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CAN THE TEMPO BE EXACTLY DOUBLED ?

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Aims

Research questions:

- Does an optimal tempo exist in music?
- Does an unambiguous representation of slow and fast tempo exist, with respect to a given tempo?
- Can the musical tempo be exactly reproduced?
- Can the musical tempo be exactly doubled?
- Which factors (cognitive, motor) the task depend on?

Methods

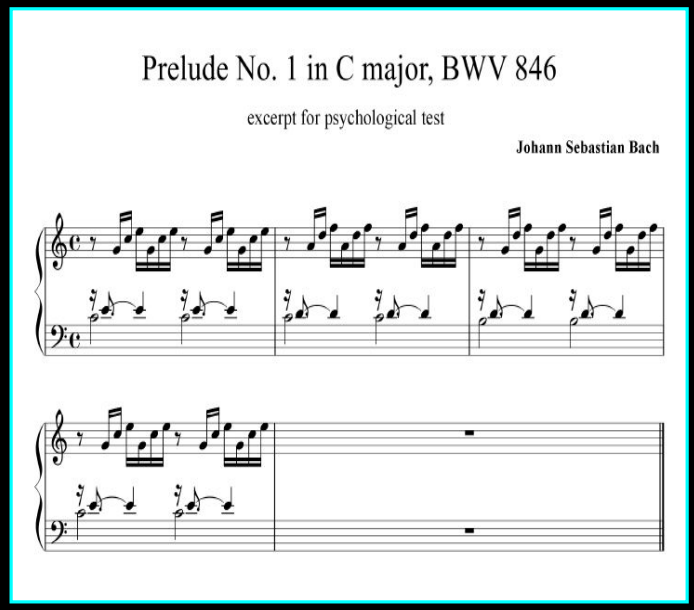
Participants:

16 trained pianists from Trieste Conservatory

Materials:

1) first 4 bars of Bach Prelude BWV 846

2) 6 audio files at 6 different tempi



scale of tempi with fixed frequency ratio (in analogy with the well temperated scale of frequencies): 40.00, 47.57, 56.57, 67.27, 80.00, 95.14

Example: 56.57 bpm

Methods

Procedure:

2 experimental conditions:

1) participants performed at 3 different tempi: "tempo correct", fast and slow;
participants were divided in two groups: 8 Correct–Fast–Slow (CFS) and 8 Correct–Slow–Fast (CSF)

participants listened to their "tempo correct" performance and reproduced at the same tempo

participants listened to their "tempo correct" performance and reproduced at the double tempo

Methods

Procedure:

2 experimental conditions:

2) participants listened to audio files at 3 different metronomic tempi (random sequence of 3 stimuli selected among the 6 audio files) and reproduced at the same tempi

participants listened to audio files at 6 different metronomic tempi (random sequence different than the previous one) and reproduced at the double tempi

Data Analysis

- ✓ Choice of the optimal tempo
- ✓ Slowing down and speeding up
- ✓ Memory for musical tempo
- ✓ Reproducing a given tempo
- ✓ Doubling a given tempo

Optimal tempo:

Refs:

Bisesi & Vicario, 2010

McKinney & Moelants, 2004

Moelants, 2002

Our results:

T_{mean} = 64 bpm

T_{min} = 50 bpm

T_{max} = 77 bpm

σ_t = 7.04 bpm

Memory for musical tempo:

Refs:

Gratton & Bruno, in progress

Levitin & Cook, 1996

Experimental conditions:

(a) 8 subjects: target >> faster >> slower

[t, F1(=t*), S1]

(b) 8 subjects: target >> slower >> faster

[t, S2(=t*), F2]

Results:

The difference between faster and first target is not significatively different within the two experimental conditions

