A Method for the Measurement of the Latency Tolerance Range of Western Musicians

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Volume II of II: Appendix

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Appendix A

Metronome Environment

This appendix describes the patch used for the visual metronome of the listening experiment. The patch was designed using the software MAX/MSP.

In the DAW Cubase, the different velocities were selected to obtain the measure 4/4 with one beat and three bars. Figure A.1 is a diagram of the patch in MAX/MSP. The patch works parallel to the DAW metronome and every change in the DAW relating to BPMs is translated into the visual metronome.

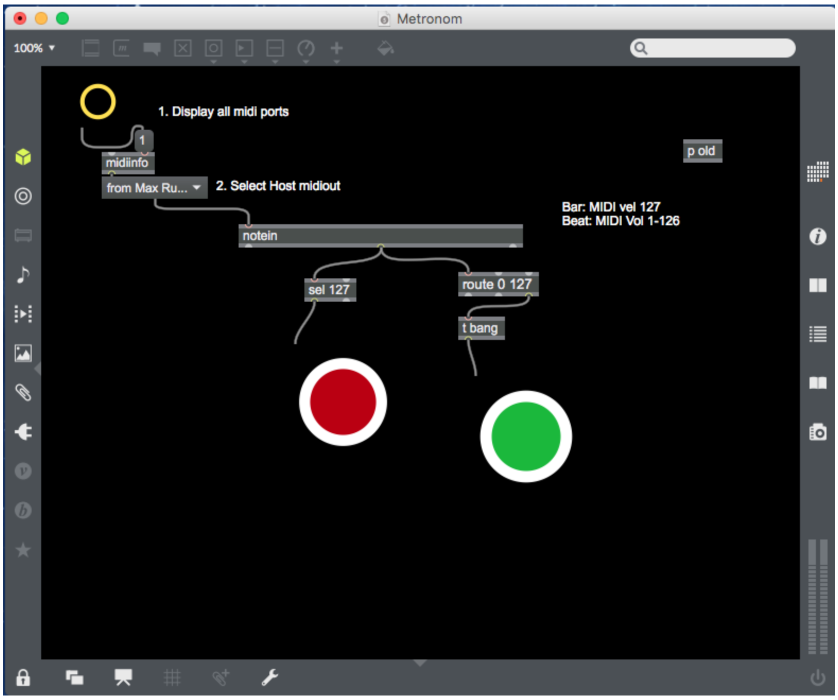
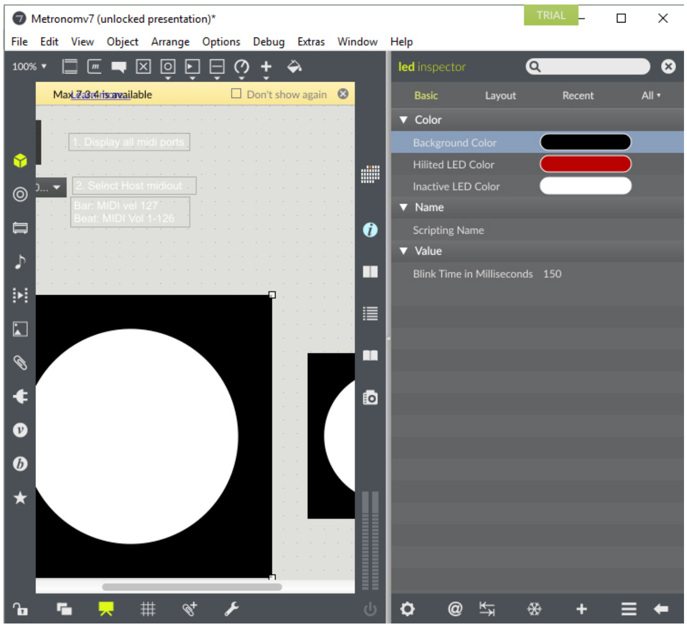


Figure A.1: Metronome patch structure in MAX/MSP

The patch searches all available MIDI ports in the computer. The command line "midi-info" activates the chosen MIDI output from the DAW (Cubase) and sends it to the patch as input. This information is gathered through the command "notein" to produce the beats and bars. For the 4/4 measure of the metronome one beat and three bars were defined. A beat was predefined with a velocity of 127 (MIDI velocity). For the remaining three bars, any velocity between 1 and 126 is a bar. In the Figure 4.9 velocity for bars and beats is defined by the slides (upper right corner). The upper slide, Hi (beats) defines the value 127 and the lower slide, Lo (bars), has a value between 1 and 126.

Figure A.2 shows the additional parameters of the metronome. The metronome blink time for each bar and each beat in the experiment is 150ms. In addition, other metronome settings such as bar and beat colour (active and inactive), background colour and descriptions are also defined here.



1. Display all midi ports

2. Select Host midiout

Bar: MIDI vel 127
Beat: MIDI Vol 1-126

▼ Color

Background Color ⬛

Hilited LED Color 🟥

Inactive LED Color ⬜

▼ Name

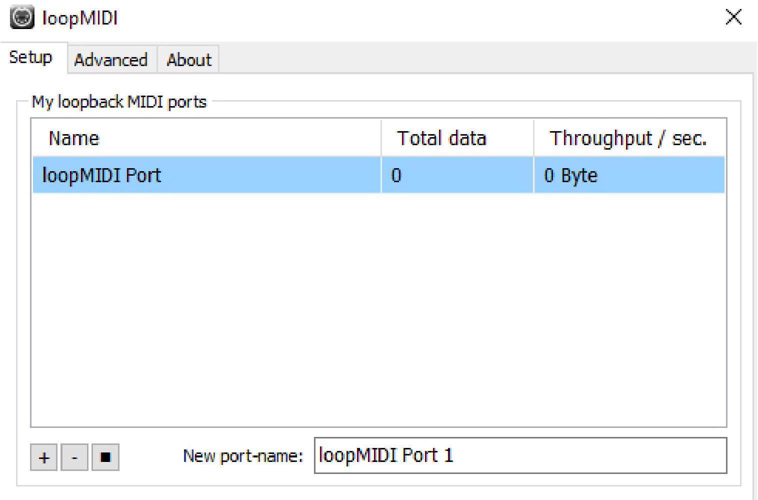
Scripting Name

▼ Value

Blink Time in Milliseconds 150

Figure A.2: Metronome blink time settings

The metronome patch works with MacOS and Windows 10. However, for the MIDI function in Windows 10, additional software is necessary. The loopMIDI[1] is a virtual MIDI connector programmed by Tobias Erichsen. This software enables MIDI data transmission within Windows 10. In order to use the metronome, both software and metronome have to be activated before beginning the listening test.



My loopback MIDI ports

Name	Total data	Throughput / sec.
loopMIDI Port	0	0 Byte

New port-name: loopMIDI Port 1

Figure A.3: The loopMIDI virtual MIDI software

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[1] LoopMIDI website, 7/26/2017, https://www.tobias-erichsen.de/software/loopmidi.html

Appendix B

Metronome Set-Up Measurements

Measurements relating to sound pressure levels (SPL) were made in the anechoic room of the Darmstadt University of Applied Sciences using a “Kunstkopf” dummy head Neumann KU100. The audio metronome signal was directed to the headphones (as in the experiment with test subjects) and the headphones placed on the dummy head as shown in Figure B.1. The level readings were obtained through the dummy head microphones. Both left and right microphones of the dummy head delivered the same value with +/- 1dB tolerance. The results of the left microphone were used for further calculations. The 24-bit resolution level meter software DIGICheck from RME was used for the measurements.

Figure B.1: Metronome level measurement with dummy head

After averaging the differences between the 1/4 and 1/2 slide positions relative to 1 (see Figure 4.10), two results are obtained as shown in Tables B.1, B.2, B.3 and B.4. Moving the slide from the far right to the middle translates into a decrease of 14.16dB at the test subject's headphones. On the other hand, lowering the slide from the far right to 1/4 as in Figure 4.10 is equivalent to a level diminution of 27.26dB.

Fireface gain value	**Peak value (dBFS)**	**Metronome slide position**	**Difference (dB)**
15	-33.1	1	—
15	-47.6	1/2	14.5
15	-61.3	1/4	28.2
20	-28.3	1	—
20	-42.5	1/2	14.2
20	-56.6	1/4	28.3
25	-23.1	1	—
25	-37.7	1/2	14.6
25	-51.6	1/4	28.5
30	-18.1	1	—
30	-32.6	1/2	14.5
30	-43.5	1/4	25.4
35	-12.8	1	—
35	-27.3	1/2	14.5
35	-41.1	1/4	28.3
40	-7.80	1	—
40	-21.7	1/2	13.9
40	-36.0	1/4	28.2
45	-2.6	1	—
45	-17.0	1/2	14.4
45	-30.4	1/4	27.8

Table B.1: Measurement of the metronome level (headphone level = -20dB)

The headphone output level was constant (-20dB, -15dB, -10dB, 0dB) for each measurement in Tables B.1, B.2, B.3 and B.4. The only change was the audio interface gain level. The different gain values of the audio interface are related to the headphone output level. Higher headphone levels allow a lower audio interface input gain range. Otherwise, the input signal would be too low or would produce distortion.

Fireface gain value	**Peak value (dBFS)**	**Metronome slide position**	**Difference (dB)**
10	-32.0	1	—
10	-46.6	1/2	14.6
10	-60.2	1/4	28.2
15	-27.2	1	—
15	-41.4	1/2	14.2
15	-55.3	1/4	28.1
20	-22.5	1	—
20	-37.0	1/2	14.5
20	-50.8	1/4	28.3
25	-17.3	1	—
25	-31.8	1/2	14.5
25	-37.7	1/4	20.4
30	-12.3	1	—
30	-26.8	1/2	14.5
30	-40.6	1/4	28.3
35	-6.9	1	—
35	-21.5	1/2	14.6
35	-34.5	1/4	27.6
40	-1.9	1	—
40	-16.5	1/2	14.6
40	-30.4	1/4	28.5

Table B.2: Measurement of the metronome level (headphone level = -15dB)

Fireface gain value	**Peak value (dBFS)**	**Metronome slide position**	**Difference (dB)**
10	-27.1	1	—
10	-40.3	1/2	13.2
10	-55.6	1/4	28.5
15	-22.2	1	—
15	-35.4	1/2	13.2
15	-50.7	1/4	28.5
20	-17.5	1	—
20	-30.7	1/2	13.2
20	-46.0	1/4	28.5
25	-12.3	1	—
25	-25.6	1/2	13.3
25	-40.8	1/4	28.5
30	-7.5	1	—
30	-20.5	1/2	13.0
30	-35.8	1/4	28.3
35	-2.0	1	—
35	-15.2	1/2	13.2
35	-30.4	1/4	28.4

Table B.3: Measurement of the metronome level (headphone level = -10dB)

Fireface gain value	**Peak value (dBFS)**	**Metronome slide position**	**Difference (dB)**
0	-27.6	1	—
0	-42.2	1/2	14.6
0	-53.4	1/4	25.8
10	-17.8	1	—
10	-32.4	1/2	14.6
10	-43.6	1/4	25.8
15	-13.0	1	—
15	-27.6	1/2	14.6
15	-38.7	1/4	25.7
20	-8.3	1	—
20	-22.9	1/2	14.6
20	-34.0	1/4	25.7
25	-3.1	1	—
25	-17.7	1/2	14.6
25	-23.8	1/4	25.7

Table B.4: Measurement of the metronome level (headphone level = 0dB)

Appendix C

Isolation Headphones Measurement

The attenuation level of the isolation headphones by VIC Firth SIH1 was tested in an anechoic room. The test signal was pink noise produced by the level meter Phonic PAA3 which was sent to a Genelec loudspeaker. The loudspeaker was positioned at a distance of 1,0m from the acoustic head Neumann KU100 as in Figure C.1. The height of the tweeter of the loudspeaker is in the same horizontal as that of the acoustic head ears. The dB SPL measure was 88.4dB(A) SPL.

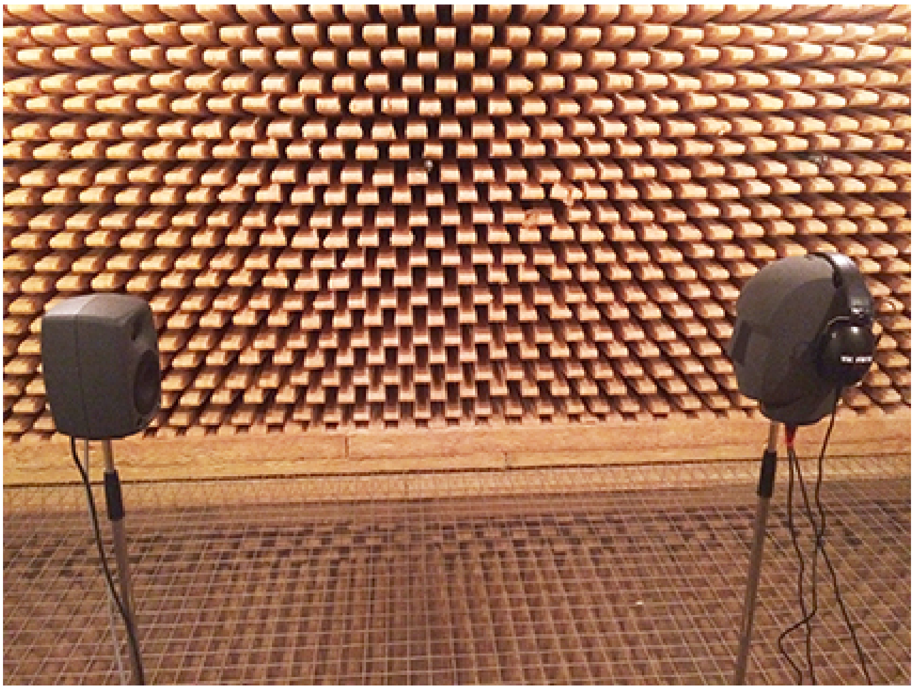


Figure C.1: Measurement set-up for the isolation headphones

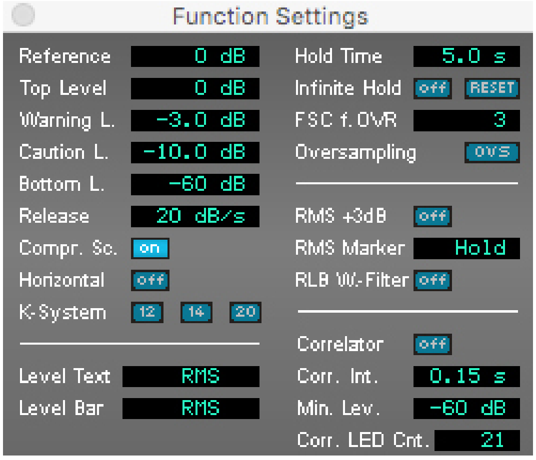
Measurements from headphones are presented in Table C.1.

Fireface gain value	**Peak value (dBFS)**	**Headphone on/off position**	**Difference (dB)**
0	-53.0	on	—
0	-43.2	off	10.2
10	-42.8	on	—
10	-32.7	off	10.1
15	-37.4	on	—
15	-27.6	off	9.8
20	-32.7	on	—
20	-22.8	off	9.9
25	-28.6	on	—
25	-18.7	off	9.9
30	-23.7	on	—
30	-12.4	off	11.3

Table C.1: Headphones attenuation

The average value of attenuation is 10.2dB, which is half the value of the 24.2dB noise reduction specified by the manufacturer. In Table C.1 the on/off position refers to measurements with the headphones covering the ears of the dummy head (on) or not on the head (off). After averaging the results of the column difference (dB) the obtained result is 10.2dB

DIGICheck from RME was also used to measure the level, with and without headphones. Figure C.2 shows the settings used.



Function Settings

Reference 0 dB
Top Level 0 dB
Warning L. -3.0 dB
Caution L. -10.0 dB
Bottom L. -60 dB
Release 20 dB/s
Compr. Sc. on
Horizontal off
K-System 12 14 20
Level Text RMS
Level Bar RMS

Hold Time 5.0 s
Infinite Hold off RESET
FSC f. OVR 3
Oversampling ovs
RMS +3dB off
RMS Marker Hold
RLB W.-Filter off
Correlator off
Corr. Int. 0.15 s
Min. Lev. -60 dB
Corr. LED Cnt. 21

Figure C.2: DIGICheck settings

The Hold Time of 5.0s which enables an accurate measurement is important, as are the reference levels of 0dB. Figures C.3 and C.4 show the measurement gain with the 30dB microphone (Fireface 400). It is easy to appreciate the level reduction using headphones and the similar values of the microphones (left and right or channel 1 and 2 of the audio interface) correspond to the ears of the acoustic head Neumann KU100.

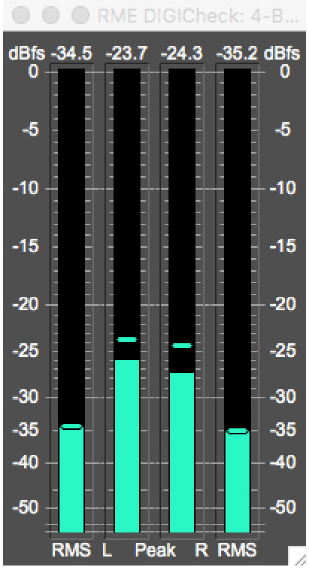


Figure C.3: Level measurement with headphones

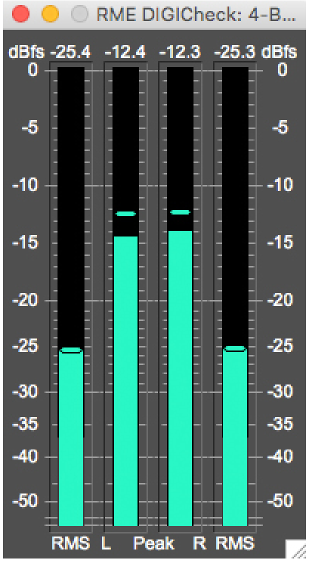
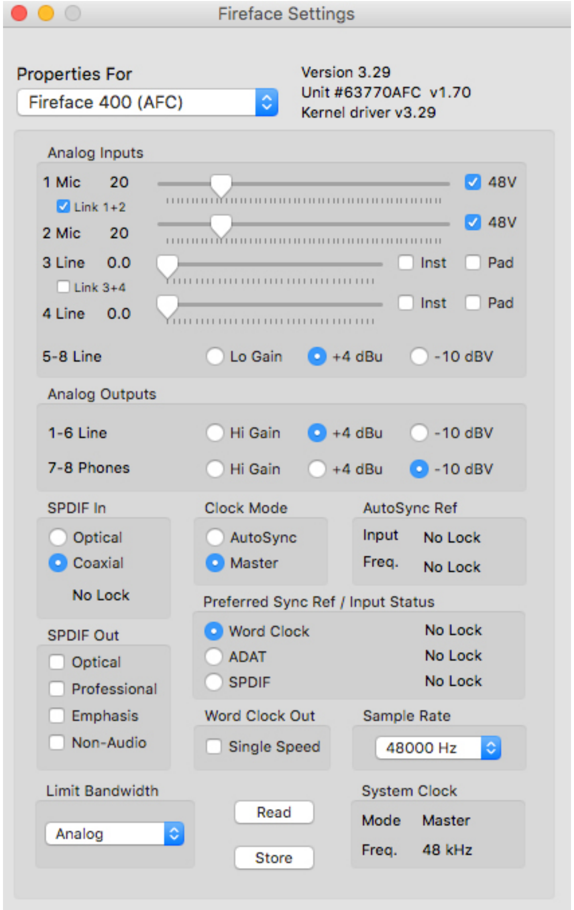


Figure C.4: Level measurement without headphones

Appendix D

Audio Interface Settings

Figure D.1 shows the different settings of the audio interface RME Fireface 400. The same settings were selected with the RME Fireface UCX used in the final experiment. The only difference is the graphical user interface for MAC and PC systems.


Fireface Settings

Properties For
Fireface 400 (AFC)

Version 3.29
Unit #63770AFC v1.70
Kernel driver v3.29

Analog Inputs
1 Mic 20 ☑ 48V
☑ Link 1+2
2 Mic 20 ☑ 48V
3 Line 0.0 ☐ Inst ☐ Pad
☐ Link 3+4
4 Line 0.0 ☐ Inst ☐ Pad
5-8 Line ○ Lo Gain ● +4 dBu ○ -10 dBV

Analog Outputs
1-6 Line ○ Hi Gain ● +4 dBu ○ -10 dBV
7-8 Phones ○ Hi Gain ○ +4 dBu ● -10 dBV

SPDIF In
○ Optical
● Coaxial
No Lock

Clock Mode
○ AutoSync
● Master

AutoSync Ref
Input No Lock
Freq. No Lock

Preferred Sync Ref / Input Status
● Word Clock No Lock
○ ADAT No Lock
○ SPDIF No Lock

SPDIF Out
☐ Optical
☐ Professional
☐ Emphasis
☐ Non-Audio

Word Clock Out
☐ Single Speed

Sample Rate
48000 Hz

Limit Bandwidth
Analog

System Clock
Mode Master
Freq. 48 kHz

Figure D.1: Audio interface settings

The following items in the audio interface are relevan for the listening test:

- Analogue Inputs.
- Analogue Outputs.
- Clock Mode.
- Sample Rate.
- System Clock.

In the Analogue Inputs section, the phantom power (48V) choice for condenser microphones is a feature. In addition, the gain level can be increased from 0dB up to 65dB in 1dB steps, with the exception of the lower range between 0dB and 10dB. In this range, there are no 1dB steps, only a 10dB jump[1]. The microphone was connected to the 1 Mic microphone input. The Analogue Output section 7-8 Phones shows the general headphone level. For the listening test, -10dBV was selected to avoid loud outputs and possible hearing damage.

The Clock Mode was set as Master, and the clock source was the Fireface 400/Fireface UCX (internal clock). The Sample Rate used was 48000Hz. Both readings are confirmed in the System Clock section.

Input Level Gain (dB)	**Output Level Peak (dBFS)**
0.00	-47.70
10.00	-37.90
15.00	-33.10
20.00	-28.30
25.00	-23.10
30.00	-18.10
35.00	-12.80
40.00	-7.80
45.00	-2.60

Table D.1: Audio interface output level measurements

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[1] RME. RME tech info - digicheck website, 7/26/2017. http://www.rme-audio.de/techinfo/digich.htm.

The Phones Line output level lies in the range of -58dB to +6dB in steps of 1dB according to the manufacturer's information[2]. Similar results within +/- 1dB tolerance were obtained for the RME Fireface UCX.

The reliability of the manufacturer's information, especially the linearity of the headphone output and microphone input, was tested with different measurements (see Appendix B). In Figure D.2, a simple linear regression shows that the manufacturer's information is accurate. Increasing the analogue input level by 5dB produces an increment of 5dB in the measured value. The plot indicates a linear relationship.

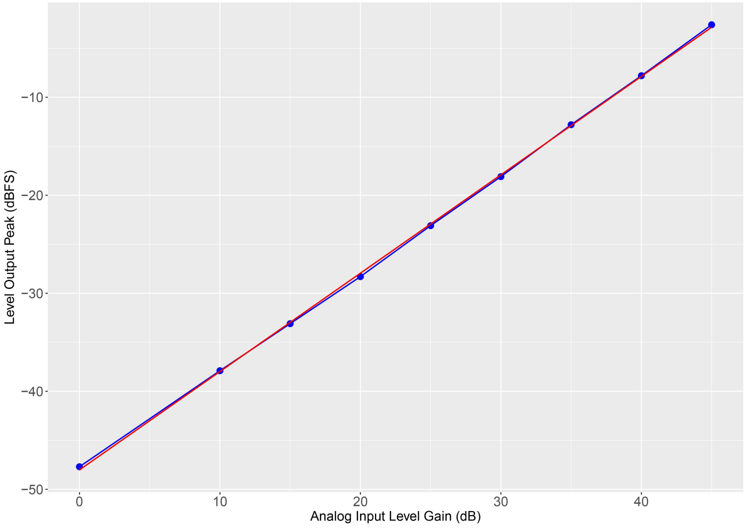

Figure D.2: Audio interface output vs. input level in 5dB steps

The headphone output was -20dB. The evaluation of the data in the open source statistical software R, produces the following results:

- The value R^2 indicates a strong correlation of 0.9998 which is a linear relationship as shown in Figure D.2.
- The blue line and the dots are the measured values, while the red line is the estimated linear regression.
- The residual standard error is 0.2381 with 7 degrees of freedom.

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[2] RME. Fireface 400 website, 7/26/2017. http://www.rme-audio.de/download/fface400_e.pdf.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-48.0232	0.1611	-298.06	1.26e-15
Input	1.0037	0.0057	174.97	5.26e-14

Table D.2: Linear regression coefficients

Several measurements with different headphone outputs (see Appendix B) delivered strong correlation values very near to 1. Between 0dB and 10dB there is a jump (see Figure D.2), and the input value 5dB gain is not defined (not plotted) in the analogue input. The RME Fireface 400 Firewire[3] and the RME Fireface UCX[4] both have an output gain of up to 65dB which is adjustable in 1dB steps over a range of 55dB. The plot shows the results up to 45dB. Higher values produced distortion when measuring the output in dBFS.

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[3] RME. Fireface 400 website, 7/26/2017, http:www.rme-audio.de/download/fface400_e.pdf.

[4] RME. Fireface UCX website, 7/26/2017, https:www.rme-audio.de/download/fface_ucx_e.pdf.

Appendix E

Audio Interface Delay Measurement

In order to test the reliability of the delay plug-in, two different configurations were used. For the pilot test, the set-up included a Macintosh with an RME Fireface 400 audio interface. The final test used a PC with an RME UCX interface. The internal latency values of both configurations were measured with the function delay finder of the software SATLive. The measurements used the dual-FFT algorithm which compares the spectrum of the signals to be measured. Pink noise at -30dBFS and 48kHz was used as the measurement signal. The set-up configuration is presented in Figure E.1.

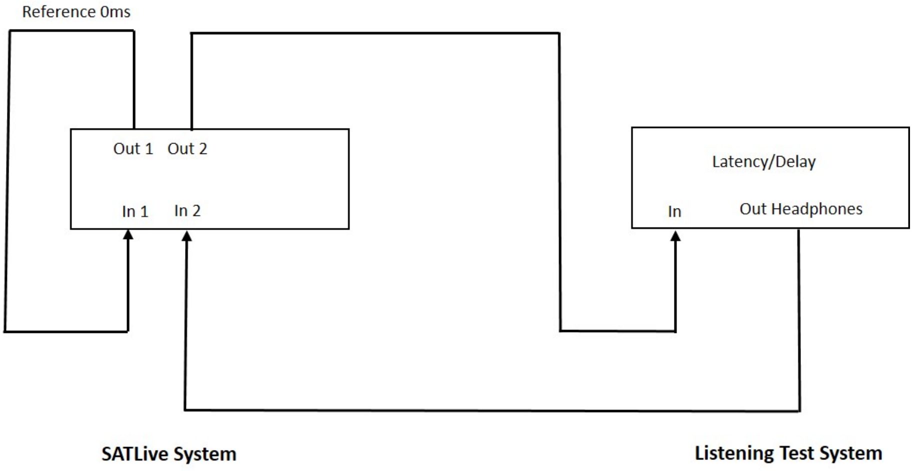


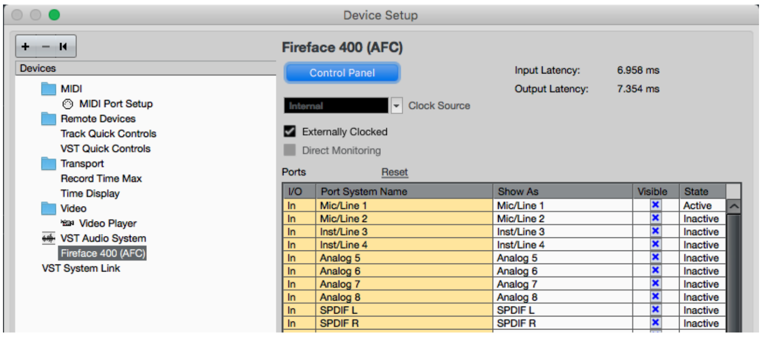
Figure E.1: Measurement procedure using SATLive

The results are shown in the Table E.1.

Cubase Artist delay (ms)	**SATLive delay measured (ms)**	**Degree (°)**	**Coherence**
0.0	14.396	3	100
10	24.375	3	100
20	34.375	3	100
30	44.375	3	100
40	54.375	3	100
50	64.375	3	100
60	74.375	3	100
70	84.375	3	100
80	94.375	3	100
90	104.375	3	100
100	114.375	3	100
110	124.375	3	100
120	134.375	6	100
130	144.375	6	100
140	154.375	6	100
150	164.375	6	100
160	174.375	6	100
170	184.375	6	100
180	194.375	6	100
190	204.375	6	100
200	214.375	6	100
210	224.375	6	100
220	234.375	6	100
230	244.375	6	100
240	254.375	6	100
250	264.375	6	100
260	274.375	6	100
270	284.375	6	100
280	294.375	6	100
290	304.375	6	100
300	314.313	6	100

Table E.1: Fireface 400 latency measurement values

The measurement of internal latency (input and output) using the configuration in Figure E.1 was 14.396ms for the Macintosh set-up. Bypassing the delay plug-in resulted in a measurement of 14.313ms. As shown in Figure E.2, the audio interface delivered similar values with an input latency of 6.958ms and an output latency of 7.354ms for a total of 14.312ms. The difference between the measured value and the audio interface value was 0.084ms. The values in Table E.1 confirm the latency increments of 10ms using the Cubase Artist software.



Fireface 400 (AFC)

Input Latency: 6.958 ms

Output Latency: 7.354 ms

Internal Clock Source

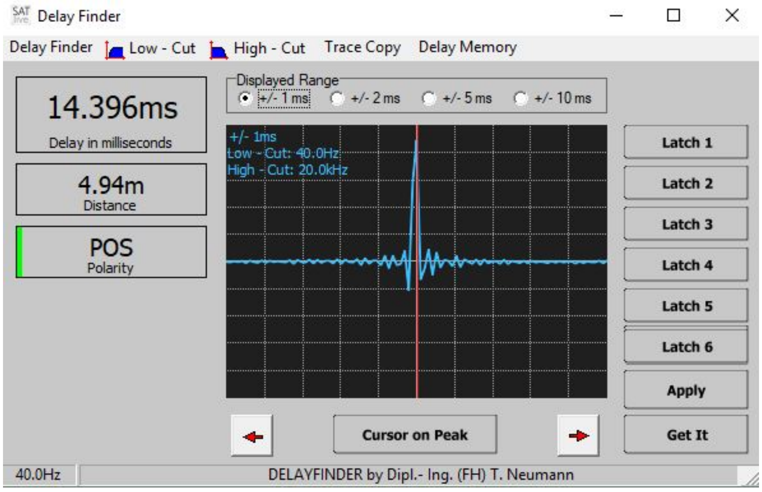
☑ Externally Clocked

☐ Direct Monitoring

Ports

I/O	Port System Name	Show As	Visible	State
In	Mic/Line 1	Mic/Line 1	☒	Active
In	Mic/Line 2	Mic/Line 2	☒	Inactive
In	Inst/Line 3	Inst/Line 3	☒	Inactive
In	Inst/Line 4	Inst/Line 4	☒	Inactive
In	Analog 5	Analog 5	☒	Inactive
In	Analog 6	Analog 6	☒	Inactive
In	Analog 7	Analog 7	☒	Inactive
In	Analog 8	Analog 8	☒	Inactive
In	SPDIF L	SPDIF L	☒	Inactive
In	SPDIF R	SPDIF R	☒	Inactive

Figure E.2: Fireface 400 latency input/output



14.396ms Delay in milliseconds

4.94m Distance

POS Polarity

Displayed Range: ● +/- 1 ms ○ +/- 2 ms ○ +/- 5 ms ○ +/- 10 ms

+/- 1ms
Low - Cut: 40.0Hz
High - Cut: 20.0kHz

40.0Hz | DELAYFINDER by Dipl.- Ing. (FH) T. Neumann

Figure E.3: Audio Interface delay (Fireface 400 set-up)

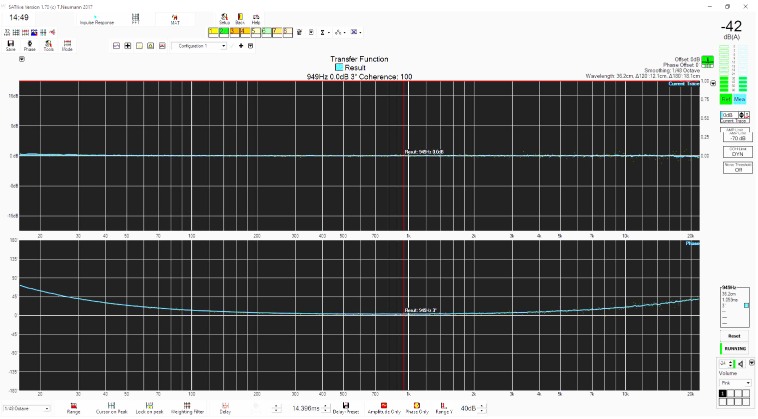


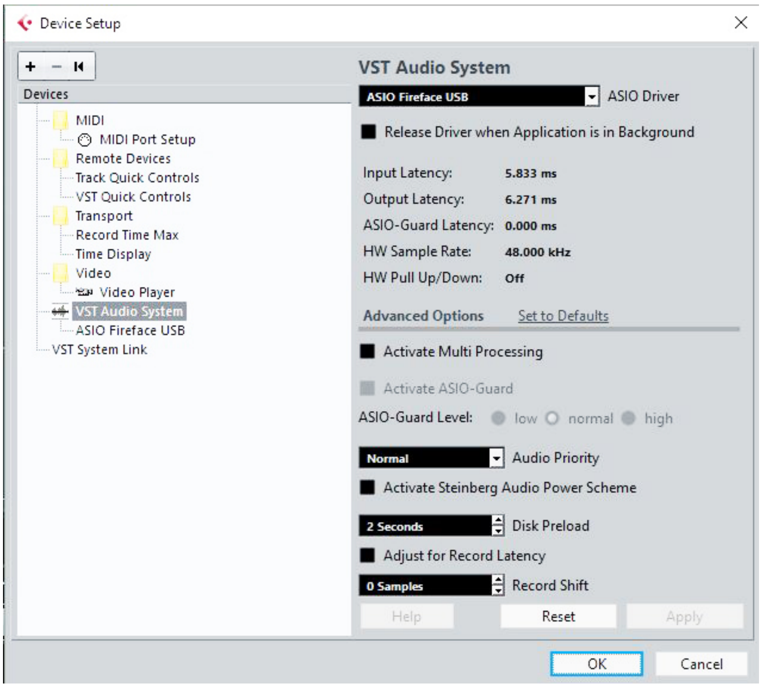
Figure E.4: Measurement phase (Fireface 400 set-up)

The second set-up used a Windows PC and an RME Fireface UCX. The results of the dual FFT at 48KHz using the configuration in Figure E.1 are displayed in the following table.

Cubase Artist delay (ms)	**SATLive delay measured (ms)**	**Degree (°)**	**Coherence**
0.0	12.208	3	100
10	22.188	3	100
20	32.188	3	100
30	42.188	3	100
40	52.188	3	100
50	62.188	3	100
60	72.188	3	100
70	82.188	3	100
80	92.188	3	100
90	102.188	3	100
100	112.188	3	100
110	122.188	3	100
120	132.188	3	100
130	142.188	3	100
140	152.188	3	100
150	162.188	3	100
160	172.188	3	100
170	182.188	3	100
180	192.188	3	100
190	202.188	3	100
200	212.188	3	100
210	222.188	3	100
220	232.188	3	100
230	242.188	3	100
240	252.188	3	100
250	262.188	3	100
260	272.188	3	100
270	282.188	3	100
280	292.188	3	100
290	302.188	3	100
300	312.125	3	100

Table E.2: Fireface UCX latency measurement values

Using the configuration shown in Figure E.1, the internal latency (input and output) for the PC set-up was 12.208ms with the delay plug-in activated. Bypassing the plug-in resulted in a value of 12.125ms. As shown in Figure E.5, the audio interface presents very similar values, with an input latency of 5.833ms and an output latency of 6.271ms for a total of 12.104ms. The difference between the measured value (plug-in active) and the Cubase Artist software information (12.104ms) was 0.104ms. The values in Table E.2 also confirm the 10ms software delay increment of the Cubase Artist DAW. The resolution of the delay measurement software for both systems (Macintosh and PC) was 105μs. In other words, the latency value read from the delay plug-in is very reliable.



