The Mazurka Project

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Backbeat: Tapping data entry

- **Command line program for recording tap times**

- **Records absolute time from first click**

- **Other fields are for error checking (during performance and afterwards)**

Space bar records beats

Any letter records barline and first beat of measure

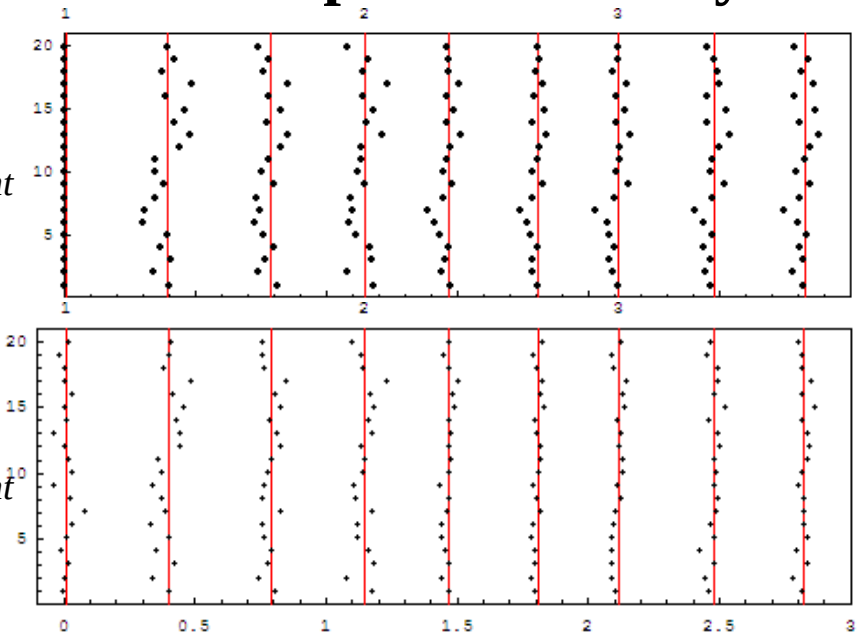
Beat duration (quarter note)	*Metric position*	*Absolute Time (ms)*	*Delta Time (ms)*
**kern	**beat	**abstm	**deltatime
=1-	=1-	=1-	=1-
4	1	0	0
4	2	391	391
4	3	741	350
=2	=2	=2	=2
4	1	1080	339
4	2	1454	374
4	3	1807	353
=3	=3	=3	=3
4	1	2108	301
4	2	2448	340
4	3	2785	337
=4	=4	=4	=4
4	1	3108	323
4	2	3472	364
4	3	3812	340

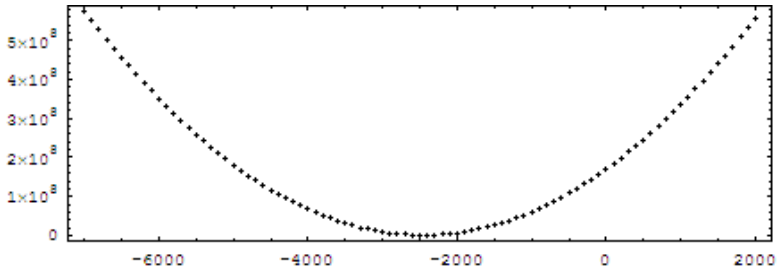
Tapped-beat alignment with audio

- **Play recordings in Windows Media Player (or anything)**
- **Computer Keyboard 5 ms time resolution**
- **Tap to performance 20 times, take average and measure standard deviation of tapping.**
- **Individual tapping trials aligned by least squares fit to a sample of manually measured beat time in audio file.**

Before alignment

After alignment





5, -12, -27, -36 ms deviations

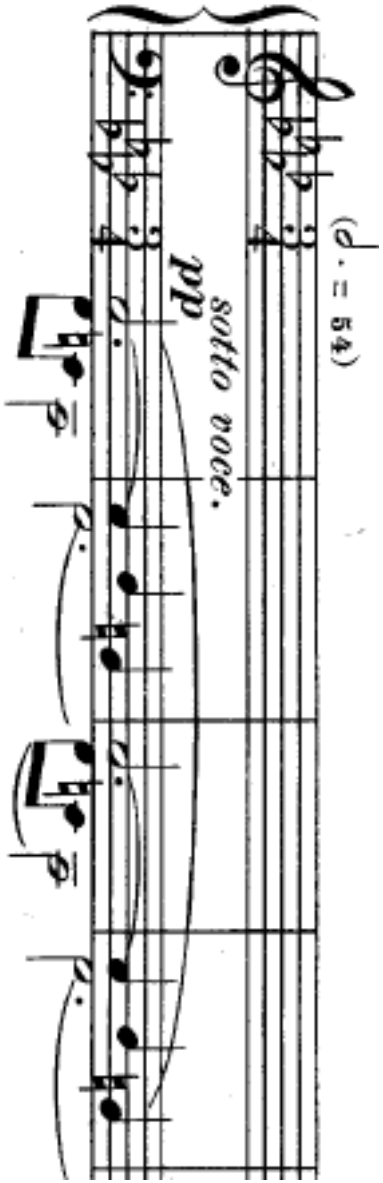
Play pid5667230-10-avg (Friedman 1930)

Play pid54293-08-avg (Perahia 1994)

Score Alignment and Interpolation

**time	**kern		**kern	**dynam
=1-	=1-		=1-	=1-
*	*^		*	*
2465	([2.C/	8FF\L	2.r	pp
2659	.	8EEn\J	.	.
2852	.	2CC\	.	.
3243	.	.	.	.
=2	=2	=2	=2	=2
3604	4C/]	[2.FF\	2.r	.
3921	4D-/	.	.	.
4261	4BBn/	.	.	.
=3	=3	=3	=3	=3
4569	[2.C/	8FF\L]	2.r	.
4759	.	8EEn\J	.	.
4935	.	2CC\	.	.
5279	.	.	.	.
=4	=4	=4	=4	=4
5604	4C/]	[2.FF\	2.r	.
5928	4D-/	.	.	.
6291	4BBn/)	.	.	.
=5	=5	=5	=5	=5