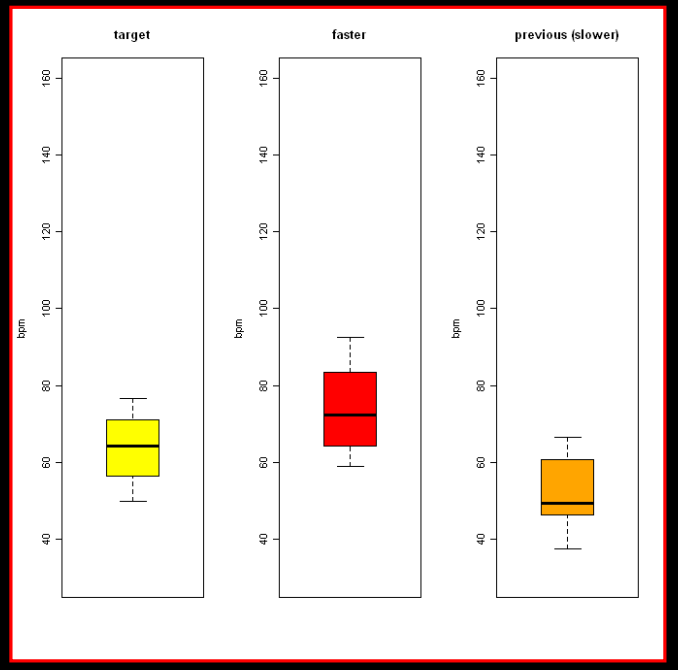
F1 — t vs. F2 — t:

t = –1.12, df = 7, p = 0.3

The difference between faster and last target is significatively different within the two experimental conditions

F1 — t vs. F2 — t*(S2):

t = –5.85, df = 7, p = 0.00063



Results:

The difference between slower and first target is not significatively different within the two experimental conditions

S1 – t vs. S2 – t:

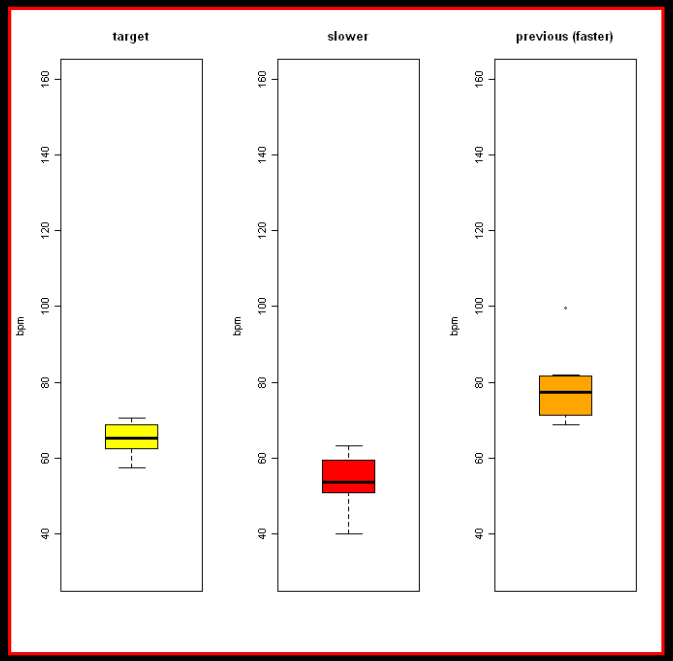
t = 0.17, df = 7, p = 0.87

The difference between slower and last target is significatively different within the two experimental conditions

S1 – t vs. S2 – t*(F2):

t = 5.0005, df = 7, p = 0.0016

Memory for musical tempo



Results:

The difference between slower and first target is not significatively different within the two experimental conditions

S1 – t vs. S2 – t:

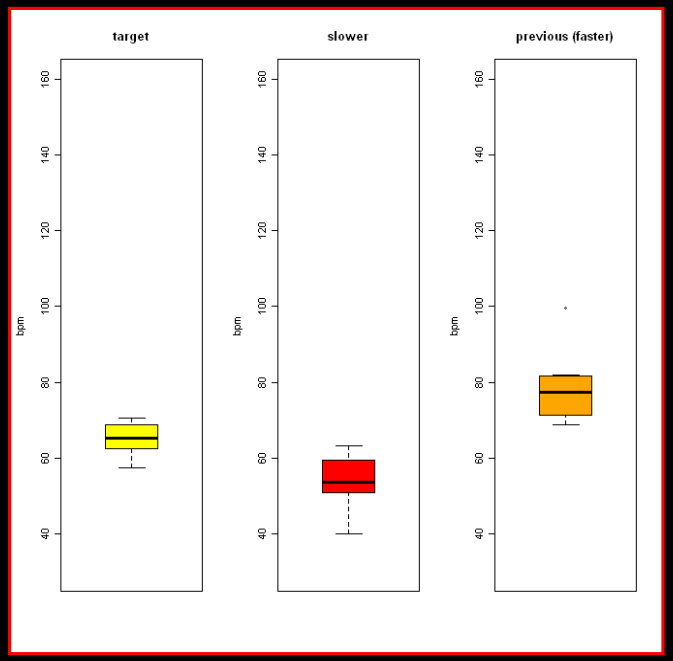
t = 0.17, df = 7, p = 0.87

The difference between slower and last target is significatively different within the two experimental conditions

S1 – t vs. S2 – t*(F2):

t = 5.0005, df = 7, p = 0.0016

Slow and fast are absolute concepts



Slowing down and speeding up:

Refs:

Krumhansl, 2000
Povel, 1981
Fraisse, 1982
Flach et al., 2004

Results:

Speeding up: 20.64 %

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	St.Dev.
58.96	70.31	75.23	76.26	81.35	99.68	10.92

Slowing down: 18.36%

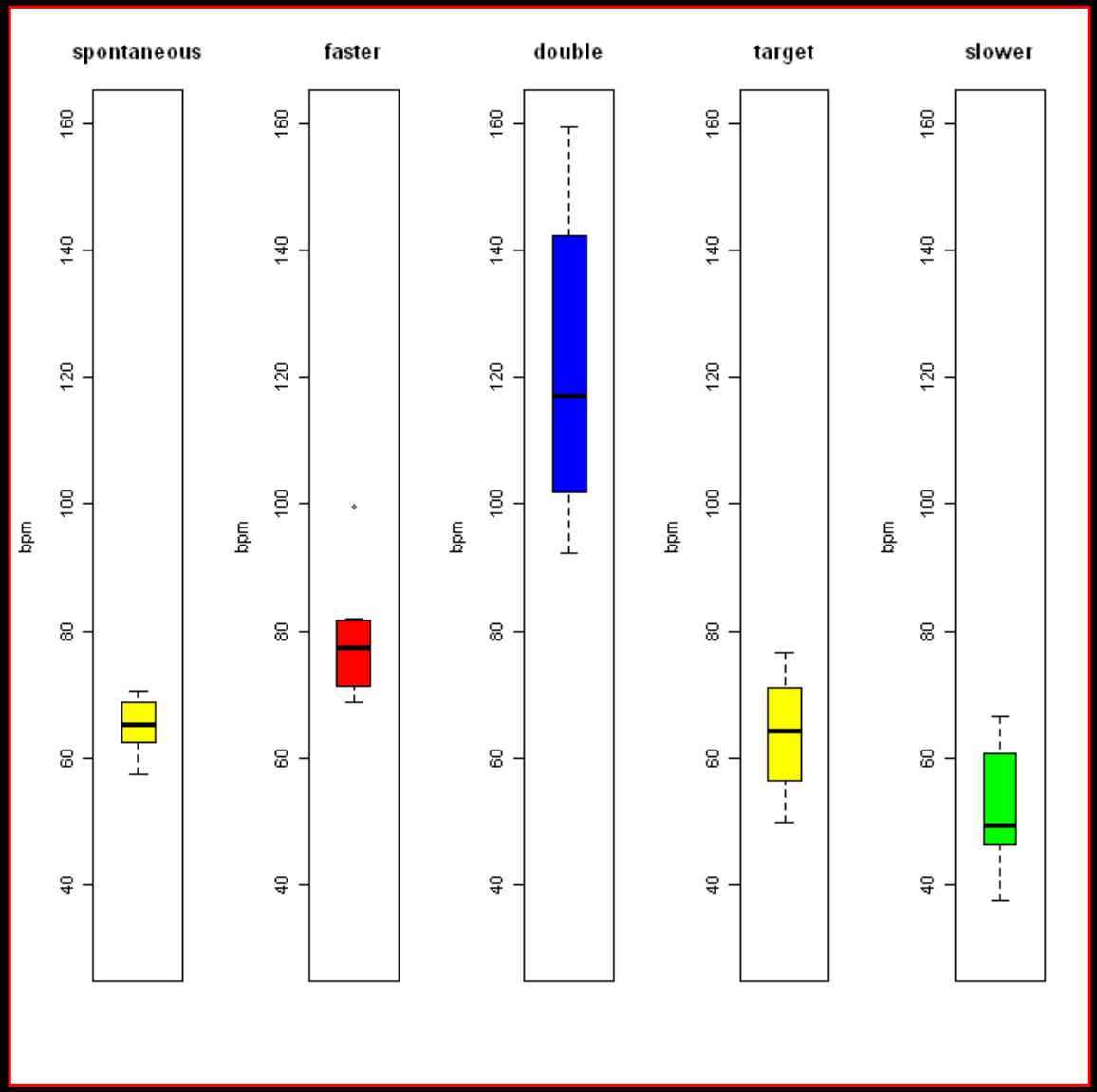
Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	St.Dev.
37.38	49.14	53.70	54.08	60.83	66.49	8.24