VST Audio System

ASIO Fireface USB ASIO Driver

■ Release Driver when Application is in Background

Input Latency: 5.833 ms
Output Latency: 6.271 ms
ASIO-Guard Latency: 0.000 ms
HW Sample Rate: 48.000 kHz
HW Pull Up/Down: Off

Advanced Options Set to Defaults

■ Activate Multi Processing

■ Activate ASIO-Guard

ASIO-Guard Level: ● low ○ normal ● high

Normal Audio Priority

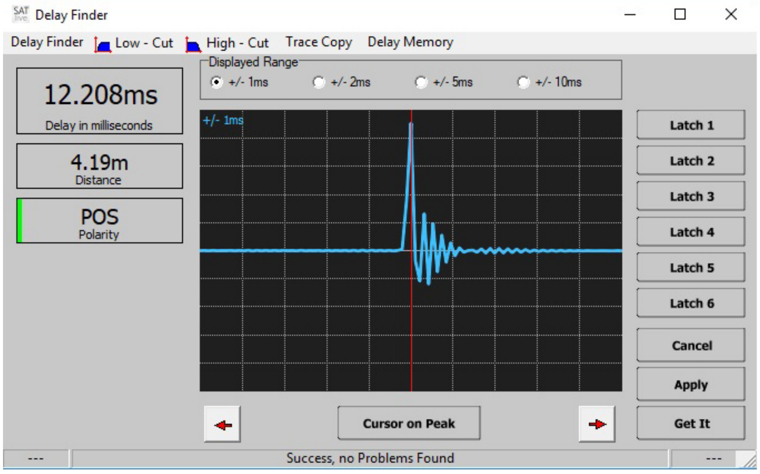
■ Activate Steinberg Audio Power Scheme

2 Seconds Disk Preload

■ Adjust for Record Latency

0 Samples Record Shift

Figure E.5: Fireface UCX latency input/output



Displayed Range
● +/- 1ms ○ +/- 2ms ○ +/- 5ms ○ +/- 10ms

12.208ms
Delay in milliseconds

4.19m
Distance

POS
Polarity

Success, no Problems Found

Figure E.6: Audio Interface delay (Fireface UCX set-up)

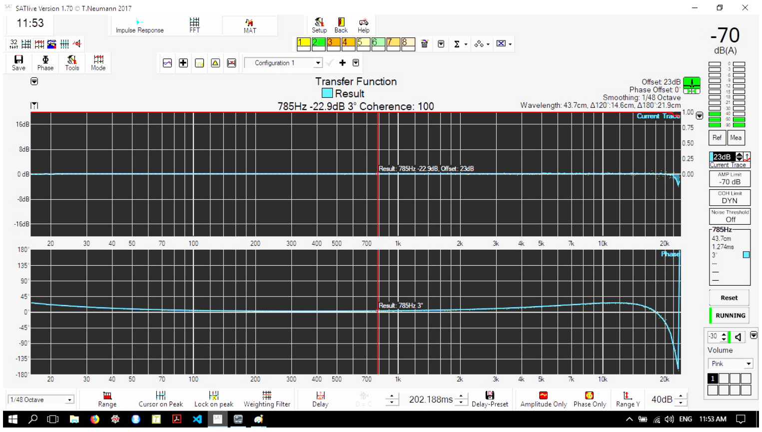


Figure E.7: Measurement phase (Fireface UCX set-up)

The delay measurements (input and output) for both Macintosh and PC were 14.396ms and 12.208ms respectively. For the listening tests, both audio interfaces used a buffer size of 256 samples and 48kHz as the sampling frequency. These values were chosen as a trade-off between a secure system without audio dropouts (lower sample values) and a relatively faster performance. Higher buffer size values (>256) may produce sound glitches while lower buffer size values (<256) would have notably increased the internal latency of the system.

Appendix F

Measurements of Sound Pressure Level on Instruments and Rooms

Table F.1 is a summary of all the measurements relating to microphone distance to musical instrument and the sound pressure level (SPL) of the instrument. In order to guarantee equality of conditions for all test subjects, measurements were made and presented as a descriptive statistical summary in Table 4.1.

In Table F.2, the item (f') is the height of the room. Not every room was square. Therefore, additional measurements such as (c), (d) and (e) are necessary. The RT60 results are the averages without specifying the frequencies.

Participant	**Musical instrument**	**Distance mic. to instrument (m)**	**Instrument level dBSPL(A)**	**Mic. gain (dB)**	**HP gain(dB)**	**Room**
1	Piano	0.292	87.3	10	-10	1 (CIT)
2	Piano	0.287	83.3	10	-10	1 (CIT)
3	Cello	0.380	84.0	10	-10	204 (CIT)
4	Cello	0.412	85.2	10	-10	204 (CIT)
5	Classical guitar	0.264	75.1	10	-10	204 (CIT)
6	French horn	0.338	89.2	10	-10	204 (CIT)
7	Alto saxophone	0.341	96.1	10	-10	204 (CIT)
8	Violin	0.367	82.2	10	-10	139 (CIT)
9	Trumpet in B	0.715	96.4	0	10	F14-30 (h-da)
10	Snare drum	0.389	93.0	0	10	1 (K. FFM)
11	Piano (upright)	0.347	82.3	10	10	2 (K. FFM)
12	Snare drum	0.388	94.0	0	10	F14-30 (h-da)
13	Violin	0.480	83.2	10	-10	F14-30 (h-da)
14	Transverse flute	0.328	83.5	10	-10	A25 (G. GU)
15	Trombone	0.437	91.3	0	10	A25 (G. GU)
16	Timpani	0.619	79.0	0	-10	A25 (G. GU)
17	Trombone	0.432	92.4	0	-5	F14-30 (h-da)
18	Violin	0.380	82.5	10	-10	F14-30 (h-da)
19	Triangle	0.286	80.0	10	-10	F14-30 (h-da)
20	Tenor saxophone	0.492	91.2	0	5	F14-30 (h-da)
21	Classical guitar	0.300	78.6	10	-5	F17-17 (h-da)
22	Violin	0.230	82.0	10	-5	F14-30 (h-da)
23	Snare drum	0.510	87.0	0	-5	F14-30 (h-da)
24	Alto saxophone	0.389	81.4	0	-5	Clubraum I
25	Triangle	0.429	82.7	10	0	F17-17 (h-da)
26	Marimba	0.405	84.1	10	-5	Cellar (Langen)
27	French horn	0.418	83.4	0	5	Probebühne
28	Double bass	0.394	82.1	10	0	Probebühne
29	Harp	0.594	81.2	10	-5	Mehrzweckraum
30	Bassoon	0.448	82,3	12	0	Room 5
31	Tenor saxophone	0.527	91.3	0	5	Linving room

Table F.1: Musical instruments recording reference values

Abbreviations in Table F.2 as follows:

- CIT: Cork Institute of Technology.
- h-da: Hochschule Darmstadt (Darmstadt University of Applied Sciences).
- K: Konservatorium (conservatory).
- FFM: Frankfurt am Main.
- G.GU: Gymnasium, Groß-Umstadt.
- DA: Darmstadt.

	Room dimensions in metres							
	(a)	(b)	(c)	(d)	(e)	(f')	**RT60 (sec.)**	**dBSPL(A)**
Room 1 (CIT)	5.38	8.70	3.37	-	-	2.87	0.50	36.7
Room 204 (CIT)	6.07	5.35	10.4	10.32	5.82	2.98	0.50	34.7
Room 139 (CIT)	3.50	8.56	0.95	9.91	7.36	2.98	0.45	34.6
F14-30 (h-da)	5.64	6.96	-	-	-	3.50	0.35	31.2
Room 1 (K. FFM)	3.51	4.00	-	-	-	2.60	0.45	33.0
Room 2 (K. FFM)	3.17	3.98	-	-	-	2.60	0.42	32.0
Room A25 (G. GU)	6.08	8.49	-	-	-	3.01	0.52	38.7
F17-17 (h-da)	3.97	5.29	-	-	-	2.58	0.30	32.4
Clubraum I	7.31	14.08	-	-	-	2.71	0.66	32.2
Cellar (Music School, Langen)	4.59	10.57	-	-	-	2.57	0.42	33.8
Probebühne Staatstheater, DA	9.24	17.24	-	-	-	4.11	0.82	34.6
Mehrzweck Raum Friedensgemeinde, DA	11.76	21.34	-	-	-	5.65	1.64	33.5
Room 5 Musikschule, GU	2.34	4.17	-	-	-	2.54	0.54	34.6
Living room	3.91	6.49	-	-	-	2.51	0.54	31.8

Table F.2: Room measurements

Appendix G

General Information Sheet for Participants

Thank you for agreeing to take part in the listening test for the research on Latency Tolerance Range for musicians.

The only thing you are expected to do is to play your instrument. The guideline for your performance is a musical score.

There is no right or wrong performance in this test. The main interest is the performance development. The quality of the performance is not evaluated in any way.

Test procedure

1. The first part of the test focuses on determining hearing ability. You will hear five different sinus tones. Any time you hear a tone, please play your instrument.
2. Your instrument will be miked. You will receive headphones to listen to your instrument audio signal.
3. Play the two bars score you see on the small screen (do not play by heart, do not memorize). During the performance, a metronome (aural, visual or aural-visual) is always active.
4. During the test, you will be asked to play the score. Your instrument signal (which you hear through the headphones) will be delayed until you are not able to perform anymore. The metronome is a guide to help you to keep the tempo during the performance.

5. The listening experiment includes three tests, each test consist of five different tempi, from 90 BPM to 210 BPM in 30 BPM steps. For each test, there is a different metronome:

    (a) A visual metronome presented on the small screen.

    (b) An aural metronome to be listened to through the headphones.

    (c) Both metronomes (visual and aural) merged.

    The succession order of the five different tempos in BPM is randomised.

Health and Safety

- The length of the listening test will not exceed 30 minutes.

- The sound reproduction levels of the headphones are controlled and harmless as recommended by the European Union legislation.

- You are free to withdraw from the listening experiment at any time and without giving any reason.

If you have any further questions, concerning the experiment, please do not hesitate to ask.

Allgemeine Informationen für die Probanden

Vielen Dank für Ihre Bereitschaft zur Teilnahme an dem Hörversuch "Latency Tolerance Range for Musicians"

Von Ihnen wird nur erwartet, Ihr Musikinstrument zu spielen. Als Vorlage dient eine Partitur, die Sie erst beim Hörversuch zu sehen bekommen.

Bei diesem Hörversuch gibt es keine richtige oder falsche Spielweise. Unser Interesse liegt hauptsächlich darin, die Entwicklung der musikalischen Performance in Abhängigkeit von der Latenz zu beobachten. Die Qualität der Musik-Performance wird in keinster Weise evaluiert.

Ablauf des Hörversuchs

1. Als erstes wird Ihre Hörfähigkeit gemessen. Sie werden fünf verschiedene Sinus-Testtöne hören. Sobald ein Testton erklingt, spielen Sie irgendeine Note auf ihrem Musikinstrument.
2. Das Musikinstrument wird mikrofoniert. Sie werden gebeten, Kopfhörer aufzusetzen, um das Audiosignal Ihres Musikinstruments zu hören.
3. Spielen Sie die zwei Takte Partitur, die auf dem kleinen Bildschirm angezeigt wird (bitte lernen Sie diese nicht auswendig). Während Ihrer Performance werden drei verschiedene Metronome (akustisch, visuell, audiovisuell) Sie aktiv begleiten.
4. Während des Hörversuchs, spielen Sie bitte die Partitur. Das Audiosignal Ihres Musikinstruments (welches Sie über die Kopfhörer hören) wird verzögert; bis Sie aufgrund der Verzögerung nicht mehr in der Lage sind, Ihr Instrument zu spielen. Das Metronom ist ein Hilfsinstrument, um das Tempo während der Performance beizubehalten.
5. Der Hörversuch sieht drei Tests vor, jeder Versuch beinhaltet fünf verschiedene Tempi von 90BPM bis 210BPM in 30BPM Schritten. Für jeden Versuch gibt es ein anderes Metronom:
   - (a) Ein visuelles Metronom wird auf dem kleinen Bildschirm gezeigt.
   - (b) Ein akustisches Metronom wird über die Kopfhörer gehört
   - (c) Beide Metronome (visuell und akustisch) werden gleichzeitig präsentiert.

Die Reihenfolge der Tempi in BPM ist zufällig.

Gesundheit und Sicherheit

- Die Gesamtdauer des Hörversuchs wird 30 Minuten nicht überschreiten.

- Der Audio-Wiedergabepegel der Kopfhörer ist nach den rechtlichen Empfehlungen der EU kontrolliert und unbedenklich.

- Sie dürfen jederzeit und ohne Angabe von Gründen von dem Hörversuch zurücktreten.

Sollten noch Unklarheiten bezüglich des Experiments bestehen, zögern Sie bitte nicht, sich mit Ihren Fragen an mich zu wenden.

Appendix H

Listening Test Consent Form

I the undersigned voluntarily agree to take part in the study (working title): *A Measurement approach to estimate the ability of Western Musicians to cope with Latency.*

I have read and understood the information sheet provided. I have been given a full explanation by the researcher about the purpose and duration of the listening test as well as what I will be expected to do. Any questions about any aspect of the test have been answered.

I understand that I am free to withdraw from the listening test at any time without any justification of my decision and with no further consequences.

I hereby confirm that I am not under 18 years of age at the time of performing the listening test.

I hereby confirm that I have read and understood the information given above and freely consent to participate in the listening test.

Name of test person ____

Signature ________________________ Date ________________________

Einverständniserklärung Hörversuch

Ich, der/die Unterzeichnende, stimme der Teilnahme an der Studie "A Measurement approach to estimate the ability of Western Musicians to cope with Latency" freiwillig zu.

Ich habe das Informationsblatt "Allgemeine Informationen für die Probanden" gelesen und verstanden. Der Leiter des Experiments hat mich über den Zweck, die Länge des Hörversuchs sowie die an mich gestellten Erwartungen ausführlich aufgeklärt. Sämtliche Fragen bezüglich des Hörversuchs wurden beantwortet.

Mir ist bekannt, dass ich jederzeit und ohne Angabe von Gründen von dem Experiment zurücktreten kann und hierdurch keine Nachteile für mich entstehen.

Ich bestätige hiermit, dass ich zum Zeitpunkt des Hörversuchs mindestens 18 Jahre alt bin.

Ich bestätige hiermit, dass ich die Einverständniserklärung gelesen und verstanden habe und dass ich freiwillig am Hörversuch teilnehme.

Name des Probanden ______________________________

Unterschrift ____________________ Datum ____________________

Appendix I

Questionnaire for the Listening Test

Item	**Question**	**Possible Answer**
1	Instrument	Name: ____________________ Group: ____________________
2	Age	____________________
3	Gender	1. Male 2. Female
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: __________ 2. No
5	Expertise	1. Professional Musician 2. Music Student
6	Years of Experience performing the instrument	Number of years: ______________
7	Playing technique	1. Plucked 2. Bowed 3. Struck
8	Current hours of practice per week	Number of hours: ______________
9	Performance on other instruments	1. Yes Instrument: ____________________ 2. No
10	Metronome preference	1. Visual 2. Audio 3. Both
11	Notes	

Table I.1: Questionnaire for the listening test

Appendix J

Friedman Test Data and Results

Subject	Aural (ms)	Visual (ms)	Both (ms)
1	224.00	219.00	205.00
2	219.00	140.00	165.00
3	300.00	280.00	260.00
4	252.00	200.00	250.00
5	93.00	182.00	118.00
6	300.00	300.00	300.00
7	300.00	300.00	300.00
8	266.00	300.00	300.00
9	300.00	300.00	300.00
10	202.00	300.00	290.00
11	61.00	72.00	80.00
12	230.00	142.00	298.00
13	128.00	143.00	99.00
14	120.00	60.00	94.00
15	192.00	138.00	203.00
16	300.00	240.00	300.00
17	280.00	201.00	253.00
18	131.00	49.00	151.00
19	232.00	300.00	300.00
20	217.00	147.00	187.00
21	176.00	187.00	172.00
22	284.00	175.00	268.00
23	300.00	249.00	239.00
24	230.00	300.00	300.00

Table J.1: Latency values for the three different metronomes at 90 BPM

Subject	**Aural (ms)**	**Visual (ms)**	**Both (ms)**
1	134.00	220.00	163.00
2	180.00	134.00	220.00
3	252.00	193.00	280.00
4	247.00	232.00	203.00
5	52.00	106.00	143.00
6	258.00	298.00	261.00
7	163.00	300.00	300.00
8	300.00	300.00	300.00
9	210.00	113.00	89.00
10	278.00	238.00	216.00
11	79.00	73.00	72.00
12	183.00	108.00	242.00
13	68.00	72.00	119.00
14	206.00	43.00	144.00
15	139.00	70.00	139.00
16	270.00	257.00	272.00
17	117.00	102.00	142.00
18	192.00	300.00	300.00
19	137.00	96.00	119.00
20	110.00	138.00	300.00
21	172.00	184.00	152.00
22	300.00	86.00	300.00
23	159.00	169.00	197.00
24	174.00	151.00	151.00
25	147.00	97.00	300.00
26	73.00	29.00	76.00

Table J.2: Latency values for the three different metronomes at 120 BPM

Subject	**Aural (ms)**	**Visual (ms)**	**Both (ms)**
1	134.00	260.00	165.00
2	148.00	145.00	195.00
3	105.00	120.00	172.00
4	156.00	300.00	200.00
5	81.00	98.00	103.00
6	183.00	130.00	163.00
7	300.00	300.00	300.00
8	300.00	300.00	300.00
9	120.00	145.00	263.00
10	62.00	58.00	82.00
11	160.00	166.00	215.00
12	78.00	76.00	80.00
13	88.00	84.00	119.00
14	100.00	83.00	83.00
15	149.00	168.00	214.00
16	123.00	91.00	97.00
17	227.00	300.00	217.00
18	181.00	90.00	158.00
19	62.00	68.00	104.00
20	151.00	138.00	139.00
21	78.00	147.00	300.00
22	300.00	172.00	212.00
23	164.00	166.00	122.00
24	145.00	149.00	154.00
25	300.00	61.00	262.00
26	63.00	43.00	67.00

Table J.3: Latency values for the three different metronomes at 150 BPM

Subject	Aural (ms)	Visual (ms)	Both (ms)
1	110.00	300.00	133.00
2	147.00	133.00	116.00
3	91.00	52.00	150.00
4	175.00	180.00	143.00
5	73.00	101.00	115.00
6	96.00	127.00	100.00
7	300.00	300.00	300.00
8	300.00	266.00	300.00
9	300.00	300.00	300.00
10	39.00	110.00	101.00
11	109.00	136.00	216.00
12	45.00	55.00	80.00
13	113.00	147.00	153.00
14	80.00	96.00	54.00
15	155.00	163.00	182.00
16	102.00	94.00	107.00
17	162.00	261.00	153.00
18	114.00	94.00	144.00
19	109.00	88.00	117.00
20	58.00	156.00	171.00
21	108.00	140.00	250.00
22	282.00	144.00	203.00
23	153.00	154.00	152.00
24	128.00	136.00	152.00
25	98.00	67.00	86.00

Table J.4: Latency values for the three different metronomes at 180 BPM

Subject	Aural (ms)	Visual (ms)	Both (ms)
1	108.00	220.00	108.00
2	121.00	75.00	105.00
3	45.00	25.00	143.00
4	183.00	238.00	165.00
5	44.00	73.00	68.00
6	137.00	106.00	30.00
7	300.00	300.00	300.00
8	300.00	103.00	300.00
9	300.00	300.00	300.00
10	56.00	100.00	77.00
11	123.00	94.00	172.00
12	72.00	59.00	82.00
13	104.00	107.00	132.00
14	69.00	78.00	73.00
15	132.00	131.00	133.00
16	76.00	67.00	87.00
17	119.00	195.00	203.00
18	111.00	109.00	107.00
19	101.00	80.00	101.00
20	61.00	108.00	131.00
21	193.00	123.00	223.00
22	130.00	131.00	160.00
23	126.00	159.00	132.00
24	117.00	102.00	142.00
25	51.00	63.00	59.00

Table J.5: Latency values for the three different metronomes at 210 BPM

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
testble.Avg.L1	216.00	174.67	280.00	234.00	131.00	300.00	300.00	288.67	300.00	145.00	264.00	71.00	223.33	113.00	123.33
testble.Avg.L2	172.33	178.00	241.67	227.33	100.33	272.33	259.00	254.33	300.00	137.33	244.00	74.67	177.67	86.00	86.33
testble.Avg.L3	186.33	162.67	132.33	218.67	94.00	158.67	300.00	300.00	300.00	93.50	176.00	67.33	180.33	78.00	97.00
testble.Avg.L4	181.00	132.00	97.67	166.00	96.33	107.67	300.00	288.67	300.00	83.33	153.67	60.00	137.67	76.67	63.00

Table J.6: Matrix for Hypothesis Testing (instruments 1 to 15)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
testble.Avg.L1	91.33	177.67	280.00	244.67	110.33	277.33	183.67	73.00	132.00	178.33	242.33	262.67	156.50	276.67	260.50	114.00
testble.Avg.L2	131.00	116.00	266.33	227.50	120.33	264.00	181.00	117.33	182.67	169.33	228.67	175.00	158.67	214.50	181.33	59.33
testble.Avg.L3	96.00	88.67	177.00	131.50	103.67	248.00	143.00	84.50	78.00	142.67	175.00	228.00	150.67	149.33	207.67	57.67
testble.Avg.L4	48.00	79.50	166.67	60.50	101.00	192.00	117.33	104.67	128.33	154.00	166.00	209.67	153.00	138.67	83.67	50.50

Table J.7: Matrix for Hypothesis Testing (instruments 16 to 31)

Comparisons	**obs.dif**	**critical dif.**	**difference**
1-2	15.0	99.59828	FALSE
1-3	4.5	99.59828	FALSE
1-4	9.5	99.59828	FALSE
1-5	48.0	99.59828	FALSE
1-6	13.0	99.59828	FALSE
1-7	38.5	99.59828	FALSE
1-8	34.0	99.59828	FALSE
1-9	42.5	99.59828	FALSE
1-10	44.0	99.59828	FALSE
1-11	11.0	99.59828	FALSE
1-12	71.0	99.59828	FALSE
1-13	6.0	99.59828	FALSE
1-14	61.5	99.59828	FALSE
1-15	53.0	99.59828	FALSE
1-16	57.0	99.59828	FALSE
1-17	47.0	99.59828	FALSE
1-18	23.5	99.59828	FALSE
1-19	21.0	99.59828	FALSE
1-20	44.0	99.59828	FALSE
1-21	29.0	99.59828	FALSE
1-22	17.0	99.59828	FALSE
1-23	52.0	99.59828	FALSE
1-24	31.5	99.59828	FALSE
1-25	17.0	99.59828	FALSE
1-26	6.5	99.59828	FALSE
1-27	12.0	99.59828	FALSE
1-28	20.0	99.59828	FALSE
1-29	0.0	99.59828	FALSE
1-30	6.0	99.59828	FALSE
1-31	69.0	99.59828	FALSE
2-3	10.5	99.59828	FALSE
2-4	24.5	99.59828	FALSE
2-5	33.0	99.59828	FALSE
2-6	28.0	99.59828	FALSE
2-7	53.5	99.59828	FALSE
2-8	49.0	99.59828	FALSE
2-9	57.5	99.59828	FALSE
2-10	29.0	99.59828	FALSE
2-11	26.0	99.59828	FALSE
2-12	56.0	99.59828	FALSE
2-13	9.0	99.59828	FALSE
2-14	46.5	99.59828	FALSE
2-15	38.0	99.59828	FALSE
2-16	42.0	99.59828	FALSE
2-17	32.0	99.59828	FALSE
2-18	38.5	99.59828	FALSE
2-19	6.0	99.59828	FALSE
2-20	29.0	99.59828	FALSE
2-21	44.0	99.59828	FALSE

Table J.8: Pairwise comparisons, post-hoc test main hypothesis, list 1/8

Comparisons	**obs.dif**	**critical dif.**	**difference**
2-22	2.0	99.59828	FALSE
2-23	37.0	99.59828	FALSE
2-24	16.5	99.59828	FALSE
2-25	2.0	99.59828	FALSE
2-26	21.5	99.59828	FALSE
2-27	27.0	99.59828	FALSE
2-28	5.0	99.59828	FALSE
2-29	15.0	99.59828	FALSE
2-30	9.0	99.59828	FALSE
2-31	54.0	99.59828	FALSE
3-4	14.0	99.59828	FALSE
3-5	43.5	99.59828	FALSE
3-6	17.5	99.59828	FALSE
3-7	43.0	99.59828	FALSE
3-8	38.5	99.59828	FALSE
3-9	47.0	99.59828	FALSE
3-10	39.5	99.59828	FALSE
3-11	15.5	99.59828	FALSE
3-12	66.5	99.59828	FALSE
3-13	1.5	99.59828	FALSE
3-14	57.0	99.59828	FALSE
3-15	48.5	99.59828	FALSE
3-16	52.5	99.59828	FALSE
3-17	42.5	99.59828	FALSE
3-18	28.0	99.59828	FALSE
3-19	16.5	99.59828	FALSE
3-20	39.5	99.59828	FALSE
3-21	33.5	99.59828	FALSE
3-22	12.5	99.59828	FALSE
3-23	47.5	99.59828	FALSE
3-24	27.0	99.59828	FALSE
3-25	12.5	99.59828	FALSE
3-26	11.0	99.59828	FALSE
3-27	16.5	99.59828	FALSE
3-28	15.5	99.59828	FALSE
3-29	4.5	99.59828	FALSE
3-30	1.5	99.59828	FALSE
3-31	64.5	99.59828	FALSE
4-5	57.5	99.59828	FALSE
4-6	3.5	99.59828	FALSE
4-7	29.0	99.59828	FALSE
4-8	24.5	99.59828	FALSE
4-9	33.0	99.59828	FALSE
4-10	53.5	99.59828	FALSE
4-11	1.5	99.59828	FALSE
4-12	80.5	99.59828	FALSE

Table J.9: Pairwise comparisons, post-hoc test main hypothesis, list 2/8

Comparisons	**obs.dif**	**critical dif.**	**difference**
4-13	15.5	99.59828	FALSE
4-14	71.0	99.59828	FALSE
4-15	62.5	99.59828	FALSE
4-16	66.5	99.59828	FALSE
4-17	56.5	99.59828	FALSE
4-18	14.0	99.59828	FALSE
4-19	30.5	99.59828	FALSE
4-20	53.5	99.59828	FALSE
4-21	19.5	99.59828	FALSE
4-22	26.5	99.59828	FALSE
4-23	61.5	99.59828	FALSE
4-24	41.0	99.59828	FALSE
4-25	26.5	99.59828	FALSE
4-26	3.0	99.59828	FALSE
4-27	2.5	99.59828	FALSE
4-28	29.5	99.59828	FALSE
4-29	9.5	99.59828	FALSE
4-30	15.5	99.59828	FALSE
4-31	78.5	99.59828	FALSE
5-6	61.0	99.59828	FALSE
5-7	86.5	99.59828	FALSE
5-8	82.0	99.59828	FALSE
5-9	90.5	99.59828	FALSE
5-10	4.0	99.59828	FALSE
5-11	59.0	99.59828	FALSE
5-12	23.0	99.59828	FALSE
5-13	42.0	99.59828	FALSE
5-14	13.5	99.59828	FALSE
5-15	5.0	99.59828	FALSE
5-16	9.0	99.59828	FALSE
5-17	1.0	99.59828	FALSE
5-18	71.5	99.59828	FALSE
5-19	27.0	99.59828	FALSE
5-20	4.0	99.59828	FALSE
5-21	77.0	99.59828	FALSE
5-22	31.0	99.59828	FALSE
5-23	4.0	99.59828	FALSE
5-24	16.5	99.59828	FALSE
5-25	31.0	99.59828	FALSE
5-26	54.5	99.59828	FALSE
5-27	60.0	99.59828	FALSE
5-28	28.0	99.59828	FALSE
5-29	48.0	99.59828	FALSE
5-30	42.0	99.59828	FALSE
5-31	21.0	99.59828	FALSE
6-7	25.5	99.59828	FALSE

Table J.10: Pairwise comparisons, post-hoc test main hypothesis, list 3/8

Comparisons	**obs.dif**	**critical dif.**	**difference**
6-8	21.0	99.59828	FALSE
6-9	29.5	99.59828	FALSE
6-10	57.0	99.59828	FALSE
6-11	2.0	99.59828	FALSE
6-12	84.0	99.59828	FALSE
6-13	19.0	99.59828	FALSE
6-14	74.5	99.59828	FALSE
6-15	66.0	99.59828	FALSE
6-16	70.0	99.59828	FALSE
6-17	60.0	99.59828	FALSE
6-18	10.5	99.59828	FALSE
6-19	34.0	99.59828	FALSE
6-20	57.0	99.59828	FALSE
6-21	16.0	99.59828	FALSE
6-22	30.0	99.59828	FALSE
6-23	65.0	99.59828	FALSE
6-24	44.5	99.59828	FALSE
6-25	30.0	99.59828	FALSE
6-26	6.5	99.59828	FALSE
6-27	1.0	99.59828	FALSE
6-28	33.0	99.59828	FALSE
6-29	13.0	99.59828	FALSE
6-30	19.0	99.59828	FALSE
6-31	82.0	99.59828	FALSE
7-8	4.5	99.59828	FALSE
7-9	4.0	99.59828	FALSE
7-10	82.5	99.59828	FALSE
7-11	27.5	99.59828	FALSE
7-12	109.5	99.59828	TRUE
7-13	44.5	99.59828	FALSE
7-14	100.0	99.59828	TRUE
7-15	91.5	99.59828	FALSE
7-16	95.5	99.59828	FALSE
7-17	85.5	99.59828	FALSE
7-18	15.0	99.59828	FALSE
7-19	59.5	99.59828	FALSE
7-20	82.5	99.59828	FALSE
7-21	9.5	99.59828	FALSE
7-22	55.5	99.59828	FALSE
7-23	90.5	99.59828	FALSE
7-24	70.0	99.59828	FALSE
7-25	55.5	99.59828	FALSE
7-26	32.0	99.59828	FALSE
7-27	26.5	99.59828	FALSE
7-28	58.5	99.59828	FALSE
7-29	38.5	99.59828	FALSE

Table J.11: Pairwise comparisons, post-hoc test main hypothesis, list 4/8

Comparisons	**obs.dif**	**critical dif.**	**difference**
7-30	44.5	99.59828	FALSE
7-31	107.5	99.59828	TRUE
8-9	8.5	99.59828	FALSE
8-10	78.0	99.59828	FALSE
8-11	23.0	99.59828	FALSE
8-12	105.0	99.59828	TRUE
8-13	40.0	99.59828	FALSE
8-14	95.5	99.59828	FALSE
8-15	87.0	99.59828	FALSE
8-16	91.0	99.59828	FALSE
8-17	81.0	99.59828	FALSE
8-18	10.5	99.59828	FALSE
8-19	55.0	99.59828	FALSE
8-20	78.0	99.59828	FALSE
8-21	5.0	99.59828	FALSE
8-22	51.0	99.59828	FALSE
8-23	86.0	99.59828	FALSE
8-24	65.5	99.59828	FALSE
8-25	51.0	99.59828	FALSE
8-26	27.5	99.59828	FALSE
8-27	22.0	99.59828	FALSE
8-28	54.0	99.59828	FALSE
8-29	34.0	99.59828	FALSE
8-30	40.0	99.59828	FALSE
8-31	103.0	99.59828	TRUE
9-10	86.5	99.59828	FALSE
9-11	31.5	99.59828	FALSE
9-12	113.5	99.59828	TRUE
9-13	48.5	99.59828	FALSE
9-14	104.0	99.59828	TRUE
9-15	95.5	99.59828	FALSE
9-16	99.5	99.59828	FALSE
9-17	89.5	99.59828	FALSE
9-18	19.0	99.59828	FALSE
9-19	63.5	99.59828	FALSE
9-20	86.5	99.59828	FALSE
9-21	13.5	99.59828	FALSE
9-22	59.5	99.59828	FALSE
9-23	94.5	99.59828	FALSE
9-24	74.0	99.59828	FALSE
9-25	59.5	99.59828	FALSE
9-26	36.0	99.59828	FALSE
9-27	30.5	99.59828	FALSE
9-28	62.5	99.59828	FALSE
9-29	42.5	99.59828	FALSE
9-30	48.5	99.59828	FALSE

Table J.12: Pairwise comparisons, post-hoc test main hypothesis, list 5/8

Comparisons	**obs.dif**	**critical dif.**	**difference**
9-31	111.5	99.59828	TRUE
10-11	55.0	99.59828	FALSE
10-12	27.0	99.59828	FALSE
10-13	38.0	99.59828	FALSE
10-14	17.5	99.59828	FALSE
10-15	9.0	99.59828	FALSE
10-16	13.0	99.59828	FALSE
10-17	3.0	99.59828	FALSE
10-18	67.5	99.59828	FALSE
10-19	23.0	99.59828	FALSE
10-20	0.0	99.59828	FALSE
10-21	73.0	99.59828	FALSE
10-22	27.0	99.59828	FALSE
10-23	8.0	99.59828	FALSE
10-24	12.5	99.59828	FALSE
10-25	27.0	99.59828	FALSE
10-26	50.5	99.59828	FALSE
10-27	56.0	99.59828	FALSE
10-28	24.0	99.59828	FALSE
10-29	44.0	99.59828	FALSE
10-30	38.0	99.59828	FALSE
10-31	25.0	99.59828	FALSE
11-12	82.0	99.59828	FALSE
11-13	17.0	99.59828	FALSE
11-14	72.5	99.59828	FALSE
11-15	64.0	99.59828	FALSE
11-16	68.0	99.59828	FALSE
11-17	58.0	99.59828	FALSE
11-18	12.5	99.59828	FALSE
11-19	32.0	99.59828	FALSE
11-20	55.0	99.59828	FALSE
11-21	18.0	99.59828	FALSE
11-22	28.0	99.59828	FALSE
11-23	63.0	99.59828	FALSE
11-24	42.5	99.59828	FALSE
11-25	28.0	99.59828	FALSE
11-26	4.5	99.59828	FALSE
11-27	1.0	99.59828	FALSE
11-28	31.0	99.59828	FALSE
11-29	11.0	99.59828	FALSE
11-30	17.0	99.59828	FALSE
11-31	80.0	99.59828	FALSE
12-13	65.0	99.59828	FALSE
12-14	9.5	99.59828	FALSE
12-15	18.0	99.59828	FALSE
12-16	14.0	99.59828	FALSE

