left hand: "Turn your palm over gradually to face the players, lowering it slowly while continuing to turn it downward (or turn it inward to the body)." (Labuta, 2003: p. 40) "Turn the hand slowly so that the palm faces the players." (Rudolf, 1995: p. 60)
Subito forte	"Make a fist on the rebound and simultaneously enlarge the size and intensity of the right-hand beat pattern." (Labuta, 2003: p. 40) "To emphasize a f beat, the right hand may move away from the body suddenly." (Rudolf, 1995: p. 54)

Subito piano	"Quickly pull back the left hand to your chest so the palm faces the players." (Labuta, 2003: p. 40) "A sudden retreat of the hand close to the body makes the change to p more effective." (Rudolf, 1995: p. 54)
Accent, *fortepiano*	"The accented count itself is indicated by the strength of the beat." (Rudolf, 1995: p. 202) "*Fp* is executed in much the same manner as an accent." (Rudolf, 1995: p. 213)
Phrasing	"The travel should be smooth to indicate a sustaining or supportive quality." (Hunsberger & Ernst, 1992: p. 64) "There is a decrease in intensity at the end of the phrase, and by contrast a fresh motion at the beginning of a new one." (Rudolf, 1995: p. 216)

Appendix 2: Consent forms and the permission of use of data for experiment

INFORMED CONSENT FORM FOR STUDY

I (print name and date) ____

Hereby give my consent to participate in the study explained to me. I am satisfied that I understand the procedures involved and agree to provide the recorded data in the study for the further investigation. Also I recognise I am at liberty to withdraw my involvement at any stage of the work.

Subject's full signature ____

Experimenter's signature ____

Supervisor's signature (STAFF) ______________________________________

PERMISSION FORM -- Conducting Movement Research

We will answer any questions you may have about this permission form.

In this study we have made anonymous 3D motion capture recordings with audio. The recordings will be stored securely for ten years and labeled only with a code number, not your name. The records which connect your recording with your code number are stored separately.

The motion capture session will also be recorded by video. We have made the digital video recordings primarily to support our analysis of motion capture data. The digital video data are not anonymous. However, we will make all reasonable efforts to disguise your identity (e.g. blur the image).

Please indicate below the way(s) we can use the recordings during this study. You can select some options and not others, or none at all (option #8). You may also get back in touch with us at any time and alter your permissions.

PERMISSION FORM -- Conducting Movement Research		
Use of Recordings	Motion Capture Data	Video Data
1. Viewing and analysis by the researchers involved in this project	☐ YES ☐ NO	☐ YES ☐ NO
2. Viewing and analysis by these researchers in future, related projects	☐ YES ☐ NO	☐ YES ☐ NO
3. Playing excerpts as an example for professional audiences (e.g., at a professional conference)	☐ YES ☐ NO	☐ YES ☐ NO
4. As still images in conference slides or publications	☐ YES ☐ NO	☐ YES ☐ NO
5. Playing excerpts for other research participants in a subsequent stage of the project	☐ YES ☐ NO	☐ YES ☐ NO
6. Available on the Internet on sites targeted at research professionals (i.e. to support/illustrate publications)	☐ YES ☐ NO	☐ YES ☐ NO
7. Available to the public via the researchers' websites	☐ YES ☐ NO	☐ YES ☐ NO
8. None of the above	☐ YES; erase the data ☐ NO; do not erase the data	☐ YES; erase the data ☐ NO; do not erase the data

Signature:___________________________________ Date:_________________

Appendix 3: Questionnaire for conductors' interviews and musicians' basic information

ORCHESTRAL CONDUCTING MOVEMENT RESEARCH

INTERVIEW FOR CONDUCTORS

1. Music background

1.1 Subject ID: ________________________

1.2 Gender: □ Male □ Female □ Prefer not to say

1.3 Handedness: □ Right-handed □ left-handed

1.4 Which instrument(s) do you play (if any)?

Instrument	No. of years playing

1.5 Which instrument(s) do you play in the orchestra (if any)?

____

1.6 For how many years have you played in the orchestra (if ever)?

____years

1.7 For how many years since you began conducting?

____years

1.8 How would you describe your status as a conductor (tick all that apply)?

□Professional conductor	□Professional music educator	□Advanced student	□Amateur

1.9 The orchestra(s) you are regularly conducting (you can select more than one)

Orchestra	**No. of years conducting**	**No. of hours conducting a week (in average)**
Student orchestra		
Amateur orchestra		
Professional orchestra		

1.10 How often do you conduct the following repertoire?

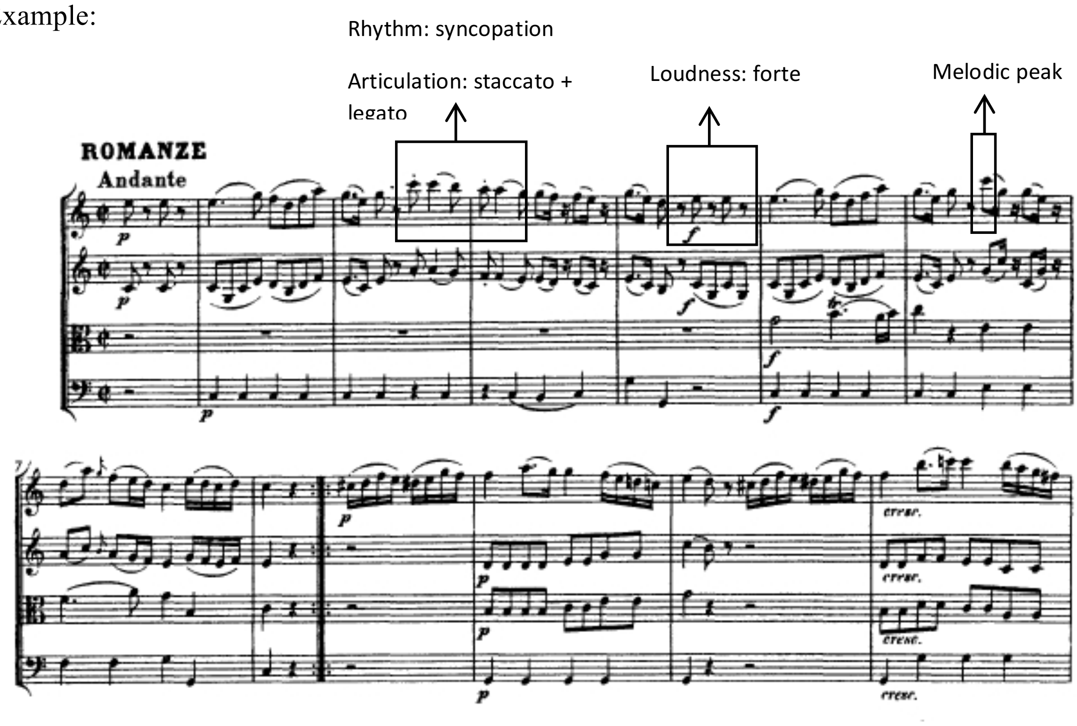
Music before 1750	□Not at all	□Not very often	□Sometimes	□Often	□A great deal
Music in Classical Period	□Not at all	□Not very often	□Sometimes	□Often	□A great deal
Music in Romantic Period	□Not at all	□Not very often	□Sometimes	□Often	□A great deal
20th century music	□Not at all	□Not very often	□Sometimes	□Often	□A great deal
Other genres of music (e.g. movie music, folk music etc.) Please specify: ______________________	□Not at all	□Not very often	□Sometimes	□Often	□A great deal

2. Interpretation of music

The scores below are the 3 pieces of music you are going to conduct in the lab. Could you please mark the music features you would like to highlight in your conducting? We'll use your marks as the guidance to understand your conducting.

(1) Please provide at least 5 comments on each piece of music
(2) The interviewer will ask you to choose 2 out of the 5 comments on each piece of music to provide further explanations of your gesture.

Example:



Example of comment explanation:

(1) Comment number: comment 1

(2) Could you describe the key features of this gesture using adjectives?
Fast, prompt movement followed by smooth movement

(3) How should the orchestra respond if they receive this gesture properly?
There should be clear distinction between staccato and legato

Music 1: Mozart, Serenade in G major, K.525, bar 1-55.


A
B

Music 1: Mozart, Serenade in G major, K.525, bar 1-55.

Comment explanation 1:

(1) Comment number: _________________

(2) Could you describe the key features of this gesture using adjectives?

____

____

(3) How should the orchestra respond if they receive this gesture properly?

____

____

Comment explanation 2:

(1) Comment number: _________________

(2) Could you describe the key features of this gesture using adjectives?

____

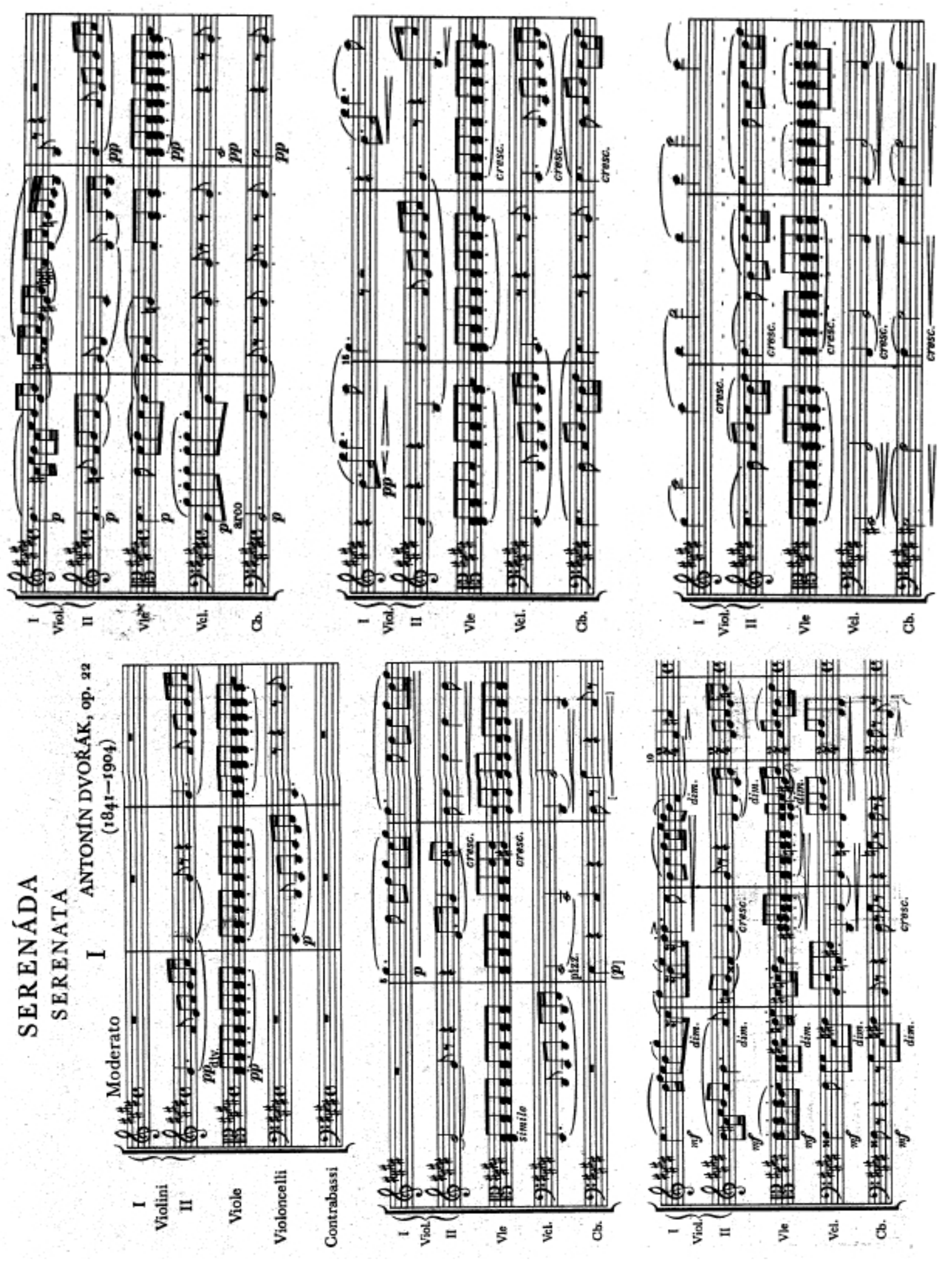
____

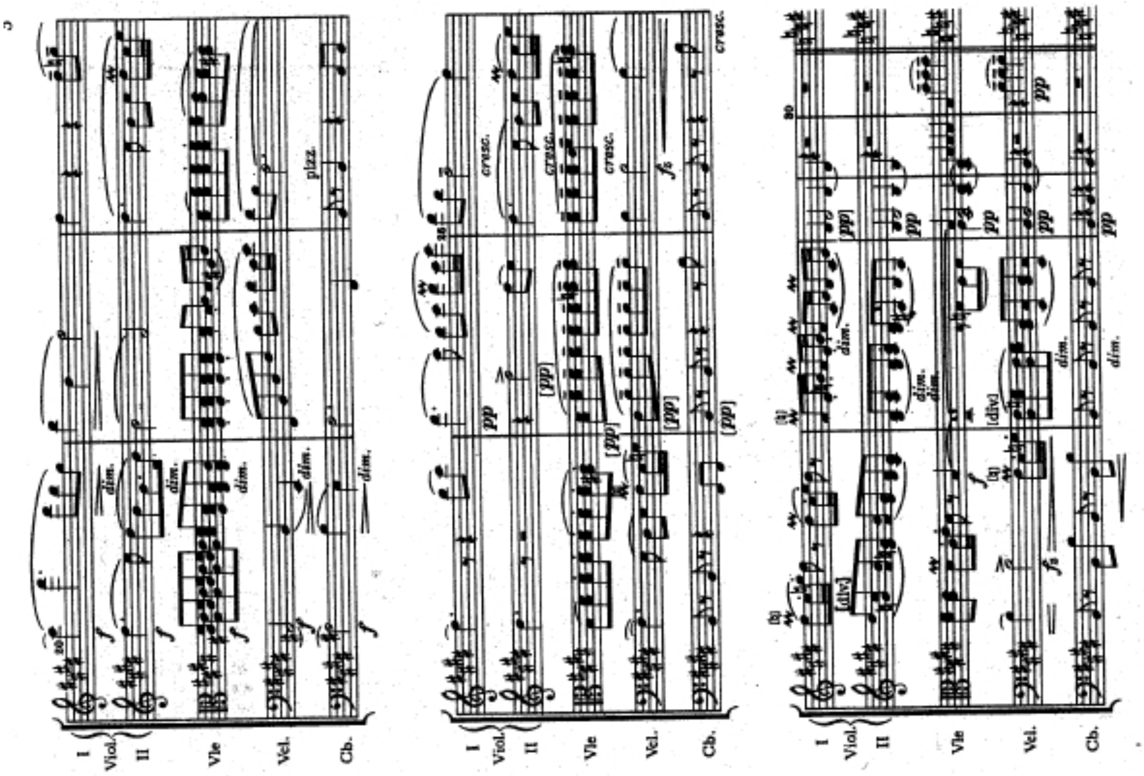
(3) How should the orchestra respond if they receive this gesture properly?

____

____

Music 2: Dvořák, Serenade in E major, Op. 22, bar 1-30.




I
Viol.
II
Vle
Vcl.
Cb.
dim.
pizz.
cresc.
[div]

Music 2: Dvořák, Serenade in E major, Op. 22, bar 1-30.

Comment explanation 1:

(1) Comment number: ________________

(2) Could you describe the key features of this gesture using adjectives?

____

____

(3) How should the orchestra respond if they receive this gesture properly?

____

____

Comment explanation 2:

(1) Comment number: ________________

(2) Could you describe the key features of this gesture using adjectives?

____

____

(3) How should the orchestra respond if they receive this gesture properly?

____

____

Music 3: Bartók, Divertimento, Sz. 113, mov. 3, bar 1- 91.

III

B.& H.8716

B.& H.8716


62
68
82
92
Vl.I
Vl.II
Vle.
Vc.
Cb.
gliss.
Solo
Tutti
2 Soli
pizz.
arco

Music 3: Bartók, Divertimento, Sz. 113, mov. 3, bar 1- 91.

Comment explanation 1:

(1) Comment number: ________________

(2) Could you describe the key features of this gesture using adjectives?

____

____

(3) How should the orchestra respond if they receive this gesture properly?

____

____

Comment explanation 2:

(1) Comment number: ________________

(2) Could you describe the key features of this gesture using adjectives?

____

____

(3) How should the orchestra respond if they receive this gesture properly?

____

____

3. General ideas of conducting

3.1 What do you think are the most important roles a conductor should play in an orchestra?

3.2 What do you think makes good conducting?

3.3 What do you consider to be the distinctive qualities of your conducting?

3.4 Do you find that you review your own conducting performances? How do you do that? (at least 3 comments)

ORCHESTRAL CONDUCTING MOVEMENT RESEARCH

QUESIONNAIRE FOR MUSICIANS

1. Background

1.1 Subject ID: ________________________

1.2 Gender: □Male □ Female □ Prefer not to say

1.3 Handedness: □ Right-handed □ left-handed

1.4 Which instrument did you play today?

____

1.5. For how many years have you played this instrument?

____ years

1.6 For how many years have you played in orchestra?

____ years

1.7 How would you describe your status as a musician (tick all that apply)?

□ Professional performer	□ Professional music educator	□ Advanced student	□ Amateur

1.8 How often do you play the following repertoire

Music before 1750	□A great deal	□Often	□Sometimes	□Not very often	□Not at all
Music in Classical Period	□A great deal	□Often	□Sometimes	□Not very often	□Not at all
Music in Romantic Period	□A great deal	□Often	□Sometimes	□Not very often	□Not at all
20th century music	□A great deal	□Often	□Sometimes	□Not very often	□Not at all
Other genres of music (e.g. movie music, folk music etc.) Please specify: ____________________	□A great deal	□Often	□Sometimes	□Not very often	□Not at all

2. Feedback

The questions ask about your experience of playing in the lab today. Please use the rating scale to express your level of agreement (5= strongly agree, 1= strongly disagree) with the following statements:

(a) I was comfortable performing in this environment.	5	4	3	2	1
(b) I was able to get involved in the performance.	5	4	3	2	1
(c) The recording equipment didn't distract me.	5	4	3	2	1
(d) I was able to perform as I normally would.	5	4	3	2	1
(e) Any other comments? (If you answered with a '2' or '1' to any of the questions, please give a little bit of detail.)					