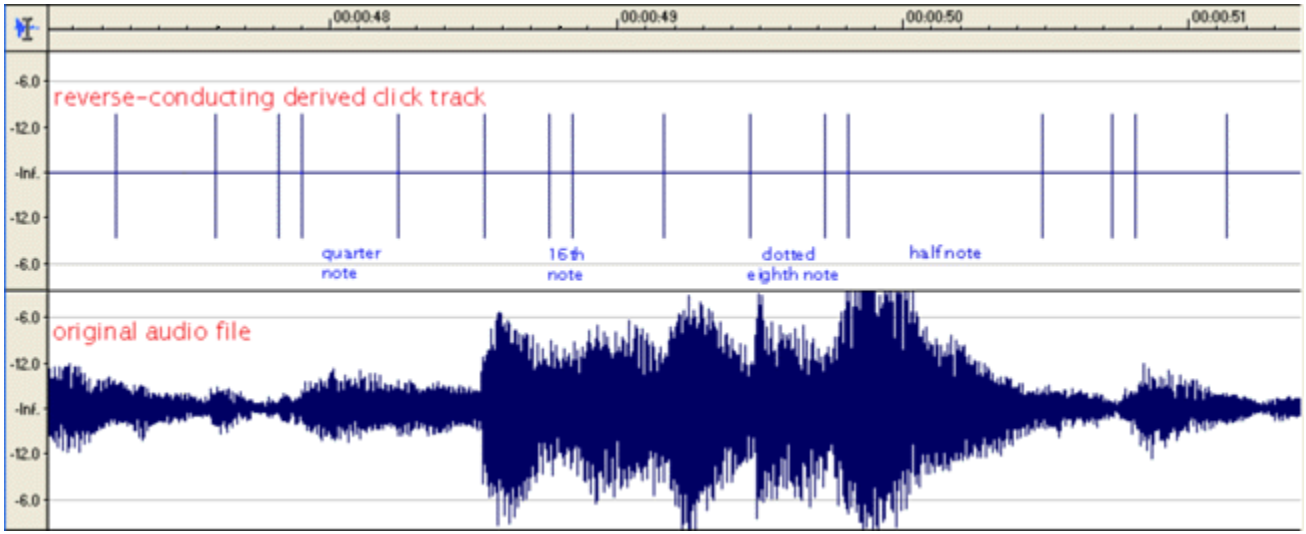
Abs times **Score**



Output data to Matlab

```
%%%col01: abstime(average absolute time in milliseconds of human beats)
%%%col02: duration       (expected duration in ms based on score duration)
%%%col03: note           (MIDI note number of pitch)
%%%col04: metlev (metric level: 1 = downbeat; 0 = beat; -1 = offbeat)
%%%col05: measure(measure number in which note occurs)
%%%col06: absbeat(absolute beat from starting beat at 0)
%%%col07: mintime(minimum absolute time of human beat for this note)
%%%col08: maxtime(maximum absolute time of human beat for this note)
%%%col09: sd             (standard deviation of human beat time in ms.)
2465    1456    48      1       1       0       2419    2535    24.1
2465    194     41      1       1       0       2419    2535    24.1
2659    193     40      -1      1       0.5     -1      -1      -1
2852    752     36      0       1       1       2762    2947    52.4
3604    1155    41      1       2       3       3550    3648    19.8
3921    340     49      0       2       4       3879    3978    26.1
4261    308     47      0       2       5       4239    4275    9.2
4569    1359    48      1       3       6       4548    4585    11.6
4759    176     40      -1      3       6.5     -1      -1      -1
4935    669     36      0       3       7       4906    4968    18.7
5604    1235    41      1       4       9       5585    5628    14.8
5928    363     49      0       4       10      5894    5977    22.2
6291    367     47      0       4       11      6241    6317    15.8
6658    4438    48      1       5       12      6636    6682    13.1
6839    175     40      -1      5       12.5    -1      -1      -1
```

Manual correction of the beat times



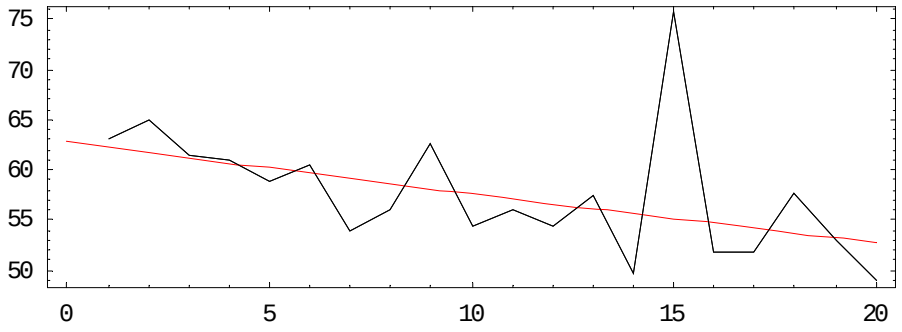
- **Align reverse conducting beats within 10 ms by ear/eye in a sound editor**
- **Each beat alignment takes about 1-2 minutes on average**
- **300 beats in each Mazurka**
- **Necessary to do for evaluation of automatic alignment**

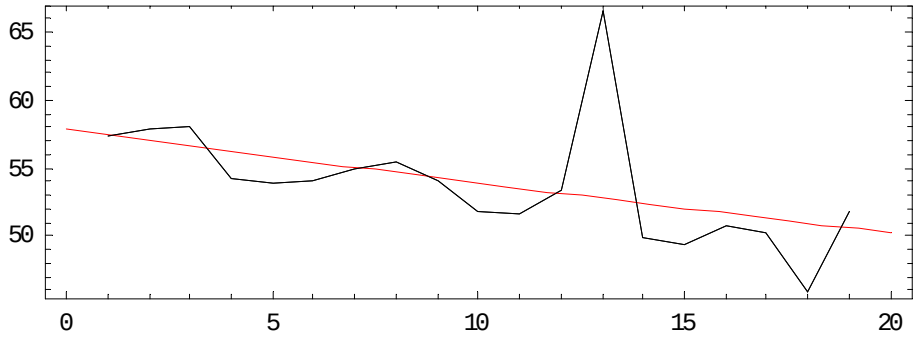
Play pid5667230-10-corr (Friedman 1930)