Table J.13: Pairwise comparisons, post-hoc test main hypothesis, list 6/8

Comparisons	**obs.dif**	**critical dif.**	**difference**
12-17	24.0	99.59828	FALSE
12-18	94.5	99.59828	FALSE
12-19	50.0	99.59828	FALSE
12-20	27.0	99.59828	FALSE
12-21	100.0	99.59828	TRUE
12-22	54.0	99.59828	FALSE
12-23	19.0	99.59828	FALSE
12-24	39.5	99.59828	FALSE
12-25	54.0	99.59828	FALSE
12-26	77.5	99.59828	FALSE
12-27	83.0	99.59828	FALSE
12-28	51.0	99.59828	FALSE
12-29	71.0	99.59828	FALSE
12-30	65.0	99.59828	FALSE
12-31	2.0	99.59828	FALSE
13-14	55.5	99.59828	FALSE
13-15	47.0	99.59828	FALSE
13-16	51.0	99.59828	FALSE
13-17	41.0	99.59828	FALSE
13-18	29.5	99.59828	FALSE
13-19	15.0	99.59828	FALSE
13-20	38.0	99.59828	FALSE
13-21	35.0	99.59828	FALSE
13-22	11.0	99.59828	FALSE
13-23	46.0	99.59828	FALSE
13-24	25.5	99.59828	FALSE
13-25	11.0	99.59828	FALSE
13-26	12.5	99.59828	FALSE
13-27	18.0	99.59828	FALSE
13-28	14.0	99.59828	FALSE
13-29	6.0	99.59828	FALSE
13-30	0.0	99.59828	FALSE
13-31	63.0	99.59828	FALSE
14-15	8.5	99.59828	FALSE
14-16	4.5	99.59828	FALSE
14-17	14.5	99.59828	FALSE
14-18	85.0	99.59828	FALSE
14-19	40.5	99.59828	FALSE
14-20	17.5	99.59828	FALSE
14-21	90.5	99.59828	FALSE
14-22	44.5	99.59828	FALSE
14-23	9.5	99.59828	FALSE
14-24	30.0	99.59828	FALSE
14-25	44.5	99.59828	FALSE

Table J.14: Pairwise comparisons, post-hoc test main hypothesis, list 7/8

Comparisons	**obs.dif**	**critical dif.**	**difference**
14-26	68.0	99.59828	FALSE
14-27	73.5	99.59828	FALSE
14-28	41.5	99.59828	FALSE
14-29	61.5	99.59828	FALSE
14-30	55.5	99.59828	FALSE
14-31	7.5	99.59828	FALSE
15-16	4.0	99.59828	FALSE
15-17	6.0	99.59828	FALSE
15-18	76.5	99.59828	FALSE
15-19	32.0	99.59828	FALSE

Table J.15: Pairwise comparisons, post-hoc test main hypothesis, list 8/8

Appendix K

Data tables

K.1 Complete Latency Values for all musical instruments

participant	instrument	group	age	gender	metronome_hours	expertise	years_experience	sound_generation	hours_practice	other_instruments	metronome_preferenc	metronome	90BPM	120BPM	150BPM	180BPM	210BPM
1	Piano	Chordophones	19	Male	8	Student	6	C. Struck	12	Saxophone	Aural	Visual	219	220	260	300	220
1	Piano	Chordophones	19	Male	8	Student	6	C. Struck	12	Saxophone	Aural	Aural	224	134	134	110	108
1	Piano	Chordophones	19	Male	8	Student	6	C. Struck	12	Saxophone	Aural	Both	205	163	165	133	108
2	Piano	Chordophones	18	Female	1	Student	8	C. Struck	14	Viola	Aural	Visual	140	134	145	133	75
2	Piano	Chordophones	18	Female	1	Student	8	C. Struck	14	Viola	Aural	Aural	219	180	148	147	121
2	Piano	Chordophones	18	Female	1	Student	8	C. Struck	14	Viola	Aural	Both	165	220	195	116	105
3	Cello	Chordophones	22	Female	0	Student	6	C. Bowed	10	Piano	Visual	Aural	300	252	105	91	45
3	Cello	Chordophones	22	Female	0	Student	6	C. Bowed	10	Piano	Visual	Visual	280	193	120	52	25
3	Cello	Chordophones	22	Female	0	Student	6	C. Bowed	10	Piano	Visual	Both	260	280	172	150	143
4	Cello	Chordophones	18	Female	2	Student	5	C. Bowed	12	Violin	Aural	Aural	252	247	156	175	183
4	Cello	Chordophones	18	Female	2	Student	5	C. Bowed	12	Violin	Aural	Visual	200	232	300	180	238
4	Cello	Chordophones	18	Female	2	Student	5	C. Bowed	12	Violin	Aural	Both	250	203	200	143	165
5	Classic guitar	Chordophones	18	Male	7	Student	4	C. Plucked	14	No instrument	Aural	Aural	93	52	81	73	44
5	Classic guitar	Chordophones	18	Male	7	Student	4	C. Plucked	14	No instrument	Aural	Both	118	143	103	115	68
5	Classic guitar	Chordophones	18	Male	7	Student	4	C. Plucked	14	No instrument	Aural	Visual	182	106	98	101	73
6	French horn	Aerophones	21	Male	3	Student	9	A. Lip_reed	21	Trumpet	Aural	Aural	300	258	183	96	137
6	French horn	Aerophones	21	Male	3	Student	9	A. Lip_reed	21	Trumpet	Aural	Both	300	261	163	100	30
6	French horn	Aerophones	21	Male	3	Student	9	A. Lip_reed	21	Trumpet	Aural	Visual	300	298	130	127	106
7	Alto saxophone	Aerophones	20	Male	1.5	Student	12	A. Mechanical_reed	8	Piano	Both	Aural	300	300	300	300	300
7	Alto saxophone	Aerophones	20	Male	1.5	Student	12	A. Mechanical_reed	8	Piano	Both	Visual	300	218	300	300	300
7	Alto saxophone	Aerophones	20	Male	1.5	Student	12	A. Mechanical_reed	8	Piano	Both	Both	300	NA	NA	300	300
8	Violin	Chordophones	20	Female	3	Student	13	C. Bowed	20	No instrument	Aural	Aural	266	163	300	300	300
8	Violin	Chordophones	20	Female	3	Student	13	C. Bowed	20	No instrument	Aural	Visual	300	300	300	266	103
8	Violin	Chordophones	20	Female	3	Student	13	C. Bowed	20	No instrument	Aural	Both	300	300	300	300	300
9	Trumpet in B	Aerophones	22	Male	0.5	Student	14	A. Lip_reed	4	Drums	Both	Aural	300	300	300	300	300
9	Trumpet in B	Aerophones	22	Male	0.5	Student	14	A. Lip_reed	4	Drums	Both	Visual	300	300	300	300	300
9	Trumpet in B	Aerophones	22	Male	0.5	Student	14	A. Lip_reed	4	Drums	Both	Both	300	300	300	300	300
10	Snare drum	Membranophones	30	Male	7	Student	12	M. Struck	21	Double bass	Both	Aural	148	210	78	39	56
10	Snare drum	Membranophones	30	Male	7	Student	12	M. Struck	21	Double bass	Both	Visual	NA	113	109	110	100
10	Snare drum	Membranophones	30	Male	7	Student	12	M. Struck	21	Double bass	Both	Both	142	89	NA	101	77
11	Piano	Chordophones	27	Male	4	Student	6	C. Strucked	30	Drums	Both	Aural	202	278	120	109	123
11	Piano	Chordophones	27	Male	4	Student	6	C. Strucked	30	Drums	Both	Visual	300	238	145	136	94
11	Piano	Chordophones	27	Male	4	Student	6	C. Strucked	30	Drums	Both	Both	290	216	263	216	172
12	Snare drum	Membranophones	26	Male	5	Student	13	M. Struck	5	Piano	Aural	Aural	61	79	62	45	72
12	Snare drum	Membranophones	26	Male	5	Student	13	M. Struck	5	Piano	Aural	Visual	72	73	58	55	59
12	Snare drum	Membranophones	26	Male	5	Student	13	M. Struck	5	Piano	Aural	Both	80	72	82	80	82
13	Violin	Chordophones	27	Male	2	Student	20	C. Bowed	7	Guitar	Both	Aural	230	183	160	113	104
13	Violin	Chordophones	27	Male	2	Student	20	C. Bowed	7	Guitar	Both	Visual	142	108	166	147	107
13	Violin	Chordophones	27	Male	2	Student	20	C. Bowed	7	Guitar	Both	Both	298	242	215	153	132
14	Transverse flute	Aerophones	18	Female	0	Student	8	A. Air_reed	5	No instrument	Both	Aural	119	80	78	80	10
14	Transverse flute	Aerophones	18	Female	0	Student	8	A. Air_reed	5	No instrument	Both	Visual	NA	NA	76	96	NA
14	Transverse flute	Aerophones	18	Female	0	Student	8	A. Air_reed	5	No instrument	Both	Both	107	92	80	54	28
15	Trombone	Aerophones	18	Male	0	Student	9	A. Lip_reed	0	Trumpet	Aural	Aural	128	68	88	NA	NA
15	Trombone	Aerophones	18	Male	0	Student	9	A. Lip_reed	0	Trumpet	Aural	Visual	143	72	84	27	NA
15	Trombone	Aerophones	18	Male	0	Student	9	A. Lip_reed	0	Trumpet	Aural	Both	99	119	119	99	NA
16	Timpani	Membranophones	18	Male	0	Student	2	M. Struck	1	Clarinet	Aural	Aural	120	206	96	48	5
16	Timpani	Membranophones	18	Male	0	Student	2	M. Struck	1	Clarinet	Aural	Visual	60	43	NA	NA	39
16	Timpani	Membranophones	18	Male	0	Student	2	M. Struck	1	Clarinet	Aural	Both	94	144	NA	NA	NA

17	Trombone	Aerophones	21	Male	0	Student	13	A. Lip_reed	0	Piano	Both	Aural	192	139	100	NA	69
17	Trombone	Aerophones	21	Male	0	Student	13	A. Lip_reed	0	Piano	Both	Visual	138	70	83	77	78
17	Trombone	Aerophones	21	Male	0	Student	13	A. Lip_reed	0	Piano	Both	Both	203	139	83	82	73
18	Violin	Chordophones	22	Female	0	Student	13	C. Bowed	0.5	Piano	Aural	Aural	300	270	149	155	132
18	Violin	Chordophones	22	Female	0	Student	13	C. Bowed	0.5	Piano	Aural	Visual	240	257	168	163	131
18	Violin	Chordophones	22	Female	0	Student	13	C. Bowed	0.5	Piano	Aural	Both	300	272	214	182	133
19	Triangle	Idiophones	56	Female	1	Student	25	I. Struck	3.5	Violin	Aural	Aural	280	155	144	53	33
19	Triangle	Idiophones	56	Female	1	Student	25	I. Struck	3.5	Violin	Aural	Visual	201	NA	NA	NA	NA
19	Triangle	Idiophones	56	Female	1	Student	25	I. Struck	3.5	Violin	Aural	Both	253	300	119	68	57
20	Tenor saxophone	Aerophones	24	Male	1	Student	12	A. Mechanical_reed	1	Guitar	Aural	Aural	131	117	123	102	76
20	Tenor saxophone	Aerophones	24	Male	1	Student	12	A. Mechanical_reed	1	Guitar	Aural	Visual	49	102	91	94	67
20	Tenor saxophone	Aerophones	24	Male	1	Student	12	A. Mechanical_reed	1	Guitar	Aural	Both	151	142	97	107	87
21	Classic guitar	Chordophones	21	Male	3.5	Student	11	C. Plucked	7	Piano	Aural	Aural	232	192	227	162	119
21	Classic guitar	Chordophones	21	Male	3.5	Student	11	C. Plucked	7	Piano	Aural	Visual	300	300	300	261	195
21	Classic guitar	Chordophones	21	Male	3.5	Student	11	C. Plucked	7	Piano	Aural	Both	300	300	217	153	203
22	Violin	Chordophones	27	Female	0	Student	17	C. Bowed	0	No instrument	Aural	Aural	217	186	181	114	111
22	Violin	Chordophones	27	Female	0	Student	17	C. Bowed	0	No instrument	Aural	Visual	147	NA	90	94	109
22	Violin	Chordophones	27	Female	0	Student	17	C. Bowed	0	No instrument	Aural	Both	187	176	158	144	107
23	Snare drum	Membranophones	25	Male	0.5	Student	15	M. Struck	0.5	No instrument	Aural	Aural	NA	137	87	109	101
23	Snare drum	Membranophones	25	Male	0.5	Student	15	M. Struck	0.5	No instrument	Aural	Visual	49	96	82	88	80
23	Snare drum	Membranophones	25	Male	0.5	Student	15	M. Struck	0.5	No instrument	Aural	Both	97	119	NA	117	101
24	Alto saxophone	Aerophones	18	Male	3	Student	5	A. Mechanical_reed	8	No instrument	Both	Aural	157	110	62	58	61
24	Alto saxophone	Aerophones	18	Male	3	Student	5	A. Mechanical_reed	8	No instrument	Both	Visual	NA	138	68	156	108
24	Alto saxophone	Aerophones	18	Male	3	Student	5	A. Mechanical_reed	8	No instrument	Both	Both	107	300	104	171	131
25	Triangle	Idiophones	20	Male	3	Student	14	I. Struck	6	Piano	Both	Aural	176	172	151	156	121
25	Triangle	Idiophones	20	Male	3	Student	14	I. Struck	6	Piano	Both	Visual	187	184	138	NA	NA
25	Triangle	Idiophones	20	Male	3	Student	14	I. Struck	6	Piano	Both	Both	172	152	139	152	132
26	Marimba	Idiophones	31	Male	5	Professional	16	I. Struck	20	Piano	Aural	Aural	284	300	78	108	193
26	Marimba	Idiophones	31	Male	5	Professional	16	I. Struck	20	Piano	Aural	Visual	175	86	147	140	123
26	Marimba	Idiophones	31	Male	5	Professional	16	I. Struck	20	Piano	Aural	Both	268	300	300	250	223
27	French horn	Aerophones	35	Male	2	Professional	22	A. Lip_reed	35	No instrument	Aural	Aural	300	159	300	282	130
27	French horn	Aerophones	35	Male	2	Professional	22	A. Lip_reed	35	No instrument	Aural	Visual	249	169	172	144	131
27	French horn	Aerophones	35	Male	2	Professional	22	A. Lip_reed	35	No instrument	Aural	Both	239	197	212	203	160
28	Double bass	Chordophones	33	Female	5	Professional	25	C. Bowed	10	No instrument	Aural	Aural	151	174	164	153	126
28	Double bass	Chordophones	33	Female	5	Professional	25	C. Bowed	10	No instrument	Aural	Visual	NA	151	166	154	159
28	Double bass	Chordophones	33	Female	5	Professional	25	C. Bowed	10	No instrument	Aural	Both	162	151	122	152	132
29	Harp	Chordophones	34	Female	8	Professional	25	C. Plucked	16	No instrument	Both	Aural	230	201	145	128	117
29	Harp	Chordophones	34	Female	8	Professional	25	C. Plucked	16	No instrument	Both	Visual	300	NA	149	136	102
29	Harp	Chordophones	34	Female	8	Professional	25	C. Plucked	16	No instrument	Both	Both	300	228	154	152	142
30	Bassoon	Aerophones	51	Female	0	Professional	8	A. Mechanical_reed	2	Clarinet	Aural	Aural	221	147	300	98	NA
30	Bassoon	Aerophones	51	Female	0	Professional	8	A. Mechanical_reed	2	Clarinet	Aural	Visual	NA	97	61	67	NA
30	Bassoon	Aerophones	51	Female	0	Professional	8	A. Mechanical_reed	2	Clarinet	Aural	Both	300	300	262	86	35
31	Tenor saxophone	Aerophones	21	Male	0.25	Student	11	A. Mechanical_reed	10	Saxophone	Both	Aural	111	73	63	NA	51
31	Tenor saxophone	Aerophones	21	Male	0.25	Student	11	A. Mechanical_reed	10	Saxophone	Both	Visual	NA	29	43	35	63
31	Tenor saxophone	Aerophones	21	Male	0.25	Student	11	A. Mechanical_reed	10	Saxophone	Both	Both	117	76	67	66	59

K.2 Categorical Information

participant	instrument	other_instruments	group	gender	expertise	sound_generation	metronome_preference
1	Piano	Saxophone	Chordophones	Male	Student	C. Struck	Aural
2	Piano	Viola	Chordophones	Female	Student	C. Struck	Aural
3	Cello	Piano	Chordophones	Female	Student	C. Bowed	Visual
4	Cello	Violin	Chordophones	Female	Student	C. Bowed	Aural
5	Classic guitar	No instrument	Chordophones	Male	Student	C. Plucked	Aural
6	French horn	Trumpet	Aerophones	Male	Student	A. Lip_reed	Aural
7	Alto saxophone	Piano	Aerophones	Male	Student	A. Mechanical_reed	Both
8	Violin	No instrument	Chordophones	Female	Student	C. Bowed	Aural
9	Trumpet in B	Drums	Aerophones	Male	Student	A. Lip_reed	Both
10	Snare drum	Double bass	Membranophones	Male	Student	M. Struck	Both
11	Piano	Drums	Chordophones	Male	Student	C. Struck	Both
12	Snare drum	Piano	Membranophones	Male	Student	M. Struck	Aural
13	Violin	Guitar	Chordophones	Male	Student	C. Bowed	Both
14	Transverse flute	No instrument	Aerophones	Female	Student	A. Air_reed	Both
15	Trombone	Trumpet	Aerophones	Male	Student	A. Lip_reed	Aural
16	Timpani	Clarinet	Membranophones	Male	Student	M. Struck	Aural
17	Trombone	Piano	Aerophones	Male	Student	A. Lip_reed	Both
18	Violin	Piano	Chordophones	Female	Student	C. Bowed	Aural
19	Triangle	Violin	Idiophones	Female	Student	I. Struck	Aural
20	Tenor saxophone	Guitar	Aerophones	Male	Student	A. Mechanical_reed	Aural
21	Classic guitar	Piano	Chordophones	Male	Student	C. Plucked	Aural
22	Violin	No instrument	Chordophones	Female	Student	C. Bowed	Aural
23	Snare drum	No instrument	Membranophones	Male	Student	M. Struck	Aural
24	Alto saxophone	No instrument	Aerophones	Male	Student	A. Mechanical_reed	Both
25	Triangle	Piano	Idiophones	Male	Student	I. Struck	Both
26	Marimba	Piano	Idiophones	Male	Professional	I. Struck	Aural
27	French horn	No instrument	Aerophones	Male	Professional	A. Lip_reed	Aural
28	Double bass	No instrument	Chordophones	Female	Professional	C. Bowed	Aural
29	Harp	No instrument	Chordophones	Female	Professional	C. Plucked	Both
30	Bassoon	Clarinet	Aerophones	Female	Professional	A. Mechanical_reed	Aural
31	Tenor saxophone	Saxophone	Aerophones	Male	Student	A. Mechanical_reed	Both

K.3 Recording Information for all musical instruments

Item	Mic distance(m)	Inst. dBSPL(A)	Mic. Gain (dB)	HP gain (dB)	RT60 (sec)	dBSPL (A)	Room
1	0.292	87.3	10	-10	0.5	36.7	CIT 1
2	0.28	83.3	10	-10	0.5	36.7	CIT 1
3	0.38	84	10	-10	0.5	34.7	CIT 204
4	0.412	85.2	10	-10	0.5	34.7	CIT 204
5	0.264	75.1	10	-10	0.5	34.7	CIT 204
6	0.338	89.2	10	-10	0.5	34.7	CIT 204
7	0.341	96.1	10	-10	0.5	34.7	CIT 204
8	0.367	82.2	10	-10	0.5	34.7	CIT 139
9	0.715	96.4	0	10	0.35	31.2	F14-30
10	0.389	93	0	10	0.45	33	K1
11	0.347	82.3	10	10	0.42	32	K2
12	0.388	94	0	10	0.35	31.2	F14-30
13	0.48	83.2	10	-10	0.35	31.2	F14-30
14	0.328	83.5	10	-10	0.52	38.7	A25
15	0.437	91.3	0	10	0.52	38.7	A25
16	0.619	79	0	-10	0.52	38.7	A25
17	0.432	92.4	0	-5	0.35	31.2	F14-30
18	0.38	82.5	10	-10	0.35	31.2	F14-30
19	0.286	80	10	-10	0.35	31.2	F14-30
20	0.492	91.2	0	5	0.35	31.2	F14-30
21	0.3	78.6	10	-5	0.35	31.2	F14-30
22	0.23	82	10	-5	0.35	31.2	F14-30
23	0.51	87	0	-5	0.35	31.2	F14-30
24	0.389	81.4	0	-5	0.66	32.2	Clubraum
25	0.429	82.7	10	0	0.3	32.4	F17-17
26	0.405	84.1	10	-5	0.42	33.8	Cellar
27	0.418	83.4	0	5	0.82	34.6	Probebuehne
28	0.394	82.1	10	0	0.82	34.6	Probebuehne
29	0.594	81.2	10	-5	1.64	33.5	Merzweckraum
30	0.448	82.3	12	0	0.54	34.6	Room 5
31	0.527	91.3	0	5	0.54	31.8	Living room