Appendix 4: Visual 3D pipeline commends for computing linear kinematic variables

1. Speed

Command 1: Lowpass_Filter
```
/SIGNAL_TYPES=TARGET
! /SIGNAL_NAMES=
! /SIGNAL_FOLDER=ORIGINAL
! /RESULT_SUFFIX=
! /RESULT_FOLDER=PROCESSED
! /FILTER_CLASS=BUTTERWORTH
/FREQUENCY_CUTOFF=10
! /NUM_REFLECTED=6
! /TOTAL_BUFFER_SIZE=6
! /NUM_BIDIRECTIONAL_PASSES=1
;
```
Command 2: First_Derivative
```
/SIGNAL_TYPES=TARGET
/SIGNAL_NAMES=BATON END
/SIGNAL_FOLDER=filtered (baton 15)
! /RESULT_NAMES=
! /RESULT_TYPES=
! /RESULT_FOLDER=PROCESSED
! /RESULT_SUFFIX=
;
```
Command 3: Signal_Magnitude
```
/SIGNAL_TYPES=TARGET
/SIGNAL_NAMES=BATON END
/SIGNAL_FOLDER=velocity on XYZ (baton)
! /RESULT_NAMES=
! /RESULT_TYPES=
! /RESULT_FOLDER=PROCESSED
! /RESULT_SUFFIX=
```

2. Acceleration

Apply command 2 and command 3 as above to speed data

3. Jerk

Apply command 2 and command 3 as above to acceleration data

Appendix 5: Full results of descriptive statistics for baton tip linear kinematic variables (musical excerpts and conductors)

Variable	**Music**	**Conductor**	**Mean**	**Standard Deviation**	**95% Confidence Intervals**	
					Lower	**Upper**
Distance (m)	Mozart	Conductor01	0.702	0.226	0.667	0.737
		Conductor02	1.485	0.380	1.426	1.544
		Conductor03	0.808	0.275	0.766	0.851
		Conductor04	1.303	0.626	1.206	1.400
		Conductor05	0.824	0.434	0.757	0.892
		Conductor06	1.209	0.472	1.136	1.282
	Dvorak	Conductor01	0.899	0.244	0.857	0.940
		Conductor02	1.218	0.242	1.177	1.258
		Conductor03	0.795	0.205	0.762	0.827
		Conductor04	1.565	0.526	1.477	1.653
		Conductor05	0.965	0.333	0.911	1.018
		Conductor06	0.801	0.309	0.749	0.854
	Bartok	Conductor01	0.984	0.397	0.951	1.017
		Conductor02	1.745	0.676	1.688	1.801
		Conductor03	0.944	0.490	0.903	0.985
		Conductor04	1.868	0.454	1.830	1.906
		Conductor05	0.959	0.472	0.919	0.998
		Conductor06	1.152	0.338	1.124	1.180
Speed (m/s)	Mozart	Conductor01	0.702	0.226	0.667	0.737
		Conductor02	1.485	0.380	1.426	1.544
		Conductor03	0.808	0.275	0.766	0.851
		Conductor04	1.303	0.626	1.206	1.400
		Conductor05	0.824	0.434	0.757	0.892
		Conductor06	1.209	0.472	1.136	1.282
	Dvorak	Conductor01	0.899	0.244	0.857	0.940
		Conductor02	1.218	0.242	1.177	1.258
		Conductor03	0.795	0.205	0.762	0.827
		Conductor04	1.565	0.526	1.477	1.653
		Conductor05	0.965	0.333	0.911	1.018
		Conductor06	0.801	0.309	0.749	0.854
	Bartok	Conductor01	0.984	0.397	0.951	1.017
		Conductor02	1.745	0.676	1.688	1.801
		Conductor03	0.944	0.490	0.903	0.985
		Conductor04	1.868	0.454	1.830	1.906
		Conductor05	0.959	0.472	0.919	0.998
		Conductor06	1.152	0.338	1.124	1.180

Detailed descriptive statistics continued (musical excerpts and conductors)

Variable	Music	Conductor	Mean	Standard Deviation	95% Confidence Intervals	
					Lower	Upper
Acceleration (m/s2)	Mozart	Conductor01	12.082	4.864	11.327	12.836
		Conductor02	27.580	10.772	25.909	29.251
		Conductor03	14.301	5.549	13.440	15.162
		Conductor04	23.563	13.660	21.444	25.683
		Conductor05	12.339	7.675	11.148	13.530
		Conductor06	26.435	13.419	24.353	28.517
	Dvorak	Conductor01	10.474	2.812	9.997	10.951
		Conductor02	18.019	6.034	17.004	19.035
		Conductor03	8.775	2.694	8.347	9.202
		Conductor04	19.512	6.694	18.393	20.630
		Conductor05	9.178	3.387	8.634	9.7230
		Conductor06	9.990	5.115	9.123	10.858
	Bartok	Conductor01	19.008	8.027	18.333	19.684
		Conductor02	31.752	11.853	30.756	32.749
		Conductor03	14.328	6.448	13.784	14.871
		Conductor04	42.555	12.797	41.479	43.631
		Conductor05	16.162	7.276	15.550	16.774
		Conductor06	26.479	8.843	25.736	27.223
Jerk (m/s3)	Mozart	Conductor01	665.175	307.610	617.448	712.903
		Conductor02	1118.820	574.290	1029.716	1207.924
		Conductor03	699.002	344.467	645.556	752.447
		Conductor04	988.388	615.473	892.894	1083.882
		Conductor05	309.577	194.451	279.407	339.747
		Conductor06	1120.540	621.241	1024.151	1216.929
	Dvorak	Conductor01	474.346	145.821	449.617	499.075
		Conductor02	801.311	370.518	738.942	863.681
		Conductor03	391.667	149.180	367.996	415.338
		Conductor04	754.985	276.527	708.776	801.193
		Conductor05	194.996	93.9980	179.881	210.110
		Conductor06	429.563	214.300	393.221	465.905
	Bartok	Conductor01	1003.366	409.378	968.920	1037.812
		Conductor02	1353.912	556.756	1307.108	1400.716
		Conductor03	687.981	318.033	661.172	714.7910
		Conductor04	2049.706	742.797	1987.262	2112.149
		Conductor05	566.681	244.349	546.140	587.223
		Conductor06	1217.029	439.098	1180.116	1253.942

Appendix 6: Full results of cross-correlations for 3213 trial pairs

(3 kinematic variables x 3 musical excerpt in time-warped data; 4 kinematic variables x 3 musical excerpts in bar data; 21 tables in total)

6.1 Mozart speed; time-warped data

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Mozart Speed	
trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	Normalised data	
1.000	.782	.796	.762	.714 (lag+28)	.732 (lag+20)	.710	.704	.699	.656	.628	.661 (lag-50)	.707 (lag-43)	.691	.712 (lag-48)	.708	.687	.718	trial1	conductor01
	1.000	.778	.730	.725	0.739 (lag+43)	.712	.728	.713	.653 (lag-26)	.631 (lag-33)	.669 (lag-34)	.752 (lag-31)	.725	.734 (lag-41)	.719	.711	.715 (lag+30)	trial2	
		1.000	.732	.714 (lag+8)	.730 (lag+9)	.700	.715	.690	.651 (lag-40)	.614 (lag-42)	.667 (lag-44)	.706 (lag-44)	.702	.701 (lag-46)	.670	.687	.705 (lag+14)	trial3	
			1.000	.741 (lag-7)	.761	.709 (lag-8)	.743	.692	.636	.631 (lag-29)	.666 (lag-40)	.716 (lag-39)	.704 (lag-23)	.715 (lag-32)	.766 (lag-10)	.738	.718	trial1	conductor02
				1.000	.868	.698	.726	.718	.667 (lag-19)	.628 (lag-16)	.649 (lag-25)	.755 (lag-23)	.756 (lag-12)	.738 (lag-25)	.763 (lag-11)	.723	.761	trial2	
					1.000	.716 (lag+7)	.742	.722	.672 (lag-12)	.652 (lag-19)	.664 (lag-18)	.747 (lag-17)	.746 (lag-11)	.738 (lag-18)	.759 (lag-10)	.733	.759	trial3	
						1.000	.812	.743	.642 (lag-37)	.606 (lag+21)	.615 (lag-30)	.702 (lag-14)	.675 (lag-8)	.676 (lag-10)	.684	.685	.700	trial1	conductor03
							1.000	.775	.628 (lag-30)	.598 (lag-15)	.631 (lag-26)	.727 (lag-17)	.697 (lag-15)	.691 (lag-15)	.719 (lag-9)	.735	.736	trial2	
								1.000	.635 (lag-26)	.597 (lag-32)	.642 (lag-36)	.702 (lag-31)	.671 (lag-9)	.670	.692	.698	.720	trial3	
									1.000	.697	.688 (lag-8)	.667 (lag-8)	.671	.643	.646	.612	.639 (lag+13)	trial1	conductor04
										1.000	.654	.647	.660	.612	.618	.597 (lag+20)	.627 (lag+15)	trial2	
											1.000	.687	.675	.679	.657	.650 (lag+27)	.651 (lag+15)	trial3	
												1.000	.843	.849	.775 (lag+18)	.744 (lag+28)	.749 (lag+23)	trial1	conductor05
													1.000	.845	.752 (lag+11)	.715 (lag+10)	.746 (lag+17)	trial2	
														1.000	.758 (lag+15)	.729 (lag+24)	.725 (lag+20)	trial3	
															1.000	.794	.782 (lag+9)	trial1	conductor06
																1.000	.791	trial2	
																	1.000	trial3	

6.2 Mozart acceleration; time-warped data

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Mozart Acceleration	
trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	Normalised data	
1.000	.652	.670	.667	.567	.577	.524	.546	.566	.526 (lag-11)	.509 (lag-36)	.502 (lag-38)	.608 (lag-19)	.600	.609 (lag-9)	.562 (lag-9)	.578	.610	**trial1**	**conductor01**
	1.000	.649	.623	.585	.588	.520	.558	.573	.546 (lag-7)	.507 (lag-40)	.525 (lag-17)	.638 (lag-18)	.622	.617 (lag-9)	.571 (lag-8)	.568	.585	**trial2**	
		1.000	.655	.587	.609	.523	.597	.558	.562 (lag-23)	.526 (lag-20)	.565 (lag-13)	.648 (lag-20)	.637	.630 (lag-9)	.608 (lag-8)	.604	.616	**trial3**	
			1.000	.636	.671	.551	.606	.603	.577 (lag-32)	.568 (lag-17)	.552 (lag-30)	.651 (lag-16)	.673 (lag-10)	.644 (lag-11)	.670	.653	.631	**trial1**	**conductor02**
				1.000	.759	.526	.580	.594	.524 (lag-17)	.515 (lag-14)	.512 (lag-10)	.666 (lag-15)	.671	.655 (lag-9)	.630	.614	.629	**trial2**	
					1.000	.561	.625	.606	.556 (lag-12)	.548 (lag-35)	.535 (lag-28)	.683 (lag-13)	.695 (lag-8)	.686 (lag-8)	.656	.633	.649	**trial3**	
						1.000	.605	.565	.492 (lag-8)	.460 (lag-13)	.435 (lag-8)	.564 (lag-15)	.566 (lag-8)	.548 (lag-10)	.501	.516	.549	**trial1**	**conductor03**
							1.000	.560	.504 (lag-8)	.466 (lag-13)	.485 (lag-9)	.618 (lag-15)	.608 (lag-8)	.594 (lag-9)	.559	.585	.611	**trial2**	
								1.000	.461	.469 (lag-43)	.485 (lag-26)	.593 (lag-17)	.593 (lag-9)	.584 (lag-10)	.556 (lag-9)	.598	.605	**trial3**	
									1.000	.582	.550	.578	.600	.550	.506	.465 (lag+7)	.504	**trial1**	**conductor04**
										1.000	.567 (lag+6)	.544	.578 (lag+8)	.532	.523 (lag+9)	.500 (lag+12)	.524 (lag+12)	**trial2**	
											1.000	.575	.579	.570 (lag+8)	.540 (lag+9)	.526 (lag+30)	.539 (lag+16)	**trial3**	
												1.000	.798	.817 (lag+8)	.683 (lag+20)	.680 (lag+24)	.682 (lag+22)	**trial1**	**conductor05**
													1.000	.807	.685	.661 (lag+9)	.685 (lag+11)	**trial2**	
														1.000	.669 (lag+9)	.662 (lag+8)	.668 (lag+10)	**trial3**	
															1.000	.683	.677	**trial1**	**conductor06**
																1.000	.699	**trial2**	
																	1.000	**trial3**	

6.3 Mozart jerk; time-warped data

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Mozart Jerk	
trial 1	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**Normalised data**	
1.000	.628	.645	.643	.507	.529	.476	.498	.536	.503 (lag-11)	.471 (lag-33)	.461 (lag-40)	.546 (lag-32)	.590 (lag-8)	.564 (lag-19)	.510	.535	.588	**trial1**	**conductor01**
	1.000	.622	.583	.524	.542	.465	.511	.540	.520	.485 (lag-34)	.496 (lag-36)	.568 (lag-30)	.569 (lag-10)	.562 (lag-7)	.519	.539	.544	**trial2**	
		1.000	.615	.543	.554	.469	.563	.500	.546 (lag-16)	.503 (lag-20)	.540 (lag-10)	.583 (lag-21)	.612 (lag-10)	.573	.565	.577	.577	**trial3**	
			1.000	.564	.610	.483	.543	.547	.546 (lag-19)	.529 (lag-21)	.504 (lag-32)	.571 (lag-27)	.637 (lag-10)	.574 (lag-17)	.634	.620	.595	**trial1**	**conductor02**
				1.000	.685	.455	.519	.531	.482 (lag-16)	.465 (lag-17)	.452 (lag-10)	.553	.606	.547 (lag-18)	.544	.560	.549	**trial2**	
					1.000	.494 (lag+4)	.567	.541	.488 (lag-8)	.493 (lag-25)	.480 (lag-20)	.591 (lag-16)	.628	.589 (lag-8)	.608	.589	.598	**trial3**	
						1.000	.534	.498	.432 (lag-8)	.416 (lag-19)	.390 (lag-9)	.460 (lag-8)	.499 (lag-9)	.458 (lag-17)	.435	.442	.490	**trial1**	**conductor03**
							1.000	.517	.474 (lag-10)	.415 (lag-33)	.437 (lag-9)	.538 (lag-9)	.567 (lag-9)	.514 (lag-19)	.514	.527	.544	**trial2**	
								1.000	.411 (lag-15)	.419 (lag-39)	.440 (lag-17)	.533 (lag-29)	.559 (lag-13)	.535 (lag-12)	.497	.550	.555	**trial3**	
									1.000	.509 (lag-5)	.491	.520	.548 (lag+8)	.496	.466 (lag+17)	.426 (lag+8)	.463 (lag+14)	**trial1**	**conductor04**
										1.000	.512	.460	.521	.480 (lag+8)	.486 (lag+21)	.458 (lag+29)	.483 (lag+30)	**trial2**	
											1.000	.490 (lag-10)	.527	.516 (lag+15)	.506 (lag+14)	.494 (lag+10)	.500 (lag+18)	**trial3**	
												1.000	.688	.691 (lag+12)	.588 (lag+18)	.589 (lag+32)	.595 (lag+28)	**trial1**	**conductor05**
													1.000	.702	.610	.603 (lag+10)	.637 (lag+15)	**trial2**	
														1.000	.579	.583 (lag+17)	.608 (lag+9)	**trial3**	
															1.000	.638	.617	**trial1**	**conductor06**
																1.000	.645	**trial2**	
																	1.000	**trial3**	

6.4 Dvorak speed; time-warped data

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Dvorak Speed	
trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	Normalised data	
1.000	.839 (lag+6)	.822 (lag+9)	.724 (lag+18)	.740 (lag+16)	.776	.810 (lag+6)	.794 (lag+3)	.820 (lag-4)	.801 (lag+19)	.780 (lag+17)	.793 (lag+16)	.805	.804	.812 (lag-9)	.803 (lag+22)	.754 (lag+5)	.794 (lag_31)	**trial1**	**conductor01**
	1.000	.835	.731	.736	.784	.810	.797	.818	.813 (lag+8)	.785 (lag+6)	.794	.811	.816 (lag-19)	.819 (lag-14)	.794 (lag+13)	.747 (lag+24)	.793 (lag+19)	**trial2**	
		1.000	.765	.753 (lag+22)	.786 (lag-15)	.803	.781	.812	.786	.761 (lag+4)	.777	.789	.807 (lag-9)	.800 (lag-11)	.791	.737 (lag+5)	.777 (lag+17)	**trial3**	
			1.000	.741	.757 (lag-24)	.732	.722	.739	.734 (lag-5)	.728	.748 (lag-6)	.716 (lag-22)	.727 (lag-20)	.725 (lag-24)	.715	.654	.713	**trial1**	**conductor02**
				1.000	.741 (lag-4)	.730	.740	.738	0.749 (lag-5)	.735 (lag-6)	.746	.733 (lag-14)	.735 (lag-21)	.724 (lag-19)	.709	.668 (lag+7)	.711	**trial2**	
					1.000	.768 (lag+5)	.751	.777	.762 (lag+16)	.751 (lag+17)	.759 (lag+8)	.759	.766	.764 (lag-5)	.756 (lag+22)	.696 (lag+35)	.755 (lag+35)	**trial3**	
						1.000	.839 (lag-2)	.864 (lag-2)	.776 (lag+9)	.772 (lag+11)	.786 (lag+10)	.797	.794 (lag-5)	.782 (lag-5)	.807	.747 (lag+15)	.800	**trial1**	**conductor03**
							1.000	.847	.779 (lag+16)	.765 (lag+14)	.784 (lag+20)	.798 (lag+11)	.792	.772	.785	.728 (lag+14)	.768	**trial2**	
								1.000	.788 (lag+25)	.780 (lag+23)	.797 (lag+16)	.806	.806	.804	.798	.744	.801	**trial3**	
									1.000	.872 (lag+1)	.872	.822 (lag-13)	.817 (lag-17)	.809 (lag-19)	.787	.782 (lag+9)	.802 (lag+4)	**trial1**	**conductor04**
										1.000	.871 (lag-3)	.802 (lag-9)	.800 (lag-19)	.783 (lag-16)	.755 (lag+4)	.742 (lag+20)	.756	**trial2**	
											1.000	.811 (lag-10)	.818 (lag-13)	.804 (lag-19)	.790	.754 (lag+6)	.787 (lag+2)	**trial3**	
												1.000	.872 (lag-12)	.843	.804 (lag+20)	.788 (lag+14)	.808 (lag+23)	**trial1**	**conductor05**
													1.000	.897	.808 (lag+15)	.768 (lag+22)	.800 (lag+24)	**trial2**	
														1.000	.804 (lag+21)	.771 (lag+8)	.815 (lag+21)	**trial3**	
															1.000	.780	.855	**trial1**	**conductor06**
																1.000	.816 (lag+4)	**trial2**	
																	1.000	**trial3**	