Learning Curves for 4 Performances

Mazurka in F Minor, Op. 7, No. 3

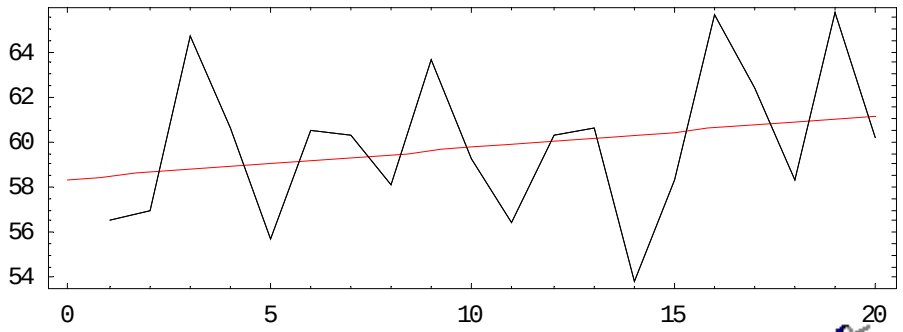
Rosen 1989 **Friedman 1930**

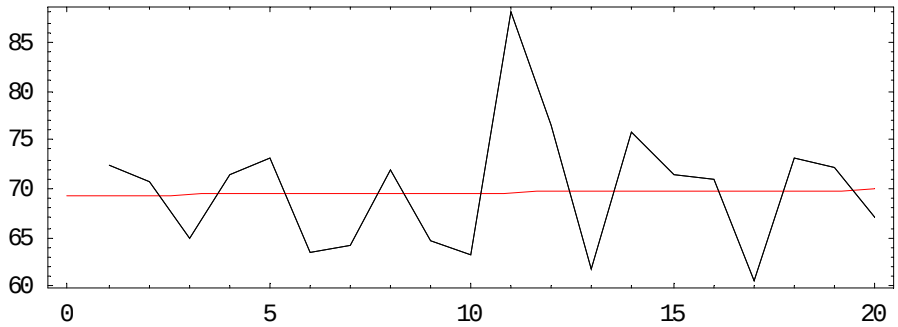




Mazurka in A Minor, Op. 7, No. 2

Chiu 1999 **Friedman 1930**

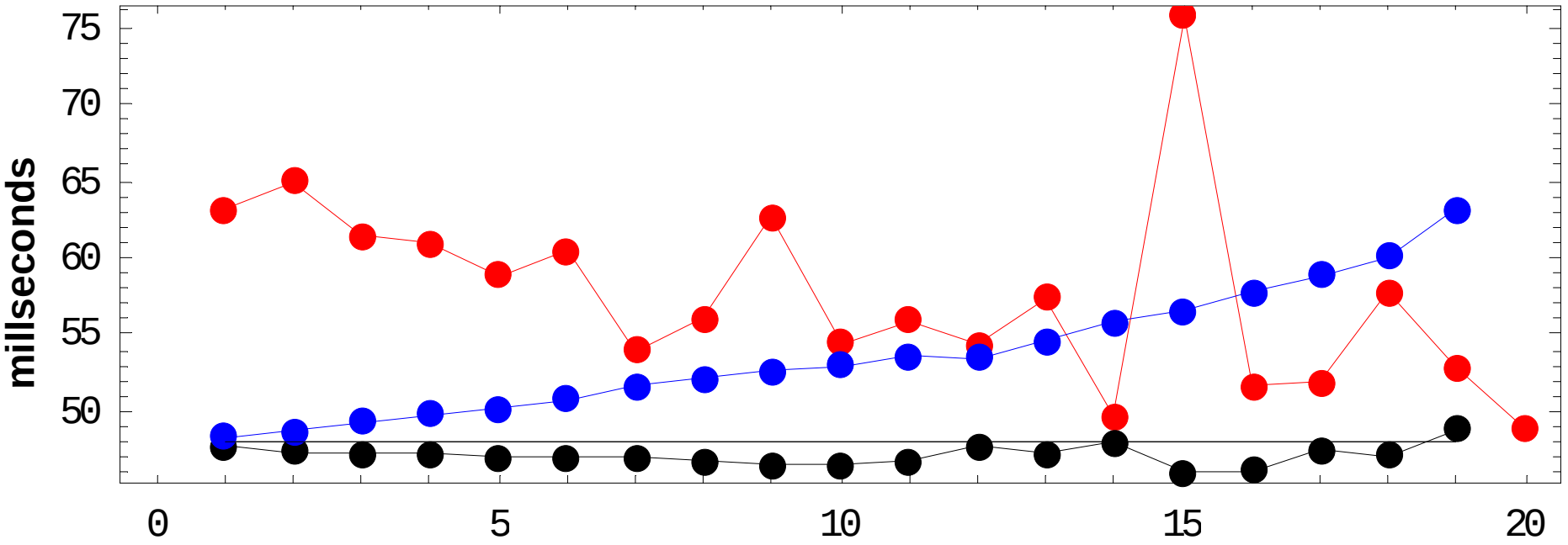




Play pid9048-06-avg (Chiu 1999)

Average Displacement Errors

Mazurka in F Minor, Op. 7, No. 3
Rosen 1989



= individual trial average displacement errors

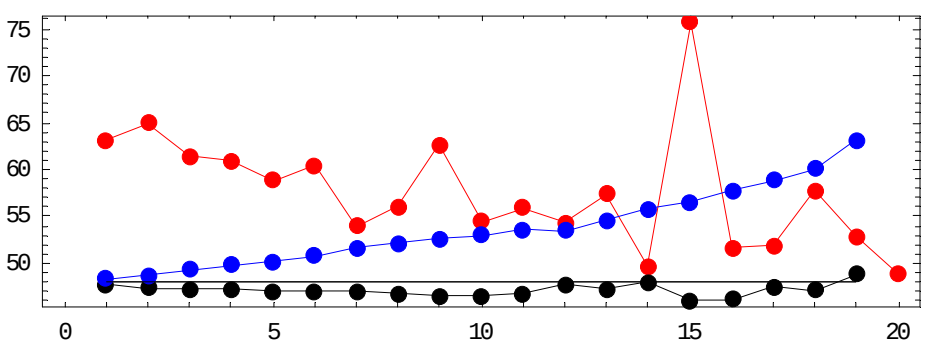
= dropping more and more later trials

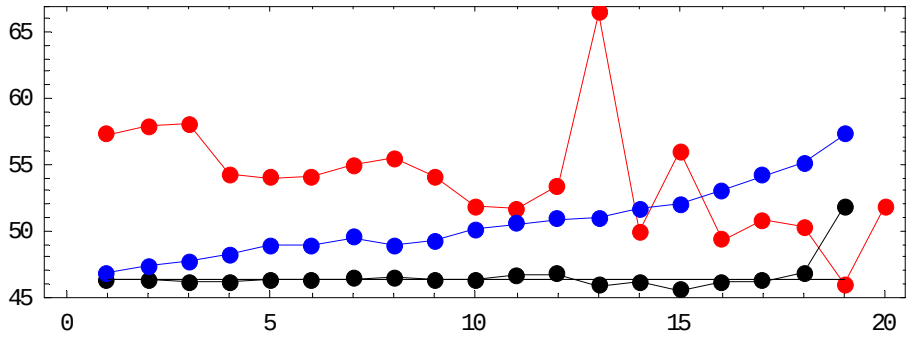
= dropping more and more earlier trials

Average Displacement Errors (2)