Appendix L

R code for the statistical analysis

```
# Author: Jorge Medina Victoria
# A Method for the Measurement of the Ability of Western Musicians to Cope with Latency
# Evaluation_Results
# Date: 06.11.18

# If you are using this code for the first time, please install all the packages by deleting # in front of the package#1 Defining
Libraries

'Setting Directory in Session/set directory'

head(test) #looking for general information of the test
head(avgtest) # the other testframe

#install.packages("dplyr")
#library(plyr)
library(dplyr)  #callin library dplyr'

#install.packages("ggplot2)

library(ggplot2)

#instal.packages("reshape")
library(reshape2)

#install.packages("pastecs")
library(pastecs)

#install.packages("moments")
library(moments)

#install.packages("GGally")
library("GGally")

#install.packages('truncnorm')
library(truncnorm)

#install.packages('xtable')
library(xtable)

#install.packages('car')
library(car)

#2 Converting, Labeling and Averaging


#convert and label the vairables of the test

gender<-factor("gender", levels=c(1:2), labels=c("Male", "Female")) #convert gender numbers 1 and 2 into
#Male and Female

test$gender <- as.factor(test$gender)   #VERY IMPORTANT---> I converted it to a factor otherwise is just a num

class("gender")  #labels of the variable gender
gender # levels of the variable----> Male and Female

str(test)

expertise<-factor("expertise", levels=c(1:2), labels=c("Musician", "Student"))
#convert expertise numbers 1 and 2 into Professional Musician and Music Student

test$expertise <- as.factor(test$expertise)

expertise

str(test)

#Grouping the different soundgeneration techniques through factors

sound_generation<-factor("sound_generation", levels=c(0:7), labels=c("I. Struck", "M. Struck", "C. Bowed",
                                                                      "C. Struck", "C. Plucked", "A. Mechanical_reed", "A.
Air_reed", "A. Lip_reed"))

test$sound_generation <- as.factor(test$sound_generation)

sound_generation

str(test)


group<-factor("group", levels=c(1:4), labels=c("Chordophones", "Aerophones", "Membranophones",
                                                "Idiophones"))
#convert group number 1,2,3 and 4 into groups 1=Chordophones, 2= Aerophones, 3= Membranophones
#and 4= Idiophones

test$group <- as.factor(test$group)

group
str(test)

#Defining factors for metronome (Aural, Visual and Both)

metronome<-factor("metronome", levels=c(1:3), labels=c("Aural", "Visual", "Both"))
```

```
test$metronome <- as.factor(test$metronome)
metronome
str(test)

#Defining factors for metronome preference (Aural, Visual, Both)

metronome_preference<-factor("metronome_preference", levels=c(1:3), labels=c("Aural", "Visual", "Both"))

test$metronome_preference <- as.factor(test$metronome_preference)

metronome_preference
str(test)

#test$"group"<- as.integer(as.character(test$"group")) lets see if it is necesary

#different levels within some of the variables
levels(group)
levels(sound_generation)
levels(gender)
levels(expertise)
levels(metronome)
levels(metronome_preference)



##---------------------------------------Converting Character variables to numerical-----------------------------


test$"90BPM"<- as.numeric(as.character(test$"90BPM"))
test$"120BPM"<- as.numeric(as.character(test$"120BPM"))  #conversion of variable 120BPM from chr to num. It was chr
                                                         #because 2 variables were NA. The same operation wered
test$"150BPM"<- as.numeric(as.character(test$"150BPM"))  #efectuated in the variable 150BPM
test$"180BPM"<- as.numeric(as.character(test$"180BPM"))
test$"210BPM"<- as.numeric(as.character(test$"210BPM"))

#ATTENTION: participant should be int not dbl (integer not double)
#I converted participant to int. it should be made with all the other integer values i.e. metronome expertise, etc

str(test)   # All latency variables should be numerical

test$participant<- as.integer(as.numeric(test$"participant"))

typeof(test)
str(test)
summary(test)
head(test)





#--------------------------------/////////////   Averaging the three different metronome measures----------------------
detach("package:dplyr", character.only = TRUE)  #to avoid problems with the function select
library("dplyr", character.only = TRUE)         #to avoid problems with the function select


head(test)


names(test)<-c("participant","instrument", "group", "age", "gender", "metronome_hours",      #other_avgtest
               "expertise", "years_experience", "sound_generation",
               "hours_practice", "other_instrument", "metronome_preference",
               "metronome", "L1", "L2", "L3", "L4", "L5")

testble <- test %>%
  select(participant, age, metronome_hours,
         years_experience, hours_practice,
         L1, L2, L3, L4, L5) %>%
  group_by(participant) %>%
  summarize( m_age = mean(age), m_metronome_hours=mean(metronome_hours),
             m_years_experience = mean(years_experience),
             m_hours_practice = mean(hours_practice),
             Avg.L1 = mean(L1, na.rm=TRUE), Avg.L2 = mean(L2, na.rm=TRUE),
             Avg.L3 = mean(L3, na.rm=TRUE), Avg.L4 = mean(L4, na.rm=TRUE),
             Avg.L5 = mean(L5, na.rm=TRUE)) %>%


  as.data.frame()  # I set it as a test frame

testble

#table: summary
table <- xtable(testble)
table
#####################################################
#####subtest without Averaging the latency values

testbox <- test %>%
  select(participant, metronome,
         L1, L2, L3, L4, L5) %>%
  group_by(participant) %>%
```

```
  as.data.frame()  # I set it as a test frame

testbox


#### ----------------------------  Descriptive Statistic for the latency values


#Table: stat.desc BPM
summary(test)
testoutlook <- round(stat.desc(test[, c("L1", "L2", "L3", "L4", "L5")], basic = TRUE, desc = TRUE, norm = TRUE, p= 0.95), digits
= 5) # descriptive statistics
testoutlook



xtable(testoutlook)


## Shapriro test for normality
shapiro.test(test$L1)
shapiro.test(test$L2)
shapiro.test(test$L3)
shapiro.test(test$L4)
shapiro.test(test$L5)

# Therefore the distribution is not normal for each Tempi from 90BMP to 210BPM

##--------------------------------Testing the Data Distribuition--------------------------------------------

eda.shape <- function(x, ...){
  par(mfrow=c(2,2))
  plot(x, pch=19, col=2, main='raw data')
  hist(x, main="histogram of x", breaks = 6)
  box()
  boxplot(x, main='boxplot of x')
  #qqnorm(x, lwd=3, col=1)
  #qqline(x, lwd=3, col=2)
  qqPlot(x, col.lines = "red", lwd=2, main = "Normal Q-Q plot")
  par(mfrow=c(1,1))
}

#Random distribuition

# The first time the fucntion sample was used. However it is not possible to obtain a random distribution
# the function truncnorm with n = samples, a and b the lower and upper limits and mean and sd is better
# the shapiro function confirms the normality

#library(truncnorm)

ra_2 <- rtruncnorm(n=465, a=0, b=300, mean=150, sd=50)



#Plot name: edarandom
eda.shape(ra_2)




ra_1 <- sample(1:300, 375, replace=TRUE)  # From 1: the number of elements in our study
                                           # xx:yy intervall, n = the number of values in this intervall and
                                           # replace = FALSE ---> no bootstraping


#Plot name: edarandom

eda.shape(ra_1)    # This random distribution have to be compared with the Ttotal
                   # function. If they are different then the outcome of the study
                   # is not random -> which is GOOD


u <- test$L1  # 90BPM values
v <- test$L2  # 120BPM values
n <- test$L3  # 150BPM values
m <- test$L4  # 180BPM values
k <- test$L5  # 210BPM values

#EDA shape plots for the different BPM values

eda.shape(u)
eda.shape(v)
eda.shape(n)
eda.shape(m)
eda.shape(k)



##BPM values for the different BPM's
u
v
n
```

```
m
k


#Creating a data set with all the values
Ttotal <- c(u,v,n,m,k)
Ttotal
eda.shape(Ttotal)   #Plot name: edatest
summary(Ttotal)    # It is clear, it is not a normal distribution



## Transformations for homoscedastic data


#sqrttrafo
Ttotal2 <- sqrt(Ttotal)
Ttotal2
eda.shape(Ttotal2)
summary(Ttotal2)


#logtrafo
Ttotal3 <- log(Ttotal)
Ttotal3
eda.shape(Ttotal3)
summary(Ttotal3)

###############  Shapiro Test for normality ##########################

#shapirowilk
shapiro.test(ra_2)
shapiro.test(Ttotal)
shapiro.test(Ttotal2)
shapiro.test(Ttotal3)

#############################





#####--------WILCOX Function-------------------

#aero
#chordo
#membra
#idio


kruskal.test(L1 ~ L2, data = test)
kruskal.test(L1 ~ L3, data = test)
kruskal.test(L1 ~ L4, data = test)
kruskal.test(L1 ~ L5, data = test)

kruskal.test(L2 ~ L1, data = test)
kruskal.test(L2 ~ L3, data = test)
kruskal.test(L2 ~ L4, data = test)
kruskal.test(L2 ~ L5, data = test)

kruskal.test(L3 ~ L1, data = test)
kruskal.test(L3 ~ L2, data = test)
kruskal.test(L3 ~ L4, data = test)
kruskal.test(L3 ~ L5, data = test)


wilcox.test(Ttotal, mu=0)





##Define the function test without outliers = testwool

testwool <- filter(.data=test, participant != "6", participant != "7" , participant != "8", participant != "9")


testwool

u1 <- testwool$L1
v1 <- testwool$L2
n1 <- testwool$L3
m1 <- testwool$L4
k1 <- testwool$L5

eda.shape(u1)
eda.shape(v1)
eda.shape(n1)
eda.shape(m1)
eda.shape(k1)
```

```
## EDA shape for the data without outliers (the instrument with always 300ms latency)
Ttotalwool <- c(u1,v1,n1,m1,k1)
Ttotalwool
eda.shape(Ttotalwool)
summary(Ttotalwool)



wilcox.test(Ttotalwool)

####----------------------------------- Join the tables test and avgtest----------



head(avgtest)


#Convert again everything to factors


#convert and label the test

gender<-factor("gender", levels=c(1:2), labels=c("Male", "Female")) #convert gender numbers 1 and 2 into
#Male and Female

avgtest$gender <- as.factor(avgtest$gender)   #VERY IMPORTANT---> I converted it to a factor otherwise is just a num

class("gender")  #labels of the variable gender
gender # levels of the variable----> Male and Female

str(avgtest)

expertise <- factor("expertise", levels=c(1:2), labels=c("Professional Musician", "Music Student"))
#convert expertise numbers 1 and 2 into Professional Musician and Music Student

avgtest$expertise <- as.factor(avgtest$expertise)

expertise

str(avgtest)

sound_generation<-factor("sound_generation", levels=c(0:7), labels=c("I. Struck", "M. Struck", "C. Bowed",
                                                                     "C. Struck", "C. Plucked", "A. Mechanical_reed", "A.
Air_reed", "A. Lip_reed"))

avgtest$sound_generation <- as.factor(avgtest$sound_generation)

sound_generation



str(avgtest)

group<-factor("group", levels=c(1:4), labels=c("Chordophones", "Aerophones", "Membranophones",
                                               "Idiophones"))
#convert group number 1,2,3 and 4 into groups 1=Chordophones, 2= Aerophones, 3= Membranophones
#and 4= Idiophones

avgtest$group <- as.factor(avgtest$group)

group

metronome_preference <- factor("metronome_preference", levels=c(1:3), labels=c("Aural", "Visual", "Both"))

#convert the metronome preferences1,2 and 3 into groups 1=Aural, 2= Visual, 3= Both

avgtest$metronome_preference <- as.factor(avgtest$metronome_preference)

metronome_preference

#different levels within some of the variables
levels(group)
levels(sound_generation)
levels(gender)
levels(expertise)
levels(metronome_preference)

#Do not forget here in instrument participant should be also an int

avgtest$participant<- as.integer(as.numeric(avgtest$"participant"))

head(avgtest)


#merging the two testframes, so I can have avgtest also

testble
avgtest

jointtest <- merge(testble,avgtest, by="participant") #VERY IMPORTANT
#I'm merging two testframes
#in the order df1 then df2
#by the ID
```

```
str(jointtest)


#3 Graphical Information

#----------------------The next operation use either testtable or jointtest----------IMPORTANT-------------------



jointtest

table1 <- table(jointtest$instrument)

plot(table1)  #historgram of the evaluated instruments

ggplot(jointtest, aes(instrument))+geom_bar() #a better version with ggplot

str(jointtest)

head(jointtest)
print(testble)  #Display of the test frame finallist

#frequency table using TABLE function

table2 <- table(testble$m_age)

plot(table2)

ggplot(jointtest, aes(m_age))+geom_histogram()


#Both above are the same, because they are based in the numerical test however



table3 <- table(jointtest$gender)

plot(table3)

ggplot(jointtest, aes(gender))+geom_bar()


table4 <- table(jointtest$sound_generation)

plot(table4)

ggplot(jointtest, aes(sound_generation))+geom_bar()

typeof(jointtest)
class(jointtest)



#Getting min and max values

min(testble$m_age)  #Either testble or jointtest can be used. The result is the same.
max(testble$m_age)



min(jointtest$instrument)
max(jointtest$instrument)


min(testble$m_hours_practice)
max(testble$m_hours_practice)

#central tendencies MEAN

mean(testble$Avg.L1, na.rm=TRUE)   #Either testble or jointtest can be used. The result is the same.
mean(testble$Avg.L2, na.rm=TRUE)
mean(testble$Avg.L3, na.rm=TRUE)
mean(testble$Avg.L4, na.rm=TRUE)
mean(testble$Avg.L5, na.rm=TRUE)

#central tendencies MEDIAN



median(testble$Avg.L1, na.rm=TRUE)
median(testble$Avg.L2, na.rm=TRUE)
median(testble$Avg.L3, na.rm=TRUE)
median(testble$Avg.L4, na.rm=TRUE)
median(testble$Avg.L5, na.rm=TRUE)


#Quantiles

quantile(testble$m_years_experience)

quantile(testble$m_metronome_hours)
```

```
quantile(testble$m_age)

quantile(testble$Avg.L1, na.rm=TRUE)
quantile(testble$Avg.L2, na.rm=TRUE)
quantile(testble$Avg.L3, na.rm=TRUE)
quantile(testble$Avg.L4, na.rm=TRUE)
quantile(testble$Avg.L5, na.rm=TRUE)


#Standard Deviation  It seems there are similar

sd(testble$Avg.L1, na.rm=TRUE)
sd(testble$Avg.L2, na.rm=TRUE)
sd(testble$Avg.L3, na.rm=TRUE)
sd(testble$Avg.L4, na.rm=TRUE)
sd(testble$Avg.L5, na.rm=TRUE)
sd(testble$m_age, na.rm=TRUE)



sd(testble$m_expertise, na.rm=TRUE)

sd(jointtest$Avg.L1, na.rm=TRUE)  #should be the same as with testble





#--------------------------------------Plots for the different instruments-------------------------------------------------------

grupos <- subset(jointtest, select = c("participant", "m_age", "m_metronome_hours", "m_years_experience", "m_hours_practice"
,"group", "gender", "sound_generation", "instrument",
                                       "Avg.L1", "Avg.L2", "Avg.L3", "Avg.L4", "Avg.L5"))

grupos


names(grupos) <- c("participant", "m_age", "m_metronome_hours", "m_years_experience", "m_hours_practice" ,"group", "gender",
"sound_generation", "instrument" ,"90BPM", "120BPM", "150BPM", "180BPM", "210BPM")
grupos




#Merging Information for the display with ggplot

library(reshape2) # to use function melt'

#information is in the wide format, it has to be converted to the long or molten format using melt (library reshape)

testforplot <- melt(grupos, id=c("participant", "m_age", "m_metronome_hours", "m_years_experience", "m_hours_practice" ,"group",
"gender", "sound_generation", "instrument"))
testforplot  # the information has 3 columns: participant, variable and value
#participant goes from 1 to 25
#variable are the 6 different variables (instrument, 90BPM, 120BPM, 150BPM, 180BPM and 210BPM)
#value is the value assigned to each variable

names(testforplot)<-c("Participant", "Age", "Metronome_Hours", "Years_Experience", "Hours_Practice",    "Group", "Gender",
"Sound_Generation", "Instrument", "Tempo", "Latency")
testforplot

x <- ggplot(testforplot, mapping=aes(x=Tempo, y=Latency))+geom_line(aes(group=Participant))+ xlab("Tempo in BPM (average of all 3
Metronomes)") +
  ylab("Latency in milliseconds")

y <- ggplot(testforplot, mapping=aes(x=Tempo, y=Latency,
colour=Sound_Generation))+geom_line(aes(group=Participant))+geom_point(size=2)+facet_wrap(~Sound_Generation)+ xlab("Tempo in BPM
(average of all 3 Metronomes)") +
  ylab("Latency (Ld) in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))


z <- ggplot(testforplot, mapping=aes(x=Tempo, y=Latency,
colour=Instrument))+geom_line(aes(group=Participant))+geom_point(size=2)+facet_wrap(~Instrument)+ xlab("Tempo in BPM (average of
all 3 Metronomes)") +
  ylab("Latency (Ld) in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))


abcd <- ggplot(testforplot, mapping=aes(x=Group, y=Latency, colour = Instrument, shape = Tempo, size=2))+geom_point( size=2.5) +
xlab("Instrument Groups") +
  ylab("Latency (Ld) in milliseconds")

dcba <- ggplot(testforplot, mapping=aes(x=Sound_Generation, y=Latency, colour = Instrument, shape = Tempo, size=2))+geom_point(
size=2.5) + xlab("Sound Generation Technique") +
  ylab("Latency (Ld) in milliseconds")


xabcd <- ggplot(testforplot, mapping=aes(x=Group, y=Latency, colour =
Sound_Generation))+geom_violin(aes(group=Instrument))+geom_point(size=2)+facet_wrap(~Tempo)+ xlab("Instruments groups and sound
generation") +
  ylab("Latency in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))
```

```
yabcd <- ggplot(testforplot, mapping=aes(x=Instrument, y=Latency, colour =
Group))+geom_violin(aes(group=Instrument))+geom_point(size=2)+facet_wrap(~Tempo)+ xlab("Musical Instruments and instruments
groups") +
  ylab("Latency in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))


str(testforplot)
## Plots of the average of the 3 Metronomes------------------------------------------

x  # Latency vs Tempo for all the participants

#Plot name: techniqueplots
y +theme(axis.text=element_text(size=11),
         axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))


#Latency vs Tempo for the different playing techniques

#Plot name: instrumentslatency
z +theme(axis.text=element_text(size=11),
         axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))
#Latency vs Tempo for each musical instrument

#Plot name: latinstgroup
abcd+theme(axis.text=element_text(size=15),
           axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))

#Latency vs Instrument group

#Plot name: latsoundgentech
dcba+theme(axis.text=element_text(size=9.5),
           axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))


#Latency vs Sound Generation Technique

#Plot name: latgroupsoundgentemp
xabcd #Instruments groups and sound generation for every tempi

#Plot name: latinstrugrupstemp
yabcd # Boxplots for all instruments and with musical group information for every tempi


#################### Plotting information for all metronomes according to each tempo

testbox

names(testbox)<-c("participant","metronome", "90BPM", "120BPM", "150BPM", "180BPM", "210BPM")


testmetval <- melt(testbox, id = c("participant", "metronome"))

testmetval

xyz <- ggplot(testmetval, mapping=aes(x=metronome, y=value))+geom_boxplot(width = 0.4)+facet_wrap(~variable)+ xlab("Metronome") +
  ylab("Latency (Ld) in milliseconds")

#metroplotforall
xyz+theme(axis.text=element_text(size=9),
          axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))



##################################################################################

#Plot Aerophones and Chordophones
####plotwomembra <- filter(.data=testforplot)  # Group != "Ideophones"
##plotwomembra == testforplot

########### Plotting information regarding Instrument Groups ###############


j <- ggplot(testforplot, mapping=aes(x=Tempo, y=Latency, colour = Instrument))+geom_line(size = 0.5,
aes(group=Participant))+geom_point(size=2)+facet_wrap(~Group) +xlab("Tempo in BPM (average of all 3 metronomes)") + ylab("Latency
(Ld) in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))


#Plot name: groupslatency
j+theme(axis.text=element_text(size=13),
        axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))

#Plot Latency vs. Tempo by Groups and Instrument

#Data Analysis----------------------------------------


grupos # Data with the average  Subset of jointtest

table(grupos$instrument)
```

```
#Inter Quartiles IQR this is the substraction from the 75% - 25% quartile
#IQR for stat.desc BPM Average (highlight)

IQR(grupos$"90BPM", na.rm=TRUE)
IQR(grupos$"120BPM", na.rm=TRUE)
IQR(grupos$"150BPM", na.rm=TRUE)
IQR(grupos$"180BPM", na.rm=TRUE)
IQR(grupos$"210BPM", na.rm=TRUE)


#Filtering AEROPHONES, CHORDOPHONES, MEMBRANOPHONES AND IDIOPHONES

aero <- filter(.data=grupos, group == "Aerophones")

aero

chordo <- filter(.data=grupos, group == "Chordophones")

chordo

membra <- filter(.data=grupos, group == "Membranophones")

membra

idio <- filter(.data=grupos, group == "Idiophones")

idio


# Descriptive Statistic table for figure boxplotsgroup


#Table: stat.desc BPM Average Aerophones
aeroavg <- round(stat.desc(aero[, c("90BPM", "120BPM", "150BPM", "180BPM", "210BPM")], basic = TRUE, desc = TRUE, norm = TRUE, p=
0.95), digits = 5) # descriptive statistics
xtable(aeroavg)

#Table: stat.desc BPM Average Cordophones
chordoavg <- round(stat.desc(chordo[, c("90BPM", "120BPM", "150BPM", "180BPM", "210BPM")], basic = TRUE, desc = TRUE, norm =
TRUE, p= 0.95), digits = 5) # descriptive statistics
xtable(chordoavg)

#Table: stat.desc BPM Average Membranophones
membraavg <- round(stat.desc(membra[, c("90BPM", "120BPM", "150BPM", "180BPM", "210BPM")], basic = TRUE, desc = TRUE, norm =
TRUE, p= 0.95), digits = 5) # descriptive statistics
xtable(membraavg)

#Table: stat.desc BPM Average Idioophones
#Attention shapiro test not possible. It needs three values. After membranophone change to norm = TRUE
idioavg <- round(stat.desc(idio[, c("90BPM", "120BPM", "150BPM", "180BPM", "210BPM")], basic = TRUE, desc = TRUE, norm = FALSE,
p= 0.95), digits = 5) # descriptive statistics
xtable(idioavg)


#IQR for Chrodophones
#IQR for stat.desc BPM Average Cordophones(highlight)
IQR(chordo$"90BPM", na.rm=TRUE)
IQR(chordo$"120BPM", na.rm=TRUE)
IQR(chordo$"150BPM", na.rm=TRUE)
IQR(chordo$"180BPM", na.rm=TRUE)
IQR(chordo$"210BPM", na.rm=TRUE)


#IQR for Aerophones
#IQR for stat.desc BPM Average Aerophones(highlight)

IQR(aero$"90BPM", na.rm=TRUE)
IQR(aero$"120BPM", na.rm=TRUE)
IQR(aero$"150BPM", na.rm=TRUE)
IQR(aero$"180BPM", na.rm=TRUE)
IQR(aero$"210BPM", na.rm=TRUE)

#IQR for Membranophones
#IQR for stat.desc BPM Average Membranophones(highlight)
IQR(membra$"90BPM", na.rm=TRUE)
IQR(membra$"120BPM", na.rm=TRUE)
IQR(membra$"150BPM", na.rm=TRUE)
IQR(membra$"180BPM", na.rm=TRUE)
IQR(membra$"210BPM", na.rm=TRUE)


#IQR for Idiophones
#IQR for stat.desc BPM Average Idiophones(highlight)
IQR(idio$"90BPM", na.rm=TRUE)
IQR(idio$"120BPM", na.rm=TRUE)
IQR(idio$"150BPM", na.rm=TRUE)
IQR(idio$"180BPM", na.rm=TRUE)
IQR(idio$"210BPM", na.rm=TRUE)


#IQR for sound_generation
```

```
#A. Air_reed
#IQR for stat.desc BPM Average air reed(highlight)
ar <- filter(.data=grupos, sound_generation == "A. Air_reed")

IQR(ar$"90BPM", na.rm=TRUE)
IQR(ar$"120BPM", na.rm=TRUE)
IQR(ar$"150BPM", na.rm=TRUE)
IQR(ar$"180BPM", na.rm=TRUE)
IQR(ar$"210BPM", na.rm=TRUE)


#A. Lip_reed
#IQR for stat.desc BPM Average lip reed(highlight)
lr <- filter(.data=grupos, sound_generation == "A. Lip_reed")

IQR(lr$"90BPM", na.rm=TRUE)
IQR(lr$"120BPM", na.rm=TRUE)
IQR(lr$"150BPM", na.rm=TRUE)
IQR(lr$"180BPM", na.rm=TRUE)
IQR(lr$"210BPM", na.rm=TRUE)


#A. Mechanical_reed
#IQR for stat.desc BPM Average mechanical reed(highlight)
mr <- filter(.data=grupos, sound_generation == "A. Mechanical_reed")

IQR(mr$"90BPM", na.rm=TRUE)
IQR(mr$"120BPM", na.rm=TRUE)
IQR(mr$"150BPM", na.rm=TRUE)
IQR(mr$"180BPM", na.rm=TRUE)
IQR(mr$"210BPM", na.rm=TRUE)


#C. Bowed
#IQR for stat.desc BPM Average bowing(highlight)
cb <- filter(.data=grupos, sound_generation == "C. Bowed")

IQR(cb$"90BPM", na.rm=TRUE)
IQR(cb$"120BPM", na.rm=TRUE)
IQR(cb$"150BPM", na.rm=TRUE)
IQR(cb$"180BPM", na.rm=TRUE)
IQR(cb$"210BPM", na.rm=TRUE)


#C. Plucked
#IQR for stat.desc BPM Average plucking(highlight)
cp <- filter(.data=grupos, sound_generation == "C. Plucked")

IQR(cp$"90BPM", na.rm=TRUE)
IQR(cp$"120BPM", na.rm=TRUE)
IQR(cp$"150BPM", na.rm=TRUE)
IQR(cp$"180BPM", na.rm=TRUE)
IQR(cp$"210BPM", na.rm=TRUE)


#C. Struck
#IQR for stat.desc BPM Average striking chordophones(highlight)
cs <- filter(.data=grupos, sound_generation == "C. Struck")

IQR(cs$"90BPM", na.rm=TRUE)
IQR(cs$"120BPM", na.rm=TRUE)
IQR(cs$"150BPM", na.rm=TRUE)
IQR(cs$"180BPM", na.rm=TRUE)
IQR(cs$"210BPM", na.rm=TRUE)


#M Struck
#IQR for stat.desc BPM Average striking membranophones(highlight)
ms <- filter(.data=grupos, sound_generation == "M. Struck")

IQR(ms$"90BPM", na.rm=TRUE)
IQR(ms$"120BPM", na.rm=TRUE)
IQR(ms$"150BPM", na.rm=TRUE)
IQR(ms$"180BPM", na.rm=TRUE)
IQR(ms$"210BPM", na.rm=TRUE)


#I. Struck
#IQR for stat.desc BPM Average striking idiophones(highlight)
is <- filter(.data=grupos, sound_generation == "I. Struck")

IQR(is$"90BPM", na.rm=TRUE)
IQR(is$"120BPM", na.rm=TRUE)
IQR(is$"150BPM", na.rm=TRUE)
IQR(is$"180BPM", na.rm=TRUE)
IQR(is$"210BPM", na.rm=TRUE)


# Descriptive statistics for the plot boxplotssoundgen


#ar lr mr cb cp cs ms is ------------- Air reed, Liup reed, etc
```

```
#Table: stat.desc BPM Average air reed(highlight)
aravg <- round(stat.desc(ar[, c("90BPM", "120BPM", "150BPM", "180BPM", "210BPM")], basic = TRUE, desc = TRUE, norm = FALSE, p=
0.95), digits = 5) # descriptive statistics
xtable(aravg)

#Table: stat.desc BPM Average lip reed(highlight)
lravg <- round(stat.desc(lr[, c("90BPM", "120BPM", "150BPM", "180BPM", "210BPM")], basic = TRUE, desc = TRUE, norm = FALSE, p=
0.95), digits = 5) # descriptive statistics
xtable(lravg)


#Table: stat.desc BPM Average mechanical reed(highlight)
mravg <- round(stat.desc(mr[, c("90BPM", "120BPM", "150BPM", "180BPM", "210BPM")], basic = TRUE, desc = TRUE, norm = FALSE, p=
0.95), digits = 5) # descriptive statistics
xtable(mravg)


#Table: stat.desc BPM Average bowing(highlight)
cbavg <- round(stat.desc(cb[, c("90BPM", "120BPM", "150BPM", "180BPM", "210BPM")], basic = TRUE, desc = TRUE, norm = FALSE, p=
0.95), digits = 5) # descriptive statistics
xtable(cbavg)

#Table: stat.desc BPM Average plucking(highlight)
cpavg <- round(stat.desc(cp[, c("90BPM", "120BPM", "150BPM", "180BPM", "210BPM")], basic = TRUE, desc = TRUE, norm = FALSE, p=
0.95), digits = 5) # descriptive statistics
xtable(cpavg)

#Table: stat.desc BPM Average striking chordophones(highlight)
csavg <- round(stat.desc(cs[, c("90BPM", "120BPM", "150BPM", "180BPM", "210BPM")], basic = TRUE, desc = TRUE, norm = FALSE, p=
0.95), digits = 5) # descriptive statistics
xtable(csavg)

#Table: stat.desc BPM Average striking membranophones(highlight)
msavg <- round(stat.desc(ms[, c("90BPM", "120BPM", "150BPM", "180BPM", "210BPM")], basic = TRUE, desc = TRUE, norm = FALSE, p=
0.95), digits = 5) # descriptive statistics
xtable(msavg)

#Table: stat.desc BPM Average striking idiophones(highlight)
isavg <- round(stat.desc(is[, c("90BPM", "120BPM", "150BPM", "180BPM", "210BPM")], basic = TRUE, desc = TRUE, norm = FALSE, p=
0.95), digits = 5) # descriptive statistics
xtable(isavg)


#//////////////////////////////////// Density Plots //////////////////////////////////////////////////////////

par(mfrow=c(3,2))



#Here should I make a plot for the normal distribuition of the whole! It's there grupos the first one



plot(density(grupos$"90BPM", na.rm=TRUE))
points(
  x = grupos$"90BPM",
  y = rep(0.000, nrow(grupos)))

plot(density(grupos$"120BPM", na.rm=TRUE))
points(
  x = grupos$"120BPM",
  y = rep(0.000, nrow(grupos)))

plot(density(grupos$"150BPM", na.rm=TRUE))
points(
  x = grupos$"150BPM",
  y = rep(0.000, nrow(grupos)))

plot(density(grupos$"180BPM", na.rm=TRUE))
points(
  x = grupos$"180BPM",
  y = rep(0.000, nrow(grupos)))


plot(density(grupos$"210BPM", na.rm=TRUE))
points(
  x = grupos$"210BPM",
  y = rep(0.000, nrow(grupos)))


################# Density Plots with ggplot #######################


densitylat <- ggplot(testforplot, aes(Latency, colour = Tempo, fill = Tempo)) + geom_density(alpha = 0.1, na.rm = TRUE, size =
1)+
                             xlab("Latency (Ld) in milliseconds") + xlim(c(0, 300))



#testforplot is the main data resource for the next plots

#selecting groups for density plots
```

```
#Aerophones
gaerophones <- filter(.data=testforplot, Group == "Aerophones")

densitylatgroupaero <- ggplot(gaerophones, aes(Latency, colour = Tempo, fill = Tempo)) + geom_density(alpha = 0.2, na.rm = TRUE,
size = 1) +
                         xlab("Latency (Ld) in milliseconds") + xlim(c(0, 300))

#Chordophones
gchordophones <- filter(.data=testforplot, Group == "Chordophones")

densitylatgroupchordo <- ggplot(gchordophones, aes(Latency, colour = Tempo, fill = Tempo)) + geom_density(alpha = 0.2, na.rm =
TRUE, size = 1) +
  xlab("Latency (Ld) in milliseconds") + xlim(c(0, 300))

#Membranophones
gmembranophones <- filter(.data=testforplot, Group == "Membranophones")

densitylatgroupmembra <- ggplot(gmembranophones, aes(Latency, colour = Tempo, fill = Tempo)) + geom_density(alpha = 0.2, na.rm =
TRUE, size = 1) +
  xlab("Latency (Ld) in milliseconds") + xlim(c(0, 300))


#Idiophones
gidiophones <- filter(.data=testforplot, Group == "Idiophones")

densitylatgroupidio <- ggplot(gidiophones, aes(Latency, colour = Tempo, fill = Tempo)) + geom_density(alpha = 0.2, na.rm = TRUE,
size = 1) +
  xlab("Latency (Ld) in milliseconds") + xlim(c(0, 300))




################ Summary Density Plots ####################
gchordophones

#densitylat
densitylat+theme(axis.text=element_text(size=15),
                 axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))


# Density probability of latency according to the different tempi

#densitylatgroupaero
densitylatgroupaero+theme(axis.text=element_text(size=15),
                          axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15),
legend.title=element_text(size=15))



#densitylatgroupchordo
densitylatgroupchordo+theme(axis.text=element_text(size=15),
                            axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15),
legend.title=element_text(size=15))



#densitylatgroupmembra
densitylatgroupmembra+theme(axis.text=element_text(size=15),
                            axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15),
legend.title=element_text(size=15))



#densitylatgroupidio
densitylatgroupidio+theme(axis.text=element_text(size=15),
                          axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15),
legend.title=element_text(size=15))




# Distribuition for Aerophones-----------------------------


plot(density(aero$"90BPM", na.rm=TRUE))
points(
  x = aero$"90BPM",
  y = rep(0.000, nrow(aero)))


plot(density(aero$"120BPM", na.rm=TRUE))
points(
  x = aero$"120BPM",
  y = rep(0.000, nrow(aero)))


plot(density(aero$"150BPM", na.rm=TRUE))
points(
  x = aero$"150BPM",
  y = rep(0.000, nrow(aero)))
```

```
plot(density(aero$"180BPM", na.rm=TRUE))
points(
  x = aero$"180BPM",
  y = rep(0.000, nrow(aero)))


plot(density(aero$"210BPM", na.rm=TRUE))
points(
  x = aero$"210BPM",
  y = rep(0.000, nrow(aero)))


##Distribuition for Chordophones--------------------------

#Most distribuition are here bimodal (2 Peaks)

plot(density(chordo$"90BPM", na.rm=TRUE))
points(
  x = chordo$"90BPM",
  y = rep(0.000, nrow(chordo)))

plot(density(chordo$"120BPM", na.rm=TRUE))
points(
  x = chordo$"120BPM",
  y = rep(0.000, nrow(chordo)))

plot(density(chordo$"150BPM", na.rm=TRUE))
points(
  x = chordo$"150BPM",
  y = rep(0.000, nrow(chordo)))

plot(density(chordo$"180BPM", na.rm=TRUE))
points(
  x = chordo$"180BPM",
  y = rep(0.000, nrow(chordo)))

plot(density(chordo$"210BPM", na.rm=TRUE))
points(
  x = chordo$"210BPM",
  y = rep(0.000, nrow(chordo)))



##Distribuition for Membranophones


plot(density(membra$"90BPM", na.rm=TRUE)) # For doing the test at least 2 results are needed
points(
  x = membra$"90BPM",
  y = rep(0.000, nrow(membra)))


plot(density(membra$"120BPM", na.rm=TRUE))
points(
  x = membra$"120BPM",
  y = rep(0.000, nrow(membra)))


plot(density(membra$"150BPM", na.rm=TRUE))
points(
  x = membra$"150BPM",
  y = rep(0.000, nrow(membra)))

plot(density(membra$"180BPM", na.rm=TRUE))
points(
  x = membra$"180BPM",
  y = rep(0.000, nrow(membra)))



plot(density(membra$"210BPM", na.rm=TRUE))
points(
  x = membra$"210BPM",
  y = rep(0.000, nrow(membra)))




##Distribuition for Ideophones


plot(density(idio$"90BPM", na.rm=TRUE)) # For doing the test at least 2 results are needed
points(
  x = idio$"90BPM",
  y = rep(0.000, nrow(idio)))


plot(density(idio$"120BPM", na.rm=TRUE))
points(
  x = idio$"120BPM",
  y = rep(0.000, nrow(idio)))
```

```
plot(density(idio$"150BPM", na.rm=TRUE))
points(
  x = idio$"150BPM",
  y = rep(0.000, nrow(idio)))

plot(density(idio$"180BPM", na.rm=TRUE))
points(
  x = idio$"180BPM",
  y = rep(0.000, nrow(idio)))



plot(density(idio$"210BPM", na.rm=TRUE))
points(
  x = idio$"210BPM",
  y = rep(0.000, nrow(idio)))






# /////////// Density Plots sorted by s, b, p and n  Struck, Bowed, Plucked and No_technique


grupos


#pdf for different sound generation groups

plot(density(ar$"90BPM", na.rm=TRUE))
plot(density(ar$"120BPM", na.rm=TRUE))
plot(density(ar$"150BPM", na.rm=TRUE))
plot(density(ar$"180BPM", na.rm=TRUE))
plot(density(ar$"210BPM", na.rm=TRUE))

plot(density(lr$"90BPM", na.rm=TRUE))
plot(density(lr$"120BPM", na.rm=TRUE))
plot(density(lr$"150BPM", na.rm=TRUE))
plot(density(lr$"180BPM", na.rm=TRUE))
plot(density(lr$"210BPM", na.rm=TRUE))

plot(density(mr$"90BPM", na.rm=TRUE))    # At least 2 points are needed
plot(density(mr$"120BPM", na.rm=TRUE))
plot(density(mr$"150BPM", na.rm=TRUE))
plot(density(mr$"180BPM", na.rm=TRUE))
plot(density(mr$"210BPM", na.rm=TRUE))


plot(density(cb$"90BPM", na.rm=TRUE))
plot(density(cb$"120BPM", na.rm=TRUE))
plot(density(cb$"150BPM", na.rm=TRUE))
plot(density(cb$"180BPM", na.rm=TRUE))
plot(density(cb$"210BPM", na.rm=TRUE))


plot(density(cs$"90BPM", na.rm=TRUE))
plot(density(cs$"120BPM", na.rm=TRUE))
plot(density(cs$"150BPM", na.rm=TRUE))
plot(density(cs$"180BPM", na.rm=TRUE))
plot(density(cs$"210BPM", na.rm=TRUE))

plot(density(cp$"90BPM", na.rm=TRUE))
plot(density(cp$"120BPM", na.rm=TRUE))
plot(density(cp$"150BPM", na.rm=TRUE))
plot(density(cp$"180BPM", na.rm=TRUE))
plot(density(cp$"210BPM", na.rm=TRUE))


plot(density(ms$"90BPM", na.rm=TRUE))
plot(density(ms$"120BPM", na.rm=TRUE))
plot(density(ms$"150BPM", na.rm=TRUE))
plot(density(ms$"180BPM", na.rm=TRUE))
plot(density(ms$"210BPM", na.rm=TRUE))


plot(density(is$"90BPM", na.rm=TRUE))
plot(density(is$"120BPM", na.rm=TRUE))
plot(density(is$"150BPM", na.rm=TRUE))
plot(density(is$"180BPM", na.rm=TRUE))
plot(density(is$"210BPM", na.rm=TRUE))







#Others Plot for Fu

par(mfrow=c(1,1))
```

```
# genderbar
plot(grupos$gender, xlab = "Gender",
           ylab = "Number of test subjects")

pie(table(grupos$gender))

boxplot(  x=grupos$m_age,
          xlab = "Age (years)",
          horizontal = TRUE)


boxplot(  x=grupos$"150BPM",
          xlab = "Age (years)",
          horizontal = FALSE)

hist(grupos$m_age)




points(
  x = grupos$"210BPM",
  y = rep(0.0005, nrow(grupos)))


plot(density(grupos$m_age))




######------Other Boxplots------------




boxplot(testforplot$Latency ~ testforplot$Tempo)

#Plot name: latencytempo
latencytempo <- ggplot(testforplot, mapping=aes(x=Tempo, y=Latency))+geom_boxplot(width = 0.5)+ xlab("Tempo in BPM (average of
all 3 metronomes)") +
  ylab("Latency (Ld) in milliseconds")

latencytempo+theme(axis.text=element_text(size=15),
                   axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15),
legend.title=element_text(size=15))



boxplot(testforplot$Latency ~ testforplot$Instrument)

# Descriptive Statistic table for figure latencytempo

#Table: stat.desc BPM Averag

#boxplotsaverage
summary(jointtest)
testoutlookavg <- round(stat.desc(jointtest[, c("Avg.L1", "Avg.L2", "Avg.L3", "Avg.L4", "Avg.L5")], basic = TRUE, desc = TRUE,
norm = TRUE, p= 0.95), digits = 5) # descriptive statistics
xtable(testoutlookavg)






round(stat.desc(jointtest[, c("group")], basic = TRUE, desc = TRUE, norm = TRUE, p= 0.95), digits = 5) # descriptive statistics



boxplot(testforplot$Latency ~ testforplot$Group)     # Boxplots for the Groups

boxplot(testforplot$Latency ~ testforplot$Sound_Generation)  # plot name: soundgenerbox






boxplot(testforplot$Latency ~ testforplot$Sound_Generation)   #Boxplots for the playing technique

#It is clear no technique is very wide



# Some ggplot Boxplots

#Plot name: groupbox
groupbox <- ggplot(testforplot, mapping=aes(x=Group, y=Latency, fill = Group))+ geom_boxplot(width=0.45, outlier.size = -1, coef
= 0, fatten = NULL)+ylab("Latency (Ld) in milliseconds")+xlab("Instrument group (average of all 3 metronomes)")


groupbox +theme(axis.text=element_text(size=15),
```

```
                 axis.title=element_text(size=15))+ theme(legend.text=element_text(size=13), legend.title=element_text(size=13))




#Plot name: playingtechniquebox
playingtechniquebox <- ggplot(testforplot, mapping=aes(x=Sound_Generation, y=Latency, fill = Group))+geom_boxplot(width=0.3,
outlier.size = -1, coef = 0 , fatten = NULL)+ylab("Latency (Ld) in milliseconds")+ xlab("Sound generation techniques (average of
all 3 metronomes)")

playingtechniquebox+theme(axis.text=element_text(size=11),
                          axis.title=element_text(size=15))+ theme(legend.text=element_text(size=13),
legend.title=element_text(size=13))



#Plot name: boxplotsinst
ggplot(testforplot, mapping=aes(x=Instrument, y=Latency))+geom_boxplot(width=0.35)+ xlab("Instrument (average of all 3
metronomes)") +
  ylab("Latency (Ld) in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))


testforplot
piano <- filter(.data=testforplot, Instrument == "Piano")#, "Violin") #, Instrument == "Alto Saxophone",
                  #Instrument == "Cello", Instrument == "Classic Guitar", Instrument == "Snare Drum",
                  #Instrument == "Triangle", Instrument == "Trombone")


#pianocomparison
ggplot(piano, mapping=aes(x=Tempo, y=Latency, colour= Instrument))+geom_boxplot(aes( ),width=0.35)+ xlab("Instrument (average of
all 3 metronomes)") +
  ylab("Latency in milliseconds")#+facet_wrap(~Participant)

testforplot
piano
  j <- ggplot(testforplot, mapping=aes(x=Tempo, y=Latency, colour = Instrument))+geom_line(size = 0.5,
aes(group=Participant))+geom_point(size=2)+facet_wrap(~Group)




violin <- filter(.data=testforplot, Instrument == "Violin")

#violincomparison
ggplot(violin, mapping=aes(x=Instrument, y=Latency))+geom_boxplot(width=0.35)+ xlab("Instrument (average of all 3 metronomes)") +
  ylab("Latency in milliseconds")+facet_wrap(~Participant)



altosaxophon <- filter(.data=testforplot, Instrument == "Alto Saxophone")


#altosaxophoncomparison
ggplot(altosaxophon, mapping=aes(x=Instrument, y=Latency))+geom_boxplot(width=0.35)+ xlab("Instrument (average of all 3
metronomes)") +
  ylab("Latency in milliseconds")+facet_wrap(~Participant)


cello <- filter(.data=testforplot, Instrument == "Cello")


#cellocomparison
ggplot(cello, mapping=aes(x=Instrument, y=Latency))+geom_boxplot(width=0.35)+ xlab("Instrument (average of all 3 metronomes)") +
  ylab("Latency in milliseconds")+facet_wrap(~Participant)



classicguitar <- filter(.data=testforplot, Instrument == "Classic Guitar")


#classicguitarcomparison
ggplot(classicguitar, mapping=aes(x=Instrument, y=Latency))+geom_boxplot(width=0.35)+ xlab("Instrument (average of all 3
metronomes)") +
  ylab("Latency in milliseconds")+facet_wrap(~Participant)


snaredrum <- filter(.data=testforplot, Instrument == "Snare Drum")


#snaredrumcomparison
ggplot(snaredrum, mapping=aes(x=Instrument, y=Latency))+geom_boxplot(width=0.35)+ xlab("Instrument (average of all 3
metronomes)") +
  ylab("Latency in milliseconds")+facet_wrap(~Participant)



trombone <- filter(.data=testforplot, Instrument == "Trombone")


#trombonecomparison
ggplot(trombone, mapping=aes(x=Instrument, y=Latency))+geom_boxplot(width=0.35)+ xlab("Instrument (average of all 3 metronomes)")
```

```
+
  ylab("Latency in milliseconds")+facet_wrap(~Participant)


triangle <- filter(.data=testforplot, Instrument == "Triangle")


#trianglecomparison
ggplot(triangle, mapping=aes(x=Instrument, y=Latency))+geom_boxplot(width=0.35)+ xlab("Instrument (average of all 3 metronomes)")
+
  ylab("Latency in milliseconds")+facet_wrap(~Participant)


french_horn <- filter(.data=testforplot, Instrument == "French Horn")


#french_horncomparison
ggplot(french_horn, mapping=aes(x=Instrument, y=Latency))+geom_boxplot(width=0.35)+ xlab("Instrument (average of all 3
metronomes)") +
  ylab("Latency in milliseconds")+facet_wrap(~Participant)


tenor_saxophone <- filter(.data=testforplot, Instrument == "Tenor Saxophone")

#tenor_saxophonecomparison
ggplot(tenor_saxophone, mapping=aes(x=Instrument, y=Latency))+geom_boxplot(width=0.35)+ xlab("Instrument (average of all 3
metronomes)") +
  ylab("Latency in milliseconds")+facet_wrap(~Participant)



instequal <- rbind(piano, cello, trombone, triangle, snaredrum, french_horn, tenor_saxophone )



#equalinst
equalinst <- ggplot(instequal, mapping=aes(x=Instrument, y=Latency))+geom_boxplot(width=0.35)+ xlab("Instrument (average of all 3
metronomes)") +