6.5 Dvorak acceleration; time-warped data

Codnductor01			**Conductor02**			**Conductor03**			**Conductor04**			**Conductor05**			**Conductor06**			**Dvorak Acceleration**	
trial 1	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**Normalised data**	
1.000	.706	.651	.529	.516	.623	.592	.585	.615	.655 (lag-9)	.625 (lag-8)	.636 (lag-5)	.727	.696	.681 (lag+8)	.588	.570	.582	**trial1**	**conductor01**
	1.000	.692	.556	.534	.635	.596	.597	.623	0.674 (lag-6)	.634	.653 (lag-5)	.723	.722 (lag-9)	.700 (lag-21)	.605	.584	.583	**trial2**	
		1.000	.583	.537	.613	.560	.576	.614	.658 (lag-7)	.616	.650 (lag-5)	.656	.676 (lag-10)	.650 (lag-12)	.608	.560	.574	**trial3**	
			1.000	.479	.548	.530	.512	.517	.561 (lag-19)	.539	.554 (lag-8)	.548 (lag-11)	.549	.536 (lag-17)	.517	.449	.513	**trial1**	**conductor02**
				1.000	.536	.504	.507	.518 (lag+3)	.562 (lag-6)	.498	.517 (lag-5)	.534	.535	.513 (lag-21)	.455	.447	.487	**trial2**	
					1.000	.574 (lag+5)	.569	.592	.619	.575	.593	.644	.646	.635 (lag-5)	.536 (lag+36)	.496	.539	**trial3**	
						1.000	.603	.614	.549 (lag-12)	.533	.556 (lag-10)	.611 (lag-5)	.584	.578 (lag-22)	.573 (lag-5)	.529 (lag-5)	.580	**trial1**	**conductor03**
							1.000	.640	.566 (lag-6)	.556 (lag-5)	.580 (lag-11)	.619 (lag-10)	.584 (lag-11)	.559 (lag-6)	.548 (lag-5)	.520	.560	**trial2**	
								1.000	.585 (lag-7)	.559 (lag-7)	.576 (lag-23)	.647	.614	.601	.554	.538	.595	**trial3**	
									1.000	.727	.725	.709	.684	.682	.604 (lag+6)	.604 (lag+6)	.620 (lag+6)	**trial1**	**conductor04**
										1.000	.693 (lag-5)	.663	.652	.631	.550	.545	.559 (lag+5)	**trial2**	
											1.000	.693	.665	.663	.583 (lag+6)	.563 (lag+10)	.593 (lag+7)	**trial3**	
												1.000	.796	.781	.651 (lag+12)	.642 (lag+15)	.648 (lag+19)	**trial1**	**conductor05**
													1.000	.808	.641	.623	.625 (lag+15)	**trial2**	
														1.000	.635 (lag+15)	.623	.647 (lag+6)	**trial3**	
															1.000	.596	.683	**trial1**	**conductor06**
																1.000	.633	**trial2**	
																	1.000	**trial3**	

6.6 Dvorak jerk; time-warped data

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Dvorak jerk	
trial 1	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**Normalised data**	
1.000	.664	.580	0.458 (lag+10)	.418	.569	.539 (lag+5)	.497	.551	.614	.577 (lag-6)	.580 (lag-7)	.500 (lag+5)	.473	.448	.567	.540	.547	**trial1**	**conductor01**
	1.000	.633	.499	.451	.596 (lag-3)	.549	0.541 (lag+1)	.575 (lag+4)	.639 (lag-5)	.583 (lag-5)	.584 (lag-8)	.502 (lag-19)	.527 (lag-32)	.480 (lag-34)	.586	.557	.558 (lag+17)	**trial2**	
		1.000	.507	.430	.545	.472	.489	.533	.594 (lag-7)	.546	.591 (lag-7)	.442 (lag-9)	.473	.425	.564	.520	.536 (lag-15)	**trial3**	
			1.000	.372	.462	.454 (lag+5)	.432	.457	.514 (lag-17)	.477	.498 (lag-8)	.334 (lag-42)	.359 (lag-9)	.345 (lag-20)	.444	.387	.442	**trial1**	**conductor02**
				1.000	.450	.413	.428	.458	.481 (lag-6)	.410	.420	.319	.380 (lag+35)	.303 (lag-24)	.378 (lag-5)	.382	.397 (lag+11)	**trial2**	
					1.000	.514	.507	.542	.558	.520	.542	.427	.448 (lag-22)	.415	.478 (lag+5)	.465 (lag-4)	.466	**trial3**	
						1.000	.532	.562	.482 (lag-9)	.462	0.477 (lag-10)	.413 (lag-39)	.446 (lag-54)	.391 (lag-41)	.519 (lag-5)	.479	.515	**trial1**	**conductor03**
							1.000	.605	.480 (lag-6)	.475 (lag+6)	.509 (lag-22)	.389 (lag-44)	.396 (lag-28)	.342 (lag-26)	.477	.472	.488	**trial2**	
								1.000	.523 (lag-19)	.492	.514 (lag-15)	.438 (lag-7)	.432 (lag-32)	.385 (lag+37)	.488	.497	.549 (lag+14)	**trial3**	
									1.000	.680	.662	.454	.462	.444	.535 (lag+6)	.540 (lag+6)	.548 (lag+12)	**trial1**	**conductor04**
										1.000	.632 (lag-6)	.430 (lag-10)	.430 (lag-21)	.396 (lag+17)	.474 (lag-15)	.485 (lag+8)	.488 (lag+6)	**trial2**	
											1.000	.437	.420	.411 (lag+16)	.503 (lag+11)	.501 (lag+11)	.511 (lag+12)	**trial3**	
												1.000	.391	.370	.446 (lag+36)	.416 (lag+33)	.414 (lag+38)	**trial1**	**conductor05**
													1.000	.450	.462 (lag+68)	.426 (lag+34)	.414 (lag+27)	**trial2**	
														1.000	.420	.414	.397 (lag+16)	**trial3**	
															1.000	.554	.621	**trial1**	**conductor06**
																1.000	.567	**trial2**	
																	1.000	**trial3**	

6.7 Bartok speed; time-warped data

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Bartok Speed	
trial 1	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**Normalised data**	
1.000	.830	.798	.715	.767	.781	.708	.702	.720	.751 (lag-27)	.746 (lag-27)	.724 (lag-29)	.752	.749	.750	.822	.811	.820	**trial1**	**conductor01**
	1.000	.779	.732	.759	.784	.725	.727	.736	.737 (lag-19)	.728 (lag-17)	.710 (lag-23)	.741	.730	.740	.799	.782	.796	**trial2**	
		1.000	.677	.696	.732	.694	.682	.685	.695 (lag-16)	.687 (lag-19)	.679 (lag-1)	.706	.692	.699	.750	.735	.752	**trial3**	
			1.000	.709	.792	.698	.725	.723	.650	.647 (lag-18)	.641 (lag-19)	.712	.703	.719	.731	.724	.721	**trial1**	**conductor02**
				1.000	.791	.681	.696	.713	.693 (lag-20)	.687 (lag-19)	.677 (lag-26)	.698	.723	.720	.773	.764	.760	**trial2**	
					1.000	.724	.746	.768	.692 (lag-18)	.696 (lag-22)	.672 (lag-28)	.747	.739	.739	.788	.789	.770	**trial3**	
						1.000	.821	.797	.661	.640	.633	.723	.706	.717	.719	.712	.709	**trial1**	**conductor03**
							1.000	.851	.661	.645	.651	.732(lag+5)	.726	.731 (lag+4)	.738 (lag+4)	.729	.725	**trial2**	
								1.000	.655	.646	.647	.718	.727	.733	.744	.736	.719	**trial3**	
									1.000	.805	.796	.654 (lag+15)	.663 (lag+3)	.655 (lag+18)	.753 (lag+9)	.739 (lag+7)	.748 (lag+10)	**trial1**	**conductor04**
										1.000	.797	.660 (lag+17)	.666 (lag+16)	.660 (lag+16)	.752 (lag+8)	.740 (lag+7)	.746 (lag+11)	**trial2**	
											1.000	.641 (lag+23)	.638 (lag+14)	.642 (lag+21)	.721 (lag+18)	.719 (lag+11)	.725 (lag+18)	**trial3**	
												1.000	.826	.834	.791	.779	.791	**trial1**	**conductor05**
													1.000	.821	.772	.746	.751	**trial2**	
														1.000	.834	.821	.827	**trial3**	
															1.000	.896	.900	**trial1**	**conductor06**
																1.000	.887	**trial2**	
																	1.000	**trial3**	

6.8 Bartok acceleration; time-warped data

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Bartok Acceleration	
trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	Normalised data	
1.000	.781	.735	.684	.718	.736	.633	.646	.685	.654	.670 (lag-27)	.638 (lag-27)	.763	.720	.750	.788	.781	.783	trial1	conductor01
	1.000	.726	.668	.688	.712	.623	.636	.667	.649	.651 (lag-27)	.636 (lag-27)	.717	.670	.715	.733	.715	.730	trial2	
		1.000	.629	.640	.670	.560	.595	.627	.617	.608 (lag-26)	.600 (lag-28)	.681	.650	.670	.698	.682	.694	trial3	
			1.000	.663	.705	.583	.618	.631	.589	.626 (lag-105)	.613 (lag-100)	.693	.674	.687	.695	.677	.696	trial1	conductor02
				1.000	.705	.601	.613	.637	.616	.625 (lag-86)	.634 (lag-82)	.680	.670	.688	.724	.702	.715	trial2	
					1.000	.622	.637	.672	.655 (lag-30)	.667(lag-105)	.624 (lag-126)	.724	.690	.720	.752	.727	.730	trial3	
						1.000	.702	.674	.572 (lag-29)	.542 (lag-33)	.550 (lag-56)	.639	.598	.631	.660	.628	.646	trial1	conductor03
							1.000	.746	.594 (lag-30)	.553 (lag-32)	.564 (lag-36)	.656	.624	.644	.670	.653	.663	trial2	
								1.000	.593 (lag-36)	.576 (lag-46)	.576 (lag-54)	.679	.660	.685	.704	.669	.675	trial3	
									1.000	.738	.752	.627 (lag+51)	.618 (lag+28)	.628 (lag+79)	.684 (lag+28)	.665 (lag+27)	.670 (lag+29)	trial1	conductor04
										1.000	.734	.663 (lag+111)	.636 (lag+106)	.663 (lag+118)	.698 (lag+109)	.681 (lag+105)	.673 (lag+111)	trial2	
											1.000	.633 (lag+100)	.597 (lag+92)	.625 (lag+119)	.671 (lag+114)	.653 (lag+99)	.662 (lag+121)	trial3	
												1.000	.805	.826	.783	.768	.795	trial1	conductor05
													1.000	.793	.737	.710	.735	trial2	
														1.000	.771	.753	.785	trial3	
															1.000	.830	.847	trial1	conductor06
																1.000	.826	trial2	
																	1.000	trial3	

6.9 Bartok jerk; time-warped data

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Bartok Jerk	
trial 1	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**Normalised data**	
1.000	.743	.708	.627	.668	.682	.554	.559	.624	.646 (lag-27)	.639 (lag-45)	.624 (lag-49)	.706	.653	.684	.708	.708	.705	**trial1**	**conductor01**
	1.000	.686	.604	.628	.656	.530	.550	.595	.635 (lag-49)	.617 (lag-78)	.614 (lag-49)	.665	.599	.653	.650	.643	.655	**trial2**	
		1.000	.579	.595	.621	.520	.530	.579 (lag+20)	.603 (lag-26)	.584 (lag-85)	.582 (lag-48)	.624	.587	.615	.633	.617	.630	**trial3**	
			1.000	.606	.622	.495	.548	.558	.574 (lag-94)	.576(lag -103)	.574(lag -102)	.648	.619	.638	.637	.616	.638	**trial1**	**conductor02**
				1.000	.636	.526	.538	.563	.590 (lag-85)	.562 (lag-96)	.591 (lag-86)	.629	.608	.641	.647	.635	.658	**trial2**	
					1.000	.536	.564	.603	.617 (lag-89)	.623 (lag-99)	.579 (lag-96)	.680	.632	.679	.683	.654	.669	**trial3**	
						1.000	.639	.594	.518 (lag-36)	.485 (lag-97)	.509(lag -115)	.560	.519	.544	.569	.536	.560	**trial1**	**conductor03**
							1.000	.677	.545 (lag-33)	.487 (lag-97)	.508 (lag-59)	.586	.547	.566	.583	.581	.591	**trial2**	
								1.000	.558(lag -101)	.521(lag -103)	.546(lag -115)	.617	.583	.617	.640	.598	.609	**trial3**	
									1.000	.664	.707	.611 (lag+87)	.579 (lag+89)	.613 (lag+96)	.658 (lag+96)	.617 (lag+93)	.647(lag +102)	**trial1**	**conductor04**
										1.000	.654	.629 (lag+98)	.589(lag +100)	.630 (lag+98)	.639(lag +105)	.631(lag +101)	.619(lag +111)	**trial2**	
											1.000	.608 (lag+99)	.552 (lag+99)	.593(lag +103)	.633(lag +113)	.614(lag +102)	.622(lag +116)	**trial3**	
												1.000	.754	.788	.726	.716	.747	**trial1**	**conductor05**
													1.000	.748	.686	.646	.683	**trial2**	
														1.000	.726	.700	.738	**trial3**	
															1.000	.751	.773	**trial1**	**conductor06**
																1.000	.749	**trial2**	
																	1.000	**trial3**	

6.10 Mozart distance; sum per musical bar

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Mozart Distance	
trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	Mean per bar	
1.000	.935	.954	.959	.948	.954	.924	.921	.924	.877	.841	.850	.878	.873	.885	.903	.917	.929	**trial1**	**conductor01**
	1.000	.936	.943	.946	.948	.911	.924	.919	.869	.864	.886	.913	.905	.923	.927	.948	.927	**trial2**	
		1.000	.942	.928	.922	.898	.902	.908	.866	.851	.869	.869	.890	.880	.874	.916	.909	**trial3**	
			1.000	.967	.977	.935	.937	.952	.906	.889	.896	.917	.913	.919	.945	.953	.948	**trial1**	**conductor02**
				1.000	.978	.944	.951	.959	.907	.875	.904	.940	.924	.944	.948	.950	.943	**trial2**	
					1.000	.927	.942	.951	.890	.885	.896	.926	.916	.927	.941	.951	.941	**trial3**	
						1.000	.964	.938	.882	.813	.867	.885	.857	.876	.903	.931	.916	**trial1**	**conductor03**
							1.000	.958	.871	.830	.869	.901	.873	.888	.915	.942	.935	**trial2**	
								1.000	.913	.857	.878	.905	.896	.891	.930	.948	.950	**trial3**	
									1.000	.888	.861	.842	.842	.813	.870	.887	.883	**trial1**	**conductor04**
										1.000	.864	.872	.891	.832	.883	.893	.975	**trial2**	
											1.000	.890	.881	.863	.890	.902	.891	**trial3**	
												1.000	.966	.973	.959	.955	.930	**trial1**	**conductor05**
													1.000	.957	.935	.943	.921	**trial2**	
														1.000	.951	.944	.920	**trial3**	
															1.000	.975	.972	**trial1**	**conductor06**
																1.000	.976	**trial2**	
																	1.000	**trial3**	

6.11 Mozart speed; mean per musical bar

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Mozart Speed	
trial 1	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**Mean per bar**	
1.000	.940	.950	.959	.952	.939	.930	.924	.924	.880	.865	.863	.884	.882	.891	.906	.911	.934	**trial1**	**conductor01**
	1.000	.922	.945	.946	.950	.923	.924	.919	.870	.865	.888	.921	.915	.921	.938	.947	.936	**trial2**	
		1.000	.933	.921	.927	.903	.888	.881	.840	.831	.867	.860	.876	.871	.876	.893	.899	**trial3**	
			1.000	.971	.982	.941	.936	.950	.912	.904	.908	.925	.928	.925	.952	.954	.956	**trial1**	**conductor02**
				1.000	.983	.948	.948	.964	.913	.889	.911	.949	.942	.948	.962	.953	.961	**trial2**	
					1.000	.944	.945	.954	.906	.890	.910	.934	.932	.932	.956	.953	.957	**trial3**	
						1.000	.976	.963	.887	.858	.887	.900	.871	.876	.928	.933	.944	**trial1**	**conductor03**
							1.000	.974	.884	.842	.892	.922	.902	.891	.928	.948	.957	**trial2**	
								1.000	.906	.870	.891	.921	.906	.902	.942	.953	.963	**trial3**	
									1.000	.923	.915	.855	.849	.817	.893	.901	.909	**trial1**	**conductor04**
										1.000	.855	.852	.867	.811	.881	.880	.880	**trial2**	
											1.000	.884	.876	.858	.896	.910	.912	**trial3**	
												1.000	.976	.977	.977	.963	.947	**trial1**	**conductor05**
													1.000	.963	.959	.945	.931	**trial2**	
														1.000	.964	.943	.930	**trial3**	
															1.000	.983	.978	**trial1**	**conductor06**
																1.000	.979	**trial2**	
																	1.000	**trial3**	

6.12 Mozart acceleration; mean per musical bar

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Mozart Acceleration	
trial 1	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**Mean per bar**	
1.000	.939	.950	.944	.954	.942	.944	.951	.934	.869	.825	.850	.914	.902	.915	.912	.919	.937	**trial1**	**conductor01**
	1.000	.960	.937	.951	.948	.952	.956	.942	.895	.815	.897	.927	.922	.917	.938	.946	.941	**trial2**	
		1.000	.950	.947	.961	.948	.953	.921	.901	.832	.903	.917	.918	.913	.927	.928	.933	**trial3**	
			1.000	.944	.963	.939	.944	.947	.889	.870	.859	.921	.932	.929	.953	.951	.943	**trial1**	**conductor02**
				1.000	.974	.960	.959	.958	.884	.827	.873	.953	.941	.954	.949	.942	.954	**trial2**	
					1.000	.948	.958	.939	.874	.831	.867	.936	.941	.943	.958	.951	.954	**trial3**	
						1.000	.976	.968	.886	.833	.852	.925	.901	.912	.928	.942	.949	**trial1**	**conductor03**
							1.000	.971	.880	.821	.880	.933	.905	.921	.942	.956	.965	**trial2**	
								1.000	.879	.850	.858	.931	.914	.918	.950	.959	.966	**trial3**	
									1.000	.903	.924	.849	.858	.817	.865	.850	.866	**trial1**	**conductor04**
										1.000	.807	.795	.840	.753	.828	.819	.828	**trial2**	
											1.000	.835	.845	.815	.856	.856	.862	**trial3**	
												1.000	.975	.978	.973	.960	.952	**trial1**	**conductor05**
													1.000	.956	.967	.953	.946	**trial2**	
														1.000	.967	.950	.946	**trial3**	
															1.000	.984	.976	**trial1**	**conductor06**
																1.000	.978	**trial2**	
																	1.000	**trial3**	