Mazurka in F Minor, Op. 7, No. 3

Rosen 1989 **Friedman 1930**

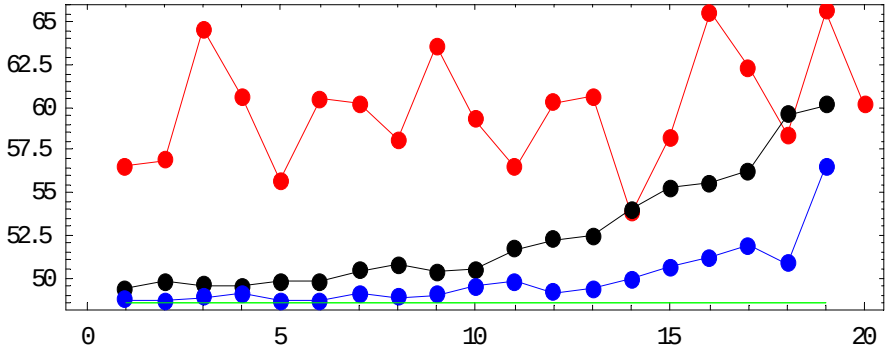


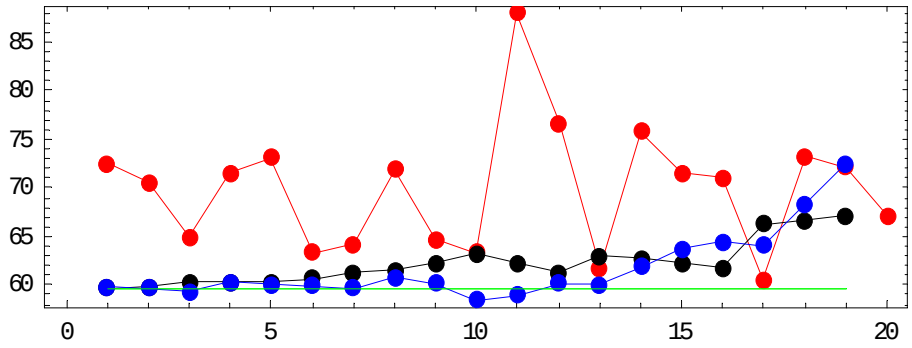


slower tempo

Mazurka in A Minor, Op. 7, No. 2

Chiu 1999 **Friedman 1930**



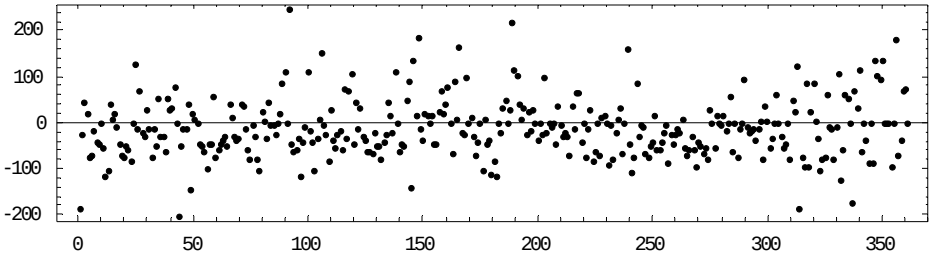


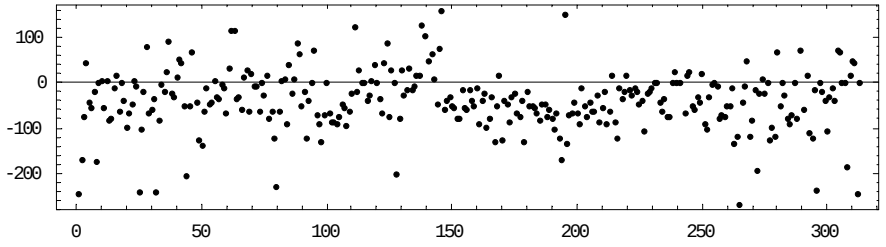
Correction Offsets

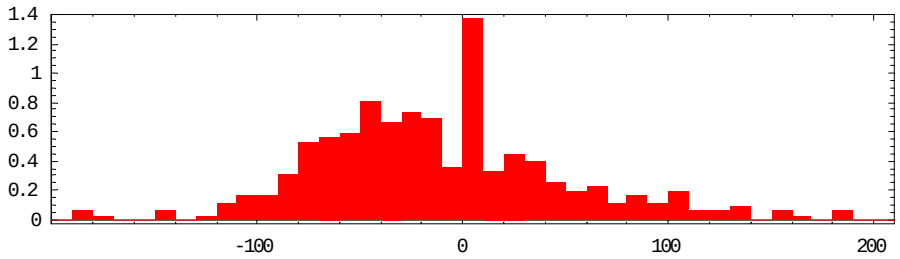
The top plots show the amoutn of time in milliseconds between the corrected beat times and the average manually tapped beat times. The lower plots display a histogram of the data in the top plots. The spike at 0 in the histograms is due to audible corrections having a resolution of 10 ms.

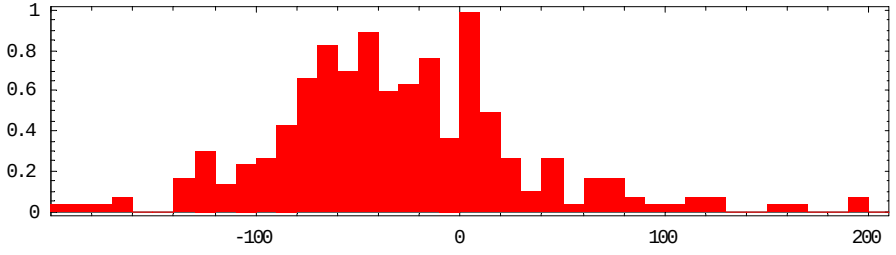
Mazurka in A Minor, Op. 7, No. 2

Chiu 1999 **Friedman 1930**









49 ms avg correction; -12 ms overall shift

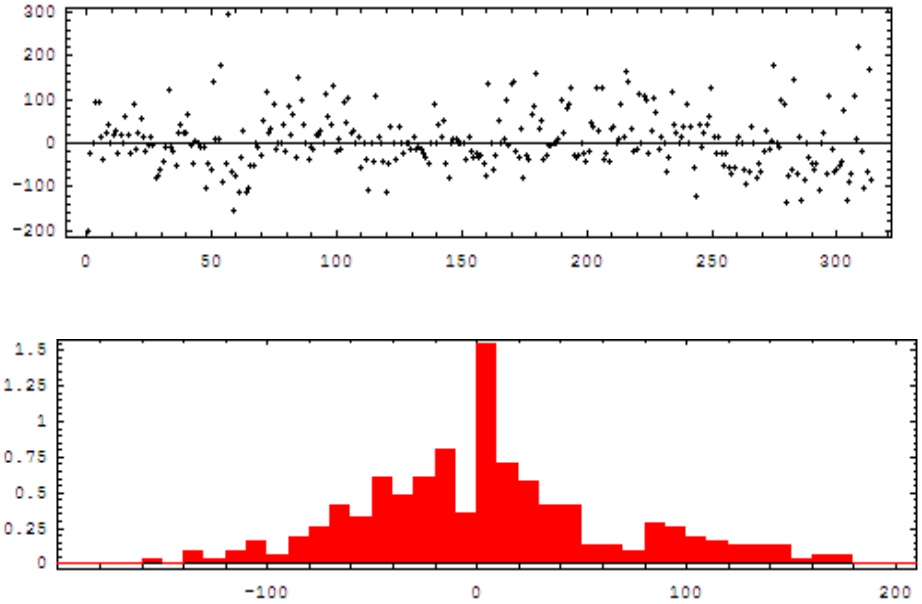
60 ms avg correction; -36 ms overall shift