Results:

Faster: 20.64%

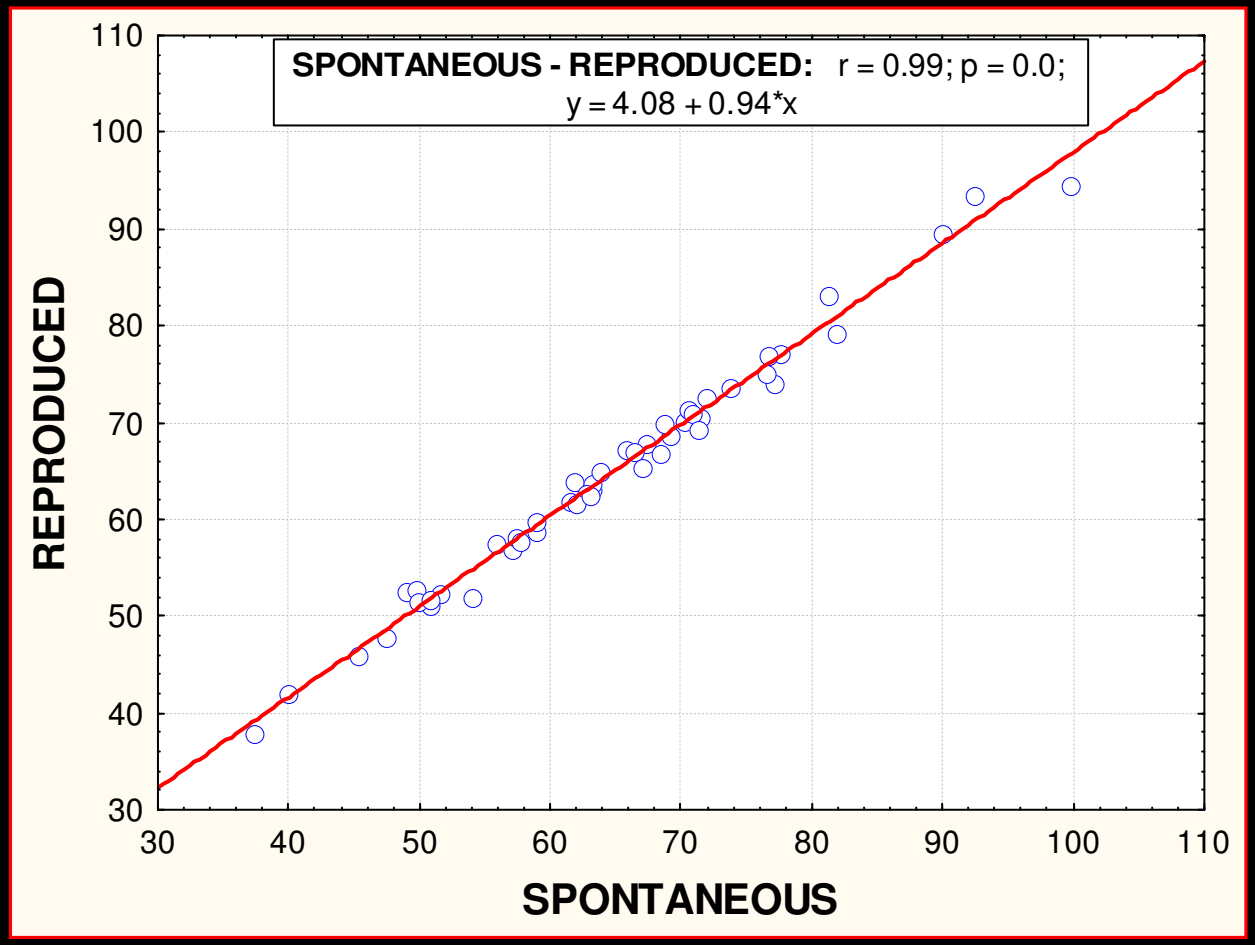
Slower: 18.36%