6.13 Mozart jerk; mean per musical bar

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Mozart Jerk	
trial 1	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**Mean per bar**	
1.000	.932	.940	.928	.940	.920	.937	.939	.922	.861	.825	.835	.905	.921	.914	.905	.921	.931	**trial1**	**conductor01**
	1.000	.953	.913	.931	.923	.943	.945	.928	.893	.818	.894	.916	.910	.907	.921	.931	.925	**trial2**	
		1.000	.920	.929	.925	.940	.948	.907	.889	.812	.895	.902	.904	.893	.914	.920	.914	**trial3**	
			1.000	.915	.934	.913	.926	.924	.875	.854	.834	.912	.947	.920	.956	.948	.939	**trial1**	**conductor02**
				1.000	.953	.948	.938	.926	.880	.807	.843	.933	.935	.935	.926	.926	.938	**trial2**	
					1.000	.928	.941	.903	.851	.810	.848	.935	.940	.933	.955	.944	.949	**trial3**	
						1.000	.956	.938	.880	.813	.844	.907	.908	.898	.912	.938	.933	**trial1**	**conductor03**
							1.000	.940	.878	.807	.872	.925	.930	.925	.941	.952	.951	**trial2**	
								1.000	.845	.823	.831	.920	.936	.927	.931	.950	.944	**trial3**	
									1.000	.868	.897	.844	.868	.847	.862	.825	.850	**trial1**	**conductor04**
										1.000	.798	.777	.839	.772	.840	.804	.809	**trial2**	
											1.000	.822	.843	.834	.852	.843	.841	**trial3**	
												1.000	.974	.977	.963	.949	.949	**trial1**	**conductor05**
													1.000	.970	.973	.960	.964	**trial2**	
														1.000	.960	.941	.954	**trial3**	
															1.000	.976	.970	**trial1**	**conductor06**
																1.000	.971	**trial2**	
																	1.000	**trial3**	

6.14 Dvorak Distance; sum per musical bar

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Dvorak Distance	
trial 1	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**Mean per bar**	
1.000	.945	.953	.901	.908	.926	.951	.926	.947	.944	.919	.930	.946	.941	.949	.957	.947	.950	**trial1**	**conductor01**
	1.000	.949	.906	.934	.937	.962	.916	.951	.950	.940	.933	.936	.935	.939	.954	.934	.941	**trial2**	
		1.000	.956	.948	.959	.961	.949	.956	.954	.947	.938	.938	.943	.941	.954	.923	.940	**trial3**	
			1.000	.947	.945	.932	.927	.935	.923	.922	.927	.903	.910	.916	.912	.874	.897	**trial1**	**conductor02**
				1.000	.954	.948	.930	.942	.919	.923	.912	.906	.913	.918	.919	.877	.902	**trial2**	
					1.000	.968	.917	.955	.936	.942	.931	.917	.921	.920	.925	.897	.920	**trial3**	
						1.000	.956	.979	.952	.942	.943	.949	.952	.943	.961	.918	.947	**trial1**	**conductor03**
							1.000	.957	.942	.933	.935	.918	.944	.931	.946	.894	.922	**trial2**	
								1.000	.955	.947	.952	.948	.952	.960	.948	.926	.948	**trial3**	
									1.000	.979	.976	.946	.959	.963	.965	.956	.967	**trial1**	**conductor04**
										1.000	.973	.927	.942	.944	.945	.923	.935	**trial2**	
											1.000	.937	.952	.954	.945	.920	.944	**trial3**	
												1.000	.983	.976	.960	.944	.961	**trial1**	**conductor05**
													1.000	.973	.965	.945	.963	**trial2**	
														1.000	.955	.952	.971	**trial3**	
															1.000	.961	.976	**trial1**	**conductor06**
																1.000	.970	**trial2**	
																	1.000	**trial3**	

6.15 Dvorak Speed; mean per musical bar

Codnuctor01			**Conductor02**			**Conductor03**			**Conductor04**			**Conductor05**			**Conductor06**			**Dvorak Speed**	
trial 1	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**Mean per bar**	
1.000	.966	.960	.927	.934	.947	.960	.954	.956	.961	.940	.943	.951	.946	.957	.963	.946	.953	**trial1**	**conductor01**
	1.000	.964	.943	.956	.960	.975	.955	.968	.972	.963	.954	.953	.956	.964	.968	.949	.966	**trial2**	
		1.000	.968	.965	.969	.964	.953	.956	.959	.950	.942	.943	.949	.948	.953	.926	.947	**trial3**	
			1.000	.975	.967	.952	.952	.951	.935	.938	.940	.924	.929	.934	.923	.890	.919	**trial1**	**conductor02**
				1.000	.978	.964	.962	.958	.943	.946	.944	.936	.940	.942	.937	.892	.928	**trial2**	
					1.000	.975	.960	.968	.949	.950	.945	.933	.941	.940	.943	.905	.939	**trial3**	
						1.000	.973	.983	.961	.944	.948	.955	.956	.951	.967	.925	.959	**trial1**	**conductor03**
							1.000	.967	.959	.953	.956	.946	.948	.948	.959	.901	.933	**trial2**	
								1.000	.962	.949	.952	.956	.953	.963	.949	.930	.958	**trial3**	
									1.000	.980	.977	.965	.965	.974	.965	.961	.972	**trial1**	**conductor04**
										1.000	.976	.949	.955	.959	.955	.929	.943	**trial2**	
											1.000	.952	.955	.961	.953	.929	.951	**trial3**	
												1.000	.987	.980	.961	.945	.958	**trial1**	**conductor05**
													1.000	.979	.968	.942	.964	**trial2**	
														1.000	.959	.956	.971	**trial3**	
															1.000	.956	.976	**trial1**	**conductor06**
																1.000	.977	**trial2**	
																	1.000	**trial3**	

6.16 Dvorak Acceleration; mean per musical bar

Codnuctor01			**Conductor02**			**Conductor03**			**Conductor04**			**Conductor05**			**Conductor06**			**Dvorak Acceleration**	
trial 1	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**Mean per bar**	
1.000	.974	.946	.933	.923	.952	.965	.966	.955	.963	.947	.943	.959	.946	.952	.927	.924	.927	**trial1**	**conductor01**
	1.000	.967	.956	.944	.970	.973	.967	.967	.975	.972	.955	.953	.968	.961	.943	.928	.941	**trial2**	
		1.000	.968	.951	.968	.955	.957	.954	.959	.959	.939	.921	.933	.919	.933	.888	.909	**trial3**	
			1.000	.966	.964	.949	.960	.953	.940	.955	.943	.910	.922	.904	.908	.854	.895	**trial1**	**conductor02**
				1.000	.971	.955	.950	.951	.940	.949	.924	.904	.920	.894	.893	.848	.893	**trial2**	
					1.000	.970	.957	.963	.956	.955	.928	.928	.938	.923	.907	.874	.917	**trial3**	
						1.000	.973	.983	.962	.943	.938	.946	.955	.941	.939	.916	.944	**trial1**	**conductor03**
							1.000	.974	.965	.961	.958	.954	.956	.945	.941	.901	.923	**trial2**	
								1.000	.960	.947	.938	.955	.957	.955	.939	.915	.949	**trial3**	
									1.000	.982	.964	.964	.959	.967	.938	.945	.952	**trial1**	**conductor04**
										1.000	.970	.945	.957	.947	.922	.904	.925	**trial2**	
											1.000	.943	.948	.945	.905	.901	.919	**trial3**	
												1.000	.977	.975	.924	.926	.932	**trial1**	**conductor05**
													1.000	.969	.946	.926	.946	**trial2**	
														1.000	.927	.942	.951	**trial3**	
															1.000	.929	.962	**trial1**	**conductor06**
																1.000	.961	**trial2**	
																	1.000	**trial3**	

6.17 Dvorak jerk; mean per musical bar

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Dvorak jerk	
trial 1	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**Mean per bar**	
1.000	.965	.915	.913	.875	.923	.943	.951	.934	.957	.931	.937	.905	.904	.916	.922	.928	.922	**trial1**	**conductor01**
	1.000	.957	.952	.920	.959	.958	.959	.952	.976	.956	.939	.892	.946	.924	.948	.924	.929	**trial2**	
		1.000	.951	.924	.935	.925	.940	.934	.946	.941	.932	.877	.922	.879	.933	.891	.890	**trial3**	
			1.000	.944	.940	.923	.955	.935	.945	.951	.944	.851	.892	.845	.901	.850	.881	**trial1**	**conductor02**
				1.000	.936	.929	.935	.927	.929	.940	.916	.834	.887	.828	.862	.832	.870	**trial2**	
					1.000	.953	.951	.951	.955	.945	.921	.892	.910	.890	.902	.881	.909	**trial3**	
						1.000	.962	.971	.957	.926	.923	.886	.920	.893	.942	.916	.945	**trial1**	**conductor03**
							1.000	.974	.963	.948	.961	.902	.920	.907	.940	.913	.932	**trial2**	
								1.000	.948	.919	.921	.891	.922	.922	.938	.913	.949	**trial3**	
									1.000	.980	.956	.909	.914	.913	.932	.932	.941	**trial1**	**conductor04**
										1.000	.965	.892	.907	.878	.885	.884	.893	**trial2**	
											1.000	.878	.896	.876	.889	.893	.901	**trial3**	
												1.000	.900	.883	.864	.849	.851	**trial1**	**conductor05**
													1.000	.921	.927	.885	.898	**trial2**	
														1.000	.890	.898	.884	**trial3**	
															1.000	.935	.957	**trial1**	**conductor06**
																1.000	.955	**trial2**	
																	1.000	**trial3**	

6.18 Bartok distance; sum per musical bar

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Bartok Distance	
trial 1	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**Mean per bar**	
1.000	.930	.915	.831	.854	.892	.827	.802	.815	.921	.924	.907	.856	.842	.847	.924	.916	.925	**trial1**	**conductor01**
	1.000	.895	.842	.862	.910	.830	.824	.830	.929	.936	.912	.863	.863	.858	.924	.918	.913	**trial2**	
		1.000	.815	.831	.878	.822	.811	.777	.893	.888	.898	.844	.828	.814	.890	.882	.900	**trial3**	
			1.000	.837	.898	.813	.871	.851	.856	.862	.853	.846	.845	.850	.875	.860	.850	**trial1**	**conductor02**
				1.000	.897	.785	.810	.801	.880	.887	.876	.830	.857	.847	.881	.866	.875	**trial2**	
					1.000	.861	.881	.879	.905	.921	.899	.887	.889	.868	.920	.916	.911	**trial3**	
						1.000	.899	.862	.839	.835	.839	.860	.837	.828	.857	.851	.848	**trial1**	**conductor03**
							1.000	.950	.841	.837	.855	.865	.865	.848	.886	.875	.869	**trial2**	
								1.000	.824	.838	.838	.836	.846	.825	.874	.865	.853	**trial3**	
									1.000	.967	.948	.865	.855	.863	.941	.926	.948	**trial1**	**conductor04**
										1.000	.967	.875	.864	.881	.942	.930	.952	**trial2**	
											1.000	.864	.863	.865	.935	.940	.945	**trial3**	
												1.000	.914	.918	.904	.903	.901	**trial1**	**conductor05**
													1.000	.931	.899	.889	.879	**trial2**	
														1.000	.899	.893	.880	**trial3**	
															1.000	.967	.969	**trial1**	**conductor06**
																1.000	.949	**trial2**	
																	1.000	**trial3**	

6.19 Bartok speed; mean per musical bar

Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Bartok Speed	
trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	Mean per bar	
1.000	.934	.930	.878	.897	.911	.846	.840	.853	.926	.931	.935	.884	.891	.867	.943	.939	.942	trial1	conductor01
	1.000	.929	.907	.916	.921	.870	.866	.871	.941	.946	.942	.884	.893	.874	.939	.936	.935	trial2	
		1.000	.869	.873	.890	.845	.829	.819	.897	.909	.907	.864	.870	.838	.907	.904	.919	trial3	
			1.000	.902	.937	.863	.890	.885	.913	.918	.909	.867	.879	.872	.909	.901	.900	trial1	conductor02
				1.000	.926	.826	.854	.858	.923	.926	.913	.854	.888	.861	.914	.916	.905	trial2	
					1.000	.864	.894	.896	.920	.926	.926	.891	.901	.863	.926	.927	.908	trial3	
						1.000	.910	.881	.871	.864	.879	.867	.861	.842	.873	.872	.866	trial1	conductor03
							1.000	.926	.882	.870	.892	.869	.876	.854	.897	.893	.881	trial2	
								1.000	.868	.877	.891	.851	.867	.843	.895	.895	.870	trial3	
									1.000	.969	.960	.885	.883	.880	.950	.945	.948	trial1	conductor04
										1.000	.967	.898	.899	.896	.951	.949	.952	trial2	
											1.000	.898	.910	.896	.958	.959	.960	trial3	
												1.000	.930	.913	.904	.911	.896	trial1	conductor05
													1.000	.931	.930	.893	.931	trial2	
														1.000	.887	.895	.890	trial3	
															1.000	.979	.968	trial1	conductor06
																1.000	.965	trial2	
																	1.000	trial3	

6.20 Bartok acceleration; mean per musical bar

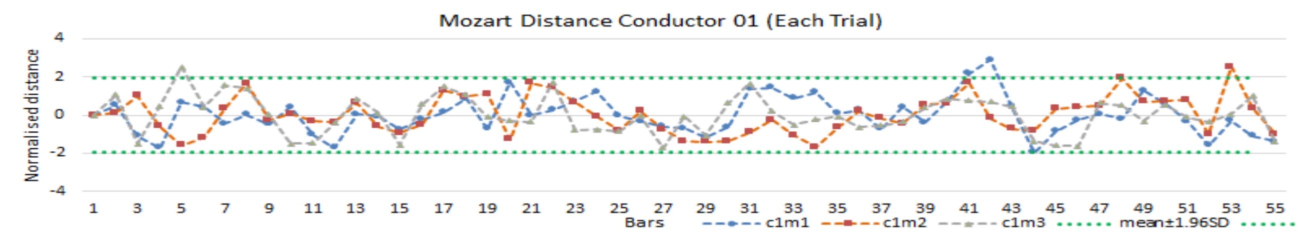
Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Bartok Acceleration	
trial 1	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**trial 1**	**trial 2**	**trial 3**	**Mean per bar**	
1.000	.946	.916	.906	.916	.933	.877	.876	.898	.940	.941	.940	.924	.910	.900	.960	.955	.954	**trial1**	**conductor01**
	1.000	.932	.915	.927	.851	.894	.885	.892	.943	.935	.941	.900	.898	.884	.939	.940	.932	**trial2**	
		1.000	.873	.880	.883	.858	.816	.829	.893	.894	.895	.855	.862	.833	.900	.896	.897	**trial3**	
			1.000	.903	.933	.868	.883	.895	.912	.920	.915	.882	.898	.891	.909	.904	.905	**trial1**	**conductor02**
				1.000	.921	.876	.865	.876	.921	.920	.918	.881	.892	.876	.920	.920	.904	**trial2**	
					1.000	.881	.895	.912	.930	.925	.927	.911	.912	.888	.935	.931	.916	**trial3**	
						1.000	.895	.886	.890	.870	.895	.872	.863	.842	.888	.875	.877	**trial1**	**conductor03**
							1.000	.926	.889	.876	.906	.875	.875	.863	.905	.882	.886	**trial2**	
								1.000	.894	.884	.912	.888	.892	.869	.908	.905	.883	**trial3**	
									1.000	.959	.952	.901	.894	.886	.934	.930	.926	**trial1**	**conductor04**
										1.000	.944	.912	.905	.904	.938	.936	.930	**trial2**	
											1.000	.917	.924	.906	.950	.943	.935	**trial3**	
												1.000	.955	.943	.932	.940	.937	**trial1**	**conductor05**
													1.000	.950	.912	.923	.917	**trial2**	
														1.000	.905	.914	.915	**trial3**	
															1.000	.967	.961	**trial1**	**conductor06**
																1.000	.967	**trial2**	
																	1.000	**trial3**	

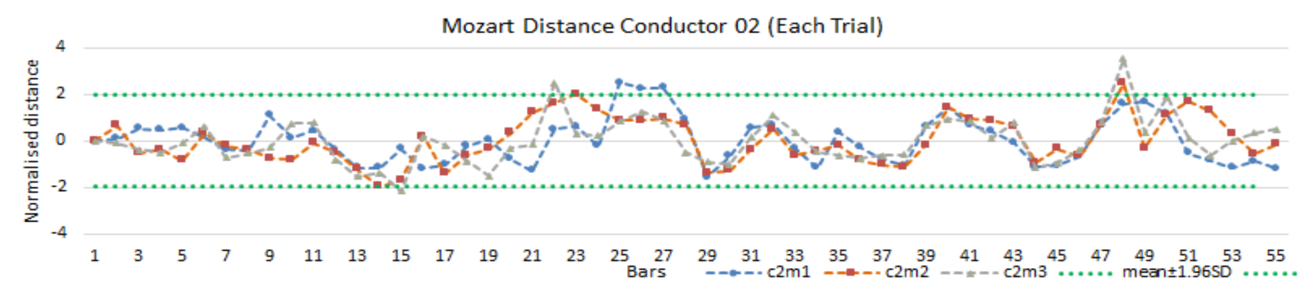
6.21 Bartok jerk; mean per musical bar

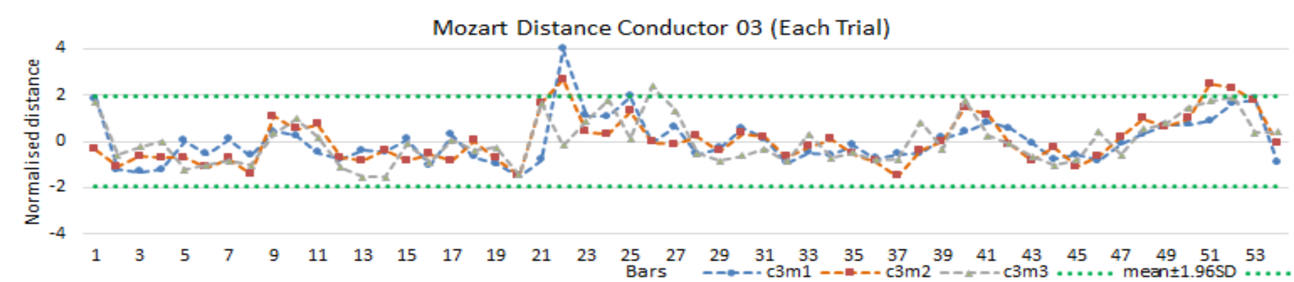
Codnuctor01			Conductor02			Conductor03			Conductor04			Conductor05			Conductor06			Bartok Jerk	
trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	trial 1	trial 2	trial 3	Mean per bar	
1.000	.939	.915	.891	.906	.923	.871	.854	.906	.929	.915	.924	.921	.907	.900	.945	.944	.941	**trial1**	**conductor01**
	1.000	.931	.896	.916	.917	.877	.863	.892	.936	.914	.931	.900	.900	.896	.924	.930	.928	**trial2**	
		1.000	.864	.877	.892	.855	.810	.850	.899	.894	.899	.854	.867	.854	.905	.905	.900	**trial3**	
			1.000	.882	.910	.849	.847	.875	.882	.883	.893	.884	.893	.891	.894	.892	.891	**trial1**	**conductor02**
				1.000	.916	.875	.850	.884	.899	.880	.906	.876	.891	.883	.906	.907	.899	**trial2**	
					1.000	.884	.872	.911	.917	.909	.915	.916	.921	.900	.930	.928	.923	**trial3**	
						1.000	.874	.880	.882	.855	.883	.851	.860	.841	.884	.870	.878	**trial1**	**conductor03**
							1.000	.897	.864	.841	.890	.852	.858	.855	.886	.860	.880	**trial2**	
								1.000	.887	.859	.910	.890	.900	.878	.908	.899	.893	**trial3**	
									1.000	.936	.943	.889	.891	.887	.918	.906	.907	**trial1**	**conductor04**
										1.000	.912	.892	.894	.897	.918	.916	.906	**trial2**	
											1.000	.906	.914	.906	.936	.920	.919	**trial3**	
												1.000	.956	.947	.923	.933	.940	**trial1**	**conductor05**
													1.000	.954	.913	.922	.928	**trial2**	
														1.000	.913	.916	.925	**trial3**	
															1.000	.956	.954	**trial1**	**conductor06**
																1.000	.958	**trial2**	
																	1.000	**trial3**	