Correction Offsets (2)

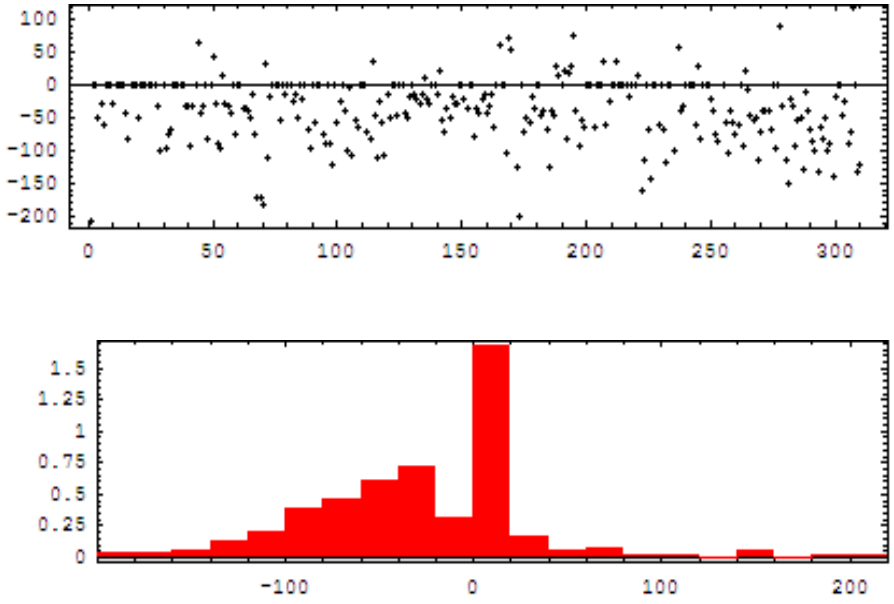
The top plots show the amoutn of time in milliseconds between the corrected beat times and the average manually tapped beat times. The lower plots display a histogram of the data in the top plots. The spike at 0 in the histograms is due to audible corrections having a resolution of 10 ms.

Mazurka in F Minor, Op. 7, No. 3

Rosen 1989 **Friedman 1930**



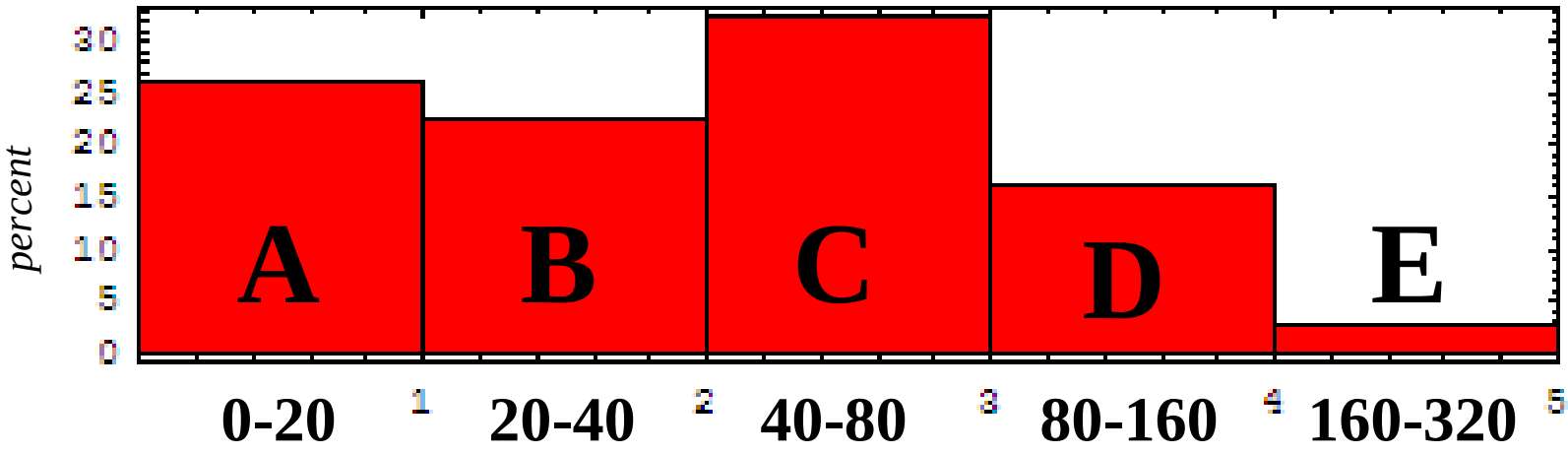
48 ms avg correction; +5 ms overall shift



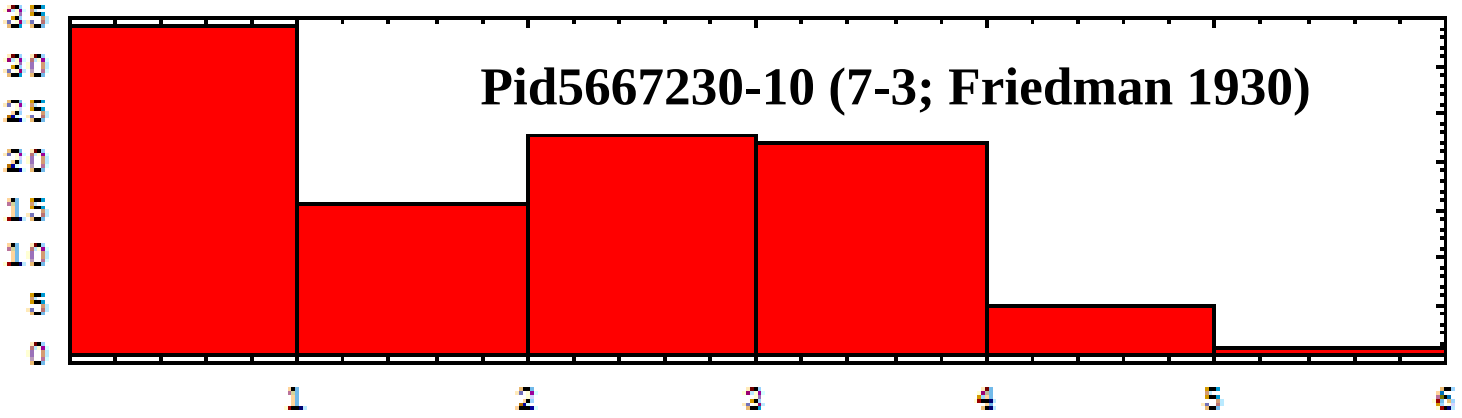
48 ms avg correction; -27 ms overall shift