  ylab("Latency (Ld) in milliseconds")+facet_wrap(~Tempo)+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))

equalinst+theme(axis.text=element_text(size=9),
                axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))



instunequal <- rbind(altosaxophon, classicguitar, violin  )

#unequalinst
unequalinst <- ggplot(instunequal, mapping=aes(x=Instrument, y=Latency))+geom_boxplot(width=0.35)+ xlab("Instrument (average of
all 3 metronomes)") +
  ylab("Latency (Ld) in milliseconds")+facet_wrap(~Tempo)+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))


unequalinst+theme(axis.text=element_text(size=9),
       axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))





#Plot name: boxplotsgroups
boxplotsgroups <- ggplot(testforplot, mapping=aes(x=Tempo, y=Latency, fill=
Group))+geom_boxplot(position=position_dodge(width=0.6), width=0.35, outlier.size = -1, coef = 0, fatten = NULL)+ xlab("Tempo in
BPM (average of all 3 metronomes)") +
                   ylab("Latency in milliseconds")

boxplotsgroups+theme(axis.text=element_text(size=15),
                     axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15),
legend.title=element_text(size=15))





#Plot name: boxplotssoundgen
boxplotssoundgen <- ggplot(testforplot, mapping=aes(x=Tempo, y=Latency, fill =
Sound_Generation))+geom_boxplot(position=position_dodge(width=0.8), width=0.5, outlier.size = -1, coef = 0, fatten = NULL)+
xlab("Tempo in BPM (average of all 3 metronomes)") +
  ylab("Latency (Ld) in milliseconds")

boxplotssoundgen+theme(axis.text=element_text(size=15),
       axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))



testforplot
```

```
#############   Cluster Analysis and scatter plots   ###################

#The variables of the jointtest (test values but averaged) are grouped and
#named in a new dataset: clustervar


selectedvar <- c("participant", "m_age","m_metronome_hours", "m_years_experience",
               "m_hours_practice", "Avg.L1",
               "Avg.L2", "Avg.L3", "Avg.L4", "Avg.L5", "instrument", "group",
               "gender", "expertise", "sound_generation", "metronome_preference" )

clustervar <- jointtest[selectedvar]

clustervar
str(clustervar)
#the variables of clustervar are renamed and the new dataset is: clusvar




names(clustervar) <- c("participant", "age", "metronome_hours",
                       "years_experience",  "practice_hours",
                       "90BPM",  "120BPM", "150BPM", "180BPM", "210BPM",
                       "instrument", "group",   "gender", "expertise", "sound_generation",
                         "metronome_preference")


str(clustervar)

#library(plyr)
#clusvar <- rename(clustervar, c("participant" ="participant", "m_age"= "participant","m_metronome_hours" = "metronome_hours",
#                     "m_years_experience" = "years_experience", "m_hours_practice" = "practice_hours",
#                     "Avg.L1" = "90BPM", "Avg.L2" = "120BPM", "Avg.L3" = "150BPM", "Avg.L4" = "180BPM", "Avg.L5" = "210BPM",
#                     "instrument" = "instrument", "group" = "group", "gender" = "gender", "expertise" = "expertise",
"sound_generation" = "sound_generation",
#                     "metronome_preference" = "metronome_preference"))


##Order of the variables for clusvar
## 1 = participant, 2 = age, 3 = metronome_hours, 4 = years_experience
## 5 = practice hours, 6 = 90BPM, 7 = 120BPM, 8 = 150BPM, 9 = 180BPM, 10 = 210BPM,
## 11 = instrument, 12 = group, 13 = gender, 14 = expertise, 15 = sound_generation,
## 16 = metronome_preference

## interesting values 6:10 or 90BPM to 210BPM

clusvar <- clustervar   #data set with average values

str(clusvar)

####################----Relationship Plots for the metronome average  (Scatter Matrix) ------######################

#relall  (1)
relall <- plot(clusvar[2:10], pch = 19,  cex = 0.8,   cex.main=1.5, cex.lab=1.5,cex.axis=1.5, cex.labels=1.15)      # clear
relationship just for the BPM values


#relgender  (2)
relgender <- plot(
                  x= clusvar[6:10],
                  col = as.integer(clusvar$gender),
                  pch = as.integer(clusvar$gender))    # Gender plays no role in latency

#relgroup   (3)
relgroup <- plot(
                 x= clusvar[6:10],
                 col = as.integer(clusvar$group),
                 pch = as.integer(clusvar$group))    #Group plays a role, there are clusters


unique(clusvar$group)          # Group order regarding col:  Chordophones = black, Aerophones =red,
                                                             #Membranophones = green , Idiophones = blue,


#relgroup1 (4)
relgroup1 <- plot(                                     # Group order for the BPM 90 to 150
                 x= clusvar[6:8],
                 col = as.integer(clusvar$group),
                 pch = as.integer(clusvar$group))


#relgroup2  (5)
relgroup2 <- plot(                                      # Group order for the BPM 180 to 210
                 x= clusvar[8:10],
                 col = as.integer(clusvar$group),
                 pch = as.integer(clusvar$group))


#relsoundgen (6)

relsoundgen <- plot(                                            # Relationship regarding sound generation
                   x= clusvar[6:10],                            # there is also a relationship
                   col = as.integer(clusvar$sound_generation),
```

```
                    pch = as.integer(clusvar$sound_generation))  # Problem: which colors are which sound generations


unique(clusvar$sound_generation)



#relsoundgen1 (7)
relsoundgen1 <- plot(
                    x= clusvar[6:8],                               #Sound generation relationship for 90 to 150BPM
                    col = as.integer(clusvar$sound_generation),
                    pch = as.integer(clusvar$sound_generation))


#relsoundgen2 (8)
relsoundgen2 <- plot(                                               #Sound generation relationship for 150 to 210BPM
                    x= clusvar[8:10],
                    col = as.integer(clusvar$sound_generation),
                    pch = as.integer(clusvar$sound_generation))


#relmetpref (9)
relmetpref <- plot(                                                  #Relationship regarding metronome preference
                   x= clusvar[6:10],                                 # No relationship
                   col = as.integer(clusvar$metronome_preference),
                   pch = as.integer(clusvar$metronome_preference))

#relmethour   (10)
relmethour <- plot(                                                 #Relationship regardin the metronome hours
                   x= clusvar[6:10],                                # No relationship
                   col = as.integer(clusvar$metronome_hours),
                   pch = as.integer(clusvar$metronome_hours))

#relyearsexp  (11)
relyearsexp <- plot(
                   x= clusvar[6:10],                                #Relationship regarding the years of experience playing the
instrument
                   col = as.integer(clusvar$years_experience),
                   pch = as.integer(clusvar$years_experience))      #No relationship

#relprachours (12)
relprachours <- plot(
                     x= clusvar[6:10],                              #Relationship regarding the hours of practice of the
instrument
                     col = as.integer(clusvar$practice_hours),
                     pch = as.integer(clusvar$practice_hours))

unique(clusvar$practice_hours)

#######################################
################  to do


legend(
       x ="topleft",
       legend = paste("Color", levels(clusvar$group)))

unique(clusvar$sound_generation)




##color order
##"black"   "red"     "green3"  "blue"    "cyan"    "magenta" "yellow"  "gray"

##############################################################



#####################################################################################################
######################---Relationship Plots for the metronome information without average---#######
#detach("package:dplyr", character.only = TRUE)  #to avoid problems with the function select
#library("dplyr", character.only = TRUE)         #to avoid problems with the function select



selectedvaralt <- c("participant", "instrument", "group", "age", "gender", "metronome_hours", "expertise",
                 "years_experience", "sound_generation", "hours_practice", "metronome_preference",
                 "metronome", "L1", "L2", "L3", "L4", "L5", "other_instrument")

#selectedvaralt = selected variables alternative = the variables of the table test

clustervaralt <- test[selectedvaralt]   # clustervaralt = cluster variables alternative


clustervaralt  # actually is the same as the dataset test with a new name


str(clustervaralt)
str(clustervar)

clustervaralt
str(clustervaralt)
```

```
unique(clustervaralt$group)





#the variables of clustervaralt are renamed and the new dataset is: clusvaralt

sessionInfo()


names(clustervaralt) <- c("participant", "instrument",
                          "group", "age", "gender", "metronome_hours", "expertise",
                          "years_experience", "sound_generation",
                          "practice_hours", "metronome_preference",
                          "metronome", "90BPM", "120BPM", "150BPM",
                          "180BPM", "210BPM", "other instrument")



#library("plyr")
#clusvaralt <- rename(clustervaralt, c("participant" ="participant", "instrument" = "instrument",
#                                       "group" = "group", "age" = "age", "gender" = "gender", "metronome_hours" =
"metronome_hours", "expertise" = "expertise",
#                                       "years_experience" = "years_experience", "sound_generation" = "sound_generation",
#                                       "hours_practice" = "practice_hours", "metronome_preference" = "metronome_preference",
#                                       "metronome" = "metronome", "L1" = "90BPM", "L2" = "120BPM", "L3" = "150BPM",
#                                       "L4" = "180BPM", "L5" = "210BPM", "other_instrument" = "other instrument"))



##Order of the variables for clusvaralt
## 1 = participant, 2 = age, 3 = metronome_hours, 4 = years_experience
## 5 = hours_practice, 6 = 90BPM, 7 = 120BPM, 8 = 150BPM, 9 = 180BPM, 10 = 210BPM,
## 11 = instrument, 12 = group, 13 = gender, 14 = expertise, 15 = sound_generation,
## 16 = metronome_preference, 17 = metronome, 18 = other_instrument

## interesting values 6:10 or 90BPM to 210BPM

clusvaralt <- clustervaralt    #data set with average values

str(clusvaralt)
str(clusvar)


## changing the order of the variables to be the same as in clusvar

clusvaralt <-  clusvaralt[c(1, 4, 6, 8, 10, 13, 14, 15, 16, 17, 2, 3, 5, 7, 9, 11, 12, 18)]

str(clusvaralt)

######################----Relationship Plots   (Scatterplot matrices) ------########################

str(clusvaralt)  ## data set with all values (not averaged)

#alternative to col is possible to use pch = shape instead colors

#relallalt (1)
relallalt <- plot(clusvaralt[2:10], pch = 19,  cex = 0.8,   cex.main=1.5, cex.lab=1.5,cex.axis=1.5, cex.labels=1.15,
cex.labels=1.15,
                  main = "")      # clear relationship just for the BPM values


levels(gender)



# <- plot(                  # Gender plays no role in latency
#                   x= clusvaralt[6:10],
#                   col = as.integer(clusvaralt$gender),
#                   pch = as.integer(clusvaralt$gender))

#relgenderalt
relgenderalt <- ggscatmat(clusvaralt, columns = 6:10, color="gender", alpha=0.9, corMethod = "kendall")

relgenderalt +theme(axis.text=element_text(size=12),
       axis.title=element_text(size=12))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))

#, corMethod = "spearman"

#relgroupalt (3)
relgroupalt <- plot(
                   x= clusvaralt[6:10],
                   col = as.integer(clusvaralt$group),
                   pch = as.integer(clusvaralt$group))    #Group plays a role, there are clusters



unique(clusvaralt$group)
```

```
# Group order regarding col:  Chordophones = black, Aerophones =red,
#Membranophones = green , Idiophones = blue,



relgroup1alt <- plot(                                     # Group order for the BPM 90 to 150
                     x= clusvaralt[6:8],
                     col = as.integer(clusvaralt$group),
                     pch = as.integer(clusvaralt$group))

#relgroup1alt (4)
ggscatmat(clusvaralt, columns = 6:10, color="group", alpha=0.9, corMethod = "kendall")+ theme(axis.text=element_text(size=15),
                                                                                               axis.title=element_text(angle = 45,
size=15)) + theme(legend.text=element_text(size=15),

legend.title=element_text(size=15))






#relgroup2alt (5)
relgroup2alt <- plot(                                      # Group order for the BPM 180 to 210
                     x= clusvaralt[8:10],
                     col = as.integer(clusvaralt$group),
                     pch = as.integer(clusvaralt$group))







#relsoundgenalt  (6)
relsoundgenalt <- plot(                                            # Relationship regarding sound generation
                       x= clusvaralt[6:10],                            # there is also a relationship
                       col = as.integer(clusvaralt$sound_generation),
                       pch = as.integer(clusvaralt$sound_generation))  # Problem: which colors are which sound generations


unique(clusvaralt$sound_generation)




relsoundgen1alt <- plot(
                       x= clusvaralt[6:8],                                  #Sound generation relationship for 90 to 150BPM
                       col = as.integer(clusvaralt$sound_generation),
                       pch = as.integer(clusvaralt$sound_generation))

#relsoundgen1alt  (7)
ggscatmat(clusvaralt, columns = 6:10, color="sound_generation", alpha=0.95, corMethod = "kendall")+
theme(axis.text=element_text(size=15),

axis.title=element_text(angle = 45, size=15)) + theme(legend.text=element_text(size=15),

legend.title=element_text(size=15))


levels(sound_generation)

#relsoundgen2alt  (8)
relsoundgen2alt <- plot(                                               #Sound generation relationship for 150 to 210BPM
                        x= clusvaralt[8:10],
                        col = as.integer(clusvaralt$sound_generation),
                        pch = as.integer(clusvaralt$sound_generation))


#relmetprefalt  (9)
relmetprefalt <- plot(                                                  #Relationship regarding metronome preference
                      x= clusvaralt[6:10],                                 # No relationship
                      col = as.integer(clusvaralt$metronome_preference),
                      pch = as.integer(clusvaralt$metronome_preference))

#relmethouralt    (10)
relmethouralt <- plot(                                                 #Relationship regardin the metronome hours
                      x= clusvaralt[6:10],                                # No relationship
                      col = as.integer(clusvaralt$metronome_hours),
                      pch = as.integer(clusvaralt$metronome_hours))

#relyearsexpalt  (11)
relyearsexpalt <- plot(
                        x= clusvaralt[6:10],                                #Relationship regarding the years of experience
playing the instrument
                        col = as.integer(clusvaralt$years_experience),
                        pch = as.integer(clusvaralt$years_experience))      #No relationship

#relprachoursalt  (12)
relprachoursalt <- plot(
                        x= clusvaralt[6:10],                              #Relationship regarding the hours of practice of the
instrument
```

```
                        col = as.integer(clusvaralt$practice_hours),
                        pch = as.integer(clusvaralt$practice_hours))


###cluster analysis regarding metronomes


relallaltmet<- plot(clusvaralt[6:10],
                    col = as.integer(clusvaralt$metronome),
                    pch = as.integer(clusvaralt$metronome))
#relallaltmet(A)
relallaltmet <- ggscatmat(clusvaralt, columns = 6:10, color="metronome", alpha=0.8, corMethod = "kendall")

relallaltmet+theme(axis.text=element_text(size=12),
                   axis.title=element_text(size=12))+ theme(legend.text=element_text(size=15),
legend.title=element_text(size=15))




#relallaltmet1  (B)
relallaltmet1<- plot(clusvaralt[6:8],
                   col = as.integer(clusvaralt$metronome),
                   pch = as.integer(clusvaralt$metronome))

#relallaltmet2  (C)
relallaltmet2<- plot(clusvaralt[8:10],
                  col = as.integer(clusvaralt$metronome),
                  pch = as.integer(clusvaralt$metronome))



############ Bar plots descriptive statistic  #################################################

# Data set used is clusvar. It means that the three metronomes were averaged. Ohterwise the frequency plots and bar plots
# are 3 times bigger


par(mfrow=c(1,1))

# groupbar  attention: here clustervar is used because of average of the three metronomes
plot(clustervar$group,  xlab = "Instrument groups",
     ylab = "Number of test subjects")

# soundgenbar
plot(clustervar$sound_generation,  xlab = "Instrument sound generation",
     ylab = "Number of test subjects")


#groupsoundbar
groupsoundbar <- ggplot(clustervar, aes(x= group, fill =sound_generation))+geom_bar() + xlab( "Musical instruments groups") +
ylab("Number of test subjects")

groupsoundbar+theme(axis.text=element_text(size=15),
       axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))



# agehisto
agehisto <- hist(clustervar$age,  xlab = "Age", #labels = TRUE,
     ylab = "Number of test subjects",
     col="darkgray", breaks = 50,
     main = '')

#agegender
agegender <- ggplot(clustervar, aes(age, fill = gender, colour = expertise))+geom_histogram(hape = expertise,binwidth =
0.49)+xlim (16,58)+
        xlab("Age") + ylab("Number of test subjects")+ scale_fill_manual(values = c("Male" = "blue", "Female" = "red")) +
       scale_colour_manual(values = c("Professional" = "cyan", "Student" = "black"))

agegender

agegender + theme( axis.line = element_line(colour = "darkblue",
                                    size = 1, linetype = "solid"))

agegender + theme(axis.text.x = element_text( color="black",     ################ face= "bold"
                                     size=15, angle=0),
                  axis.text.y = element_text(color="black",
                                             size=15, angle=0))

agegender+theme(axis.text=element_text(size=15),
                axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))

####face="bold"  or face="italic"


#darkblue, cyan, black, red

#otherinst
otherinst <- ggplot(jointtest, mapping=aes(x=other_instruments, fill = instrument))+geom_bar( width = 0.4)+
  xlab("Additional instrument performed")+ ylab("Number of test subjects")

otherinst+theme(axis.text=element_text(size=13),
```

```
                axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))



plot(clustervar$gender,  xlab = "Gender",
     ylab = "Number of test subjects")




# genderbar
ggplot(clustervar, aes(x= gender))+geom_bar() + ylab("Number of test subjects")




plot(clustervar$metronome_preference,  xlab = "Metronome preference",
     ylab = "Number of test subjects")


#prefmetbar
prefmetbar <- ggplot(clustervar, aes(metronome_preference, fill = group)) + geom_bar() + xlab( "Metronome prefernce") +
       ylab("Number of test subjects")

prefmetbar+theme(axis.text=element_text(size=15),
                 axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))



clustervar

#otherinstbar
plot(clustervar$other_instrument,  xlab = "Instrument sound generation",  #it does not work. It has to be
     ylab = "Number of test subjects")                                    #converted to factores (every instrument)


################################################################################
############################ Correlation only numerical #####################################

str(clustervaralt)

cor(clustervaralt[, c("age", "metronome_hours", "years_experience", "practice_hours")])

cor(clustervaralt[, c( "90BPM", "120BPM", "150BPM", "180BPM", "210BPM")], use = "complete.obs")  #, method = "pearson" default

#Matrix with the tempi average
str(clustervar)

cor(clustervar[, c("age", "metronome_hours", "years_experience", "practice_hours")])

cor(clustervar[, c(  "90BPM", "120BPM", "150BPM", "180BPM", "210BPM")], use = "complete.obs")

#############################################################################################
############################ Correlation Matrix Plot for different variables

#install.packages("GGally")

#library("GGally")


# changing the names of clusvaralt to fit the correlation plot

clusvaralt


names(clusvaralt) <- c("participant", "age", "metro hrs.",
                       "years_exp.", "hours_prac.","90BPM", "120BPM",
                       "150BPM",  "180BPM", "210BPM")


clusvaraltname <- clusvaralt


#clusvaraltname <- rename(clusvaralt, c("participant"="participant", "age"="age", "metronome_hours" = "metro hrs.",
#                                        "years_experience" = "years_exp.", "practice_hours" = "hours_prac.", "90BPM" = "90BPM",
"120BPM" = "120BPM",
#                                        "150BPM"= "150BPM", "180BPM" = "180BPM", "210BPM" = "210BPM"  ))

#summary correlation plot for all numerical variables. Spearman correlation for non-normal distribution
# four possibilities everything = NA would result in NA correlation, pairwise, complete = eliminates NA, all.obs = error by
missing values
#choice = complete
cpnv <- ggcorr(clusvaraltname[, 2:10], hjust = 0.75, size = 7, method = c("complete", "kendall"), palette = "RdBu", label = TRUE,
label_size = 8) #Correlation matrix Plot for latency values



#cormatplotnumvar
cpnv +theme(axis.text=element_text(size=15),
            axis.title=element_text(size=1))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))
```

```
names(clusvaralt) <- c("participant", "age", "metronome_hours.",
                       "years_expierence", "practice_hours","90BPM", "120BPM",
                       "150BPM",  "180BPM", "210BPM")


# correlation matrix plot for age, metronome_hours, years_experience and practice_hours
#method choice spearman complete
cpls <- ggcorr(clusvaralt[, 2:5], hjust = 0.75, size = 7, method = c("complete", "kendall"), palette = "RdBu", label = TRUE,
label_size = 10) #Correlation matrix Plot for test subject information

#cormatplotsub
cpls+theme(axis.text=element_text(size=15),
           axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))




# correlation matrix plot for the latency values
#method = complete pearson
cpl <- ggcorr(clusvaralt[, 6:10], hjust = 0.75, size = 7, method = c("complete", "kendall"), palette = "RdBu", label = TRUE,
label_size = 11) #Correlation matrix Plot for latency values

#cormatplotlat
cpl+theme(axis.text=element_text(size=15),
          axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))


###### Correlations with linear regression


# Correlation plot without linear regression
ggpairs(clusvaralt[, 6:10])

# Correlation plot without linear regression
ggpairs(clusvaralt[, 6:10], lower=list(continuous= wrap(ggally_points, size = 1, color = "red")))


#Correlation matrix plot for latency values
#First a function is defined. The linear method used is lm
regfunction <- function(data, mapping, method="lm", ...){      #method could be lm (linear) or loess (segmented linear)
  p <- ggplot(data = data, mapping = mapping) +
    geom_point(colour = "blue")+
    geom_smooth(method=method, colour = "red", ...)
  p
}

#The plot with linear regression
cpll <- ggpairs(clusvaralt[, 6:10], lower = list(continuous = regfunction),    #Density plots
        #diag = list(continuous = wrap("barDiag", colour = "blue")),      #it can be activated to display a distribution plot in
the diagonal
        upper = list(continuous = wrap("cor", method = "kendall", size = 6)))


#cormatplotlatlin
cpll+theme(axis.text=element_text(size=15),
           axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))
+theme(panel.grid.major = element_blank())





#################################################################################


#Statistical Model Linear regression for 90Bpm bis 210BPM for average values -----------------------------------
# only to compare if the plots are right
#First I make 6 different windows for the plots


par(mfrow=c(2,3))


#Scatter Plot

plot(
  x = jointtest$m_years_experience,
  y = jointtest$Avg.L1,
  main = "Years of Experience vs. Latency 90BPM",
  xlab = "Years of Experience playing the instrument",
  ylab = "Latency 90BPM")



plot(
  x = jointtest$m_years_experience,
  y = jointtest$Avg.L2,
  main = "Years of Experience vs. Latency 120BPM",
  xlab = "Years of Experience playing the instrument",
  ylab = "Latency 120BPM")
```

```
plot(
  x = jointtest$m_years_experience,
  y = jointtest$Avg.L3,
  main = "Years of Experience vs. Latency 150BPM",
  xlab = "Years of Experience playing the instrument",
  ylab = "Latency 150BPM")

plot(
  x = jointtest$m_years_experience,
  y = jointtest$Avg.L4,
  main = "Years of Experience vs. Latency 180BPM",
  xlab = "Years of Experience playing the instrument",
  ylab = "Latency 180BPM")

plot(
  x = jointtest$m_years_experience,
  y = jointtest$Avg.L5,
  main = "Years of Experience vs. Latency 210BPM",
  xlab = "Years of Experience playing the instrument",
  ylab = "Latency 210BPM")



#However, there is not a observable relation
##############################################################################################
#Alternative Cluster using kmeans ##########################################################

plot(
  x = clustervaralt$L3,
  y = clustervaralt$L4,
  col = as.numeric(clusvaralt$group))


uu <- jointtest$Avg.L1  # 90BPM values
vv <- jointtest$Avg.L2  # 120BPM values
nn <- jointtest$Avg.L3  # 150BPM values
mm <- jointtest$Avg.L4  # 180BPM values
kk <- jointtest$Avg.L5  # 210BPM values

Ttotalu <- c(uu,vv,nn,mm,kk)

uu

kk



Ttotal

tryu <- kmeans(na.omit(uu),4)
tryv <- kmeans(na.omit(vv),4)
tryn <- kmeans(na.omit(nn),4)
trym <- kmeans(na.omit(mm),4)
tryk <- kmeans(na.omit(kk),4)

tryu
tryv
tryn
trym
tryk

try
try$size

try$cluster

clusvaralt$sound_generation

table(clusvaralt$sound_generation, try$cluster)

####################################################
```

```
# Author: Jorge Medina Victoria
# A Method for the Measurement of the Ability of Western Musicians to Cope with Latency
# Metronome Data
# Date: 06.11.18

# If you are using this code for the first time, please install all the packages by deleting # in front of the
package'Setting Directory in Session/set directory'

head(test) #looking for general information of the test
head(avgtest) # the other testframe

library(dplyr)  #callin library dplyr'


#convert and label the test

gender<-factor("gender", levels=c(1:2), labels=c("Male", "Female")) #convert gender numbers 1 and 2 into
#Male and Female

test$gender <- as.factor(test$gender)   #VERY IMPORTANT---> I converted it to a factor otherwise is just a num

class("gender")  #labels of the variable gender
gender # levels of the variable----> Male and Female

str(test)

expertise<-factor("expertise", levels=c(1:2), labels=c("Musician", "Student"))
#convert expertise numbers 1 and 2 into Professional Musician and Music Student

test$expertise <- as.factor(test$expertise)

expertise

str(test)

#Grouping the different soundgeneration techniques

sound_generation<-factor("sound_generation", levels=c(0:7), labels=c("I. Struck", "M. Struck", "C. Bowed",
                                                                     "C. Struck", "C. Plucked", "A. Mechanical_reed",
"A. Air_reed", "A. Lip_reed"))

test$sound_generation <- as.factor(test$sound_generation)

sound_generation

str(test)

group<-factor("group", levels=c(1:4), labels=c("Chordophones", "Aerophones", "Membranophones",
                                               "Idiophones"))
#convert group number 1,2,3 and 4 into groups 1=Chordophones, 2= Aerophones, 3= Membranophones
#and 4= Idiophones

test$group <- as.factor(test$group)

group

metronome<-factor("metronome", levels=c(1:3), labels=c("Aural", "Visual", "Both"))


test$metronome <- as.factor(test$metronome)


metronome_preference<-factor("metronome_preference", levels=c(1:3), labels=c("Aural", "Visual", "Both"))


test$metronome_preference <- as.factor(test$metronome_preference)

#different levels within some of the variables
levels(group)
levels(sound_generation)
levels(gender)
levels(expertise)
levels(metronome)
levels(metronome_preference)

summary(test)


test$"90BPM"<- as.numeric(as.character(test$"90BPM"))
test$"120BPM"<- as.numeric(as.character(test$"120BPM"))  #conversion of variable 120BPM from chr to num. It was chr
str(test)                                                #because 2 variables were NA. The same operation wered
test$"150BPM"<- as.numeric(as.character(test$"150BPM"))  #efectuated in the variable 150BPM
test$"180BPM"<- as.numeric(as.character(test$"180BPM"))
test$"210BPM"<- as.numeric(as.character(test$"210BPM"))
```

```
#ATTENTION: participant should be int not dbl (integer not double)
#I converted participant to int. it should be made with all the other integer values i.e. metronome expertise, etc

str(test)



test$participant<- as.integer(as.numeric(test$"participant"))

typeof(test)
str(test)
summary(test)
head(test)





################################

#-------------Filtering by Metronome

summary(test)
library(dplyr)
audiotest <- filter(test, metronome == 'Aural')

audiotest

#write as a csv file with the name avg_test.csv
write.csv(
  x=audiotest,
  file='audiotest.csv',
  row.names = FALSE) #FALSE The unique ID won't be overwrite

videotest <- filter(test, metronome == "Visual")

videotest

#write as a csv file with the name avg_test.csv
write.csv(
  x=videotest,
  file='videotest.csv',
  row.names = FALSE) #FALSE The unique ID won't be overwrite

bothtest <- filter(test, metronome == 'Both')

bothtest

#write as a csv file with the name avg_test.csv
write.csv(
  x=bothtest,
  file='bothtest.csv',
  row.names = FALSE) #FALSE The unique ID won't be overwrite

#########################################

#-----------------------------------------------------------------PLOTS  FOR  Different Metronomes
#---------------------------------------------------------


library(ggplot2)

audiotest


str(audiotest)

#Merging Information for the display with ggplot

library(reshape2) # to use function melt'

#information is in the wide format, it has to be converted to the long or molten format using melt (library reshape)

audiotestplot <- melt(audiotest, id=c("participant", "instrument", "group", "age", "gender",
                                      "metronome_hours", "expertise", "years_experience", "sound_generation",
                                      "hours_practice", "other_instruments", "metronome_preference", "metronome"))



audiotestplot

audiotestplot  # the information has 3 columns: participant, variable and value
#participant goes from 1 to 9
#variable are the 6 different variables (instrument, 90BPM, 120BPM, 150BPM, 180BPM and 210 BPM)
#value is the value assigned to each variable
```

```
names(audiotestplot)<-c("Participant", "Instrument", "Group", "Age", "Gender",
                      "Metronome_Hours", "Expertise", "Years_Experience", "Sound_Generation",
                      "Hours_Practice", "Other_Instrument", "Metronome_Preference", "Metronome",
                      "Tempo", "Latency")
audiotestplot

ggplot(audiotestplot, mapping=aes(x=Tempo, y=Latency))+geom_line(aes(group=Participant))+ xlab("Tempo in BPM (aural
metronome)") +
  ylab("Latency in milliseconds")

ggplot(audiotestplot, mapping=aes(x=Tempo, y=Latency,
colour=Sound_Generation))+geom_line(aes(group=Participant))+geom_point(size=2)+facet_wrap(~Sound_Generation)+
xlab("Tempo in BPM (aural metronome)") +
  ylab("Latency in milliseconds")



a <- ggplot(audiotestplot, mapping=aes(x=Tempo, y=Latency,
colour=Instrument))+geom_line(aes(group=Participant))+geom_point(size=2)+facet_wrap(~Instrument)+ xlab("Tempo in BPM
(aural metronome)") +
         ylab("Latency in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))


a   # audiotestplot by instruments

audiotestplot



#Videotestplot-----

str(videotest)


videotestplot <- melt(videotest, id=c("participant", "instrument", "group", "age", "gender",
                                      "metronome_hours", "expertise", "years_experience", "sound_generation",
                                      "hours_practice", "other_instruments", "metronome_preference", "metronome"))



videotestplot

videotestplot  # the information has 3 columns: participant, variable and value
#participant goes from 1 to 9
#variable are the 6 different variables (instrument, 90BPM, 120BPM, 150BPM, 180BPM and 210 BPM)
#value is the value assigned to each variable

names(videotestplot)<-c("Participant", "Instrument", "Group", "Age", "Gender",
                        "Metronome_Hours", "Expertise", "Years_Experience", "Sound_Generation",
                        "Hours_Practice", "Other_Instrument", "Metronome_Preference", "Metronome",
                        "Tempo", "Latency")
videotestplot

ggplot(videotestplot, mapping=aes(x=Tempo, y=Latency))+geom_line(aes(group=Participant), na.rm=TRUE)+ xlab("Tempo in
BPM (visual metronome)") +
  ylab("Latency in milliseconds")

ggplot(videotestplot, mapping=aes(x=Tempo, y=Latency, colour=Sound_Generation))+geom_line(aes(group=Participant),
na.rm=TRUE)+geom_point(size=2, na.rm=TRUE)+facet_wrap(~Sound_Generation)+xlab("Tempo in BPM (visual metronome)") +
  ylab("Latency in milliseconds")



b <- ggplot(videotestplot, mapping=aes(x=Tempo, y=Latency, colour=Instrument))+geom_line(aes(group=Participant),
na.rm=TRUE)+geom_point(size=2, na.rm=TRUE)+facet_wrap(~Instrument)+ xlab("Tempo in BPM (visual metronome)") +
       ylab("Latency in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))


b  # videotestplot by Instruments

videotestplot


#Bothtestplot

bothtestplot <- melt(bothtest, id=c("participant", "instrument", "group", "age", "gender",
                                      "metronome_hours", "expertise", "years_experience", "sound_generation",
                                      "hours_practice", "other_instruments", "metronome_preference", "metronome"))



bothtestplot

bothtestplot  # the information has 3 columns: participant, variable and value
```

```
#participant goes from 1 to 9
#variable are the 6 different variables (instrument, 90BPM, 120BPM, 150BPM, 180BPM and 210 BPM)
#value is the value assigned to each variable

names(bothtestplot)<-c("Participant", "Instrument", "Group", "Age", "Gender",
                        "Metronome_Hours", "Expertise", "Years_Experience", "Sound_Generation",
                        "Hours_Practice", "Other_Instrument", "Metronome_Preference", "Metronome",
                        "Tempo", "Latency")
bothtestplot

ggplot(bothtestplot, mapping=aes(x=Tempo, y=Latency))+geom_line(aes(group=Participant))+xlab("Tempo in BPM (aural &
visual metronome)") +
  ylab("Latency in milliseconds")

ggplot(bothtestplot, mapping=aes(x=Tempo, y=Latency,
colour=Sound_Generation))+geom_line(aes(group=Participant))+geom_point(size=2,
na.rm=TRUE)+facet_wrap(~Sound_Generation)+xlab("Tempo in BPM (Aural & Visual Metronome)") +
  ylab("Latency in milliseconds")




c <- ggplot(bothtestplot, mapping=aes(x=Tempo, y=Latency,
colour=Instrument))+geom_line(aes(group=Participant))+geom_point(size=2, na.rm=TRUE)+facet_wrap(~Instrument)+
xlab("Tempo in BPM (Aural & Visual Metronome)") +
        ylab("Latency in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))


c  # bothtestplot by Instruments

bothtestplot


#plot: metraural
a  # audiotestplot by Instruments

#plot: metrovisual
b  # videotestplot by Instruments

#plot:metroboth
c  # bothtestplot by Instruments

d <- ggplot(bothtestplot, mapping=aes(x=Tempo, y=Latency, colour=Instrument))+geom_line(aes(group=Participant),
na.rm=TRUE)+geom_point(size=2, na.rm=TRUE)+ xlab("Tempo in BPM") +
       ylab("Latency in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))

e <-ggplot(audiotestplot, mapping=aes(x=Tempo, y=Latency, colour=Instrument))+geom_line(aes(group=Participant),
na.rm=TRUE)+geom_point(size=2, na.rm=TRUE)+ xlab("Tempo in BPM") +
      ylab("Latency in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))

f <- ggplot(videotestplot, mapping=aes(x=Tempo, y=Latency, colour=Instrument))+geom_line(aes(group=Participant),
na.rm=TRUE)+geom_point(size=2, na.rm=TRUE)+ xlab("Tempo in BPM") +
       ylab("Latency in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))


d + xlab("Tempo in BPM (Aural Metronome)") + ylab("Latency in milliseconds")  # Tempo Vs. Latency Audio metronome
e + xlab("Tempo in BPM (Visual Metronome)") +ylab("Latency in milliseconds") # Tempo Vs. Latency Video metronome
f + xlab("Tempo in BPM (Aural & Visual Metronome)") + ylab("Latency in milliseconds")# Tempo Vs. Latency Both
metronome


#############################  PLOTS BY GROUPS   ############################################


g <- ggplot(audiotestplot, mapping=aes(x=Tempo, y=Latency,
colour=Instrument))+geom_line(aes(group=Participant))+geom_point(size=2)+facet_wrap(~Group)+ xlab("Tempo in BPM") +
  ylab("Latency in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))


h <- ggplot(videotestplot, mapping=aes(x=Tempo, y=Latency,
colour=Instrument))+geom_line(aes(group=Participant))+geom_point(size=2)+facet_wrap(~Group)+ xlab("Tempo in BPM") +
  ylab("Latency in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))

i <- ggplot(bothtestplot, mapping=aes(x=Tempo, y=Latency,
colour=Instrument))+geom_line(aes(group=Participant))+geom_point(size=2)+facet_wrap(~Group)+ xlab("Tempo in BPM") +
  ylab("Latency in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))


#plot: groupmetraural
g + xlab("Tempo in BPM (Aural Metronome)") + ylab("Latency in milliseconds")

#plot: groupmetrovisual
h + xlab("Tempo in BPM (Visual Metronome)") + ylab("Latency in milliseconds")

#plot: groupmetroboth
```

```
i + xlab("Tempo in BPM (Aural & Visual Metronome)") + ylab("Latency in milliseconds")


audiotestplot



##---------------BOXPLOTS ACOORDING TO EACH METRONOME-----------------------------------------


#Boxplot for Audio Metronome

j <- ggplot(audiotestplot, mapping=aes(x=Tempo, y=Latency, colour= Group))+geom_boxplot() + xlab("Tempo in BPM (aural
metronome)") + ylab("Latency in milliseconds")

j

#Boxplot for Video Metronome

k <- ggplot(videotestplot, mapping=aes(x=Tempo, y=Latency, colour= Group))+geom_boxplot() + xlab("Tempo in BPM
(visual metronome)") + ylab("Latency in milliseconds")

k

#Boxplot for Audio & Viceo Metronomes

l <- ggplot(bothtestplot, mapping=aes(x=Tempo, y=Latency, colour= Group))+geom_boxplot() + xlab("Tempo in BPM (aural
& visual Metronome)") + ylab("Latency in milliseconds")

l


###-----Regarding Sound Generation Techniques------------------------------

m <- ggplot(audiotestplot, mapping=aes(x=Tempo, y=Latency,
colour=Sound_Generation))+geom_line(aes(group=Participant))+geom_point(size=2)+facet_wrap(~Sound_Generation)+
xlab("Tempo in BPM (aural metronome)") +
  ylab("Latency in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))


m

n <- ggplot(videotestplot, mapping=aes(x=Tempo, y=Latency,
colour=Sound_Generation))+geom_line(aes(group=Participant))+geom_point(size=2)+facet_wrap(~Sound_Generation)+
xlab("Tempo in BPM (visual metronome)") +
  ylab("Latency in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))


n

o <- ggplot(bothtestplot, mapping=aes(x=Tempo, y=Latency,
colour=Sound_Generation))+geom_line(aes(group=Participant))+geom_point(size=2)+facet_wrap(~Sound_Generation)+
xlab("Tempo in BPM (aural & visual metronome)") +
  ylab("Latency in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))


o



#plot: genmetraural
m

#plot: genmetrovisual
n

#plot: genmetroboth
o


## Sound Generation Box plots


p <- ggplot(audiotestplot, mapping=aes(x=Tempo, y=Latency, colour= Sound_Generation))+geom_boxplot() + xlab("Tempo in
BPM (aural metronome)") + ylab("Latency in milliseconds")

p

q <- ggplot(videotestplot, mapping=aes(x=Tempo, y=Latency, colour= Sound_Generation))+geom_boxplot() + xlab("Tempo in
BPM (visual metronome)") + ylab("Latency in milliseconds")

q

r <- ggplot(bothtestplot, mapping=aes(x=Tempo, y=Latency, colour= Sound_Generation))+geom_boxplot() + xlab("Tempo in
BPM (aural & visual metronome)") + ylab("Latency in milliseconds")
```

```
r


p
q
r

##############################Average of the 3 different metronomes for each
instrument##############################################
detach("package:dplyr", character.only = TRUE)  #to avoid problems with the function select
library("dplyr", character.only = TRUE)         #to avoid problems with the function select

head(test)