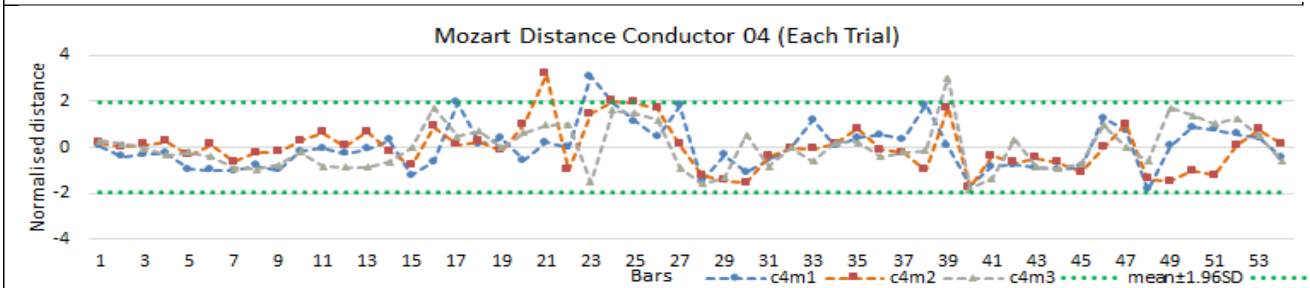
Appendix 7: Full results of Deviation Point Analyses for 54 trials