Beat Accuracy Metric

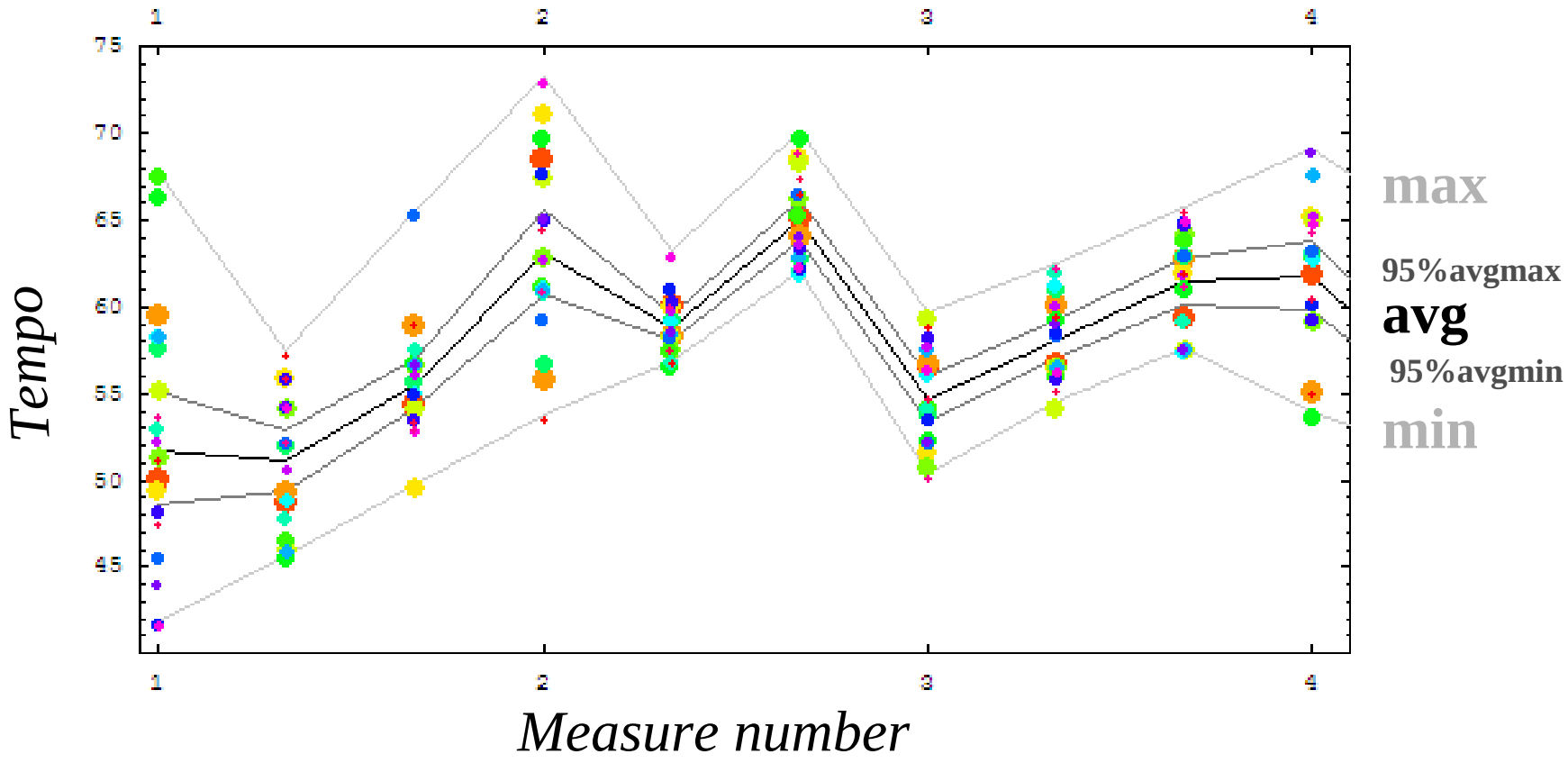
pid9048-06 (7-2; Chiu 1999)



- **Human tapper: 48% within 40 milliseconds**
- **Current automatic rating: 98% for same piece.**



Tempo Plots

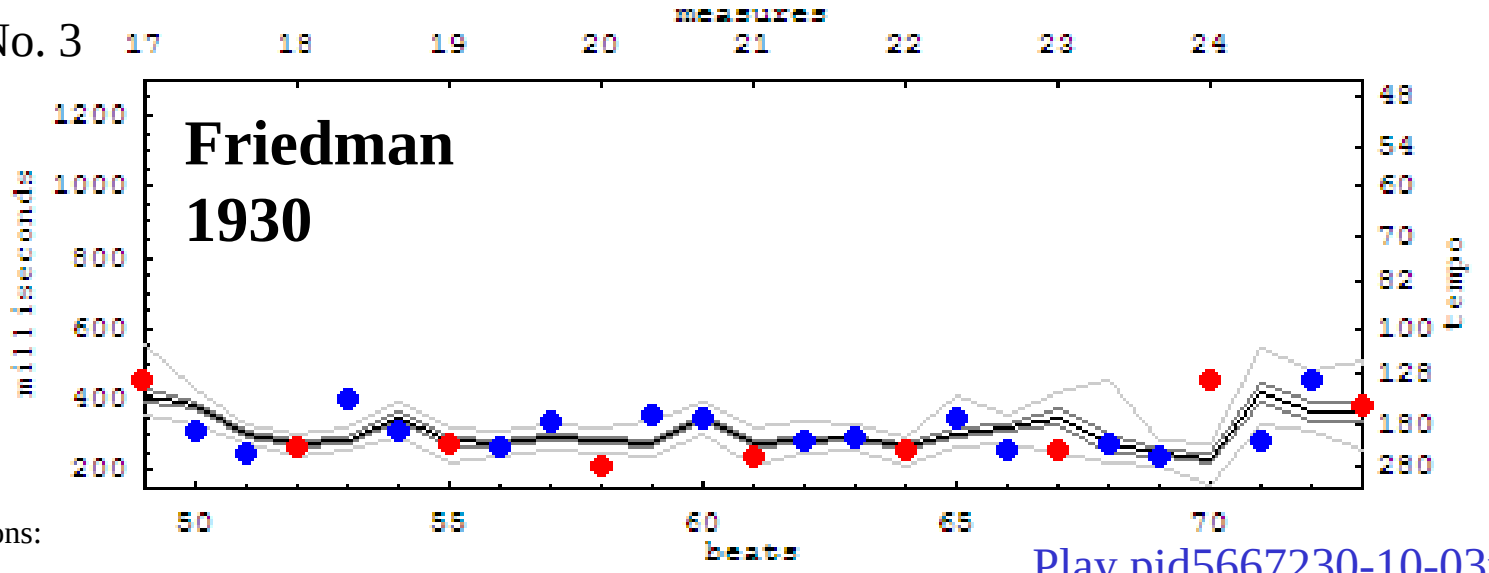


Individual trials
(smaller = earlier trial) &
(red = earlier; purple=later trial)