Double: 54.8 %



Reproduction of a given tempo

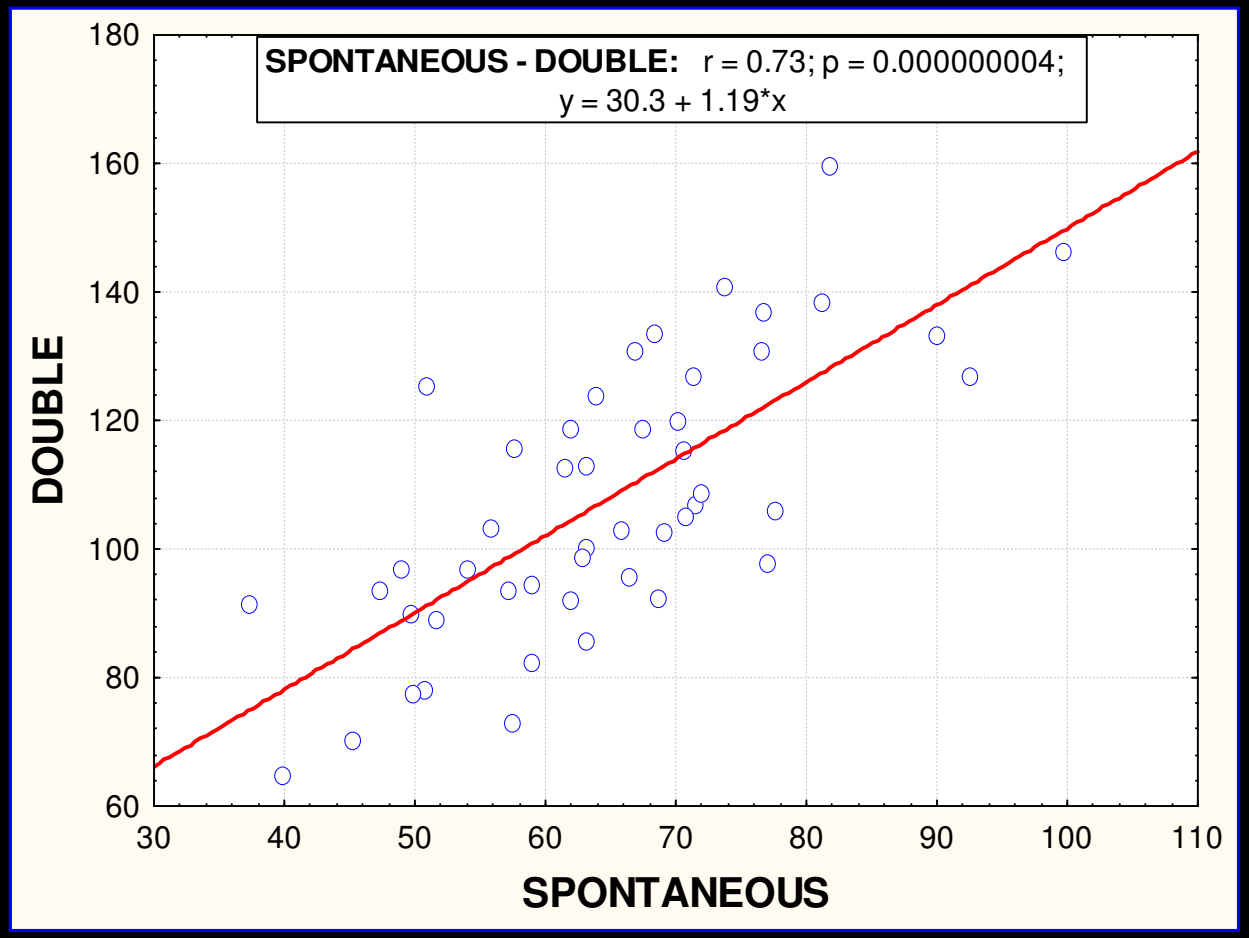
Exp 1:



spontaneous reproduction of musical tempi is homogeneous along the whole scale of speeds

Reproduction of a given tempo

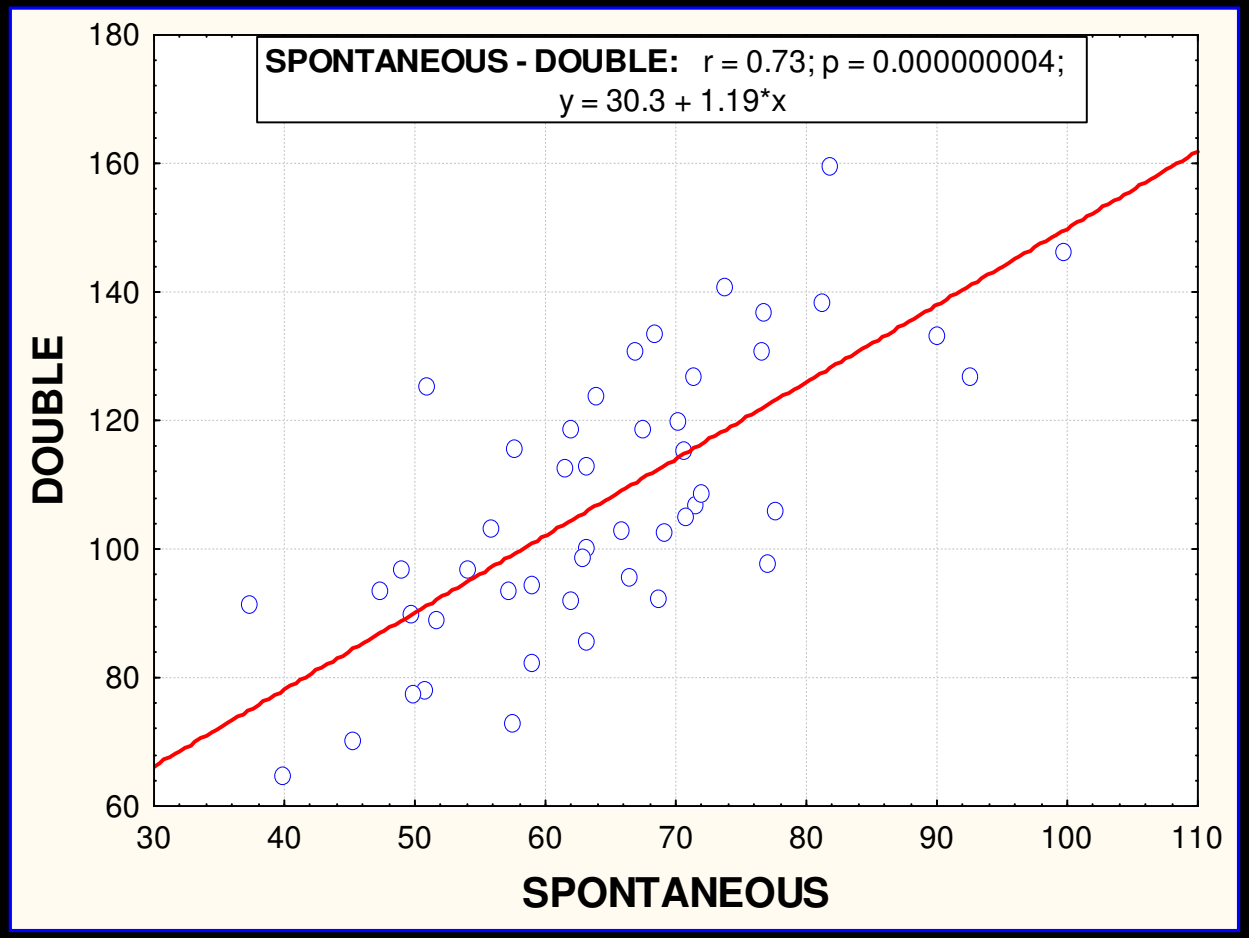
Exp 1:



reproduction at a double tempo is (less) homogeneous along the whole scale of speeds

Reproduction of a given tempo

Exp 1:



reproduction at

double tempo corresponds to a constant shift

scale of speeds

Spontaneous vs. selected tempi:

Refs:

Shea et al., 2001

Schmidt, 1975

No task effect

(1) spontaneous:

t = –1.41, df = 15, p = 0.18

(2) double:

t = –1.17, df = 15, p = 0.26

Only 1 subject found difficulties in task (1)

General Linear Models:

Exp 1:

Effect	f	F	p
REPRODUCED	1	34.03	0
ID_VEL	2	0.98	0.38

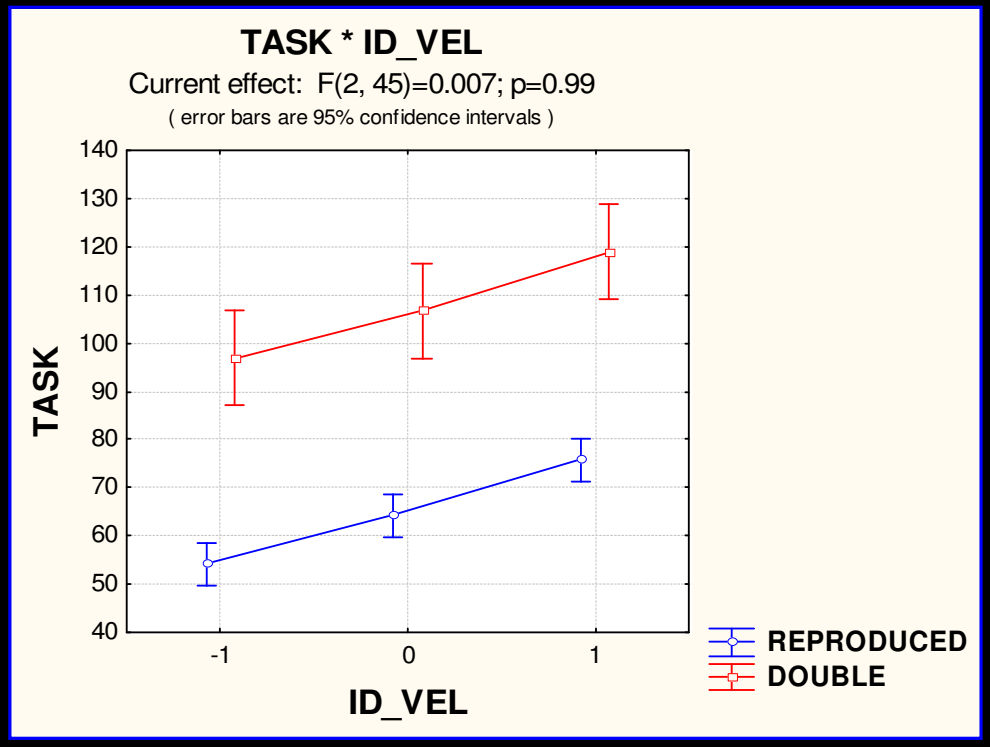
There is no constant modulation

Effect	f	F	p
SPONTANEOUS	1	166.9	0
TASK	1	5.7	0.02
TASK * SPONTANEOUS	1	2.4	0.13

There is an effect of SPONTANEOUS and TASK: subjects modulate according with spontaneous tempo

General Linear Models:

Exp 1:



Lines are parallel:
there is no interaction (p=.131 in previous table)

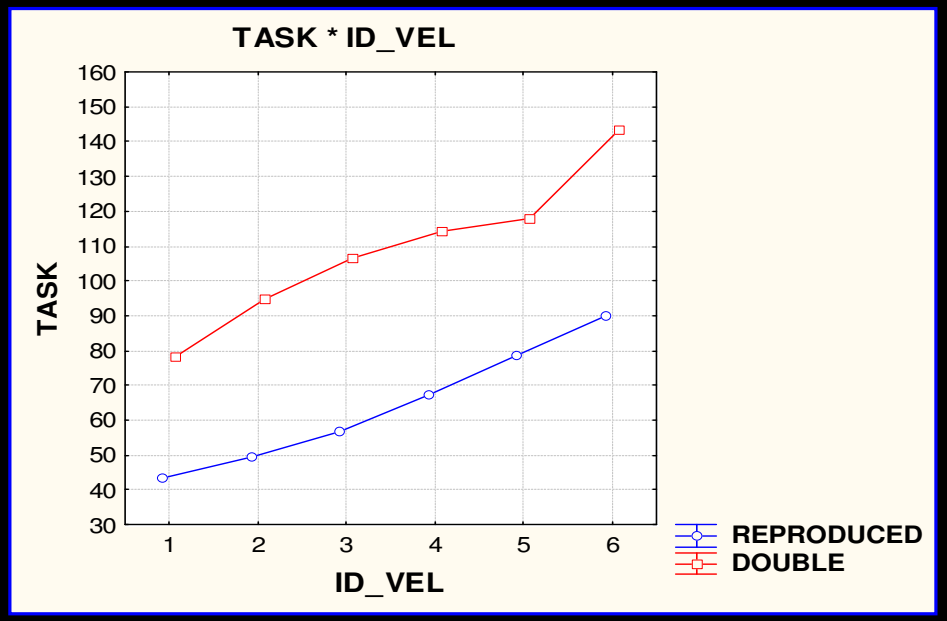
Spontantaneous or doubled reproduction have the same behavior: once the slope due to spontaneous reproduction is left out, there is no task effect (reproduced, double)

General Linear Models:

Exp 2:

Effect	f	F	p
VEL	1	269.3	0
TASK	1	12.3	0.025
TASK * VEL	1	1.7	0.26
REP	7	0.7	0.70
REP * VEL	7	0.8	0.56
TASK * REP	7	0.8	0.63
TASK * REP * VEL	7	1.2	0.35

Task and velocity are both significative



double tempo

=

spontaneous tempo

+

a constant value

Conclusion

- Results support the conclusion of the existence of an "optimum" tempo
- Slow and fast are absolute concepts
- Participants exibit a memory for musical tempo
- Spontaneous reproduction of musical tempi is homogeneous along the whole scale of speeds
- Double tempo corresponds to a constant shift

Improvements

- Confirm results with another experimental method (for instance, choice)
- Search for a correspondence inside other perceptual domains (visual, motor)
- Search for correlation with cognitive or motor competence

"It is not that we have so little time,

but that we lose so much"

Seneca

"Music is the best means we have of digesting time"

W. H. Auden