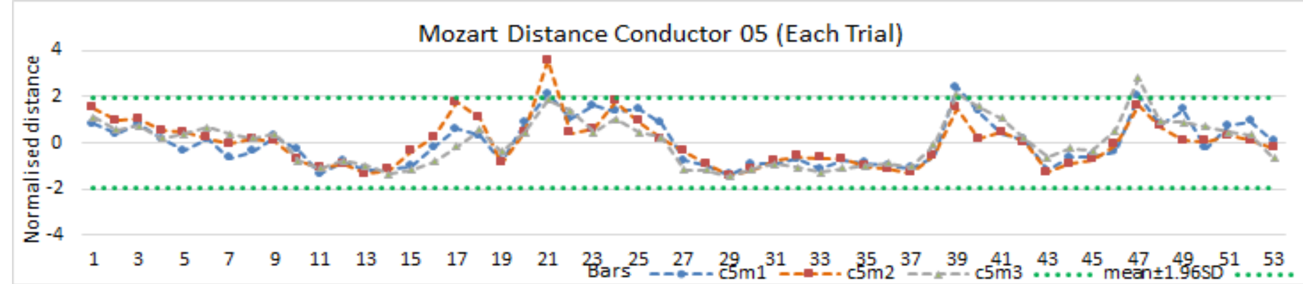
Mozart Distance

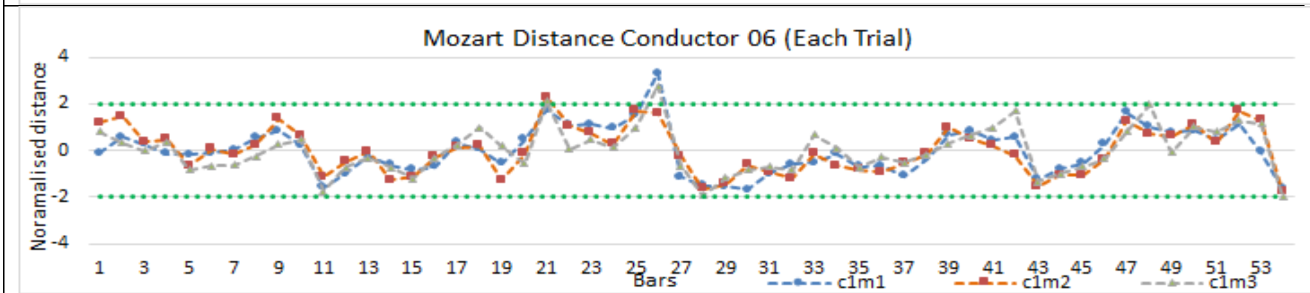




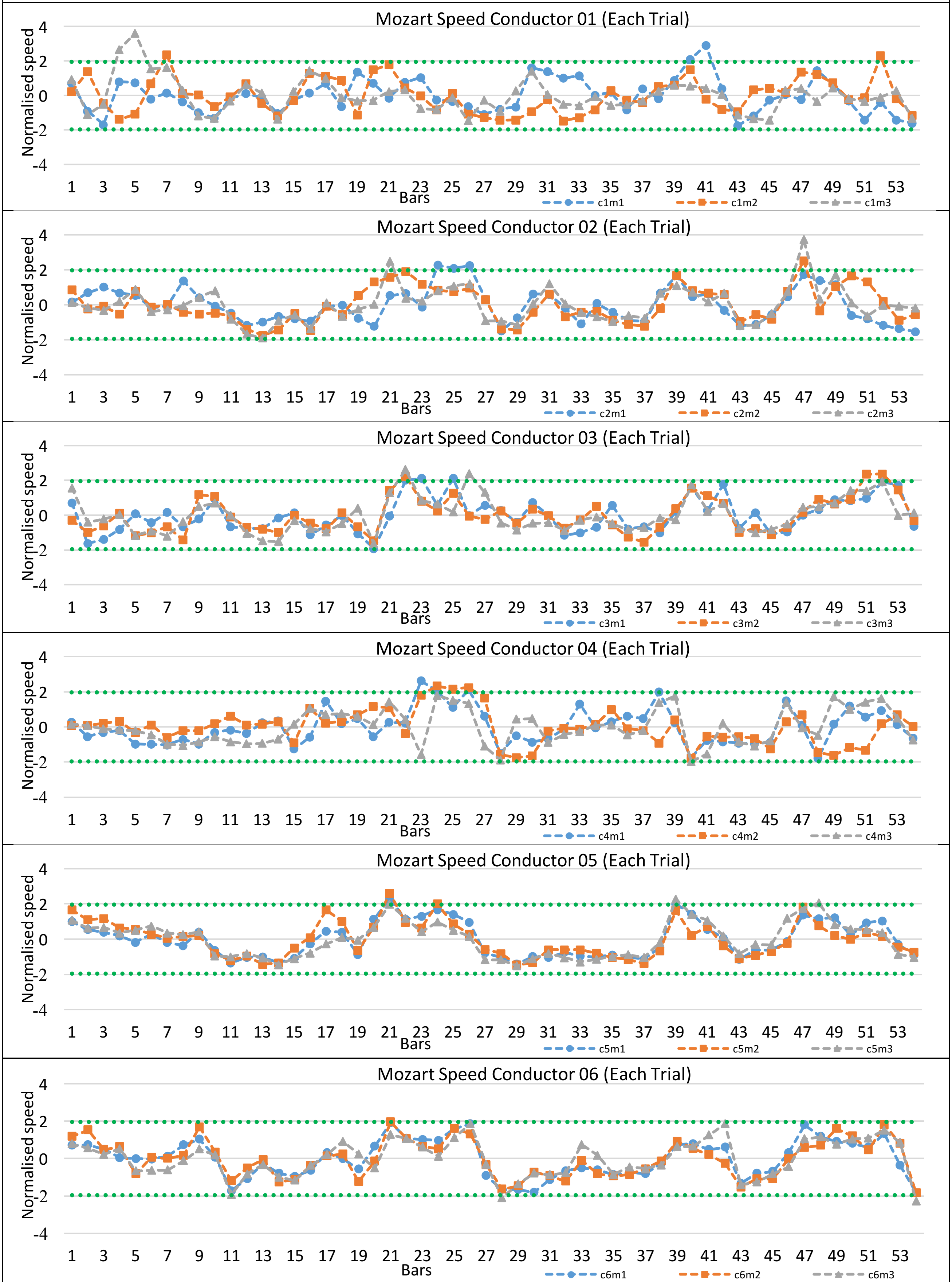




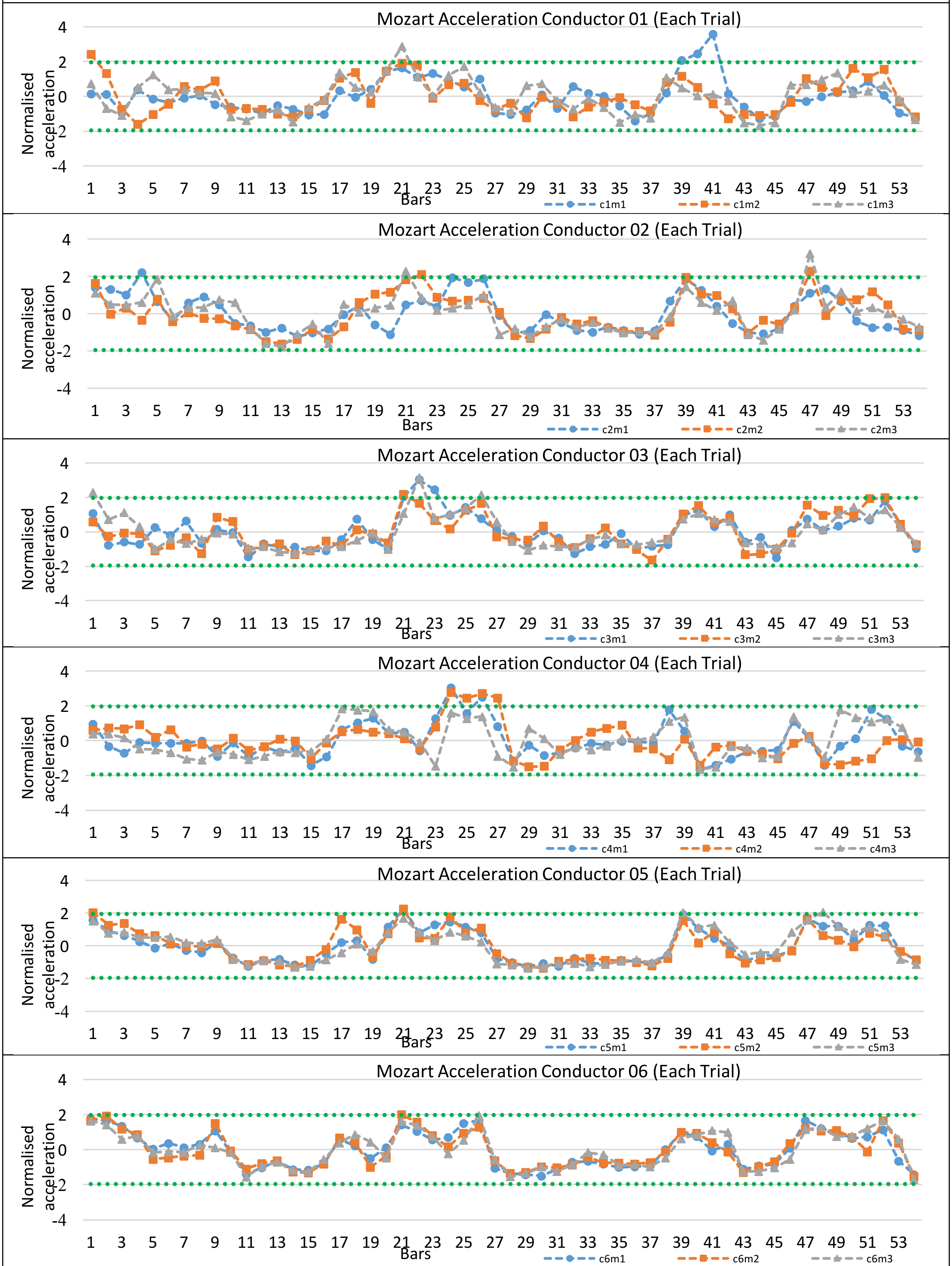




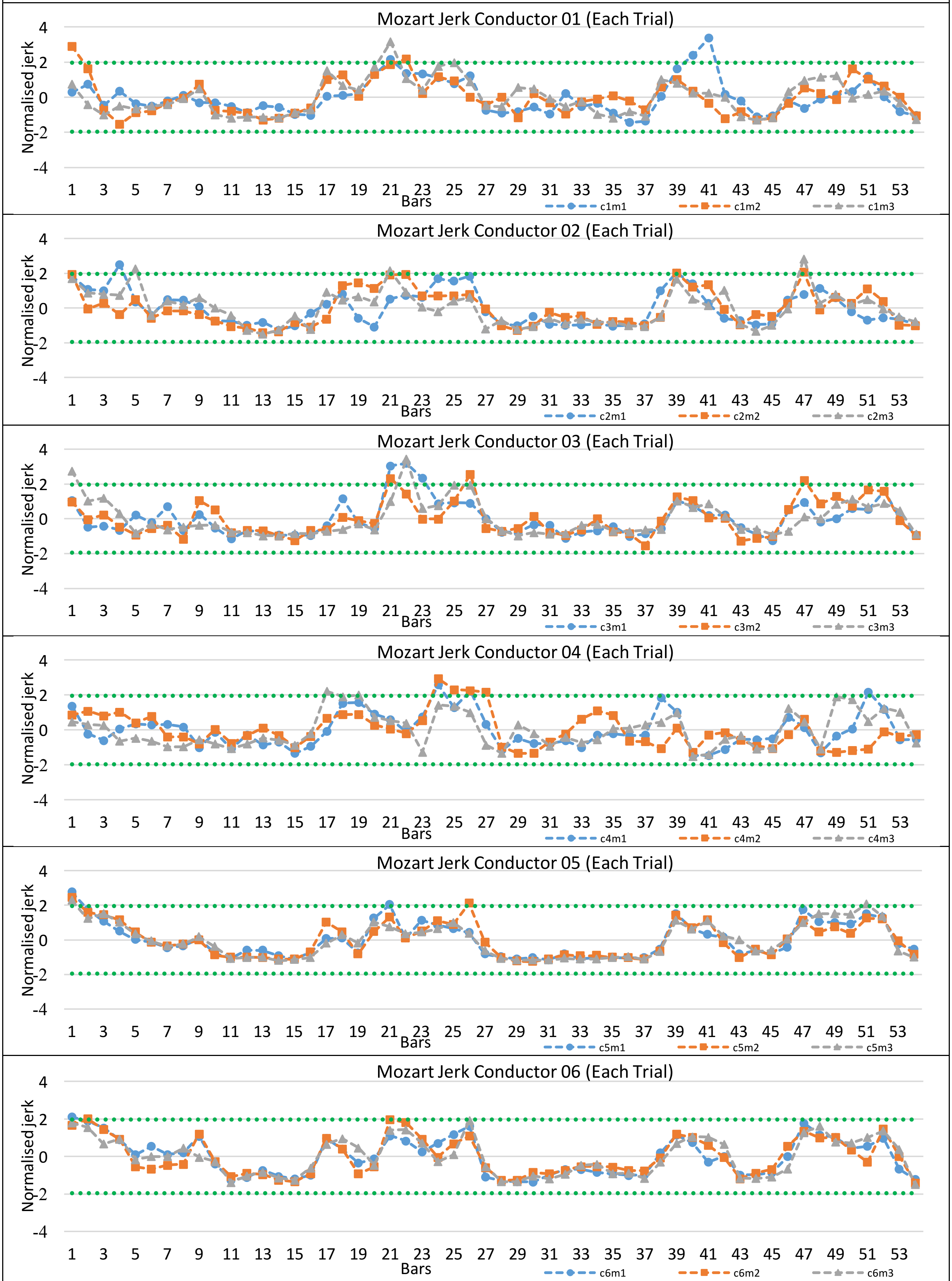
Mozart Speed



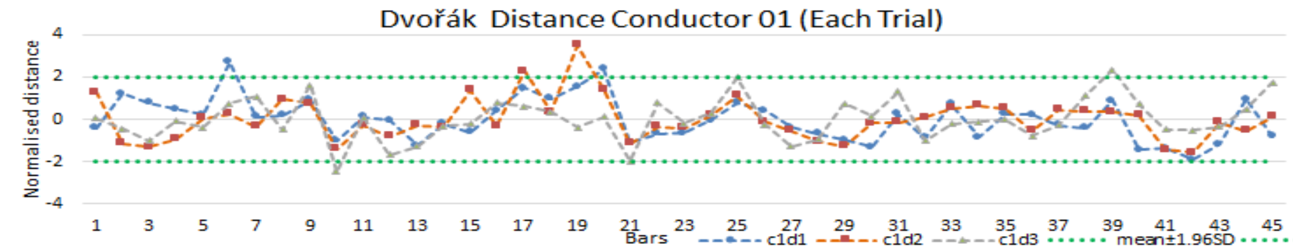
Mozart Acceleration

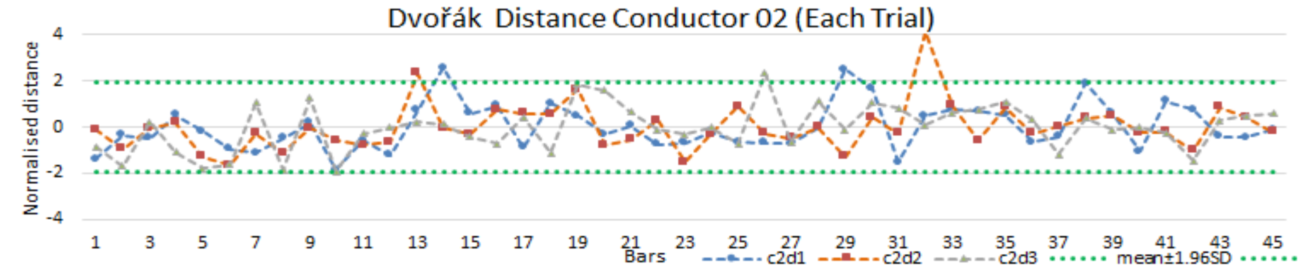


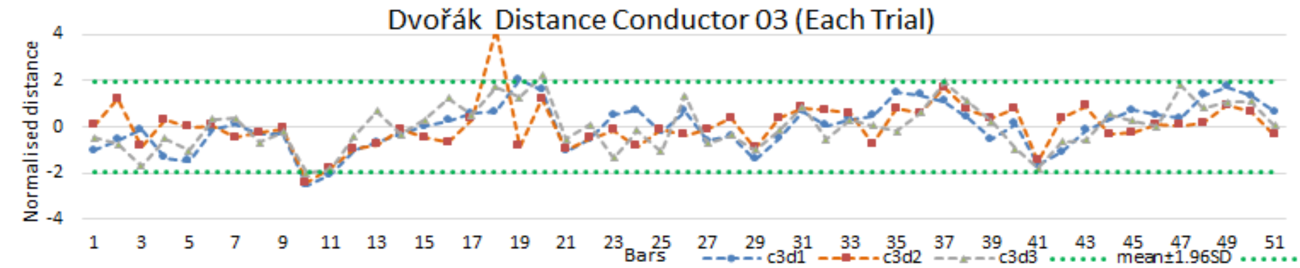
Mozart Jerk

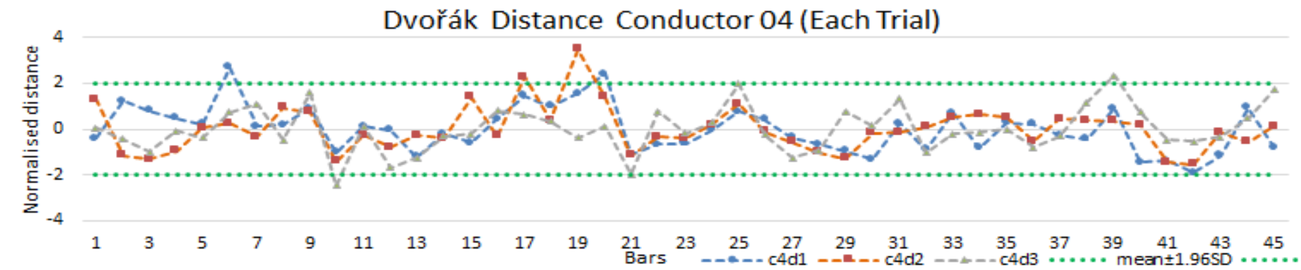

Mozart Jerk Conductor 01 (Each Trial)
Normalised jerk
Bars
c1m1
c1m2
c1m3
Mozart Jerk Conductor 02 (Each Trial)
c2m1
c2m2
c2m3
Mozart Jerk Conductor 03 (Each Trial)
c3m1
c3m2
c3m3
Mozart Jerk Conductor 04 (Each Trial)
c4m1
c4m2
c4m3
Mozart Jerk Conductor 05 (Each Trial)
c5m1
c5m2
c5m3
Mozart Jerk Conductor 06 (Each Trial)
c6m1
c6m2
c6m3