names(test)<-c("participant","instrument", "group", "age", "gender", "metronome_hours",       #other_avgtest
               "expertise", "years_experience", "sound_generation",
               "hours_practice", "other_instrument", "metronome_preference",
               "metronome", "L1", "L2", "L3", "L4", "L5")

metronomes <- test %>%
  select( instrument, metronome,
          L1, L2, L3, L4, L5) %>%
  group_by(metronome, instrument) %>%
  summarize(
    Avg.L1 = mean(L1, na.rm=TRUE), Avg.L2 = mean(L2, na.rm=TRUE),
    Avg.L3 = mean(L3, na.rm=TRUE), Avg.L4 = mean(L4, na.rm=TRUE),
    Avg.L5 = mean(L5, na.rm=TRUE)) %>%


  as.data.frame()  # I set it as a test frame

metronomes






names(metronomes) <- c("Metronome", "Instrument", "90BPM", "120BPM", "150BPM", "180BPM", "210BPM")
metronomes




library(reshape2)

avgmetronomes <- melt(metronomes, id=c("Metronome", "Instrument"))

avgmetronomes


names(avgmetronomes)<-c("Metronome", "Instrument", "Tempo", "Latency")
avgmetronomes



yy <- ggplot(avgmetronomes, mapping=aes(x=Tempo, y=Latency,
colour=Metronome))+geom_line(aes(group=Metronome))+geom_point(size=2) +facet_wrap(~Instrument)+ xlab("Tempo in BPM
(average within instruments)") +
  ylab("Latency (Ld) in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))

#plot: avgmetroinst
yy+theme(axis.text=element_text(size=9),
         axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15),
legend.title=element_text(size=15))






##################################Average of the 3 different metronomes for all instruments
detach("package:dplyr", character.only = TRUE)  #to avoid problems with the function select
library("dplyr", character.only = TRUE)         #to avoid problems with the function select

metronomesall <- test %>%
  select( metronome,
          L1, L2, L3, L4, L5) %>%
  group_by(metronome) %>%
  summarize(
    Avg.L1 = mean(L1, na.rm=TRUE), Avg.L2 = mean(L2, na.rm=TRUE),
    Avg.L3 = mean(L3, na.rm=TRUE), Avg.L4 = mean(L4, na.rm=TRUE),
    Avg.L5 = mean(L5, na.rm=TRUE)) %>%
```

```
  as.data.frame()  # I set it as a test frame

metronomesall






names(metronomesall) <- c("Metronome", "90BPM", "120BPM", "150BPM", "180BPM", "210BPM")
metronomesall




library(reshape2)

avgmetronomesall <- melt(metronomesall, id=c("Metronome"))

avgmetronomesall


names(avgmetronomesall)<-c("Metronome", "Tempo", "Latency")
avgmetronomesall



xx <- ggplot(avgmetronomesall, mapping=aes(x=Tempo, y=Latency,
colour=Metronome))+geom_line(aes(group=Metronome))+geom_point(size=2)+ xlab("Tempo in BPM (average of all
instruments)") +
  ylab("Latency (Ld) in milliseconds") + ylim (0, 300)


#plot: avgmetroall
xx+theme(axis.text=element_text(size=15),
         axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15),
legend.title=element_text(size=15))
```

```
# Author: Jorge Medina Victoria
# A Method for the Measurement of the Ability of Western Musicians to Cope with Latency
# Hypothesis Testing
# Date: 06.11.18

# If you are using this code for the first time, please install all the packages by deleting # in front of the
package


#1 Defining Libraries

'Setting Directory in Session/set directory'

head(test) #looking for general information of the test


#install.packages("dplyr")

library(dplyr)  #callin library dplyr'

#install.packages("ggplot2)

library(ggplot2)

#instal.packages("reshape")
library(reshape2)

#install.packages("pastecs")
library(pastecs)

#install.packages("moments")
library(moments)

#install.packages("pgirmess")   ### pgirmess packet for friedmanmc
library(pgirmess)


#install.packages("PMCMR")
library(PMCMR)

#install.packages("agricolae")
library(agricolae)

#install.packages("scales")
#install.packages("tibble")
#install.packages("NSM3")
library(NSM3)

#instal..packages("xtable")
library(xtable)

#2 Converting, Labeling and Averaging


#convert and label the test

gender<-factor("gender", levels=c(1:2), labels=c("Male", "Female")) #convert gender numbers 1 and 2 into
#Male and Female

test$gender <- as.factor(test$gender)   #VERY IMPORTANT---> I converted it to a factor otherwise is just a num

class("gender")  #labels of the variable gender
gender # levels of the variable----> Male and Female

str(test)

expertise<-factor("expertise", levels=c(1:2), labels=c("Musician", "Student"))
#convert expertise numbers 1 and 2 into Professional Musician and Music Student

test$expertise <- as.factor(test$expertise)

expertise

str(test)

#Grouping the different soundgeneration techniques

sound_generation<-factor("sound_generation", levels=c(0:7), labels=c("I. Struck", "M. Struck", "C. Bowed",
                                                                     "C. Struck", "C. Plucked", "A. Mechanical_reed",
"A. Air_reed", "A. Lip_reed"))

test$sound_generation <- as.factor(test$sound_generation)

sound_generation
```

```
str(test)

group<-factor("group", levels=c(1:4), labels=c("Chordophones", "Aerophones", "Membranophones",
                                               "Idiophones"))
#convert group number 1,2,3 and 4 into groups 1=Chordophones, 2= Aerophones, 3= Membranophones
#and 4= Idiophones

test$group <- as.factor(test$group)

group


metronome<-factor("metronome", levels=c(1:3), labels=c("Aural", "Visual", "Both"))


test$metronome <- as.factor(test$metronome)


metronome_preference<-factor("metronome_preference", levels=c(1:3), labels=c("Aural", "Visual", "Both"))


test$metronome_preference <- as.factor(test$metronome_preference)

#different levels within some of the variables
levels(group)
levels(sound_generation)
levels(gender)
levels(expertise)
levels(metronome)
levels(metronome_preference)


##---------------------------------------Converting Character variables to numerical-----------------------------


test$"90BPM"<- as.numeric(as.character(test$"90BPM"))
test$"120BPM"<- as.numeric(as.character(test$"120BPM"))  #conversion of variable 120BPM from chr to num. It was chr
#because 2 variables were NA. The same operation wered
test$"150BPM"<- as.numeric(as.character(test$"150BPM"))  #efectuated in the variable 150BPM
test$"180BPM"<- as.numeric(as.character(test$"180BPM"))
test$"210BPM"<- as.numeric(as.character(test$"210BPM"))

#ATTENTION: participant should be int not dbl (integer not double)
#I converted participant to int. it should be made with all the other integer values i.e. metronome expertise, etc

str(test)   # All latency variables should be numerical

test$participant<- as.integer(as.numeric(test$"participant"))

typeof(test)
str(test)
summary(test)
head(test)




#--------------------------------/////////////   Averaging the three different metronome measures--------------------
--
detach("package:dplyr", character.only = TRUE)  #to avoid problems with the function select
library("dplyr", character.only = TRUE)         #to avoid problems with the function select

head(test)


names(test)<-c("participant","instrument", "group", "age", "gender", "metronome_hours",
               "expertise", "years_experience", "playing_technique",
               "hours_practice", "other_avgtest", "metronome_preference",
               "metronome", "L1", "L2", "L3", "L4", "L5")

testble <- test %>%
  select(participant, age, metronome_hours,
         years_experience, hours_practice,
         L1, L2, L3, L4, L5) %>%
  group_by(participant) %>%
  summarize( m_age = mean(age), m_metronome_hours=mean(metronome_hours),
             m_years_experience = mean(years_experience),
             m_hours_practice = mean(hours_practice),
             Avg.L1 = mean(L1, na.rm=TRUE), Avg.L2 = mean(L2, na.rm=TRUE),
             Avg.L3 = mean(L3, na.rm=TRUE), Avg.L4 = mean(L4, na.rm=TRUE),
             Avg.L5 = mean(L5, na.rm=TRUE)) %>%


  as.data.frame()  # I set it as a test frame
```

```
testble   # Average of the 5 different metronomes for all participants



##################### AEROPHONES AVG  revisar

names(test)<-c("participant","instrument", "group", "age", "gender", "metronome_hours",      #other_avgtest
               "expertise", "years_experience", "sound_generation",
               "hours_practice", "other_instrument", "metronome_preference",
               "metronome", "L1", "L2", "L3", "L4", "L5")

aerophonesavg <- test %>%
  select(participant, group,
         L1, L2, L3, L4, L5) %>%
  group_by(participant, group == "Aerophones") %>%
  summarize(
    Avg.L1 = mean(L1, na.rm=TRUE), Avg.L2 = mean(L2, na.rm=TRUE),
    Avg.L3 = mean(L3, na.rm=TRUE), Avg.L4 = mean(L4, na.rm=TRUE),
    Avg.L5 = mean(L5, na.rm=TRUE)) %>%


  as.data.frame()  # I set it as a test frame



aerophonesavg

#lista aerophones
listaerophonesavg <- aerophonesavg [ c(6,7,9,14,15,17,20,24,27,30, 31), ]

listaerophonesavg



###### Inverse the matrix for the instruments   ##### Friedmantest for Aerophones

aerophonesavginv <- t(listaerophonesavg)
aerophonesavginv

aerophonesavginv1 <- na.omit(aerophonesavginv)
aerophonesavginv1

xtable(aerophonesavginv1)

friedman.test(as.matrix(aerophonesavginv1))
friedmanmc(as.matrix(aerophonesavginv1))
#The results means, there is no relevant difference within the aerophones group

####################################################################
names(test)<-c("participant","instrument", "group", "age", "gender", "metronome_hours",      #other_avgtest
               "expertise", "years_experience", "sound_generation",
               "hours_practice", "other_instrument", "metronome_preference",
               "metronome", "L1", "L2", "L3", "L4", "L5")

chordophonesavg <- test %>%
  select(participant, group,
         L1, L2, L3, L4, L5) %>%
  group_by(participant, group == "Chordophones") %>%
  summarize(
    Avg.L1 = mean(L1, na.rm=TRUE), Avg.L2 = mean(L2, na.rm=TRUE),
    Avg.L3 = mean(L3, na.rm=TRUE), Avg.L4 = mean(L4, na.rm=TRUE),
    Avg.L5 = mean(L5, na.rm=TRUE)) %>%


  as.data.frame()  # I set it as a test frame



chordophonesavg

#lista cordophones

listacordophonesavg <- chordophonesavg [ c(1,2,3,4,5,8,11,13,18,21,22, 28, 29), ]

listacordophonesavg



###### Inverse the matrix for the instruments   ##### Friedmantest for Chordophones
chordophonesavginv <- t(listacordophonesavg)
chordophonesavginv

chordophonesavginv1 <- na.omit(chordophonesavginv)
chordophonesavginv1
```

```
xtable(chordophonesavginv1)

friedman.test(as.matrix(chordophonesavginv1))
friedmanmc(as.matrix(chordophonesavginv1))


#The results means, there are relevant differences within the chordophones group


#####################################################################
names(test)<-c("participant","instrument", "group", "age", "gender", "metronome_hours",      #other_avgtest
               "expertise", "years_experience", "sound_generation",
               "hours_practice", "other_instrument", "metronome_preference",
               "metronome", "L1", "L2", "L3", "L4", "L5")

membranophonesavg <- test %>%
  select(participant, group,
         L1, L2, L3, L4, L5) %>%
  group_by(participant, group == "Membranophones") %>%
  summarize(
    Avg.L1 = mean(L1, na.rm=TRUE), Avg.L2 = mean(L2, na.rm=TRUE),
    Avg.L3 = mean(L3, na.rm=TRUE), Avg.L4 = mean(L4, na.rm=TRUE),
    Avg.L5 = mean(L5, na.rm=TRUE)) %>%


  as.data.frame()  # I set it as a test frame



membranophonesavg


#lista membranophones
listamembranophonesavg<- membranophonesavg [ c(10,12,16,23), ]

listamembranophonesavg



###### Inverse the matrix for the instruments   ##### Friedmantest for Chordophones
membranophonesavginv <- t(listamembranophonesavg)
membranophonesavginv

membranophonesavginv1 <- na.omit(membranophonesavginv)
membranophonesavginv1

xtable(membranophonesavginv1)


friedman.test(as.matrix(membranophonesavginv1))
friedmanmc(as.matrix(membranophonesavginv1))

#The results means, there ia no relevant difference within the membranophones group

######################################################################

names(test)<-c("participant","instrument", "group", "age", "gender", "metronome_hours",      #other_avgtest
               "expertise", "years_experience", "sound_generation",
               "hours_practice", "other_instrument", "metronome_preference",
               "metronome", "L1", "L2", "L3", "L4", "L5")

idiophonesavg <- test %>%
  select(participant, group,
         L1, L2, L3, L4, L5) %>%
  group_by(participant, group == "Idiophones") %>%
  summarize(
    Avg.L1 = mean(L1, na.rm=TRUE), Avg.L2 = mean(L2, na.rm=TRUE),
    Avg.L3 = mean(L3, na.rm=TRUE), Avg.L4 = mean(L4, na.rm=TRUE),
    Avg.L5 = mean(L5, na.rm=TRUE)) %>%


  as.data.frame()  # I set it as a test frame



idiophonesavg


#lista idiophones
listaidiophonesavg<- idiophonesavg [ c(19,25,26), ]

listaidiophonesavg
```

```
###### Inverse the matrix for the instruments   ##### Friedmantest for Chordophones
idiophonesavginv <- t(listaidiophonesavg)
idiophonesavginv

idiophonesavginv1 <- na.omit(idiophonesavginv)
idiophonesavginv1
xtable(idiophonesavginv1)


friedman.test(as.matrix(idiophonesavginv1))
friedmanmc(as.matrix(idiophonesavginv1))

#The results means, there ia no relevant difference within the membranophones group



####################################################
########################################################################################
######################################################################################
####################### Fiedman Test for the whole data



##---Friedmann Test step by step--------------------------

testblemat  #List of all latency values

testble$Avg.L1  # checking the rows for L1 (90BPM)


testblemat <-  data.frame(testble$Avg.L1, testble$Avg.L2, testble$Avg.L3, testble$Avg.L4, testble$Avg.L5)

testblemat   # data frame with just the numerical information of the latency for 90BPM = Avg.L1, 120BPM =Avg.L2,
# 150BPM = Avg.L3, 180BPM = Avg.l4 and 210BPM = Avg.L5


ftestmat <- data.matrix(testblemat, rownames.force = NA)  #Friedman Test

ftestmat    # the data frame was converted into a matrix



##sample <- matrix(c(testble$Avg.L1, testble$Avg.L2, testble$Avg.L3, testble$Avg.L4, testble$Avg.L5), ncol = 5)

##sample

##friedman.test(sample)

ftestmatwona <- na.omit(ftestmat)

ftestmatwona  # For the case of NA values, it should be omited. Important for the not averaged values of latency


#table Avg Friedman
xtable(ftestmatwona)


####-- Friedman Test--##

friedman.test(as.matrix(ftestmatwona))   ##### should be significant  p < 0.005




###---Post hoc test for Friedman's ANOVA---###

#install.packages("pgirmess")   ### pgirmess packet for friedmanmc

library(pgirmess)


friedmanmc(as.matrix(ftestmatwona))




####---Paarwise Comparisons-----#####

#install.packages("PMCMR")
library(PMCMR)

posthoc.friedman.nemenyi.test(ftestmatwona)

#####################################################
###------Creation of a data frame for the different values of latency------###
```

```
detach("package:dplyr", character.only = TRUE)  #to avoid problems with the function select
library("dplyr", character.only = TRUE)         #to avoid problems with the function select

###Aural Metronome 90BPM###

str(test)


testbl90a <- test %>%
  select(participant, metronome, L1) %>%
  group_by(participant, metronome == "Aural") %>%

  as.data.frame()  # I set it as a test frame

testbl90a

lista90a <- subset(testbl90a, metronome == "Aural")
str(lista90a)

L1A <- (lista90a$L1)
L1A  ## L1 Values for Aural metronome 90BPM



###Visual Metronome 90BPM###


testbl90v <- test %>%
  select(participant, metronome, L1) %>%
  group_by(participant, metronome == "Visual") %>%

  as.data.frame()  # I set it as a test frame

testbl90v

lista90v <- subset(testbl90v, metronome == "Visual")
str(lista90v)

L1V <- (lista90v$L1)
L1V  ## L1 Values for Visual metronome 90BPM


###Both Metronome 90BPM###


testbl90b <- test %>%
  select(participant, metronome, L1) %>%
  group_by(participant, metronome == "Both") %>%

  as.data.frame()  # I set it as a test frame

testbl90b

lista90b <- subset(testbl90b, metronome == "Both")
str(lista90b)

L1B <- (lista90b$L1)
L1B  ## L1 Values for Visual metronome 90BPM


L1A
L1V
L1B

# creating a data frame for the Friedman Test with Latency Values at 90BPM-----#

L1AVB <- data.frame(L1A, L1V, L1B)
L1AVB      # data frame with the three different metronome values for all 25 test subjects



ftestmat90 <- data.matrix(L1AVB, rownames.force = NA)
ftestmat90



ftestmatwona90 <- na.omit(ftestmat90)
ftestmatwona90

#table ftestmatwona90
xtable(ftestmatwona90)

friedman.test(as.matrix(ftestmatwona90))
posthoc.friedman.nemenyi.test(ftestmatwona90)
```

```
friedmanmc(as.matrix(ftestmatwona90))



##Quade Test for 90BPM
qtestmatwona90 <- as.matrix(ftestmatwona90)

quade.test(qtestmatwona90)

posthoc.quade.test(qtestmatwona90)


#if p > 0.005, then the metronome values L1a, L1V and L1B do not differ much (90BPM values)



###Aural Metronome 120BPM###



testbl120a <- test %>%
  select(participant, metronome, L2) %>%
  group_by(participant, metronome == "Aural") %>%

  as.data.frame()  # I set it as a test frame

testbl120a

lista120a <- subset(testbl120a, metronome == "Aural")
str(lista120a)

L2A <- (lista120a$L2)
L2A  ## L2 Values for Aural metronome 120BPM


###Visual Metronome 120BPM###


testbl120v <- test %>%
  select(participant, metronome, L2) %>%
  group_by(participant, metronome == "Visual") %>%

  as.data.frame()  # I set it as a test frame

testbl120v

lista120v <- subset(testbl120v, metronome == "Visual")
str(lista120v)

L2V <- (lista120v$L2)
L2V  ## L2 Values for Visual metronome 120BPM


###Both Metronome 120BPM###


testbl120b <- test %>%
  select(participant, metronome, L2) %>%
  group_by(participant, metronome == "Both") %>%

  as.data.frame()  # I set it as a test frame

testbl120b

lista120b <- subset(testbl120b, metronome == "Both")
str(lista120b)

L2B <- (lista120b$L2)
L2B  ## L2 Values for Visual metronome 120BPM


L2A
L2V
L2B


# creating a data frame for the Friedman Test with Latency Values at 120BPM-----#

L2AVB <- data.frame(L2A, L2V, L2B)
L2AVB

ftestmat120 <- data.matrix(L2AVB, rownames.force = NA)
ftestmat120

ftestmatwona120 <- na.omit(ftestmat120)
```

```
ftestmatwona120   #wona = without NA

#table ftestmatwona120
xtable(ftestmatwona120)

friedman.test(as.matrix(ftestmatwona120))

posthoc.friedman.nemenyi.test(ftestmatwona120)
friedmanmc(as.matrix(ftestmatwona120))


#if p > 0.005, then the metronome values L2a, L2V and L2B do not differ much (120BPM values)

##Quade Test for 120BPM
qtestmatwona120 <- as.matrix(ftestmatwona120)
qtestmatwona120
quade.test(qtestmatwona120)
posthoc.quade.test(qtestmatwona120)

###Aural Metronome 150BPM###



testbl150a <- test %>%
  select(participant, metronome, L3) %>%
  group_by(participant, metronome == "Aural") %>%

  as.data.frame()  # I set it as a test frame

testbl150a

lista150a <- subset(testbl150a, metronome == "Aural")
str(lista150a)

L3A <- (lista150a$L3)
L3A  ## L2 Values for Aural metronome 150BPM


###Visual Metronome 150BPM###


testbl150v <- test %>%
  select(participant, metronome, L3) %>%
  group_by(participant, metronome == "Visual") %>%

  as.data.frame()  # I set it as a test frame

testbl150v

lista150v <- subset(testbl150v, metronome == "Visual")
str(lista150v)

L3V <- (lista150v$L3)
L3V  ## L2 Values for Visual metronome 150BPM


###Both Metronome 150BPM###


testbl150b <- test %>%
  select(participant, metronome, L3) %>%
  group_by(participant, metronome == "Both") %>%

  as.data.frame()  # I set it as a test frame

testbl150b

lista150b <- subset(testbl150b, metronome == "Both")
str(lista150b)

L3B <- (lista150b$L3)
L3B  ## L3 Values for Visual metronome 150BPM


L3A
L3V
L3B


# creating a data frame for the Friedman Test with Latency Values at 150BPM-----#

L3AVB <- data.frame(L3A, L3V, L3B)
L3AVB

ftestmat150 <- data.matrix(L3AVB, rownames.force = NA)
```

```
ftestmat150

ftestmatwona150 <- na.omit(ftestmat150)
ftestmatwona150

#table ftestmatwona150
xtable(ftestmatwona150)

friedman.test(as.matrix(ftestmatwona150))

posthoc.friedman.nemenyi.test(ftestmatwona150)
friedmanmc(as.matrix(ftestmatwona150))


#if p > 0.005, then the metronome values L3a, L3V and L3B do not differ much (150BPM values)

##Quade Test for 150BPM
qtestmatwona150 <- as.matrix(ftestmatwona150)
qtestmatwona150
quade.test(qtestmatwona150)
posthoc.quade.test(qtestmatwona150)

###Aural Metronome 180BPM###



testbl180a <- test %>%
  select(participant, metronome, L4) %>%
  group_by(participant, metronome == "Aural") %>%

  as.data.frame()  # I set it as a test frame

testbl180a

lista180a <- subset(testbl180a, metronome == "Aural")
str(lista180a)

L4A <- (lista180a$L4)
L4A  ## L4 Values for Aural metronome 180BPM


###Visual Metronome 180BPM###


testbl180v <- test %>%
  select(participant, metronome, L4) %>%
  group_by(participant, metronome == "Visual") %>%

  as.data.frame()  # I set it as a test frame

testbl180v

lista180v <- subset(testbl180v, metronome == "Visual")
str(lista180v)

L4V <- (lista180v$L4)
L4V  ## L4 Values for Visual metronome 180BPM


###Both Metronome 180BPM###


testbl180b <- test %>%
  select(participant, metronome, L4) %>%
  group_by(participant, metronome == "Both") %>%

  as.data.frame()  # I set it as a test frame

testbl180b

lista180b <- subset(testbl180b, metronome == "Both")
str(lista180b)

L4B <- (lista180b$L4)
L4B  ## L4 Values for Visual metronome 180BPM


L4A
L4V
L4B


# creating a data frame for the Friedman Test with Latency Values at 180BPM-----#

L4AVB <- data.frame(L4A, L4V, L4B)
```

```
L4AVB

ftestmat180 <- data.matrix(L4AVB, rownames.force = NA)
ftestmat180

ftestmatwona180 <- na.omit(ftestmat180)
ftestmatwona180

#table ftestmatwona180
xtable(ftestmatwona180)



friedman.test(as.matrix(ftestmatwona180))

posthoc.friedman.nemenyi.test(ftestmatwona180)
friedmanmc(as.matrix(ftestmatwona180))

#if p > 0.005, then the metronome values L4a, L4V and L4B do not differ much (180BPM values)

##Quade Test for 180BPM
qtestmatwona180 <- as.matrix(ftestmatwona180)
qtestmatwona180
quade.test(qtestmatwona180)
posthoc.quade.test(qtestmatwona150)
###Aural Metronome 210BPM###



testbl210a <- test %>%
  select(participant, metronome, L5) %>%
  group_by(participant, metronome == "Aural") %>%

  as.data.frame()  # I set it as a test frame

testbl210a

lista210a <- subset(testbl210a, metronome == "Aural")
str(lista210a)

L5A <- (lista210a$L5)
L5A  ## L2 Values for Aural metronome 120BPM


###Visual Metronome 210BPM###


testbl210v <- test %>%
  select(participant, metronome, L5) %>%
  group_by(participant, metronome == "Visual") %>%

  as.data.frame()  # I set it as a test frame

testbl210v

lista210v <- subset(testbl210v, metronome == "Visual")
str(lista210v)

L5V <- (lista210v$L5)
L5V  ## L2 Values for Visual metronome 120BPM


###Both Metronome 210BPM###


testbl210b <- test %>%
  select(participant, metronome, L5) %>%
  group_by(participant, metronome == "Both") %>%

  as.data.frame()  # I set it as a test frame

testbl210b

lista210b <- subset(testbl210b, metronome == "Both")
str(lista210b)

L5B <- (lista210b$L5)
L5B  ## L2 Values for Visual metronome 180BPM


L5A
L5V
L5B
```

```
# creating a data frame for the Friedman Test with Latency Values at 210BPM-----#

L5AVB <- data.frame(L5A, L5V, L5B)
L5AVB

ftestmat210 <- data.matrix(L5AVB, rownames.force = NA)
ftestmat210

ftestmatwona210 <- na.omit(ftestmat210)
ftestmatwona210

#table ftestmatwona210
xtable(ftestmatwona210)


friedman.test(as.matrix(ftestmatwona210))


posthoc.friedman.nemenyi.test(ftestmatwona210)
friedmanmc(as.matrix(ftestmatwona210))


#if p > 0.005, then the metronome values L5a, L5V and L5B do not differ much (210BPM values)


##Quade Test for 210BPM
qtestmatwona210 <- as.matrix(ftestmatwona210)
qtestmatwona210
quade.test(qtestmatwona210)
posthoc.quade.test(qtestmatwona210)
###################### Summary Friedman Test for the 3 metronomes Aural, Visual and Both.

## if p > 0.005 the metronomes are not different. Each tempi from 90BPM, 120BPM, 150BPM, 180BPM and 210BPM is
##tested separatedly



############################################
library(ggplot2)
library(plyr)



par(mfrow=c(2,3))

L1AVB

rL1AVB <- rename(L1AVB, c( "L1A"= "Aural", "L1V" = "Visual", "L1B" = "Both"))
rL1AVB


# boxplot for the 3 metronomes at 90BPM (aural, visual and both)
#bp90
boxplot(rL1AVB, xlab ='Metronome at 90BPM', ylab = 'Latency in milliseconds', ylim = c(0, 300))


L2AVB

rL2AVB <- rename(L2AVB, c( "L2A"= "Aural", "L2V" = "Visual", "L2B" = "Both"))
rL2AVB


# boxplot for the 3 metronomes at 120BPM (aural, visual and both)
#bp120
boxplot(rL2AVB, xlab ='Metronome at 120BPM', ylab = 'Latency in milliseconds',  ylim = c(0, 300))



L3AVB

rL3AVB <- rename(L3AVB, c( "L3A"= "Aural", "L3V" = "Visual", "L3B" = "Both"))
rL3AVB


# boxplot for the 3 metronomes at 150BPM (aural, visual and both)
#bp150
boxplot(rL3AVB, xlab ='Metronome at 150BPM', ylab = 'Latency in milliseconds', ylim = c(0, 300))



L4AVB

rL4AVB <- rename(L4AVB, c( "L4A"= "Aural", "L4V" = "Visual", "L4B" = "Both"))
rL4AVB
```

```
# boxplot for the 3 metronomes at 180BPM (aural, visual and both)
#bp180
boxplot(rL4AVB, xlab ='Metronome at 180BPM', ylab = 'Latency in milliseconds', ylim = c(0, 300))


L5AVB

rL5AVB <- rename(L5AVB, c( "L5A"= "Aural", "L5V" = "Visual", "L5B" = "Both"))
rL5AVB


# boxplot for the 3 metronomes at 210BPM (aural, visual and both)
#bp210
boxplot(rL5AVB, xlab ='Metronome at 210BPM', ylab = 'Latency in milliseconds', ylim = c(0, 300))


# the same plot can be find under metroplotforall in Evaluation_Results



iL1AVB <- t(L1AVB)

summary(L1AVB)

friedman.test(as.matrix(iL1AVB))

#if p < 0.005, then the instrument are different for 90BPM



friedman.test(as.matrix(L1AVB))

#if p < 0.005, then the metronome values obtained are different for 90BPM

posthoc.friedman.nemenyi.test(iL1AVB)
friedmanmc(as.matrix(iL1AVB))




iL2AVB <- t(L2AVB)
iL2AVB

summary(L2AVB)


friedman.test(as.matrix(iL2AVB))
#if p < 0.005, then the instrument are different for 120BPM

friedman.test(as.matrix(L2AVB))
#if p < 0.005, then the metronome values obtained are different for 120BPM

posthoc.friedman.nemenyi.test(iL2AVB)
friedmanmc(as.matrix(iL2AVB))




iL3AVB <- t(L3AVB)
iL3AVB

summary(L3AVB)

friedman.test(as.matrix(iL3AVB))
#if p < 0.005, then the instrument are different for 150BPM


friedman.test(as.matrix(L3AVB))
#if p < 0.005, then the metronome values obtained are different for 150BPM



posthoc.friedman.nemenyi.test(iL3AVB)
friedmanmc(as.matrix(iL3AVB))



iL4AVB <- t(L4AVB)
iL4AVB

summary(L4AVB)

friedman.test(as.matrix(iL4AVB))
#if p < 0.005, then the instrument are different for 180BPM
```

```
friedman.test(as.matrix(L4AVB))
#if p < 0.005, then the metronome values obtained are different for 180BPM


posthoc.friedman.nemenyi.test(iL4AVB)
friedmanmc(as.matrix(iL4AVB))




iL5AVB <- t(L5AVB)
iL5AVB

iL1AVB

friedman.test(as.matrix(iL5AVB))   #, na.action = na.exclude oder , na.action = na.omit
#if p < 0.005, then the instrument are different for 210BPM

friedman.test(as.matrix(L5AVB))
#if p < 0.005, then the metronome values obtained are different for 210BPM

summary(L5AVB)

posthoc.friedman.nemenyi.test(iL5AVB)

library(pgirmess)

friedmanmc(as.matrix(iL5AVB))

#### It seems the results of all the different metronomes (aural, visual and both) are not different between
#### each other


###########################

######################################### Friedman Test for the Main Hypothesis
###################################################

testblemat    # List of Latency values and Participants (instruments)
testblematfinal <- na.omit(testblemat)

xtable(testblematfinal)

testblematinv <- t(testblemat)

testblematinv  # Inverse of the list of latency values and participants. The Friedman test has to be done comparing
the participants (instruments)

testblematinvna <- na.omit(testblematinv)

testblematinvna

xtable(testblematinvna)




#Friedman test for 5 Tempi Avg. Values

friedman.test(as.matrix(testblematfinal))

friedmanmc(as.matrix(testblematfinal))    ##Friedman Test with all combination. Where it is TRUE, there are
significant differences.

posthoc.friedman.nemenyi.test(testblematfinal)   #It does not work



friedman.test(as.matrix(testblematinvna))

#Friedman Test Table for all comparison 30 instruments
friedmanmc(as.matrix(testblematinvna))    ##Friedman Test with all combination. Where it is TRUE, there are
significant differences.




posthoc.friedman.nemenyi.test(testblematinv)  ### Posthoc Friedman Nemenyi. Columns comparation
```

```
#With Quade
quade.test(testblematinv)
posthoc.quade.test(testblematinv)




friedman.test(as.matrix(testblematinvna))

friedmanmc(as.matrix(testblematinvna))    ##Friedman Test with all combination. Where it is TRUE, there are
significant differences.


posthoc.friedman.nemenyi.test(testblematinvna)


testblematinvna1 <- testblematinv[(3:5),]

testblematinvna1

friedman.test(as.matrix(testblematinvna1))
################### Plots Hypothesis Testing  ###############

par(mfrow=c(1,1))

# Boxplot for all instruments separated through subject
uio <- boxplot(testblematinv, xlab="Musical instruments", ylab="Latency (Ld) in milliseconds", col=rainbow(30, alpha
= 0.8))


#instplotfried
uio




# This boxplot should be presented to the Frieman test. It indicates that the instruments have an influence
#regarding to the ability to cope with latency
```

```
# Author: Jorge Medina Victoria
# A Method for the Measurement of the Ability of Western Musicians to Cope with Latency
# Pilot Test
# Date: 06.11.18

# Data Manipulation and Plot generation for the Pilot Test

#Set the working directory

#Import the dataset pilot and avginfo

library(dplyr)        #callin library dplyr
library(ggplot2)      #callin library ggplot
library(reshape2)     #callin library reshape

head(pilot)
head(avginfo)

#convert and label the data

group<-factor("group", levels=c(1:4), labels=c("Chordophones", "Aerophones", "Membranophones",
                                               "Ideophones"))
#convert group number 1,2,3 and 4 into groups 1=Chordophones, 2= Aerophones, 3= Membranophones
#and 4= Ideophones

#different levels within some of the variables
levels(group)
summary(pilot)

#participant ist int

pilot$participant<- as.integer(as.numeric(pilot$"participant"))

avginfo$participant<- as.integer(as.numeric(avginfo$"participant"))

head(pilot)
head(avginfo)
typeof(pilot)
summary(pilot)
summary(avginfo)

#Get rid of the NA for some variables

pilot$"180BPM"<- as.numeric(as.character(pilot$"180BPM"))  #conversion of variable 120BPM from chr to num. It was chr
str(pilot)                                                #because 2 variables were NA. The same operation wered

pilot$"210BPM"<- as.numeric(as.character(pilot$"210BPM"))

pilot$"240BPM"<- as.numeric(as.character(pilot$"240BPM"))


str(pilot)

summary(pilot)


#Create a subset


#Attention the variables do not need a " or a ' except when they begin with numbers as in 90BPM

pilottemp <- select(.data=pilot, participant, instrument, "60BPM",'90BPM', "120BPM", "150BPM", "180BPM", "210BPM",
'240BPM')

head(pilottemp)


summary(pilottemp)


#Get rid of the NA for some variables AGAIN

pilottemp$"180BPM"<- as.numeric(as.character(pilottemp$"180BPM"))  #conversion of variable 120BPM from chr to num. It
was chr
str(pilot)                                                #because 2 variables were NA. The same operation wered

pilottemp$"210BPM"<- as.numeric(as.character(pilottemp$"210BPM"))

pilottemp$"240BPM"<- as.numeric(as.character(pilottemp$"240BPM"))

summary(pilottemp)


#Calculate the average
```

```
#First we change the name of the variables
#especifically 90BPM up to 210BPM
#variable names with number are difficult to compute

names(pilottemp)<-c("participant","instrument", "L1", "L2", "L3", "L4", "L5", "L6", "L7")

head(pilottemp)

avgpilottemp <- pilottemp %>%
  select(participant, instrument,
          L1, L2, L3, L4, L5,
         L6, L7) %>%
  #filter(gender == 2) %>%   #Here I filtered just the women (If you want to filter)
  #mutate(newparticipant = participant*10) %>%     ## I create a column named newparticipant, which is the result of
participant by 10
  group_by(participant) %>%
  summarize(Avg.L1 = mean(L1), Avg.L2 = mean(L2, na.rm=TRUE),
            Avg.L3 = mean(L3, na.rm=TRUE), Avg.L4 = mean(L4),
            Avg.L5 = mean(L5, na.rm=TRUE), Avg.L6 = mean(L6, na.rm=TRUE), Avg.L7 = mean(L7, na.rm=TRUE)   ) %>%
  ## VERY IMPORTANT
  ## Here I summarize for all participants the average of the latency data from 90BMP to 210BPM
  ## with na.rm=TRUE I set NA as value so the mean can be computed and a number can be displayed

  #arrange(desc(participant))  # it displays the participants in descending order

  as.data.frame()  # I set it as a data frame

print(avgpilottemp)  #Display of the data frame finallist



#Change the names for Avg to BPM


names(avgpilottemp)<-c("participant", "60BPM", "90BPM", "120BPM", "150BPM", "180BPM", "210BPM", "240BPM")

head(avgpilottemp)


#write as a csv file with the name avg_data.csv
write.csv(
  x=avgpilottemp,
  file='pilotmean.csv',
  row.names = FALSE) #FALSE The unique ID won't be overwrite


#MERGING INFORMATION OF AVGPILOTTEMP AND AVGINFO FOR PLOTS

#merging the two dataframes, so I can have instruments also


jointpilot <- merge(avgpilottemp,avginfo, by="participant") #VERY IMPORTANT
#I'm merging two dataframes
#in the order df1 then df2
#by the ID

str(jointpilot)
summary(jointpilot)




par(mfrow=c(2,2))



#Merging Information for the display with ggplot

library(reshape2) # to use function melt'

#information is in the wide format, it has to be converted to the long or molten format using melt (library reshape)





pilotplot <- melt(jointpilot, id=c('participant', 'group',  'instrument'))
pilotplot  # the information has 3 columns: participant, variable and value
#participant goes from 1 to 9
#variable are the 6 different variables (instrument, 90BPM, 120BPM, 150BPM, 180BPM and 210 BPM)
#value is the value assigned to each variable

names(pilotplot)<-c("Participant", "Group", "Instrument", "Tempo", "Latency")

pilotplot
```

```
par(mfrow=c(2,2))  # ATTENTION IT DOESN'T WORK WITH GGPLOT"


ggplot(pilotplot, mapping=aes(x=Tempo, y=Latency))+geom_line(aes(group=Participant))



#pilotinstruments
pilotinstruments <- ggplot(pilotplot, mapping=aes(x=Tempo, y=Latency,
colour=Instrument))+geom_line(aes(group=Participant))+geom_point(size=2) + facet_wrap(~Instrument) + xlab("Tempo in
BPM") +
                      ylab("Latency (Ld) in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1,
hjust= 0))

pilotinstruments+theme(axis.text=element_text(size=11),
                       axis.title=element_text(size=16))+ theme(legend.text=element_text(size=15),
legend.title=element_text(size=15))


#Alternative Plot without Instrument legend

ggplot(pilotplot, mapping=aes(x=Tempo, y=Latency))+geom_line(aes(group=Participant))+geom_point(size=2) +
facet_wrap(~Instrument) + xlab("Tempo in BPM") +
  ylab("Latency in milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))

#Alternative one can give a name to the plot i.e. instrument <- ggplot(pilotplot ...........)


#WOW Facet Wrap is cool. it separate the whole thing by instruments

pilotplot


ggplot(pilotplot, mapping=aes(x=Tempo, y=Latency, colour=Group))+geom_line(aes(group=Participant))+geom_point(size=2)


#Plot Groups vs. Latency


#instrumentgroup
instrumentgroup <- ggplot(pilotplot, mapping=aes(x=Group, y=Latency, colour = Tempo, shape = Instrument,
size=2))+geom_point( size=2.5) + xlab("Instrument Groups") +
  ylab("Latency (Ld) in milliseconds")+ scale_shape_manual(values=seq(0,8))

instrumentgroup+theme(axis.text=element_text(size=14),
                      axis.title=element_text(size=16))+ theme(legend.text=element_text(size=15),
legend.title=element_text(size=15))


pilotplot


#Plotting Chordophones and Aerophones


#First we filter the Membranophones

jointpilot

plotwomembra <- filter(.data=pilotplot, Group != "Membranophones")

pilotplot

plotwomembra


#comparisongroups
comparisongroups <- ggplot(plotwomembra, mapping=aes(x=Tempo, y=Latency, colour = Instrument))+geom_line(size = 0.5,
aes(group=Participant))+geom_point(size=2)+facet_wrap(~Group) +xlab("Tempo in BPM") + ylab("Latency (Ld) in
milliseconds")+theme(axis.text.x = element_text(angle = -30, vjust = 1, hjust= 0))

comparisongroups+theme(axis.text=element_text(size=11),
                        axis.title=element_text(size=16))+ theme(legend.text=element_text(size=15),
legend.title=element_text(size=15))




#Filter a subset of rows

# CHORDOPHONES

chord <- filter( .data=jointpilot, group == "Chordophones")
```

```
chordplot <- melt(chord, id=c('participant', 'group',  'instrument'))

names(chordplot)<-c("Participant", "Group", "Instrument", "Tempo", "Latency")

chordplot


ggplot(chordplot, mapping=aes(x=Tempo, y=Latency, colour=Group))+geom_line(aes(group=Participant))+geom_point(size=2)

#AEROPHONES'

aero <- filter( .data=jointpilot, group == "Aerophones")

aeroplot <- melt(aero, id=c('participant', 'group',  'instrument'))

names(aeroplot)<-c("Participant", "Group", "Instrument", "Tempo", "Latency")

aeroplot


ggplot(aeroplot, mapping=aes(x=Tempo, y=Latency, colour=Group))+geom_line(aes(group=Participant))+geom_point(size=2)

#MEMBRANOPHONES

membra <- filter( .data=jointpilot, group == "Membranophones")

membranoplot <- melt(membra, id=c('participant', 'group',  'instrument'))

names(membranoplot)<-c("Participant", "Group", "Instrument", "Tempo", "Latency")

membranoplot


ggplot(membranoplot, mapping=aes(x=Tempo, y=Latency,
colour=Group))+geom_line(aes(group=Participant))+geom_point(size=2)


#Data Analysis---------------------------------------


jointpilot # Data with the average

table(jointpilot$instrument)

table(jointpilot$"180BPM")
summary(jointpilot)

#Inter Quartiles IQR this is the substraction from the 75% - 25% quartile

IQR(jointpilot$"60BPM")
IQR(jointpilot$"90BPM")
IQR(jointpilot$"120BPM")
IQR(jointpilot$"150BPM")
IQR(jointpilot$"180BPM")
IQR(jointpilot$"210BPM", na.rm=TRUE)
IQR(jointpilot$"240BPM", na.rm=TRUE)

#Standard Deviation

sd(jointpilot$"60BPM")
sd(jointpilot$"90BPM")
sd(jointpilot$"120BPM")
sd(jointpilot$"150BPM")
sd(jointpilot$"180BPM")
sd(jointpilot$"210BPM", na.rm=TRUE)
sd(jointpilot$"240BPM", na.rm=TRUE)


#For Kurtosis and skewness
install.packages("moments")

library(moments)

skewness(jointpilot$"60BPM")
skewness(jointpilot$"90BPM")
skewness(jointpilot$"120BPM")
skewness(jointpilot$"150BPM")
skewness(jointpilot$"180BPM")
skewness(jointpilot$"210BPM", na.rm=TRUE)
skewness(jointpilot$"240BPM", na.rm=TRUE)


kurtosis(jointpilot$"60BPM")
kurtosis(jointpilot$"90BPM")
```

```
kurtosis(jointpilot$"120BPM")
kurtosis(jointpilot$"150BPM")
kurtosis(jointpilot$"180BPM")
kurtosis(jointpilot$"210BPM", na.rm=TRUE)
kurtosis(jointpilot$"240BPM", na.rm=TRUE)


plot(density(jointpilot$"60BPM"))
plot(density(jointpilot$"90BPM"))
plot(density(jointpilot$"120BPM"))
plot(density(jointpilot$"150BPM"))
plot(density(jointpilot$"180BPM"))
plot(density(jointpilot$"210BPM", na.rm=TRUE))
plot(density(jointpilot$"240BPM", na.rm=TRUE))
```

```
# Author: Jorge Medina Victoria
# A Method for the Measurement of the Ability of Western Musicians to Cope with Latency
# Descriptive Statistic Rooms
# Date: 25.10.18

# If you are using this code for the first time, please install all the packages by deleting # in front of the
package#1 Defining Libraries

'Setting Directory in Session/set directory'

head(test) #looking for general information of the test
head(avgtest) # the other testframe

#install.packages("dplyr")
#library(plyr)
library(dplyr)  #callin library dplyr'

#install.packages("ggplot2)

library(ggplot2)

#instal.packages("reshape")
library(reshape2)

#install.packages("pastecs")
library(pastecs)

#install.packages("moments")
library(moments)

#install.packages("GGally")
library("GGally")

#install.packages('truncnorm')
library(truncnorm)

#install.packages('xtable')
library(xtable)

#install.packages('car')
library(car)


str(rooms)
room <- stat.desc(rooms)
xtable(room)
```

```
# Author: Jorge Medina Victoria
# A Method for the Measurement of the Ability of Western Musicians to Cope with Latency
# Linear regression Audio Interface
# Date: 09.11.18


library(dplyr)
library(ggplot2)
str(fireface)

#chartlinear2
p <- ggplot(fireface, aes(Input, Output)) + xlab("Analog Input Level Gain (dB)") + ylab("Level Output Peak
(dBFS)")+theme(axis.text=element_text(size=15),

axis.title=element_text(size=15))+ theme(legend.text=element_text(size=15), legend.title=element_text(size=15))
p+geom_line(size = 0.7, colour = "blue")+ geom_point(size = 3, colour= "blue", size = 0.2) +geom_smooth(method =
"lm", se = FALSE, colour = "red", size = 0.7)

#olivedrab1 is the former colour
# Add text on a specific positions:
#p + annotate("text", x = c(10), y = c(-10), label = c("label 1") , color="orange", size=5 , angle=45,
fontface="bold")

result<-lm(Output ~ Input, data = fireface)
result
summary(result)

library(xtable)  # transform information into LaTeX format
xtable(result)

summary(fireface)
fireface
xtable(fireface)
```