Friedman 1930
Op. 7, No. 3

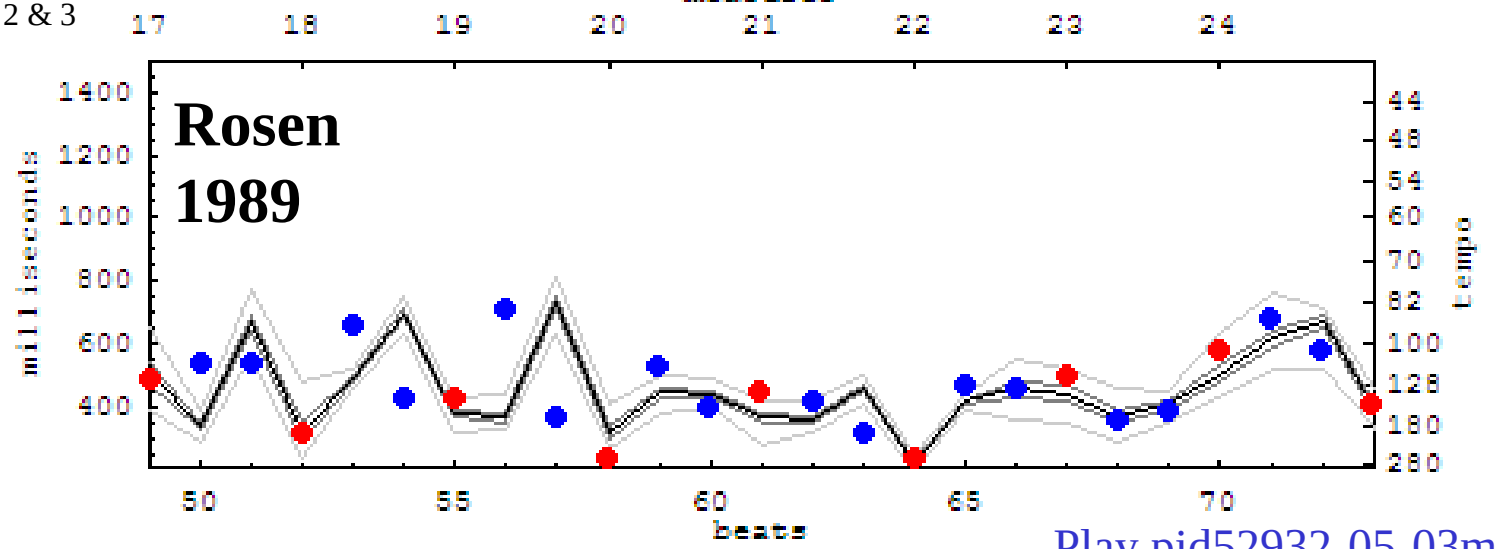
Tempo Plots Op. 7, No. 3

Mazurka in F minor
Op. 7, No. 3



Manual corrections:
Red dot = beat 1
Blue dots = beats 2 & 3

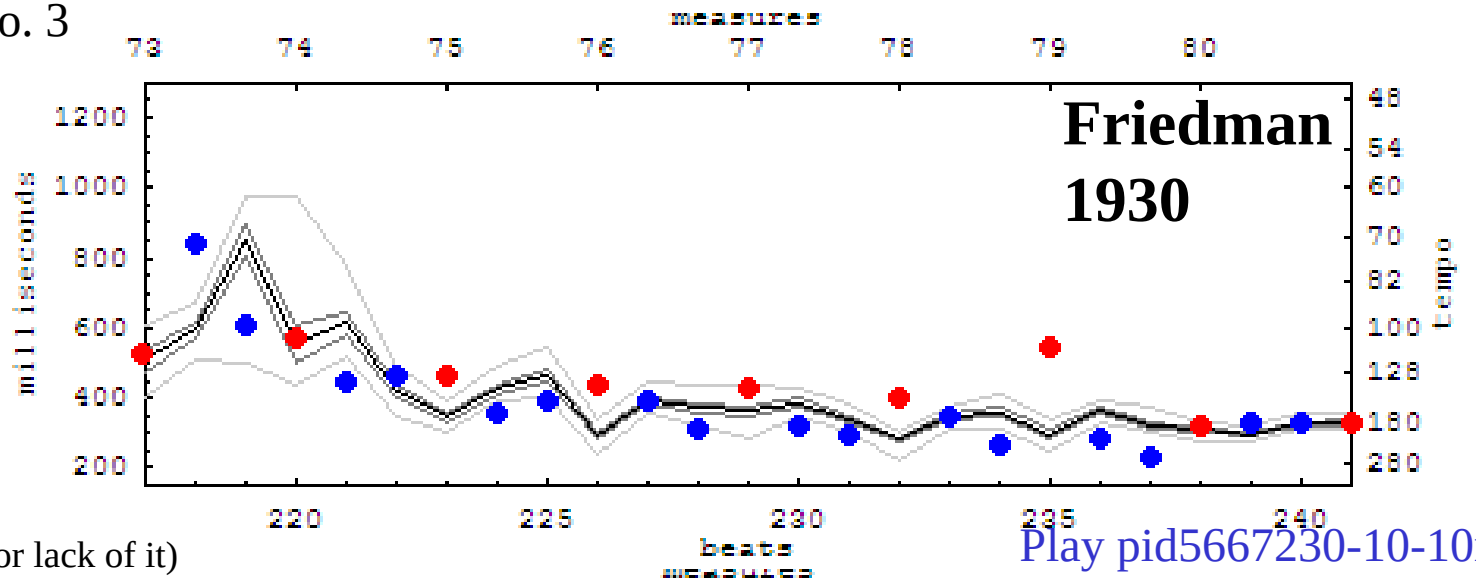
Play pid5667230-10-03m



Play pid52932-05-03m

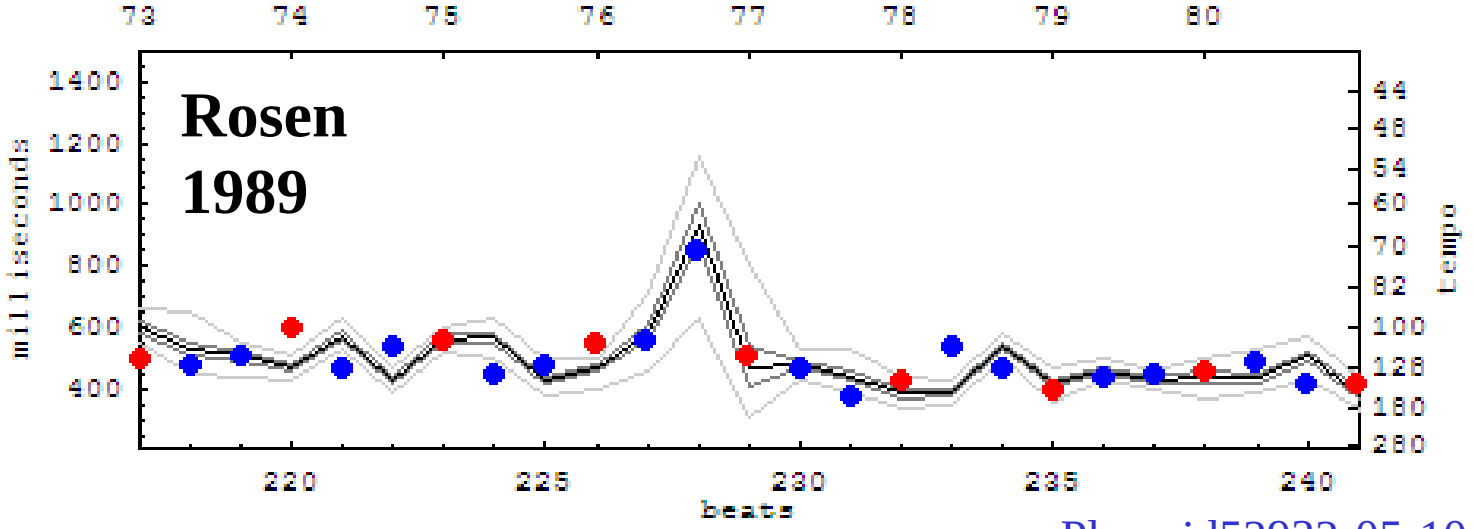
Tempo Plots Op. 7, No. 3 (2)