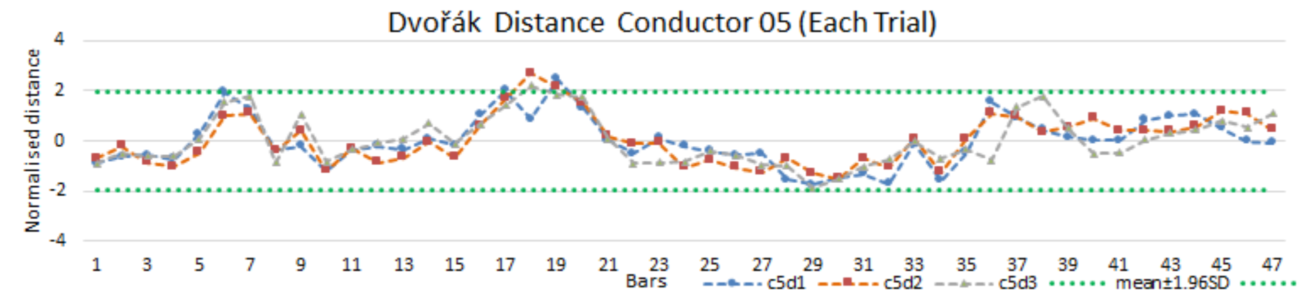
Dvořák Distance

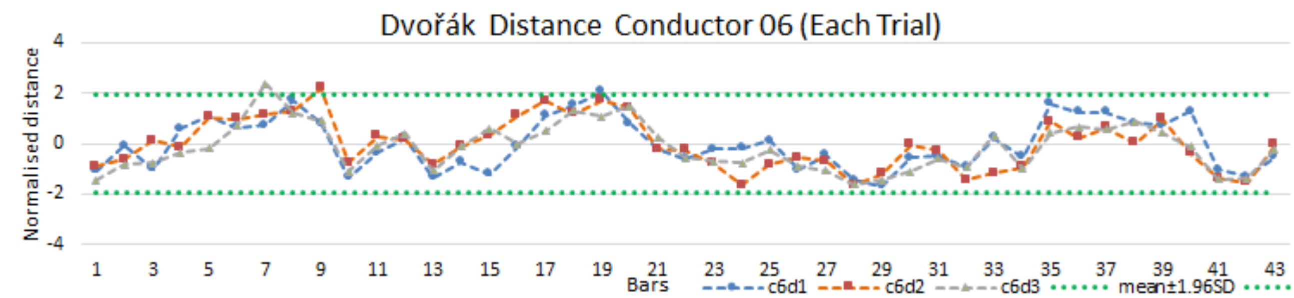




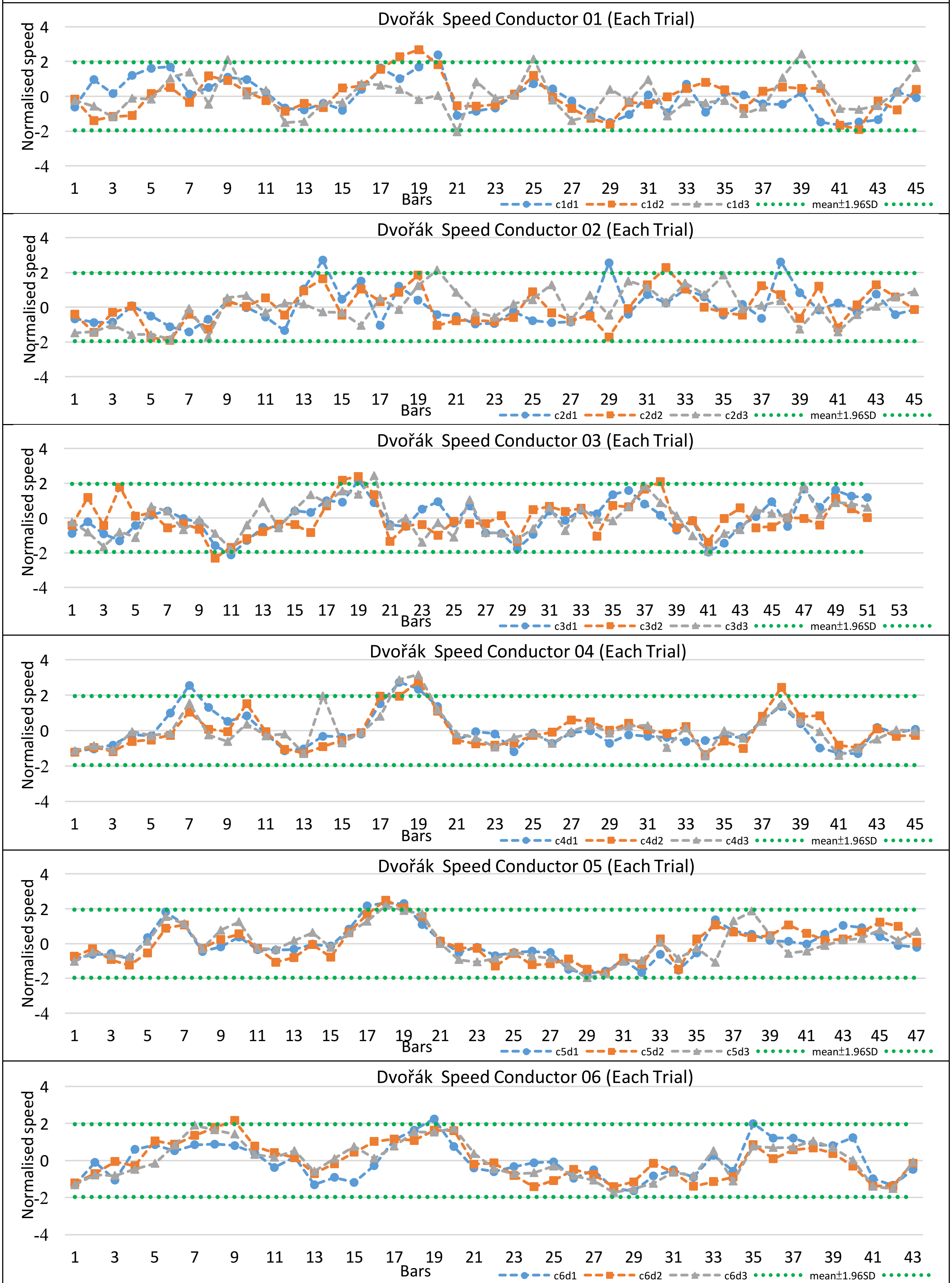




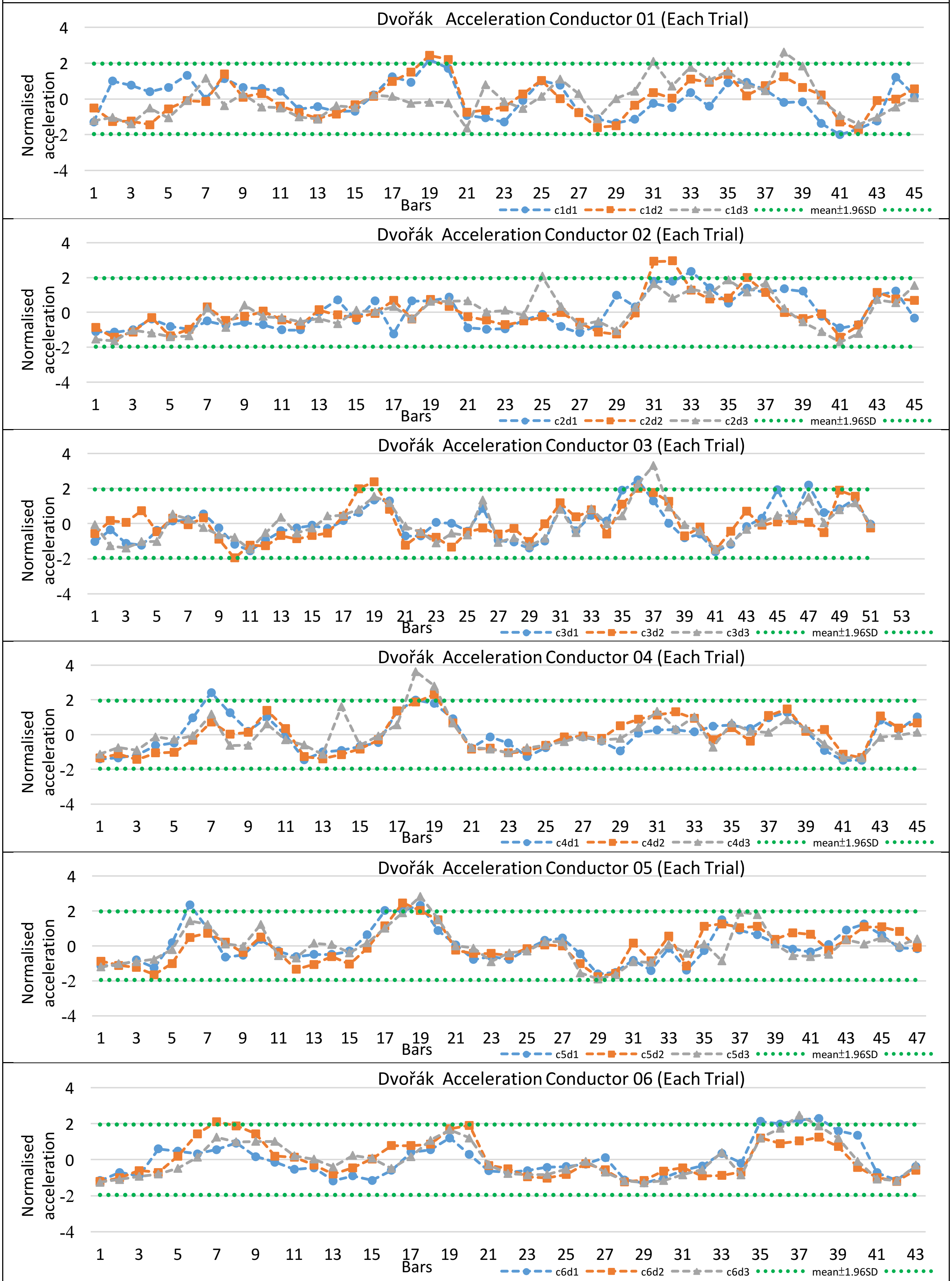


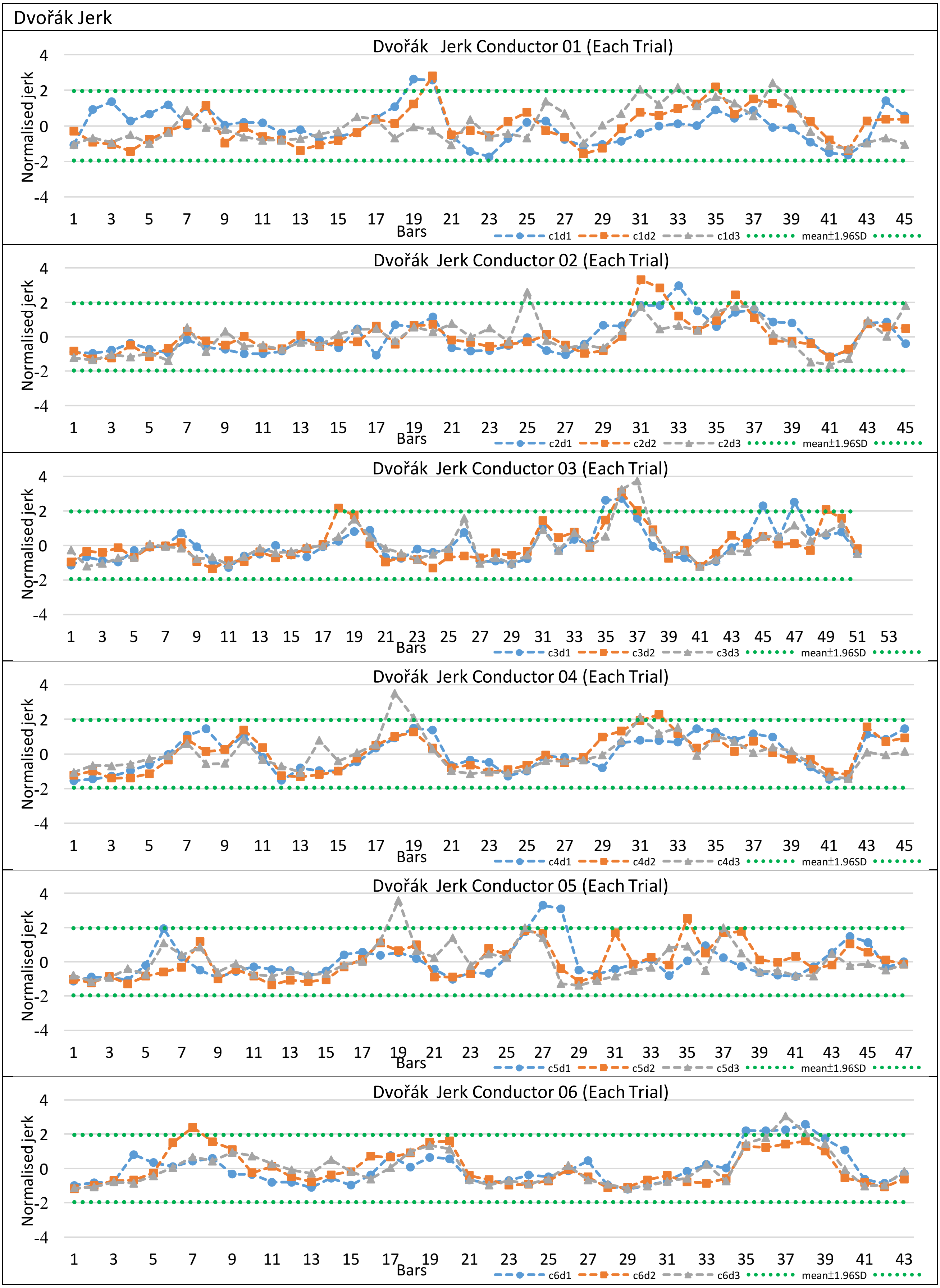


Dvořák Speed

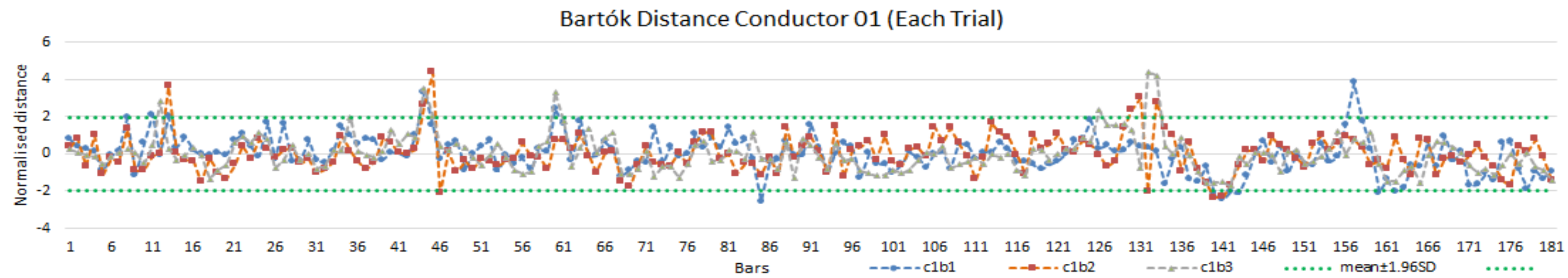


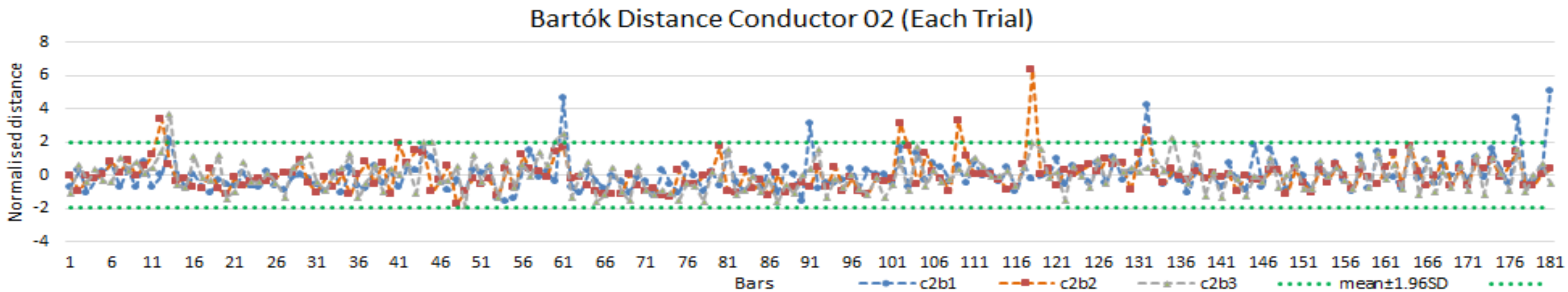
Dvořák Acceleration

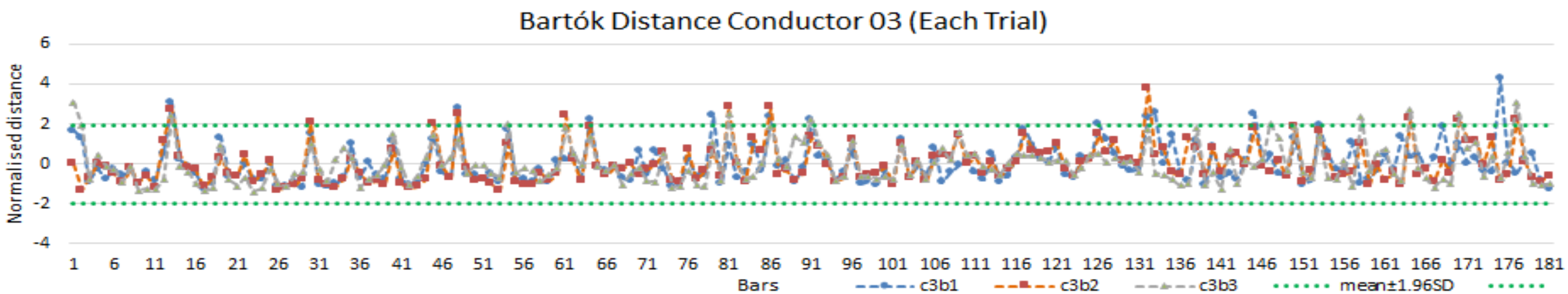


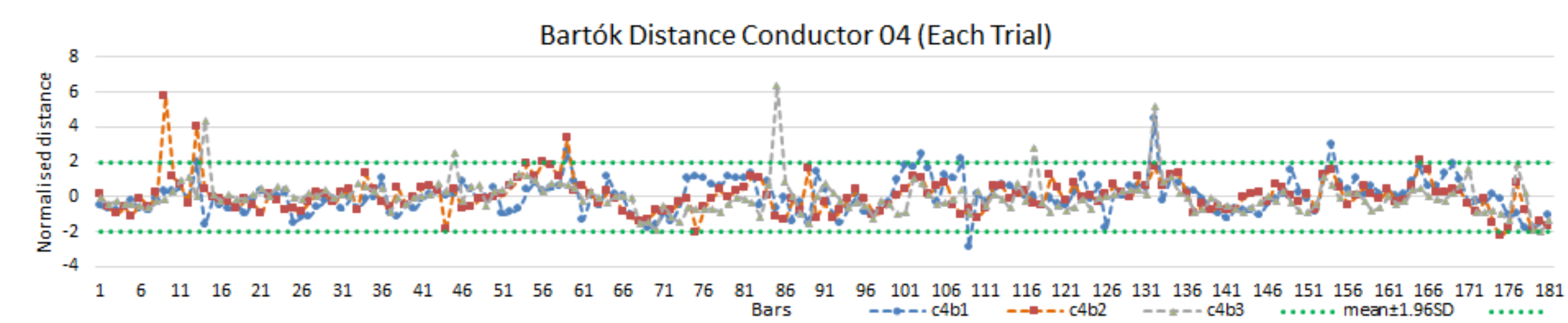

Dvořák Jerk
Dvořák Jerk Conductor 01 (Each Trial)
Normalised jerk
Bars
c1d1
c1d2
c1d3
mean±1.96SD
Dvořák Jerk Conductor 02 (Each Trial)
Normalised jerk
Bars
c2d1
c2d2
c2d3
mean±1.96SD
Dvořák Jerk Conductor 03 (Each Trial)
Normalised jerk
Bars
c3d1
c3d2
c3d3
mean±1.96SD
Dvořák Jerk Conductor 04 (Each Trial)
Normalised jerk
Bars
c4d1
c4d2
c4d3
mean±1.96SD
Dvořák Jerk Conductor 05 (Each Trial)
Normalised jerk
Bars
c5d1
c5d2
c5d3
mean±1.96SD
Dvořák Jerk Conductor 06 (Each Trial)
Normalised jerk
Bars
c6d1
c6d2
c6d3
mean±1.96SD

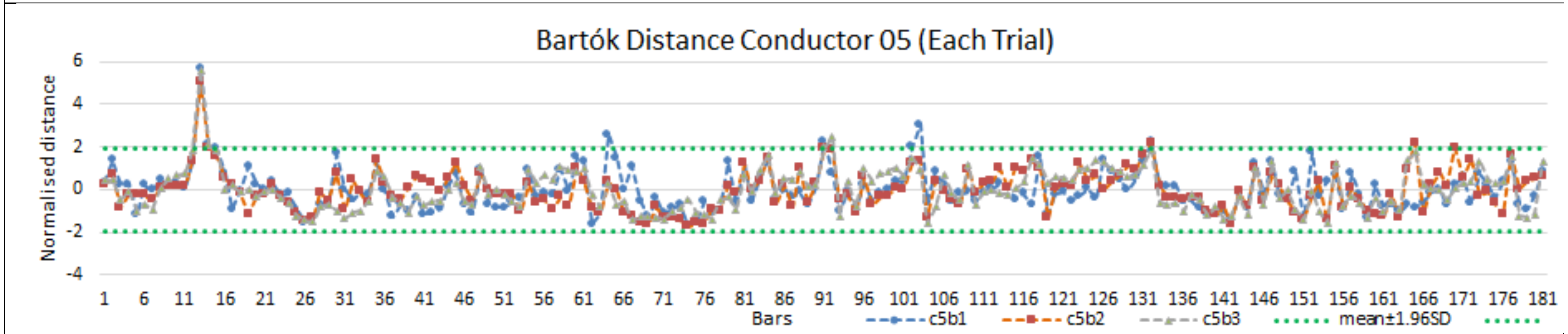
Bartók Distance

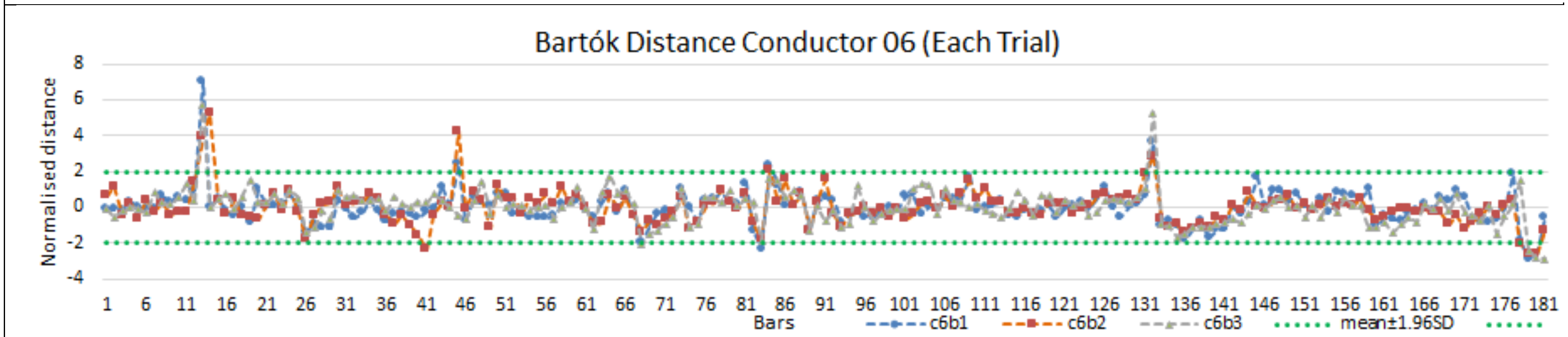


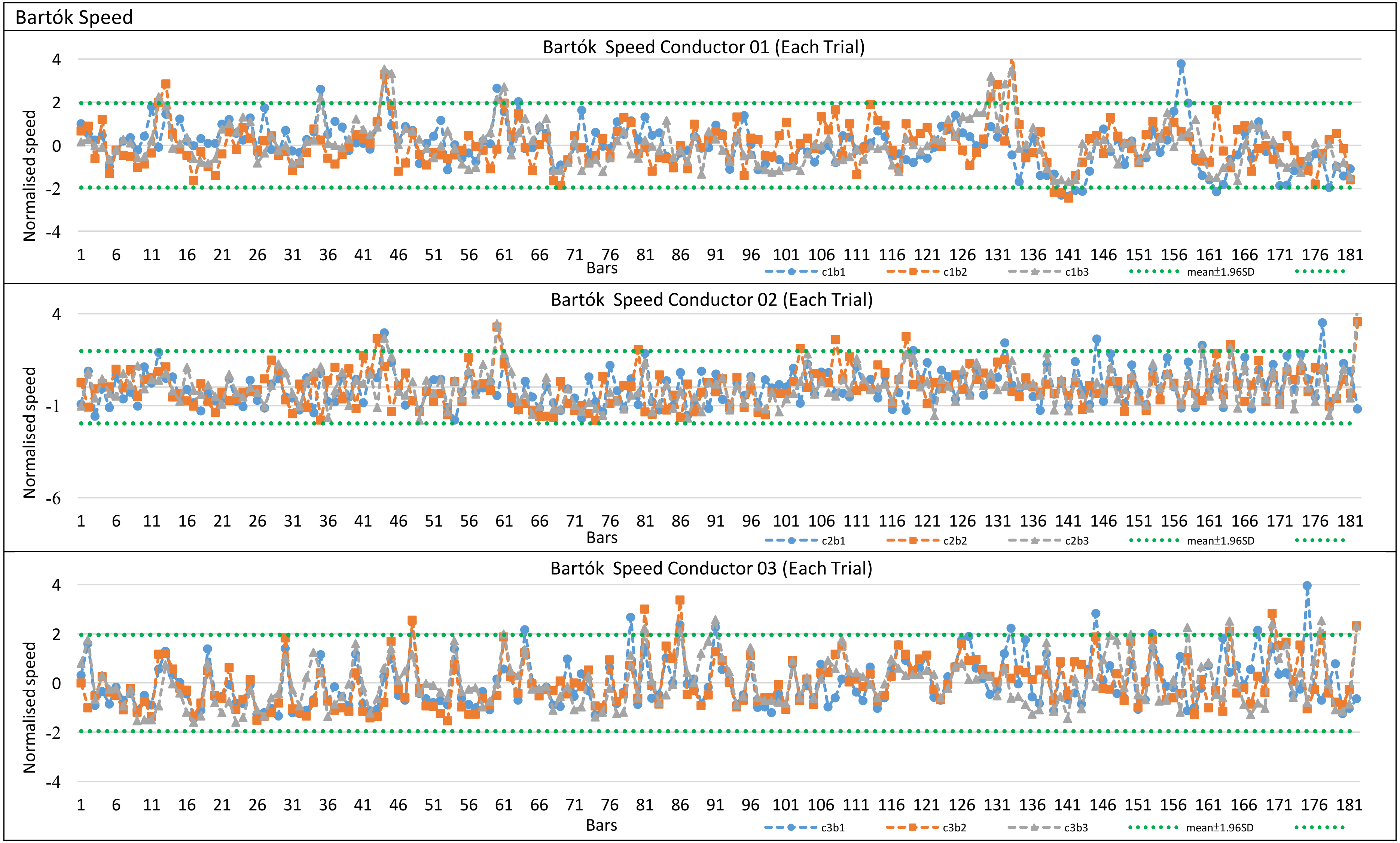


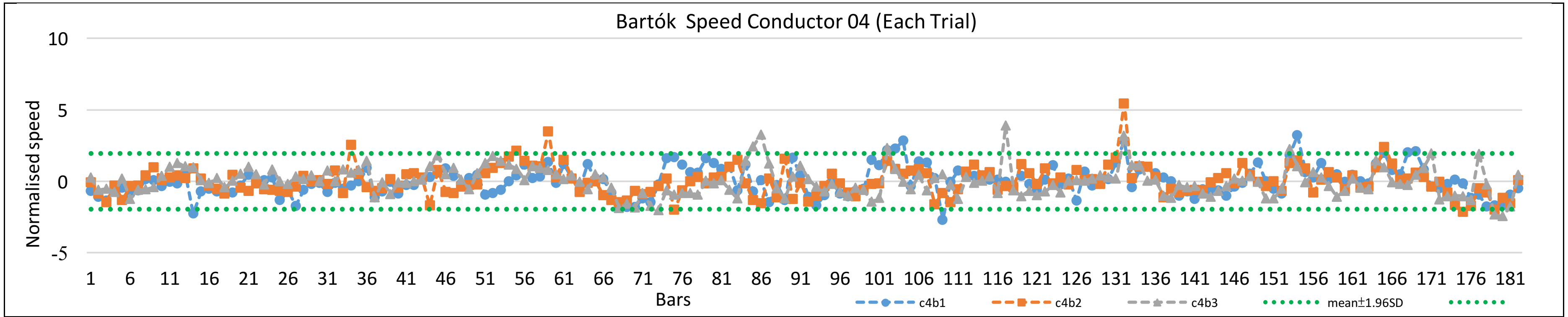


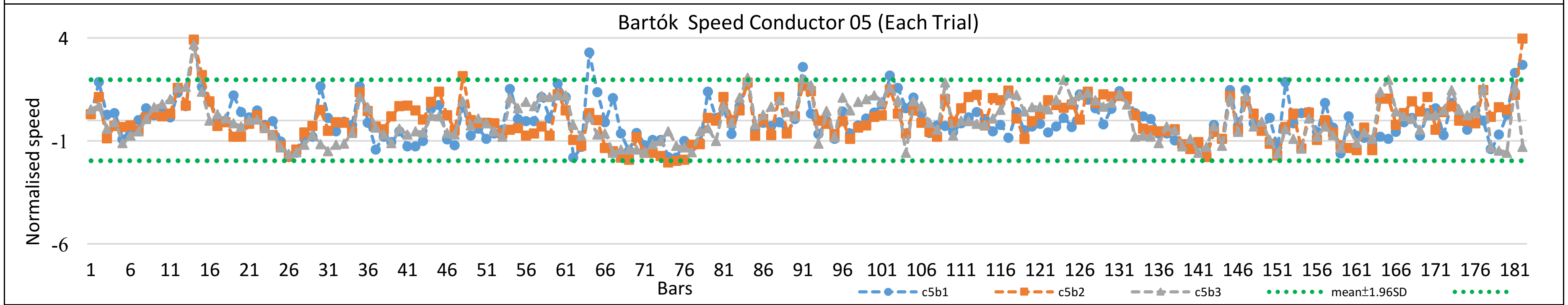

Bartók Distance Conductor 04 (Each Trial)
Normalised distance
8
6
4
2
0
-2
-4
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141 146 151 156 161 166 171 176 181
Bars
c4b1
c4b2
c4b3
mean±1.96SD

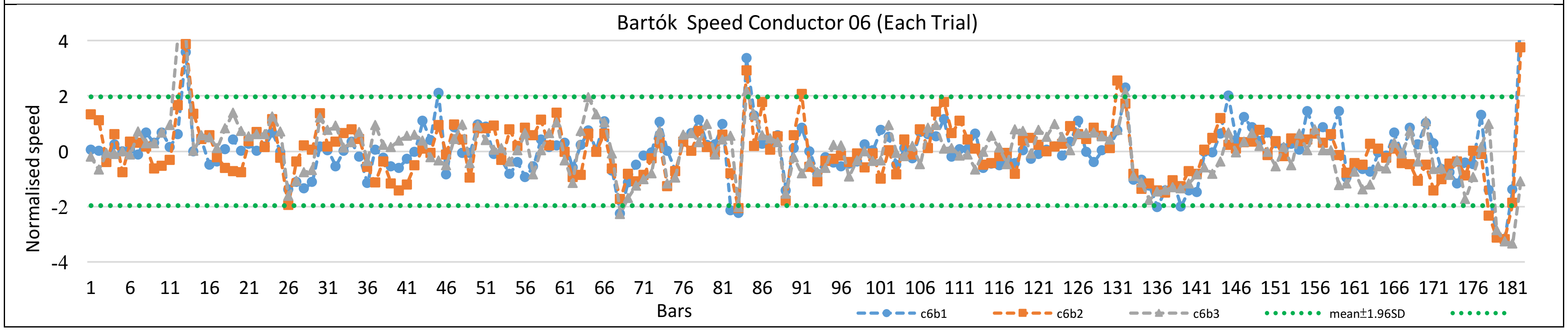

Bartók Distance Conductor 05 (Each Trial)
Normalised distance
6
4
2
0
-2
-4
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141 146 151 156 161 166 171 176 181
Bars
c5b1
c5b2
c5b3
mean±1.96SD


Bartók Distance Conductor 06 (Each Trial)
Normalised distance
8
6
4
2
0
-2
-4
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141 146 151 156 161 166 171 176 181
Bars
c6b1
c6b2
c6b3
mean±1.96SD