Appendix M

Listening test results and questionnaire results

Participant No. 1 **Test A**

Instrument: Piano **Distance (mic-inst in m):** 0.292

dBSPL (~~C~~A): 87.3 **Room dBSPL (~~C~~A):** 34.7 **Mic. Gain:** 10

Headphones Gain: -10 **Datafile name:** Piano 17.11.17
1-15

Order Tempo Latency (ms)

			BPM	Visual	Audio	Both
3	1	1	90	· 219	150 224	· 205
5	2	4	120	220/256	134	· 163
1	3	5	150	· ≈260	134	~~163~~ 160-170
2	4	3	180	≈300	110	· 133
4	5	2	210	·≈220	≈108	·108 / 160
			~~240~~			

Notes: Visual (150-180) Review
* he uses the foot for the bpm.
* great error should be also disruption
getting louder with more latency

Participant No. 2 **Test A**

Instrument: Piano **Distance (mic-inst in m):** 0.287

dBSPL (~~C~~A): ~~35.7~~ 83.3 **Room dBSPL (~~C~~A):** 38.7 **Mic. Gain:** 10

Headphones Gain: -10 **Datafile name:** 16-30

Order Tempo Latency (ms)

			BPM	Visual	Audio	Both
3	1	2	90	·140	· 219	·165
5	2	1	120	134	· 180	· 220
1	4	5	150	·144 / 150	142.8	195
2	3	3	180	133 / 142	· 147	·116
4	5	4	210	· 75	· 121	·105
			~~240~~			

Notes: she did disrupt

Participant No. 3　　　　　　　　　**Test B**

Instrument: Cello　　　**Distance (mic-inst in m):** 0.38

dBSPL (~~C~~ A): 84　**Room dBSPL (~~C~~ A):** room ~ 2　**Mic. Gain:** 10

Headphones Gain: -10　　**Datafile name:** 31 - 48

Order　Tempo　　　　Latency (ms)

			BPM	Audio	Visual	Both
3	1	1	90	· > 300	· ~~88~~ → 280	· 260
5	4	2	120	252	· 193 - ~~280~~	· 280
1	5	4	150	· 105	120 - 157	· 172
2	3	3	180	· 91 - ~~[illegible]~~	· 32 ~ 72	· 150 180
4	2	5	210	45	· 25 → 60	145
			240			

Notes: Visual was difficult

Participant No. 4　　　　　　　　　**Test B**/

Instrument: Cello　　　**Distance (mic-inst in m):** ~~0.446~~ 0.412

dBSPL (~~C~~ A): 85.2　**Room dBSPL (~~C~~ A):** 34.8　**Mic. Gain:** 10

Headphones Gain: -10　　**Datafile name:** ab 49 - 66

Order　Tempo　　　　Latency (ms)

			BPM	Audio	Visual	Both
1	1	2	90	· 252	· 200	· 250
4	2	1	120	· 247	· 232	· 203
5	4	5	150	136	· 300	200
3	3	3	180	175	· 180 ~~222~~	· 142.9
2	5	4	210	· 183	· 238	· 165
			240			

2　1

Notes: Audio is easy for the participant

Participant No. 5 **Test A**

Instrument: Guitar **Distance (mic-inst in m):** 0.264

dBSPL (C): 75.1 **Room dBSPL (~~C~~A):** 34.8 **Mic. Gain:** 10

Headphones Gain: -10 **Datafile name:** 67-88

Order Tempo Latency (ms)

			BPM	Visual	Audio	Both
2	5	2	90	93	118	182
1	3	4	120	· 52	· 143	· ~~82~~ 166
5	4	5	150	81	103	98
3	2	3	180	· 73	· 115	· 101
4	1	1	210	· 44	· — 68	· 73
			240			
				3	1	2

Notes: Both 120 repeated → Reihenfolge not the same with visual he played with himself

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Participant No. 6 **Test A**

Instrument: French Horn **Distance (mic-inst in m):** 0,338

dBSPL (C): 89.2 93.2 **Room dBSPL (~~C~~A):** 204 room **Mic. Gain:** 10

Headphones Gain: -10 **Datafile name:** 89-110

Order Tempo Latency (ms)

			BPM	Visual	Audio	Both
3	1	1	90	· 300	· 300	· 300
5	4	2	120	258	261	· 298
1	5	4	150	· ~~51~~ 183	163	130
2	3	3	180	96	100	· 127
4	2	3	210	137	30	106
			240			
				3	1	2

Notes: he memorizes

Participant No. 7 **Test A**

Instrument: 101 Alto sax **Distance (mic-inst in m):** 0,341

dBSPL (C): ~~76~~.1 **Room dBSPL (C A):** 34.2 215 **Mic. Gain:** 10

Headphones Gain: -10 **Datafile name:** fehlt ere

Order Tempo Latency (ms)

			BPM	Visual	Audio	Both
1	2	5	90	·300	300 →	NA 1
2	1	3	120	·300	·218 3	NA 2
4	3	4	150	·300	·300	300
3	3	2	180	·300	·300	300
5	4	1	210	·300	·300	·300
			~~240~~			
				2	1	3

Notes: Audio 110 not recorded. first → 218 not 300
Jazz player

Participant No. 8 **Test A**

Instrument: Violin **Distance (mic-inst in m):** 0,367

dBSPL (C A): 82.2 **Room dBSPL (C A):** 34.6 139 **Mic. Gain:** 10

Headphones Gain: -10 **Datafile name:** 122 -136

Order Tempo Latency (ms)

			BPM	Visual	Audio	Both
2	5	4	90	·266	·300	·300
1	3	2	120	·163	·300	·300
3	1	3	150	·300	·300	·300
4	4	1	180	·300	·266-275	·300
5	2	3	210	300	·*103-220	300
			~~240~~			
				2	1	3

Notes: Dexterity she learned how it works and
just repeated it
Visual distracting

Participant No. 9 **Test B**

Instrument: Trumpet in B **Distance (mic-inst in m):** ~~0,598~~ 0.715

dBSPL (A): 96.4 **Room dBSPL (A):** 31.2 **Mic. Gain:** 0

Headphones Gain: 10 **Datafile name:** Instrument 01

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
1	2	5	90	~~268~~ ~300	· 300	300
3	1	4	120	· 300	· 300	· 300
2	3	1	150	· 300	300	· 300
5	4	3	180	· 300	300	· 300
4	5	2	210	· 300	300	· 300

Notes: schon mit Latenz eingespielt → Immer mit Reverb geübt
als zweite Stimme wahrgenommen (Latenz) → Elektro Producer
Producer / nur auf das Rot geachtet Drumbeats
Pause because tiredness → Embouchure

Participant No. 10 **Test B**

Instrument: Snare Drum **Distance (mic-inst in m):** 0,389

dBSPL (A): 93 **Room dBSPL (A):** 33 **Mic. Gain:** 0

Headphones Gain: + 10 **Datafile name:** Order 10

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
5	3	1	90	148	NA	142
3	5	2	120	210	113	89
2	1	3	150	78	109	NA
1	2	4	180	39	110	101
4	4	5	210	56	100	77

Notes: NA Values are learned by heart (Both) or
there was no possible to play (Visual)

Participant No. 11 **Test B**

Instrument: Piano (Upright) **Distance (mic-inst in m):** 0,347

dBSPL (A): 82.3 **Room dBSPL (A):** 32 **Mic. Gain:** +10

Headphones Gain: +10 **Datafile name:** Order 10

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
3	1	1	90	202	300	290
5	2	4	120	278	238	216
1	3	5	150	120	145	263
2	4	3	180	109	136	216
4	5	2	210	123	94	172

Notes: Each stop is considered a full stop

Participant No. 12 **Test B**

Instrument: Snare Drum **Distance (mic-inst in m):** 0,388

dBSPL (A): 94 **Room dBSPL (A):** 31,2 **Mic. Gain:** 0

Headphones Gain: +10 **Datafile name:** Instrument 01

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
3	1	1	90	61	72	80
5	4	2	120	79	73	72
1	5	4	150	62	58	82
2	3	3	180	45	55	80
4	2	5	210	72	59	82

} learned

Notes: The last values (3) with metronome Both are learned by heart!

Participant No. 13 **Test B**

Instrument: Violin **Distance (mic-inst in m):** 0,48

dBSPL (A): 83.2 **Room dBSPL (A):** Rec. Studio **Mic. Gain:** 10

Headphones Gain: -10 **Datafile name:** ______

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
3	1	1	90	· 230	· 142*	· 298
5	4	2	120	183	· 108	· 242
1	5	4	150	· 160	· 166	~~153~~ 215
2	3	3	180	113 ~~114~~	·147 ~~179~~ **	- 153
4	2	5	210	· 104*	· 107*	132

Notes: Lose of vibrato! Begleitung mit dem Fuß! wegen Unsicherheit.

Participant No. 14 **Test B**

Instrument: Traverse Flute **Distance (mic-inst in m):** 0,328

dBSPL (A): 83.5 **Room dBSPL (A):** 38.7 **Mic. Gain:** 10

Headphones Gain: -10 **Datafile name:** Test 14

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
2	5	5	90	119	NA	107
4	3	2	120	80	NA	92
5	2	1	150	78	76	80
3	1	3	180	80	96	54
1	4	4	210	10	NA	25

Notes: Difficulties with the visual metronome. By strong variations NA was written!

Participant No. 15 **Test B**

Instrument: Trombone **Distance (mic-inst in m):** 0,4377

dBSPL (A): 91.3 **Room dBSPL (A):** 38.7 **Mic. Gain:** 0

Headphones Gain: 10 **Datafile name:** Test 15

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
2	5	5	90	128	143	99
1	4	3	120	68	72	119
3	1	1	150	88	84	119
4	3	4	180	NA	27	99
5	2	2	210	NA	NA	NA

Notes: HP were low leveled

Participant No. 16 **Test B**

Instrument: Timpani **Distance (mic-inst in m):** 0,619

dBSPL (A): 79 **Room dBSPL (A):** 38.7 **Mic. Gain:** 0

Headphones Gain: -10 **Datafile name:** Test 16

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
3	1	1	90	120	60	94
5	2	4	120	206	43	144
1	3	5	150	96	NA	NA
2	4	3	180	48	NA	NA
4	5	2	210	5	39	NA

Notes: difficulties with visual metronome
It was harder playing faster Tempi

Participant No. 17 **Test B**

Instrument: Trombone **Distance (mic-inst in m):** 0.432

dBSPL (A): 92.4 **Room dBSPL (A):** Rec. Studio **Mic. Gain:** 0dB

Headphones Gain: -5dB **Datafile name:** Test 17

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
2	3	4	90	192	138	203
3	4	2	120	139	70	139
4	5	3	150	100	83	83
1	2	1	180	NA	77	82
5	1	5	210	69	78	73

Notes: The visual metronome alone is difficult to follow
Using both metronomes, the faster tempi are easier to play

- -

Participant No. 18 **Test B**

Instrument: Violin **Distance (mic-inst in m):** 0,38

dBSPL (A): 82.5 **Room dBSPL (A):** 714.30 **Mic. Gain:** 10

Headphones Gain: -10 **Datafile name:** Test 18

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
3	1	1	90	300	240	300
5	2	5	120	270	257	272
1	3	4	150	149	168	214
2	4	3	180	155	163	182
4	5	2	210	132	131	133

Notes: 22 Tracks recorded Begin Track 7
The first attempt, there was no feedback signal
from HD → no vibrato after correction use of
vibrato.

Participant No. 19 **Test B**

Instrument: Triangle **Distance (mic-inst in m):** 0.286

dBSPL (A): 80 **Room dBSPL (A):** 714-30 **Mic. Gain:** 10

Headphones Gain: -10 **Datafile name:**

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
4	4	2	90	280	201	253
1	3	4	120	155	NA	300
5	1	1	150	144	NA	119
3	2	3	180	53	NA	68
2	5	5	210	33	NA	57

Notes:

Participant No. 20 **Test B**

Instrument: Tenor Sax **Distance (mic-inst in m):** ~~0.492~~ 0.492

dBSPL (A): 91.2 **Room dBSPL (A):** 714-30 **Mic. Gain:** 0

Headphones Gain: -~~10~~ +5 **Datafile name:** .528

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
4	4	5	90	~~130~~ 131	~~52~~ 49	150
3	1	4	120	117	102	142
1	5	3	150	~~123~~ 123	91	~~100~~ 97
2	3	2	180	~~102~~ 102	94	107
5	2	1	210	76	67	87

Notes: Bei Both metronome visuell wurde eher benutzt.

Participant No. 21 **Test B**

Instrument: Guitar (Classical) **Distance (mic-inst in m):** 0.30

dBSPL (A): 78.6 **Room dBSPL (A):** 717.17 **Mic. Gain:** 10

Headphones Gain: -5 **Datafile name:**

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
3	2	5	90	232	300	300
2	1	2	120	192	300	300
1	3	4	150	227	300	217
5	4	1	180	162	261	153
4	5	3	210	119	198	203

Notes:

Participant No. 22 **Test B**

Instrument: Violin **Distance (mic-inst in m):** 0.23

dBSPL (A): 82 **Room dBSPL (A):** 714-30 **Mic. Gain:** 10

Headphones Gain: -5 **Datafile name:** Test 22

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
4	4	5	90	217	147	187
3	1	4	120	186	NA	176
1	5	3	150	181	90	158
2	3	2	180	114	94	144
5	2	1	210	111	109	107

Notes: slower tempi induces a lot of Vibrato

Participant No. 23 **Test B**

Instrument: Snare Drum **Distance (mic-inst in m):** 0,51

dBSPL (A): 87 **Room dBSPL (A):** F14-30 **Mic. Gain:** 0

Headphones Gain: - 5 **Datafile name:** Test 23

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
4	3	2	90	NA	49	97
5	5	4	120	137	96	119
2	4	1	150	87	82	136 NA → auswendig
1	1	3	180	109	88	117
3	2	5	210	101	80	~~107~~ ~~97~~ 101

Notes:

Participant No. **Test B**

Instrument: **Distance (mic-inst in m):**

dBSPL (A): **Room dBSPL (A):** **Mic. Gain:**

Headphones Gain: **Datafile name:**

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
			90			
			120			
			150			
			180			
			210			

Notes:

Participant No. 24 **Test B**

Instrument: Trombone **Distance (mic-inst in m):** 0.657

dBSPL (A): 92 **Room dBSPL (A):** ______ **Mic. Gain:** 0

Headphones Gain: -5 **Datafile name:** ______

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
2	1	3	90	· 79	35	42
1	4	5	120	· 80 ~144	37	46
4	3	4	150	· 24	· NA	· 30
5	3	2	180	49	53	28
3	2	1	210	· NA	55	· 30

X No

Notes: Discarded. The test subject had problems with the headphones

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Participant No. 25 **Test B**

Instrument: Alt Sax **Distance (mic-inst in m):** 0.312

dBSPL (A): 82 **Room dBSPL (A):** Clubroom 1 **Mic. Gain:** 0

Headphones Gain: -5 **Datafile name:** 8

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
4	1	3	90	300	· 115	· 300
5	5	1	120	· 300	132	· 297
2	4	5	150	42	· 68	120
1	2	2	180	· NA	· NA ?	· NA
3	3	4	210	58	NA	52

X No

Notes: Metronome Visual NA . discarded
Test subject wasn't able to play the score

Participant No. 26 (24) **Test B**

Instrument: Alto Saxophone **Distance (mic-inst in m):** 0,389

dBSPL (A): 81,4 **Room dBSPL (A):** Club **Mic. Gain:** 0

Headphones Gain: -5 **Datafile name:** Test 26

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
4	1	2	90	157	NA	107
3	5	3	120	110	138	300
2	2	1	150	62	68	104
1	4	4	180	58	156	171
5	3	5	210	61	108	131

Notes:

- -

Participant No. 27 **Test B**

Instrument: Trumpet B **Distance (mic-inst in m):** 0,51

dBSPL (A): 87.2 **Room dBSPL (A):** club **Mic. Gain:** 0

Headphones Gain: -5 **Datafile name:** Test37

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
2	2	3	90	NA	87	171
4	1	1	120	300	113	300
5	5	5	150	306	50	300
1	3	2	180	NA	NA	300
4	4	4	210	300	NA	40

X No

Notes: he played by heart (memorized the score)! Discarded

x

Participant No. 28 **Test B**

Instrument: Kontrabass **Distance (mic-inst in m):** 0.37

dBSPL (A): 72.8 **Room dBSPL (A):** Club **Mic. Gain:** 10

Headphones Gain: ~~-10~~ -5 **Datafile name:** 48

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
2	4	4	90	110	~~58~~ NA	160
3	1	2	120	97	130	61
4	3	1	150	89 / 145	120	66
1	2	3	180	188 ?: NA	76 / 105	150
3	5	3	210	60	61	79

NoX

Notes: ~~anstrengen~~ Hand Anstrengend => Hand hurts! It was not performed to the limit, she/he told at the end of the experiment. Discarded

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Participant No. 29 **Test B** x

Instrument: Violin **Distance (mic-inst in m):** 0.26

dBSPL (A): 80.9 **Room dBSPL (A):** club **Mic. Gain:** 10

Headphones Gain: -5 **Datafile name:** 64

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
3	3	2	90	300	300	300
3	4	1	120	300	116	300
4	1	4	150	206	190	300
2	5	3	180	NA	NA ?	257
1	2	5	210	NA	72	73

NoX

Notes: Maybe the tempo is always the same during playing. Use of vibrato. Auswendig Play by heart. Discarded

Participant No. 30 **Test B**

Instrument: Triangle **Distance (mic-inst in m):** 0.294

dBSPL (A): 82.1 **Room dBSPL (A):** club **Mic. Gain:** 10

Headphones Gain: -5 **Datafile name:** ab 80

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
3	5	4	90	· 300		
1	4	1	120	· 300		
5	1	3	150	300		
2	3	2	180	300		
4	2	5	210	· 300		

No x

Notes: gedämpft Erfahrung.
Auswendig → play by heart. Discarded

Participant No. 31 **Test B**

Instrument: Tenor Sax **Distance (mic-inst in m):** 0.579

dBSPL (A): 78 **Room dBSPL (A):** club **Mic. Gain:** 0

Headphones Gain: 0 **Datafile name:** ab 85

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
5	1	4	90	300	· 206	· 300
4	5	3	120	· 300	· 300	· 300
1	3	5	150	· 300	· 300	300
3	4	1	180	· 300	· 300	· ~~300~~ 300
2	2	2	210	· 300	NA (~~[illegible]~~ NA	306

No X

Notes: difficult to isolate
visual is difficult
verinnerlicht → also auswendig gelernt.
(eyes closed) play by heart. Discarded

Participant No. 32 (25) **Test B**

Instrument: Triangle **Distance (mic-inst in m):** 0.429

dBSPL (A): 82.7 **Room dBSPL (A):** 717-17 **Mic. Gain:** 10

Headphones Gain: 0 **Datafile name:** Test 32-25

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
3	1	1	90	176	187	172
5	4	2	120	172	184	152
1	5	4	150	151	138	139
2	3	3	180	156	NA	152
4	2	5	210	121	NA	132

Notes: By foster tempi, the player mutes the stroke to have bette controll

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Participant No. 33 C **Test B** NoX

Instrument: Traverse Flute **Distance (mic-inst in m):** 0,45

dBSPL (A): 81.9 **Room dBSPL (A):** 717.-7 **Mic. Gain:** 10

Headphones Gain: +6 **Datafile name:** Test 33_no

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
2	5	2	90			
1	3	4	120			
5	4	5	150			
3	2	3	180			
4	1	1	210			

Notes: NA it was difficult to estimate the note duration. The player thougt the metronome variated and wasn't constant The player was not able to perform. the score

Participant No. 34 (26) **Test B**

Instrument: Marimba **Distance (mic-inst in m):** 0.405

dBSPL (A): 84.1 **Room dBSPL (A):** 33.8 **Mic. Gain:** 10

Headphones Gain: -5 **Datafile name:** test 34

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
2	4	5	90	284	175	268
4	1	3	120	300	86	300
1	2	1	150	78	147	300
3	5	2	180	108	140	250
5	3	4	210	193	123	223

Notes: cope with latency playing louder
the musician is aware of the memory effect
for the player was very difficult to use the visual metronome

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Participant No. ____ **Test B**

Instrument: ____ **Distance (mic-inst in m):** ____

dBSPL (A): ____ **Room dBSPL (A):** ____ **Mic. Gain:** ____

Headphones Gain: ____ **Datafile name:** ____

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
			90			
			120			
			150			
			180			
			210			

Notes: ____

Participant No. 35 (27) **Test B**

Instrument: French Horn **Distance (mic-inst in m):** 0.418

dBSPL (A): 83.4 **Room dBSPL (A):** Probebühne **Mic. Gain:** 0

Headphones Gain: +5 **Datafile name:** Test 35

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
3	1	1	90	300	249	239
5	4	2	120	159	169	197
1	5	4	150	300	172	212
2	3	3	180	282	144	203
4	2	5	210	130	131	160

Notes:

Participant No. 36 (28) **Test B**

Instrument: Double Bass **Distance (mic-inst in m):** 0.394

dBSPL (A): 82.1 **Room dBSPL (A):** Probebühne **Mic. Gain:** +10

Headphones Gain: 0 **Datafile name:** Test 36

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
2	5	2	90	151	NA	162
1	3	4	120	174	151	151
5	4	5	150	164	166	122
3	2	3	180	133	154	152
4	1	1	210	126	159	132

Notes:

Participant No. 37(29) **Test B**

Instrument: Harp **Distance (mic-inst in m):** 0,594

dBSPL (A): 81.2 **Room dBSPL (A):** Church Mehrzweckraum **Mic. Gain:** 10

Headphones Gain: -5 **Datafile name:** Test 37

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
3	2	2	90	230	300	300
5	1	4	120	201	NA	228
1	5	5	150	145	149	154
2	3	3	180	128	136	152
4	4	1	210	117	102	142

Notes: the musicians perceived a variation of the temp in the visual metronome. Temp was always steady.

Participant No. 38(30) **Test B**

Instrument: Bassoon **Distance (mic-inst in m):** 0.448

dBSPL (A): 82.3 **Room dBSPL (A):** Room 5 Tonart Musikhalle **Mic. Gain:** +12

Headphones Gain: 0 **Datafile name:** Test 38

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
3	2	5	90	221	NA	300
5	1	4	120	147	97	300
1	3	1	150	300	61	262
2	4	3	180	98	67	86
4	5	2	210	NA	NA	35

Notes: 90 BPM Visual NA -> musician was distracted by breath!

Participant No. 37 (31) **Test B**

Instrument: Tenor Saxophone **Distance (mic-inst in m):** 0,527

dBSPL (A): 91.3 **Room dBSPL (A):** Living room **Mic. Gain:** 0

Headphones Gain: 5 **Datafile name:** 39

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
3	1	2	90	111	NA	117
5	3	1	120	73	29	76
1	2	5	150	· 63	43	67
2	4	3	180	NA	35	66
4	5	4	210	51	63	59

Notes: Feet / increase of playing level (volume) during latency

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X No

Participant No. 40 **Test B**

Instrument: Baroque violin **Distance (mic-inst in m):** 0.449

dBSPL (A): 80.5 **Room dBSPL (A):** Office **Mic. Gain:** 10

Headphones Gain: 0 **Datafile name:** 40

Order Tempo Latency (ms)

			BPM	Audio	Visual	Both
5	1	5	90	300	300	300
3	4	3	120	300	300	300
4	5	2	150	300	300	300
2	3	1	180	300	300	300
1	2	4	210	300	300	300

Notes: The musician admitted being able to cope with latency due to some techniques and strategies used for playing contemporary works with latency as part of the performance. For this reason the results were not included. In the questionnaire (Notes) the an explanation is written by the musician.

Participant No. 1

Item	**Question**	**Possible Answer**
1	Instrument	Name Piano Group: Chordophones
2	Age	Age: 19
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 8 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 6
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ✓
8	Current hours of practice per week	Number of hours: 12
9	Performance on other instruments	[✓ 1. Yes] Instrument: Saxophone 2. No
10	Metronome preference	1. Visual _ 2. Audio ✓ 3. Both _
11	Notes : Really difficult experience. A lot of things are happening at the same time. This is really difficult to assimilate.	

Participant No. 2

Item	**Question**	**Possible Answer**
1	Instrument	Name Piano Group: Chordophones
2	Age	Age: 18
3	Gender	1. Male [✓ 2. Female]
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 1 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 8
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ✓
8	Current hours of practice per week	Number of hours: 14
9	Performance on other instruments	[✓ 1. Yes] Instrument: Viola 2. No
10	Metronome preference	1. Visual _ [✓ 2. Audio] _ 3. Both _
11	Notes : Visual metronome was more difficult to follow difficult to concentrate on the metronome as the delay increased.	

Participant No. 3

Item	**Question**	**Possible Answer**
1	Instrument	Name CELLO Group: STRINGS
2	Age	Age: 22
3	Gender	1. Male 2. [✓ Female]
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: ____ 2. [✓ No]
5	Expertise	1. Professional Musician 2. [✓ Music Student]
6	Years of Experience performing the instrument	Number of years: 6
7	Playing technique	1. Plucked ~~✓~~ 2. Bowed ✓ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 10
9	Performance on other instruments	1. [✓ Yes] Instrument: PIANO 2. No
10	Metronome preference	1. Visual ✓ 2. Audio _ 3. Both _
11	Notes : Try to hear the original signal	

Participant No. 4

Item	**Question**	**Possible Answer**
1	Instrument	Name Cello Group: Chordophones
2	Age	Age: 18
3	Gender	1. Male [✓ 2. Female]
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 2 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 5
7	Playing technique	1. Plucked ___ 2. Bowed ✓ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 12
9	Performance on other instruments	[✓ 1. Yes] Instrument: violin 2. No
10	Metronome preference	1. Visual _ [✓ 2. Audio] _ 3. Both _
11	Notes : Visual difficult / Both then concentrate in the aural.	

Participant No. 5

Item	**Question**	**Possible Answer**
1	Instrument	Name Caspas [illegible] Group: Chordophones
2	Age	Age: 18
3	Gender	1. Male ✓ 2. Female
4	Use of a metronome for musical training (more than once a week)	1. Yes ✓ Aprox. number of hours: 7 2. No
5	Expertise	1. Professional Musician 2. Music Student ✓
6	Years of Experience performing the instrument	Number of years: 4
7	Playing technique	1. Plucked ✓ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 14
9	Performance on other instruments	1. Yes Instrument: ___ 2. No ✓
10	Metronome preference	1. Visual _ [✓ 2. Audio] _ 3. Both _
11	Notes : Visual was a distraction	

Participant No. 6

Item	**Question**	**Possible Answer**
1	Instrument	Name: Horn Group: Aerophones
2	Age	Age: 21
3	Gender	[✓ 1. Male] ~~2. Female~~
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 3 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 9
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 21
9	Performance on other instruments	[✓ 1. Yes] Instrument: Trompet 2. No
10	Metronome preference	1. Visual _ [✓ 2. Audio] _ 3. Both _
11	Notes : When the last note mix with the first ist almost impossible to play. The rest are very important. I play with memory.	