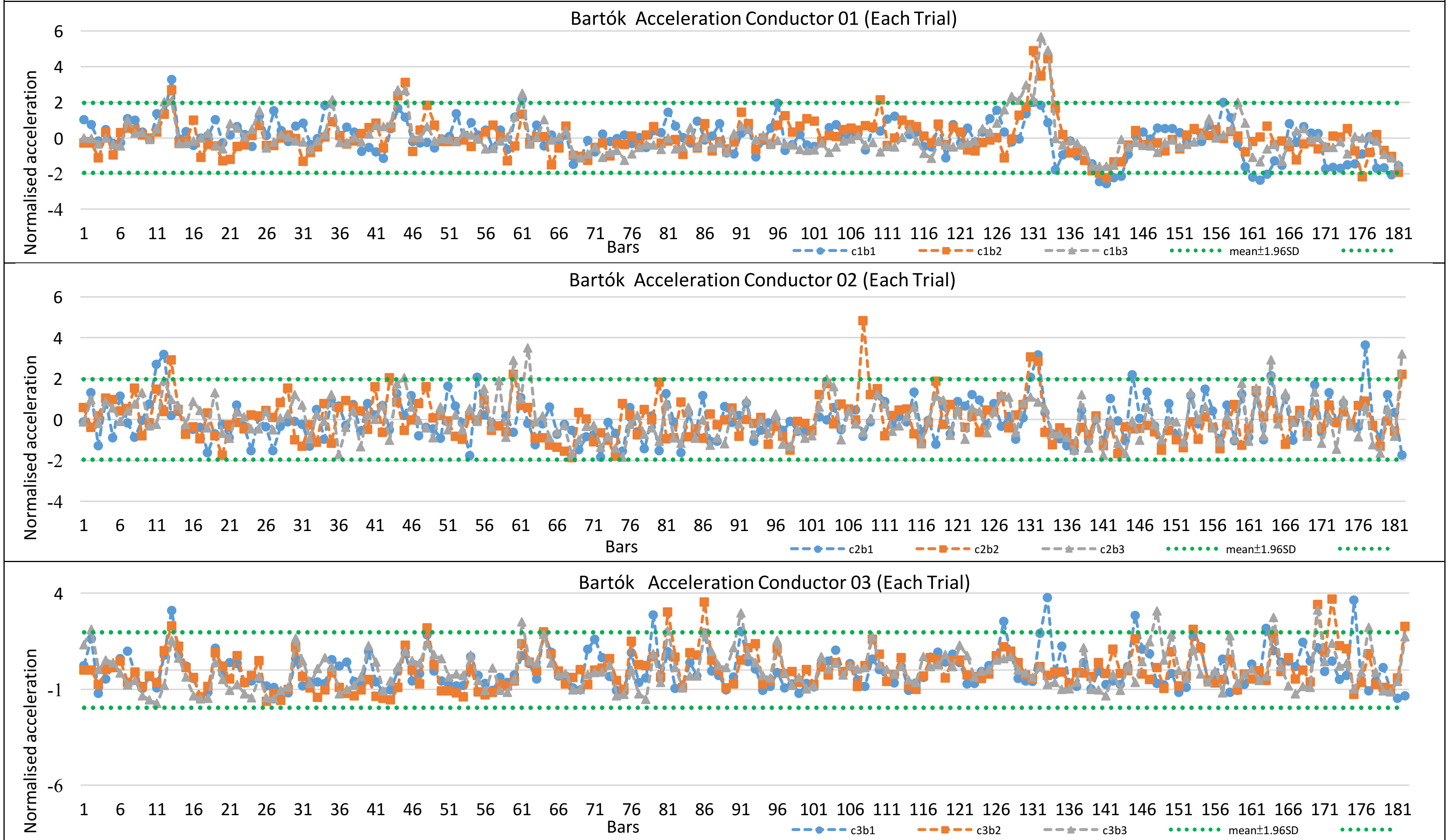

Bartók Speed
Bartók Speed Conductor 01 (Each Trial)
Normalised speed
4
2
0
-2
-4
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141 146 151 156 161 166 171 176 181
Bars
c1b1
c1b2
c1b3
mean±1.96SD
Bartók Speed Conductor 02 (Each Trial)
Normalised speed
4
-1
-6
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141 146 151 156 161 166 171 176 181
Bars
c2b1
c2b2
c2b3
mean±1.96SD
Bartók Speed Conductor 03 (Each Trial)
Normalised speed
4
2
0
-2
-4
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141 146 151 156 161 166 171 176 181
Bars
c3b1
c3b2
c3b3
mean±1.96SD

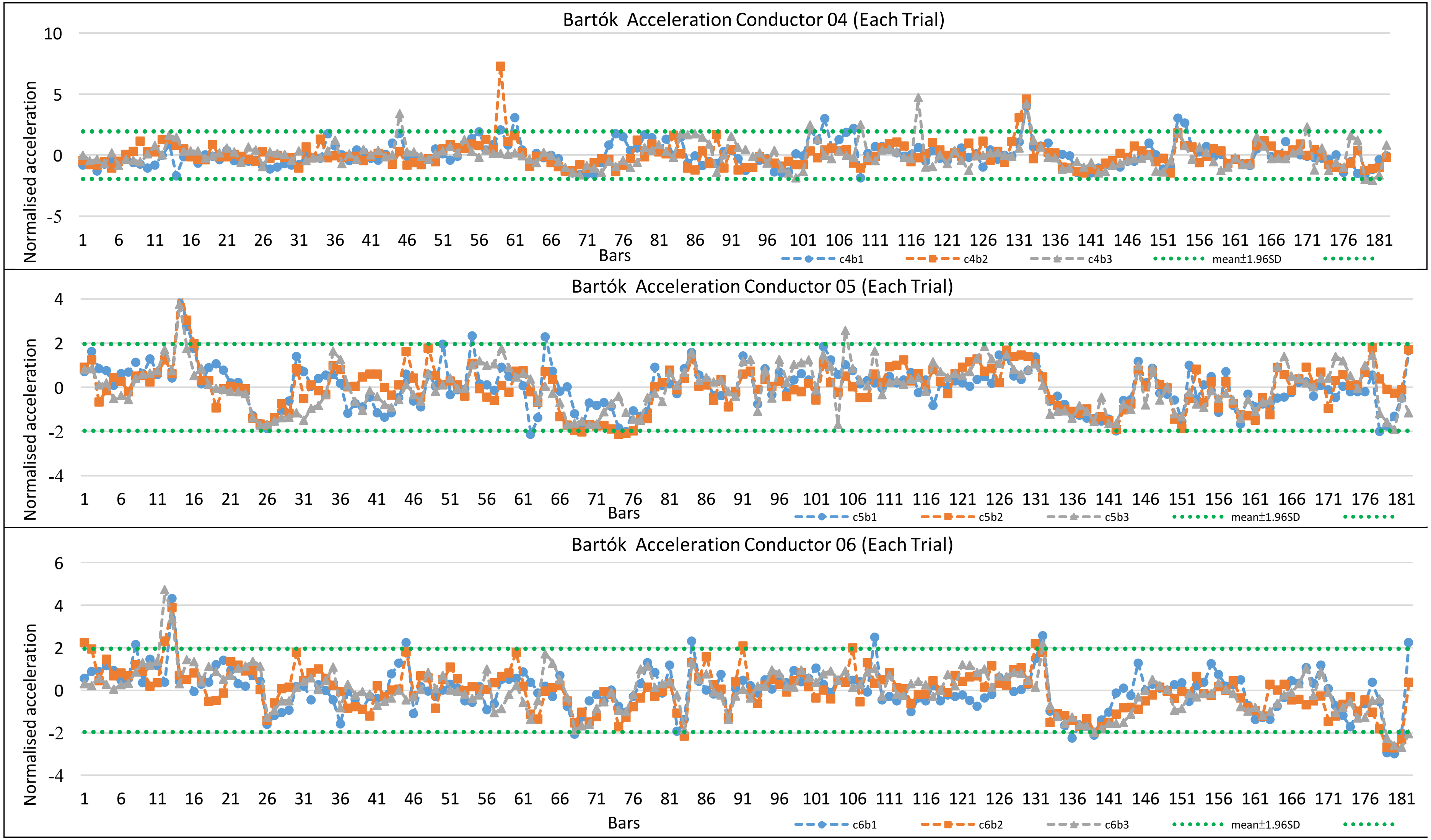

Bartók Speed Conductor 04 (Each Trial)
Normalised speed
Bars
c4b1
c4b2
c4b3
mean±1.96SD

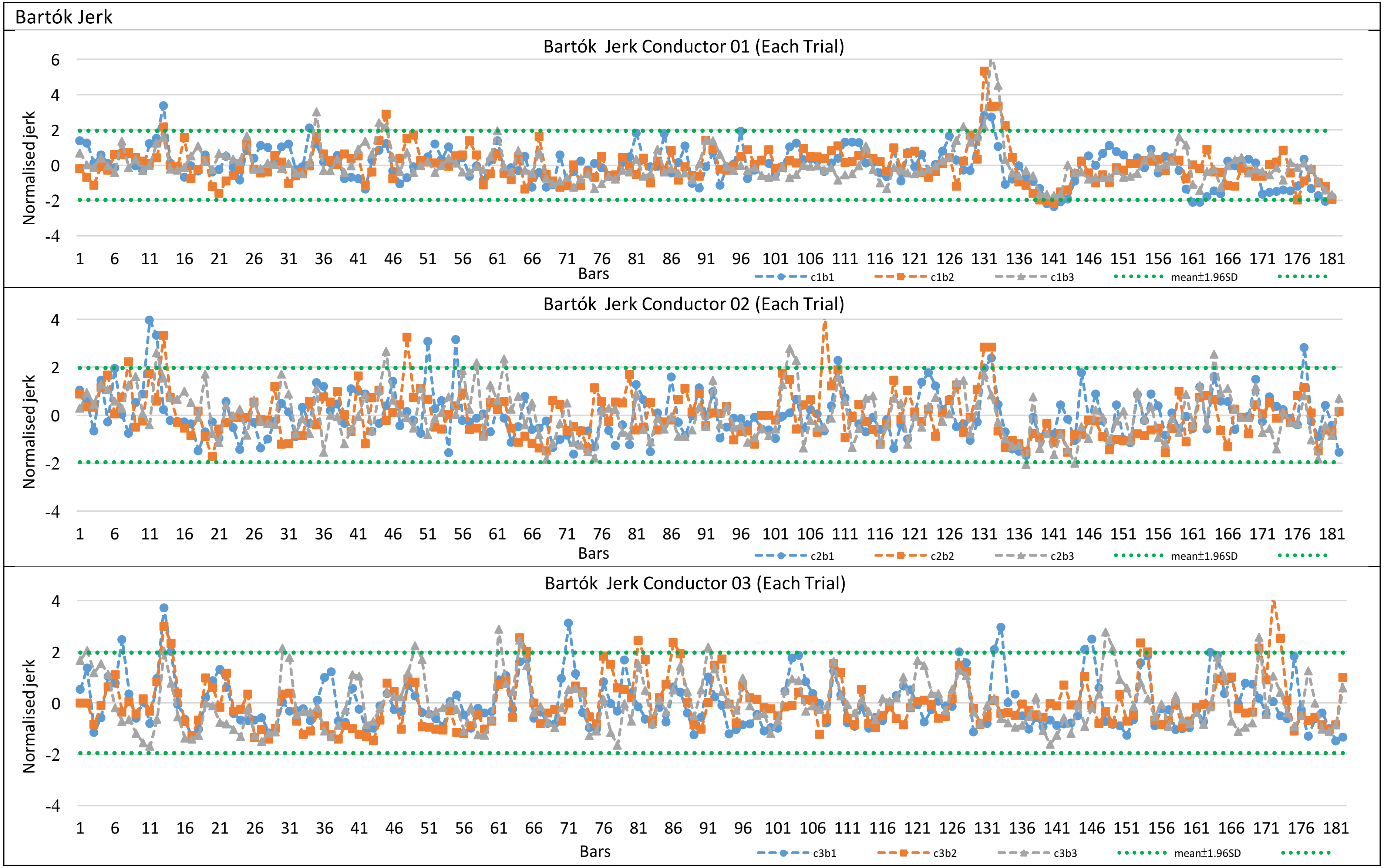

Bartók Speed Conductor 05 (Each Trial)
Normalised speed
Bars
c5b1
c5b2
c5b3
mean±1.96SD

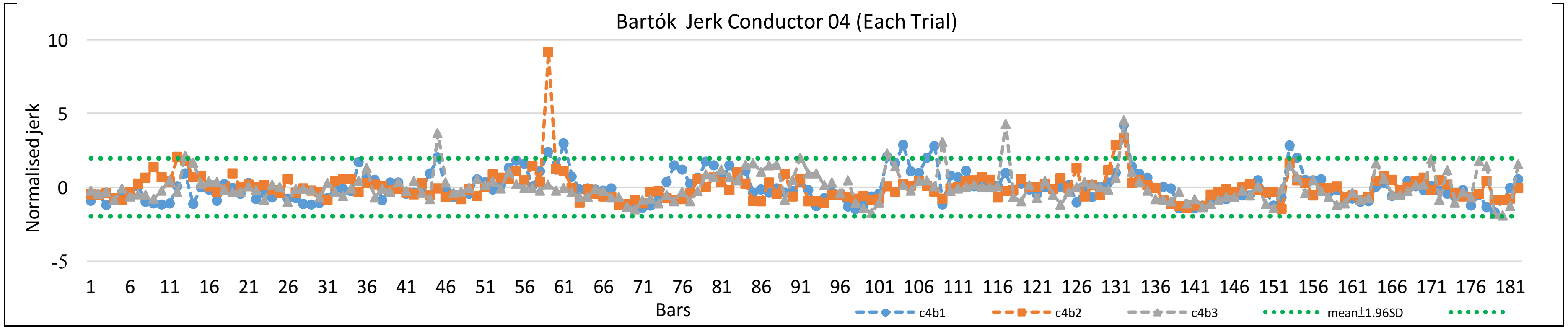

Bartók Speed Conductor 06 (Each Trial)
Normalised speed
Bars
c6b1
c6b2
c6b3
mean±1.96SD

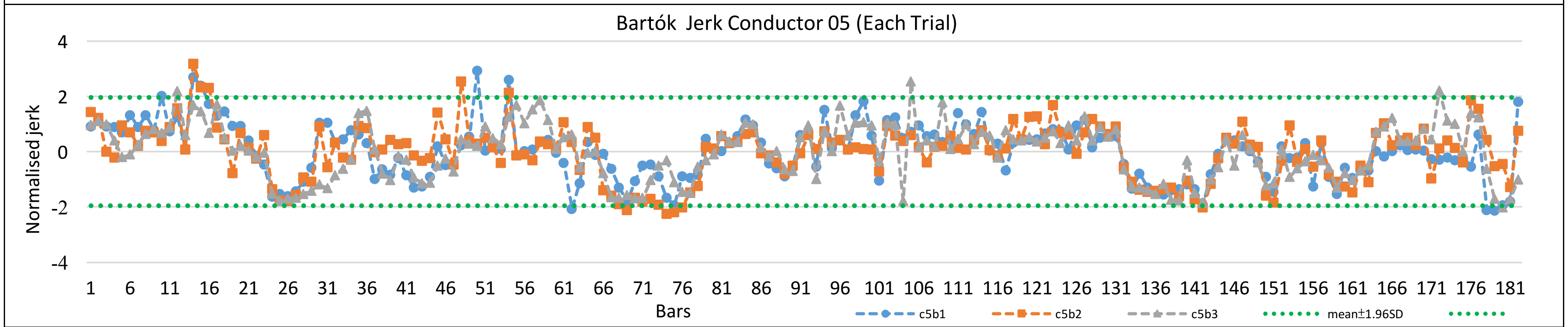
Bartók Acceleration

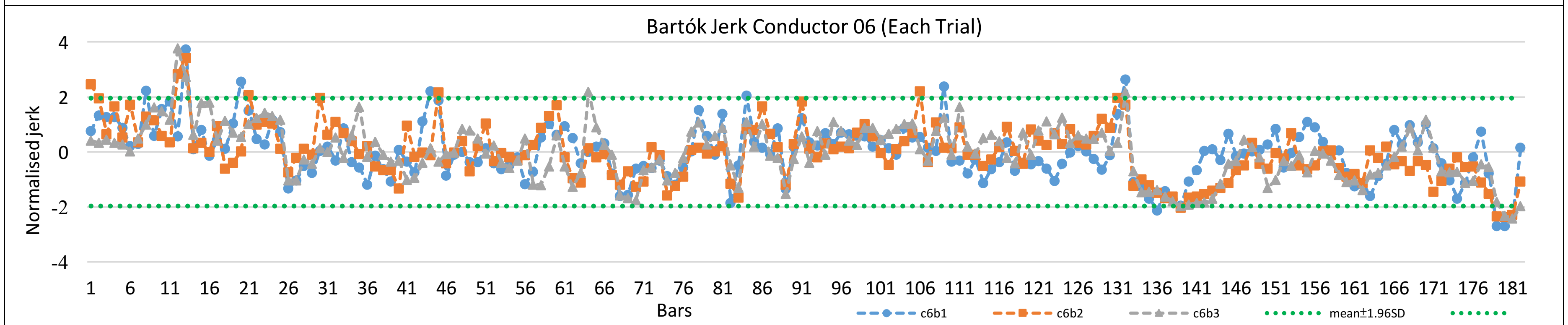



Bartók Acceleration Conductor 04 (Each Trial)
Normalised acceleration
10
5
0
-5
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141 146 151 156 161 166 171 176 181
Bars
c4b1
c4b2
c4b3
mean±1.96SD
Bartók Acceleration Conductor 05 (Each Trial)
Normalised acceleration
4
2
0
-2
-4
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141 146 151 156 161 166 171 176 181
Bars
c5b1
c5b2
c5b3
mean±1.96SD
Bartók Acceleration Conductor 06 (Each Trial)
Normalised acceleration
6
4
2
0
-2
-4
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141 146 151 156 161 166 171 176 181
Bars
c6b1
c6b2
c6b3
mean±1.96SD


Bartók Jerk
Bartók Jerk Conductor 01 (Each Trial)
Normalised jerk
6
4
2
0
-2
-4
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141 146 151 156 161 166 171 176 181
Bars
c1b1
c1b2
c1b3
mean±1.96SD
Bartók Jerk Conductor 02 (Each Trial)
Normalised jerk
4
2
0
-2
-4
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141 146 151 156 161 166 171 176 181
Bars
c2b1
c2b2
c2b3
mean±1.96SD
Bartók Jerk Conductor 03 (Each Trial)
Normalised jerk
4
2
0
-2
-4
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141 146 151 156 161 166 171 176 181
Bars
c3b1
c3b2
c3b3
mean±1.96SD


Bartók Jerk Conductor 04 (Each Trial)
Normalised jerk
Bars
c4b1
c4b2
c4b3
mean±1.96SD


Bartók Jerk Conductor 05 (Each Trial)
Normalised jerk
Bars
c5b1
c5b2
c5b3
mean±1.96SD


Bartók Jerk Conductor 06 (Each Trial)
Normalised jerk
Bars
c6b1
c6b2
c6b3
mean±1.96SD

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