Participant No. 7

Item	**Question**	**Possible Answer**
1	Instrument	Name Alto saxophone Group: Aerophones
2	Age	Age: 20
3	Gender	1. [✓ Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	1. [✓ Yes] Aprox. number of hours: 7,5 2. No
5	Expertise	1. Professional Musician 2. [✓ Music Student]
6	Years of Experience performing the instrument	Number of years: 72
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 8
9	Performance on other instruments	1. [✓ Yes] Instrument: Piano, voice, electric bass 2. No
10	Metronome preference	1. Visual _ 2. Audio _ 3. Both ✓
11	Notes : Usually easier when the delay hit the "rhythmic grid" (e.g. at beginning and at the end).	

Participant No. 8

Item	**Question**	**Possible Answer**
1	Instrument	Name Violin Group: String
2	Age	Age: 20
3	Gender	1. Male [✓ 2. Female]
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 3 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 13
7	Playing technique	1. Plucked ___ 2. Bowed ✓ 3. Strucked ___
8	Current hours of practice per week	Number of hours: [redacted] 20
9	Performance on other instruments	1. Yes Instrument: ___ [✓ 2. No]
10	Metronome preference	1. Visual _ [✓ 2. Audio] _ 3. Both _
11	Notes : it was easier after some time she gets used to the tune	

Participant No. 7

Item	**Question**	**Possible Answer**
1	Instrument	Name Trompete in B Group: Aerophones
2	Age	Age: 22
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: 0,5 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 14
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 4
9	Performance on other instruments	[✓ 1. Yes] Instrument: Drums 2. No
10	Metronome preference	1. Visual _ 2. Audio _ [✓ 3. Both]
11	Notes : Mit Audio war das Spielen am einfachsten.	

Participant No. 10

Item	**Question**	**Possible Answer**
1	Instrument	Name Snaredrum Group: Membranophon
2	Age	Age: 30
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 7 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 12
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 21
9	Performance on other instruments	[✓ 1. Yes] Instrument: Double Bass, Piano 2. No
10	Metronome preference	1. Visual 3 2. Audio 2 3. Both 1
11	Notes : Mich stört die Latenz sehr. Gefühl der inneren Unruhe entsteht. Bei längstem Durchgang auswendig gespielt. Bei höherer Latenz werde ich sehr verwirrt.	

Participant No. 11

Item	**Question**	**Possible Answer**
1	Instrument	Name Piano Group: Chordophone
2	Age	Age: 27
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 4 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: ~~[illegible]~~ 6
7	Playing technique	1. Plucked ___ 2. Bowed ___ [✓ 3. Strucked]
8	Current hours of practice per week	Number of hours: 30
9	Performance on other instruments	[✓ 1. Yes] Instrument: Drums 2. No
10	Metronome preference	1. Visual _ 2. Audio _ [✓ 3. Both]

11 Notes : Es war verwirrend, man hat es nicht verstanden, warum man immer schlechter ~~[illegible]~~ wurde.

Participant No. 12

Item	Question	Possible Answer
1	Instrument	Name: Snare Drum Group: Membranophon
2	Age	Age: 26
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: 5-6 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 13 Jahre
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 5
9	Performance on other instruments	[✓ 1. Yes] Instrument: Piano 2. No
10	Metronome preference	1. Visual _ [✓ 2. Audio] _ 3. Both _
11	Notes : Durch den eher körperlichen Einsatz ~~vom Körper~~ bei einen Perk. Instrument lässt sich die Verzögerung später spüren oder man kann länger damit spielen. Der körperliche Input kompensiert die Verzögerung. Anders ist es beim Klavier wo man die Verzögerung früher merkt (Midi und Buffer size)	

Participant No. 13

Item	**Question**	**Possible Answer**
1	Instrument	Name Violin Group: Chordophones
2	Age	Age: 27
3	Gender	1. Male ✓ 2. Female
4	Use of a metronome for musical training (more than once a week)	1. Yes ✓ Aprox. number of hours: 2 2. No
5	Expertise	1. Professional Musician 2. Music Student ✓
6	Years of Experience performing the instrument	Number of years: 20
7	Playing technique	1. Plucked ___ 2. Bowed ✓ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 7
9	Performance on other instruments	1. Yes ✓ Instrument: Guitar, Piano 2. No
10	Metronome preference	1. Visual _ 2. Audio _ 3. Both X
11	Notes : Man spürt den Klang am Hals Bild ist ganz schwer. (Steinbrenner P-13)	

Participant No. 14

Item	**Question**	**Possible Answer**
1	Instrument	Name Querflöte Group: Aerophone
2	Age	Age: 18
3	Gender	1. Male [✓ 2. Female]
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: ____ [✓ 2. No]
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 8
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 5
9	Performance on other instruments	1. Yes Instrument: ____________ [✓ 2. No]
10	Metronome preference	1. Visual _ 2. Audio _ [✓ 3. Both] _
11	Notes : Überschneidung schrecklich	

Participant No. 15

Item	**Question**	**Possible Answer**
1	Instrument	Name Posaune Group: ____
2	Age	Age: 18
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: ____ [✓ 2. No]
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 3
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 0
9	Performance on other instruments	[✓ 1. Yes] Instrument: Trompete 2. No
10	Metronome preference	1. Visual _ [✓ 2. Audio] _ 3. Both _
11	Notes : Er spielt schnellere Sachen	

Participant No. 16

Item	**Question**	**Possible Answer**
1	Instrument	Name Timpani Group: Idrophones
2	Age	Age: 18
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: ____ [✓ 2. No]
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 2
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 1
9	Performance on other instruments	[✓ 1. Yes] Instrument: Klarinette 2. No
10	Metronome preference	1. Visual _ [✓ 2. Audio _] 3. Both _
11	Notes :	

Participant No. 17

Item	**Question**	**Possible Answer**
1	Instrument	Name Trombone Group: Aerophones
2	Age	Age: 27
3	Gender	1. Male ✓ 2. ~~Female~~
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: ____ 2. No ✓
5	Expertise	1. Professional Musician 2. Music Student ✓
6	Years of Experience performing the instrument	Number of years: 13
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 0
9	Performance on other instruments	1. Yes ✓ Instrument: Keys (piano) 2. No
10	Metronome preference	1. Visual _ 2. Audio _ 3. Both _ ✓
11	Notes : ~~Visual~~ Both · good for latency visual complicated	

Participant No. 18

Item	**Question**	**Possible Answer**
1	Instrument	Name Violin Group: Chordophones
2	Age	Age: 22
3	Gender	1. Male [✓ 2. Female]
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: ____ [✓ 2. No]
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 13 years
7	Playing technique	1. Plucked ___ [✓ 2. Bowed] ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 1/2
9	Performance on other instruments	[✓ 1. Yes] Instrument: piano, 2. No
10	Metronome preference	1. Visual _ 2. Audio ✓ 3. Both _
11	Notes : Fuß, Takt zu folgen Vibrato	

Participant No. 19

Item	Question	Possible Answer
1	Instrument	Name ~~Gitarre~~ Triangl. Group: Idiophones
2	Age	Age: > 18 50
3	Gender	1. Male [✓ 2. Female]
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: 1 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 25
7	Playing technique	[✓ 1. Plucked] ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 3-4
9	Performance on other instruments	[✓ 1. Yes] Instrument: Violine Piano 2. No
10	Metronome preference	1. Visual _ [✓ 2. Audio _] 3. Both _
11	Notes : Mittlere Tempi schwerer auszuhalten als beim schnellen Tempo	

Participant No. 20

Item	**Question**	**Possible Answer**
1	Instrument	Name T Sax Group: Aerophones
2	Age	Age: 24
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 1 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 12
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: ~ 1
9	Performance on other instruments	[✓ 1. Yes] Instrument: Guitar 2. No
10	Metronome preference	1. Visual _ [✓ 2. Audio _] [✓ 3. Both _]
11	Notes :	

Participant No. 21

Item	**Question**	**Possible Answer**
1	Instrument	Name Gitarre Group: Chordophones
2	Age	Age: 21
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: ½ h per day 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 11
7	Playing technique	1. Plucked X 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 7
9	Performance on other instruments	[✓ 1. Yes] Instrument: Piano 2. No
10	Metronome preference	1. Visual _ 2. Audio X 3. Both _
11	Notes : Hat versuch zu kompensieren niedrigeren ~~Tempi~~ Latenz kompensiert größeren ~~schnelleren Tempi~~ größeren Latenz gespürt noch gefühlt (Finger und Widerstand der Saite)	

Participant No. 22

Item	Question	Possible Answer
1	Instrument	Name: Violin Group: Chordophones
2	Age	Age: 27
3	Gender	1. Male 2. [✓ Female]
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: ____ 2. [✓ No]
5	Expertise	1. Professional Musician 2. [✓ Music Student]
6	Years of Experience performing the instrument	Number of years: 17
7	Playing technique	1. Plucked ___ 2. Bowed ✓ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 0
9	Performance on other instruments	1. Yes Instrument: ____ 2. [✓ No]
10	Metronome preference	1. Visual _ 2. Audio ✓ 3. Both _
11	Notes :	

Participant No. 28

Item	**Question**	**Possible Answer**
1	Instrument	Name Snare Drum Group: Membranophone
2	Age	Age: 25
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: 0,5 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 15
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 0,5
9	Performance on other instruments	1. Yes Instrument: ___ [✓ 2. No]
10	Metronome preference	1. Visual _ 2. Audio ✓ 3. Both _
11	Notes : ___	

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Participant No. 24

Item	**Question**	**Possible Answer**
1	Instrument	Name Trombone Group: ______
2	Age	Age: 18
3	Gender	1. [✓ Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: ____ 2. [✓ No]
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 3
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 0 $\frac{1}{2}$
9 —	Performance on other instruments	1. [✓ Yes] Instrument: Euphonium 2. No
10	Metronome preference	1. Visual _ 2. [✓ Audio] 3. Both _
11	Notes : KH Problem Discarded	

Participant No. 25

Item	**Question**	**Possible Answer**
1	Instrument	Name Alt Sax Group: chordophones
2	Age	Age: 18
3	Gender	1. Male 2. Female
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: 0 2. No
5	Expertise	1. Professional Musician 2. Music Student
6	Years of Experience performing the instrument	Number of years: 3
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 3
9	Performance on other instruments	1. Yes Instrument: Blockflöte 2. No
10	Metronome preference	1. Visual _ [✓ 2. Audio _] 3. Both _
11	Notes :	

Participant No. 26 (24)

Item	**Question**	**Possible Answer**
1	Instrument	Name Saxophon Alt Group: Holzblasinstrument
2	Age	Age: 18
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 3 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 5
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 8
9	Performance on other instruments	1. Yes Instrument: ________ [✓ 2. No]
10	Metronome preference	1. Visual _ 2. Audio _ 3. Both [✓]
11	Notes :	

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Participant No. 27

Item	**Question**	**Possible Answer**
1	Instrument	Name Trompete in B Group: ____
2	Age	Age: 18
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: ____ [✓ 2. No]
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 11
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 8
9	Performance on other instruments	[✓ 1. Yes] Instrument: Klavier 2. No
10	Metronome preference	1. Visual _ 2. Audio ✓ 3. Both _
11	Notes : ____	

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Participant No. 28

Item	**Question**	**Possible Answer**
1	Instrument	Name Kontrabass Group: ____
2	Age	Age: 18
3	Gender	1. Male [✓ 2. Female]
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: ____ [✓ 2. No]
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 4
7	Playing technique	1. Plucked ___ 2. Bowed ✓ 3. Strucked ✓
8	Current hours of practice per week	Number of hours: 1
9	Performance on other instruments	1. Yes Instrument: Gitarre + E-Bass 2. No
10	Metronome preference	1. Visual _ 2. Audio ✓ 3. Both _
11	Notes : ____	

1

Participant No. 29

Item	**Question**	**Possible Answer**
1	Instrument	Name Violin Group: chordophone
2	Age	Age: 18
3	Gender	~~1. Male~~ [✓ 2. Female]
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 1 2. No
5	Expertise	~~1. Professional Musician~~ [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 12
7	Playing technique	1. Plucked ___ 2. Bowed x 3. Strucked ___
8	Current hours of practice per week	Number of hours: 4-5
9	Performance on other instruments	[✓ 1. Yes] Instrument: Gitarre 2. No
10	Metronome preference	1. Visual _ [✓ 2. Audio _] 3. Both _
11	Notes :	

Participant No. 30

Item	**Question**	**Possible Answer**
1	Instrument	Name: Triangle Group: Idiophone
2	Age	Age: 18
3	Gender	[✓ 1. Male] ~~2. Female~~
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 2 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 13
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 14
9	Performance on other instruments	[✓ 1. Yes] Instrument: Piano 2. No
10	Metronome preference	1. Visual _ 2. Audio _ 3. Both _
11	Notes :	

Participant No. 31

Item	**Question**	**Possible Answer**
1	Instrument	Name Tenor Sax Group: Chordophones
2	Age	Age: 56
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 6 2. No
5	Expertise	[✓ 1. Professional Musician] 2. Music Student
6	Years of Experience performing the instrument	Number of years: 30
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 15
9	Performance on other instruments	1. Yes Instrument: Klavier 2. No
10	Metronome preference	1. Visual _ [✓ 2. Audio _] 3. Both _
11	Notes :	

Participant No. 32 (25)

Item	**Question**	**Possible Answer**
1	Instrument	Name Triangle Group: Idiophones
2	Age	Age: 20
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 3 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 14
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 6
9	Performance on other instruments	[✓ 1. Yes] Instrument: Piano 2. No
10	Metronome preference	1. Visual _ 2. Audio _ [✓ 3. Both _]
11	Notes : long strokes for a better contact to mute and have a better control.	

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Participant No. 33 (vo)

Item	**Question**	**Possible Answer**
1	Instrument	Name Flûte Traverse Group: Aerophones
2	Age	Age: 38
3	Gender	1. Male X 2. Female
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: ____ 2. No X
5	Expertise	1. Professional Musician 2. Music Student X
6	Years of Experience performing the instrument	Number of years: 20
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 4
9	Performance on other instruments	1. Yes Instrument: ____________ 2. No X
10	Metronome preference	1. Visual _ 2. Audio _ 3. Both _
11	Notes : ______________________________	

Participant No. 34 (26)

Item	**Question**	**Possible Answer**
1	Instrument	Name Marimba Group: Idiophon
2	Age	Age: 31
3	Gender	1. Male ~~2. Female~~
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: 5 ~~2. No~~
5	Expertise	1. Professional Musician ~~2. Music Student~~
6	Years of Experience performing the instrument	Number of years: 16
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 20
9	Performance on other instruments	1. Yes Instrument: Drums/Percussion, Piano ~~2. No~~
10	Metronome preference	1. Visual _ 2. Audio [✓] 3. Both _
11	Notes : ______	

Participant No. 35 (27)

Item	**Question**	**Possible Answer**
1	Instrument	Name HORN Group: AEROPHONE
2	Age	Age: 35
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 2 2. No
5	Expertise	[✓ 1. Professional Musician] 2. Music Student
6	Years of Experience performing the instrument	Number of years: 22
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 35
9	Performance on other instruments	1. Yes Instrument: ______ [✓ 2. No]
10	Metronome preference	1. Visual _ [✓ 2. Audio] _ 3. Both _
11	Notes : temp variation ?	

Participant No. 36 (28)

Item	**Question**	**Possible Answer**
1	Instrument KONTRABASS	Name NEREA Group: Chordophone
2	Age 33	Age: 33
3	Gender	1. Male [✓ 2. Female]
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 5 2. No
5	Expertise	[✓ 1. Professional Musician] 2. Music Student
6	Years of Experience performing the instrument	Number of years: 25
7	Playing technique	1. Plucked ___ [✓ 2. Bowed ___] 3. Strucked ___
8	Current hours of practice per week	Number of hours: 10
9	Performance on other instruments	1. Yes Instrument: ________ [✓ 2. No]
10	Metronome preference	1. Visual _ [✓ 2. Audio _] 3. Both _
11	Notes : ________	

Participant No. 37

Item	**Question**	**Possible Answer**
1	Instrument	Name Harp Group: Chordphones
2	Age	Age: 34
3	Gender	1. Male [✓ 2. Female]
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: 8 2. No
5	Expertise	[✓ 1. Professional Musician] 2. Music Student
6	Years of Experience performing the instrument	Number of years: 25
7	Playing technique	[✓ 1. Plucked ___] 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 16
9	Performance on other instruments	1. Yes Instrument: ___ [✓ 2. No]
10	Metronome preference	1. Visual _ 2. Audio _ [✓ 3. Both _]
11	Notes : ___	

Participant No. 38

Item	**Question**	**Possible Answer**
1	Instrument	Name Bassoon Group: Aerophones
2	Age	Age: 51
3	Gender	1. Male [✓ 2. Female]
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: ____ [✓ 2. No]
5	Expertise	[✓ 1. Professional Musician] 2. Music Student
6	Years of Experience performing the instrument	Number of years: 8
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 2
9	Performance on other instruments	[✓ 1. Yes] Instrument: Flute Clar Sax Cello 2. No
10	Metronome preference	1. Visual _ [✓ 2. Audio] _ 3. Both _
11	Notes : You get used to the metronome, there begins a flow! The breathing pattern different the coping with latency.	

Participant No. 39

Item	**Question**	**Possible Answer**
1	Instrument	Name Tenorsaxophon Group: Aerophon
2	Age	Age: 21
3	Gender	[✓ 1. Male] 2. Female
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 0,25 2. No
5	Expertise	1. Professional Musician [✓ 2. Music Student]
6	Years of Experience performing the instrument	Number of years: 11
7	Playing technique	1. Plucked ___ 2. Bowed ___ 3. Strucked ___
8	Current hours of practice per week	Number of hours: 10
9	Performance on other instruments	[✓ 1. Yes] Instrument: Altsax; Bariton-sax 2. No
10	Metronome preference	1. Visual _ 2. Audio _ 3. Both ✓
11	Notes :	

Participant No. 40

Item	**Question**	**Possible Answer**
1	Instrument Baroque Violin	Name George Violin Group: Chordophone
2	Age 44	Age: 44
3	Gender ♀	1. Male [✓ 2. Female]
4	Use of a metronome for musical training (more than once a week)	[✓ 1. Yes] Aprox. number of hours: 4 2. No
5	Expertise	[✓ 1. Professional Musician] 2. Music Student
6	Years of Experience performing the instrument	Number of years: 30
7	Playing technique	1. Plucked ___ [✓ 2. Bowed] X 3. Strucked ___
8	Current hours of practice per week	Number of hours: 28
9	Performance on other instruments	[✓ 1. Yes] Instrument: piano, viola, voice 2. No
10	Metronome preference	1. Visual _ [✓ 2. Audio] _ 3. Both _
11	Notes : It was possible for me to just listen to the audio of the metronome and to accept my sound as a background or a chamber music partner – just like in Steve Reich's "phase violin". In my string quartet we sometimes phase in and out of each other – on purpose since we combine "old and contemporary" playing techniques. I found that certain	

moments were tricky, whereas other moments ~~they~~ there was something like a musical pleasure in enjoying the rhythms phrasing.

The moments around the tricky bits – in slow tempo felt like walking in thick honey – very heavy and full of weight – as if leading a very slow orchestra or playing in a church with huge echo.

In the fast tempi the tricky bits felt like a chaos and I had more trouble to listen to the metronome in my focus.

The visual metronome I found less helpful as I felt not enough impulse from the visual trigger and too much room for speculation.

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Appendix N

CIT Research Ethics Application Form

CIT RESEARCH ETHICS APPLICATION FORM

Name of applicant(s)	Jorge Medina Victoria	Date 30.09.16
Contact Details	Phone +49 176 64626....	Email jorge.medina.victoria@h-da.de
Department/Unit	Electrical Engineering	
Title of Research	Latency Tolerance Range for musicians in non-collaborative performances on western musical instruments	
Name of Supervisor (Principal Investigator)	Prof. Dr. Kyrill Fischer (h-da)	

CIT is committed to promoting and protecting ethics in research undertaken in CIT or by CIT staff and students. Overleaf are a number of tables to indicate the primary ethical concerns that may apply to your research. A rationale for points in all relevant sections should be submitted with this application.

Please note if your research involves **Clinical Trials** the 'CIT- Clinical Trials Ethics Application Form' will need to be completed.

Intellectual Property Rights

Please refer to CIT IPR policy document - INTELLECTUAL PROPERTY POLICY, July 2011

Conflict of Interest Declaration

The CIT Research Conflict of Interest declaration needs to be signed. This refers to circumstances in which personal interests (financial or other) may compromise, or have the appearance of compromising, your professional competence as a researcher in undertaking or reporting the research.

I/We declare that I/We know of no conflict of interest pertaining to the research outlined in this proposal.

I/We agree to the above ☒

I/We do not agree to the above ☐
(Please tick one box only)

Signed ________________ Date 30.09.16
Applicant

Signed ________________ Date 4th of Oct. 2016
Supervisor/Principal Investigator

Signed ________________ Date 13th Nov 2017
Head of Department/Function

Note. A potential conflict of interest if it exists needs to be explained in a supplementary letter submitted with this application.

Latency Tolerance Range for musicians in non-collaborative performances on western musical instruments

Applicant: Jorge Medina Victoria

DESCRIPTION OF THE RESEARCH

3.1 The objective of the research is to find the latency tolerance range. The range where musicians are able to cope with latency (delay). For this purpose, a listening test is designed to find this tolerance range.

3.2 There is no ethical issues in connection with the designed listening test. The test satisfies every parameter necessary to guarantee the safety of the participants. The general information sheet for participants and the listening consent form are attached.

General information sheet for participants

Thank you for agreeing to take part in the listening test for the research on Latency
Tolerance Range for musicians.

The only action you are expected to do is to play your instrument. The guideline for your
performance is a musical score.

There is no right or wrong performance for this test. We are interested in the performance
development. We are not evaluating the quality of the performance in any form.

Test procedure

1. The first part of the test is an audiometry. You receive a set of headphones you will hear five different frequency tones (beeps). Any time you hear one tone, play your instrument.

2. Your instrument will be miked (a microphone is placed in front of your instrument). You will listen to your instrument signal through the headphones.

3. Play the score you see in the small screen. During the performance, a metronome is always active.

4. During the test. You play the score. Your instrument signal, which you hear through the headphones, will be delayed until you are not able to perform any more. The metronome is a guide to help you regarding the musical tempo of the performance.

5. For each of the three trials there is a different metronome. A visual metronome also in the small screen. An aural metronome through headphones and both (visual and aural) combined. Each trial has five attempts with different tempi in BPM from 90BPM to 210BPM in 30BPM steps.

Health and Safety

- The time duration of the listening test will not exceed 25 minutes. Average between 10 to 15 minutes.
- Sound reproduction levels (headphones) are controlled under safe limits as recommended by the European Union legislation.
- You are free to withdrawn from the listening experiment at any time and without giving any reason.

If you still have any question, please do not hesitate to ask anything related to the experiment.

3.4 Test subjects are professional musicians or music students. The recruitment will be achieved by word of mouth and personal contacts.

3.5 See section 3.3 and attachments.

3.6 Data information, especially recordings will be kept in a safe place. There is no possibility to identify test subjects. The name is not included in the questions.

3.7 The only investigator is the author.

3.8 Is not an issue, both question answered with No.

3.9 Additional insurance is not necessary.

3.10 In November 2017 will begin the test phase. First in the Cork Music School. Additional test subjects will be interviewed in Germany.

Listening test consent form

I the undersigned voluntarily agree to take part in the study: Latency Tolerance Range for musicians in non-collaborative performances on western musical instruments.

I have read and understood the information sheet provided. I have been given a full explanation by the researcher about the purpose, duration of the listening test and what

I will be expected to do. Any question about any aspect of the test has been answered.

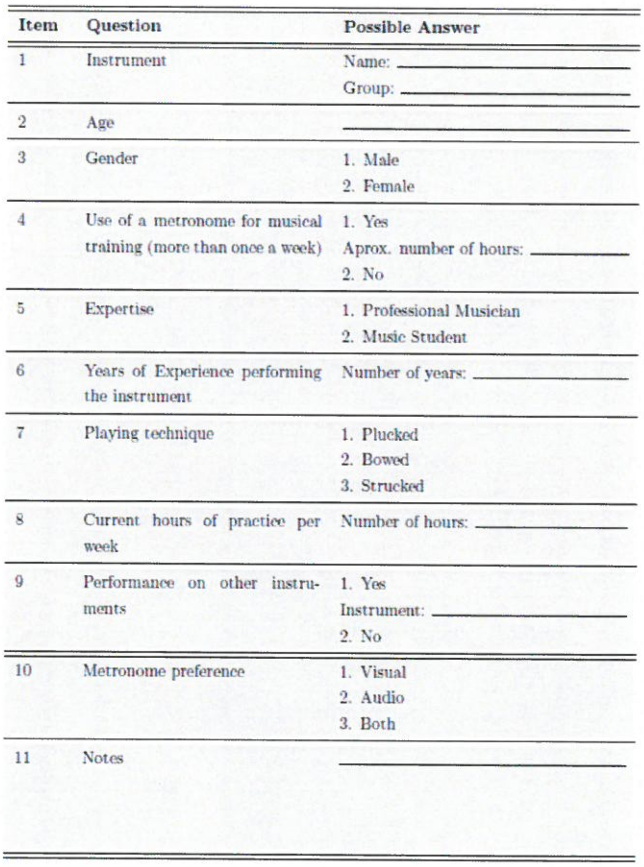
I understand that I am free to withdraw from the listening test at any time without any justification of my decision and with no further consequences.

I confirm that my I am not under 18 years of age at the moment of presenting the listening test.

I confirm that I have read and understood the above and freely consent to participating in the listening test.

Name of test subject____
Signed ______________________________ Date __________________

3.3 Questionnaire



Item	Question	Possible Answer
1	Instrument	Name: ________________ Group: ________________
2	Age	________________
3	Gender	1. Male 2. Female
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: ________ 2. No
5	Expertise	1. Professional Musician 2. Music Student
6	Years of Experience performing the instrument	Number of years: __________
7	Playing technique	1. Plucked 2. Bowed 3. Strucked
8	Current hours of practice per week	Number of hours: __________
9	Performance on other instruments	1. Yes Instrument: ____________ 2. No
10	Metronome preference	1. Visual 2. Audio 3. Both
11	Notes	________________

Questions 1 to 9 will be asked previous the beginning of the listening test. Questions 10 and 11 after the experiment.

Instructions to Investigators

Investigators should pay particular attention to their responsibilities especially those outlined below:

- Provide the Research Ethics Committee with the appropriate information on the research protocol by filling the forms in detail. Notify the Committee of subsequent modifications, terminations, and adverse reactions if significant, and if changes in focus or direction occur which may require ethical approval.

- Ensure that all documentation is submitted electronically as a PDF.

- Ensure that no direct research, i.e. research involving ethical issues, will be initiated (except emergency or compassionate) until Research Ethics Committee approval is received.

- Obtain appropriate informed consent from participant(s) where necessary.

- Carry out the protocol as approved; initiating modifications only after the Research Ethics Committee has approved the amendment. (Exceptions only where necessary to eliminate apparent immediate hazards to the participant(s)).

- Where the research results in any severe reaction or unforeseen injury, the research actions responsible should be immediately suspended and the matter immediately reported to the Chair of the Research Ethics Committee and any other relevant committee or officer of the Institute.

- Ensure that the research will be carried out only by the approved investigator and or co-investigators.

- Keep appropriate records, including names and access information for all research subjects, and maintain confidentiality of all records.

Notes:

1. Please submit this form and any attachments electronically to Dr Ger Kelly (Email ger.kelly@cit.ie), Chair, Research Ethics Committee, Department of Mechanical Biomedical and Manufacturing Engineering, Cork Institute of Technology.

2. Guidelines on the design of an informed consent form (ICF) are attached as appendix 1.

This form is adopted from pp. 13-14 of "Guidelines for Minimum Standards of Ethical Approval in Psychological Research" (British Psychological Society, July, 2004) and from the "Code of Professional Ethics" from the Psychological Society of Ireland – 2011.

ETHICS CHECKLIST FOR RESEARCH INVOLVING HUMAN PARTICIPANTS

The CIT Research Ethics Committee (REC) has produced the following checklist to assist researchers whose project involves the participation of humans and the associated ethical implications. If you answer YES to any of these questions, you will need to complete and submit the CIT Ethics Application Form, which can be downloaded on the CIT website.

	1. Research with Human Participants	**YES**	**NO**
1	Will/did you obtain consent from any organisations involving/representing potential participants?	✓	
2	Will you describe the main research procedures to participants in advance, so that they are informed about what to expect?	✓	
3	Will participation be voluntary?	✓	
4	Will you obtain informed consent in writing from participants?	✓	
5	Will you tell participants that they may withdraw from the research at any time and for any reason (without repercussions), and (where relevant) omit questionnaire items to which they do not wish to respond?	✓	
6	Will your research involve the processing of genetic information or personal data *(e.g., ethnicity, health, sexual lifestyle, political opinion, religious or philosophical opinion)*?		✓
7	Will data be treated with full confidentiality / anonymity (as appropriate)?	✓	
8	If results are published, will anonymity be maintained and participants not identified?	✓	
9	Will you debrief participants at the end of their participation?	✓	
10	Will your research involve the tracking or observation of people?		✓
11	Will your project involve deliberately misleading participants in any way?		✓
12	Is there a realistic risk of participants experiencing physical or psychological distress? *(if yes, outline support measures to be put in place- short and long-term in section 3.5)*		✓
14	Will compensation be awarded to participants upon participation? *(if yes, please describe).*		✓

	2. Research with Vulnerable Human Groups	Yes	No
1	Will your participants include children (under 18 years of age)?		✓
2	Will your participants include people with learning or communication difficulties?		✓
3	Will your participants include patients?		✓
4	Will your participants include people in custody?		✓
5	Will your participants include people known to be engaged in illegal activities (e.g., drug taking; illegal Internet behaviour)?		✓
6.	Will your research involve any other vulnerable groups? *(if yes, please identify).*		✓
7.	Will your research involve any benefit sharing with the vulnerable groups? *(if yes, please explain)*		✓
8.	Could your research further stigmatise a population group? *(if yes, please explain how this will be addressed).*		✓

3. DESCRIPTION OF THE RESEARCH

Please provide a detailed description of the research to be undertaken addressing as a minimum the headings below.

3.1 Objectives of the Research.

3.2 Concise statement of ethical issues raised by the research and how you intend to deal with them.

3.3 Description and justification of methodology to be followed. *(Attach copy of questionnaire/ interview protocol / discussion guide / etc.).*

3.4 Sample explanation (number, composition, recruitment, exclusion/inclusion criteria; relevant licences, approval or support letters should be attached).

3.5 Permission, informed consent/assent, support measures and debriefing procedures (where relevant) *if you answered YES to Question 12 section 1, give details here. State what you will advise participants to do if they should experience problems (e.g., who to contact for help).*

3.6 Data protection procedures (including access, retention, destruction).

3.7 Identify the research investigators or co-investigators covered by the application.

3.8 Measures to be taken to address any other ethical concerns raised by the research (in relation to the points in sections 1 and 2).

3.9 Has additional insurance cover being taken out? (*if yes, please attach a copy of same)*

3.10 Please give an estimated start date and duration of the research study.

4. Additional Information

4.1 Is there anything else of an ethical nature you wish to disclose? **Yes** or [✓ **No.**]

Latency Tolerance Range for musicians in non-collaborative performances on western musical instruments

Applicant: Jorge Medina Victoria

DESCRIPTION OF THE RESEARCH

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There is no right or wrong performance for this test. We are interested in the performance development. We are not evaluating the quality of the performance in any form.

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2. Your instrument will be miked. You receive a set of headphones. You will listen to your instrument signal through the headphones.

3. Play the score you see in the small screen. During the performance a metronome is always active.

4. During the test. You play the score. Your instrument signal, which you hear through the headphones, will be delayed until you are not able to perform any more. The metronome is a guide to help you with the performance.

5. For each of the three trials there is a different metronome. A visual metronome also in the small screen. An auditive metronome through headphones and both (visual and aural) combined. Each trial has 5 attempts with different tempo in BPM from 90BPM to 210BPM in 30BPM steps.

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If you still have any question, please do not hesitate to ask anything related to the experiment.

Listening test consent form

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I will be expected to do. Any question about any aspect of the test has been answered.

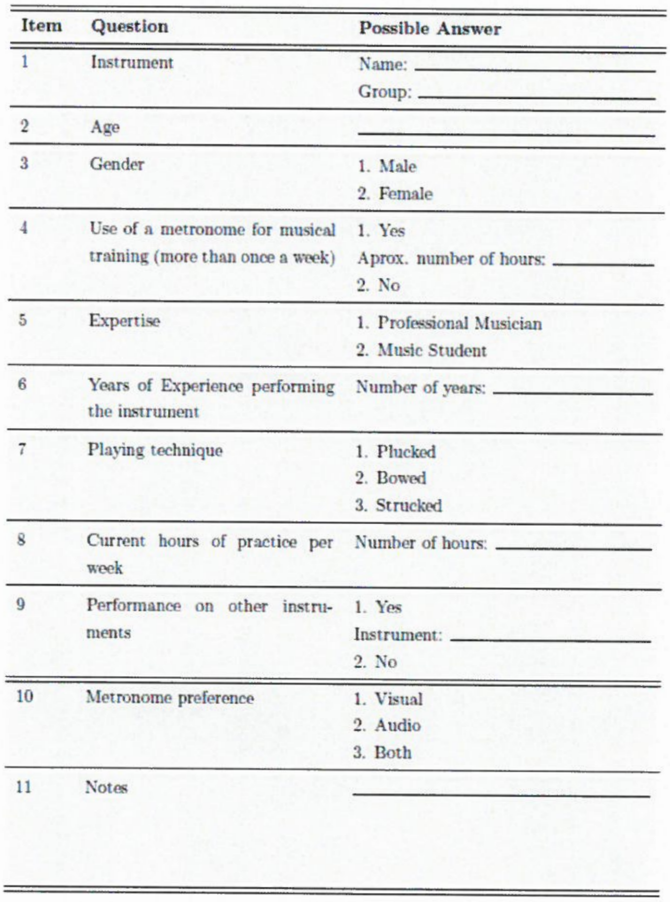
I understand that I am free to withdraw from the listening test at any time without any justification of my decision and with no further consequences.

I confirm that my I am not under 18 years of age at the moment of presenting the listening test.

I confirm that I have read and understood the above and freely consent to participating in the listening test.

Name of test subject________________________________
Signed ______________________ Date ______________

3.3 Questionnaire



Item	Question	Possible Answer
1	Instrument	Name: __________ Group: __________
2	Age	__________
3	Gender	1. Male 2. Female
4	Use of a metronome for musical training (more than once a week)	1. Yes Aprox. number of hours: ______ 2. No
5	Expertise	1. Professional Musician 2. Music Student
6	Years of Experience performing the instrument	Number of years: ______
7	Playing technique	1. Plucked 2. Bowed 3. Strucked
8	Current hours of practice per week	Number of hours: ______
9	Performance on other instruments	1. Yes Instrument: ______ 2. No
10	Metronome preference	1. Visual 2. Audio 3. Both
11	Notes	__________

Questions 1 to 9 will be asked previous the beginning of the listening test. Questions 10 and 11 after the experiment.

3.4 Test subjects are professional musicians or music students. The recruitment will be achieved by word of mouth and personal contacts.

3.5 See section 3.3 and attachments.

3.6 Data information, especially recordings will be kept in a safe place. There is no possibility to identify test subjects. The name is not included in the questions.

3.7 The only investigator is the author.

3.8 Is not an issue, both question answered with No.

3.9 Additional insurance is not necessary.

3.10 In November 2017 will begin the test phase. First in the Cork Music School. Additional test subjects will be interviewed in Germany.

(Please circle either yes or no. If your answer is 'yes' then please elaborate in the space provided)

Signed ______________________ Date 30.09.16

Applicant

Signed ______________________ Date 26.10.2017

Supervisor/Principal Investigator

Signed ______________________ Date ______________________

Approval Head of Department/Function