Mazurka in F minor
Op. 7, No. 3



(Note surprise or lack of it)

Play pid5667230-10-10m

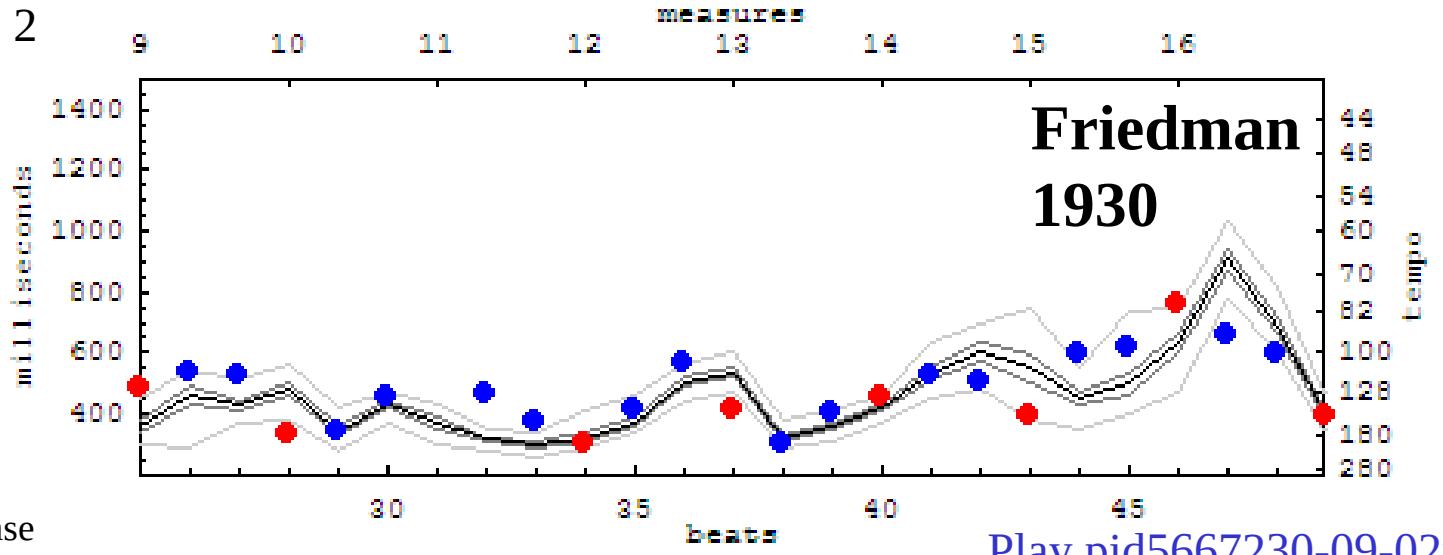


Play pid52932-05-10m

Tempo Plots Op. 7, No. 2

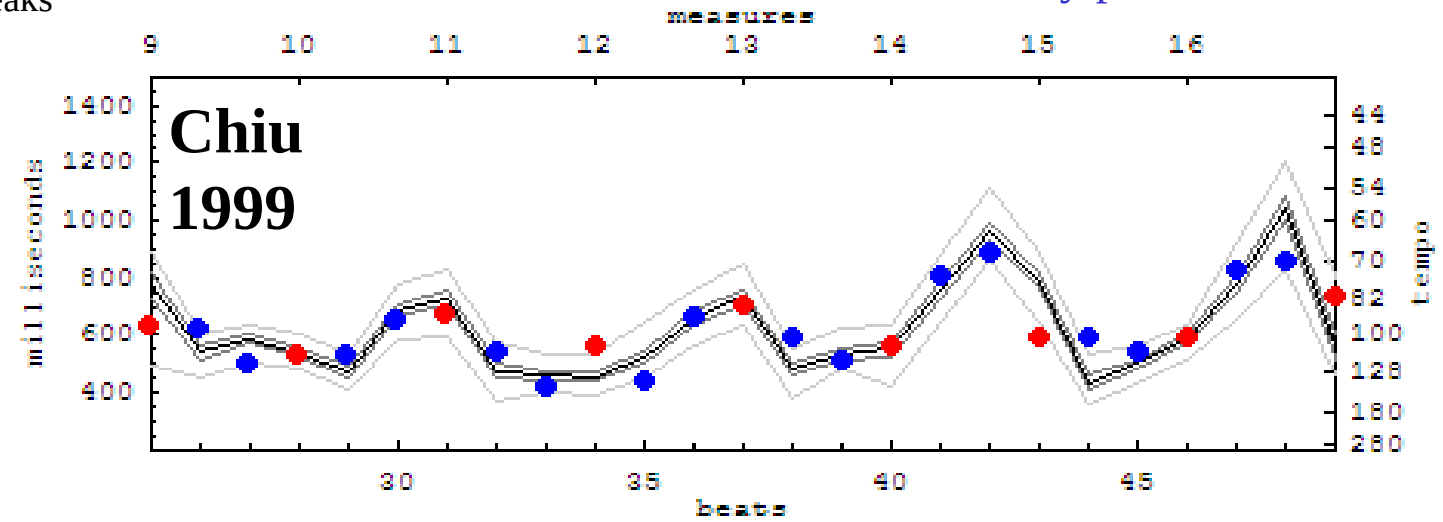
Mazurka in A minor
Op. 7, No. 2

(Third beats red)



Very clear phrase boundaries (peaks every two measures):

Play pid5667230-09-02m

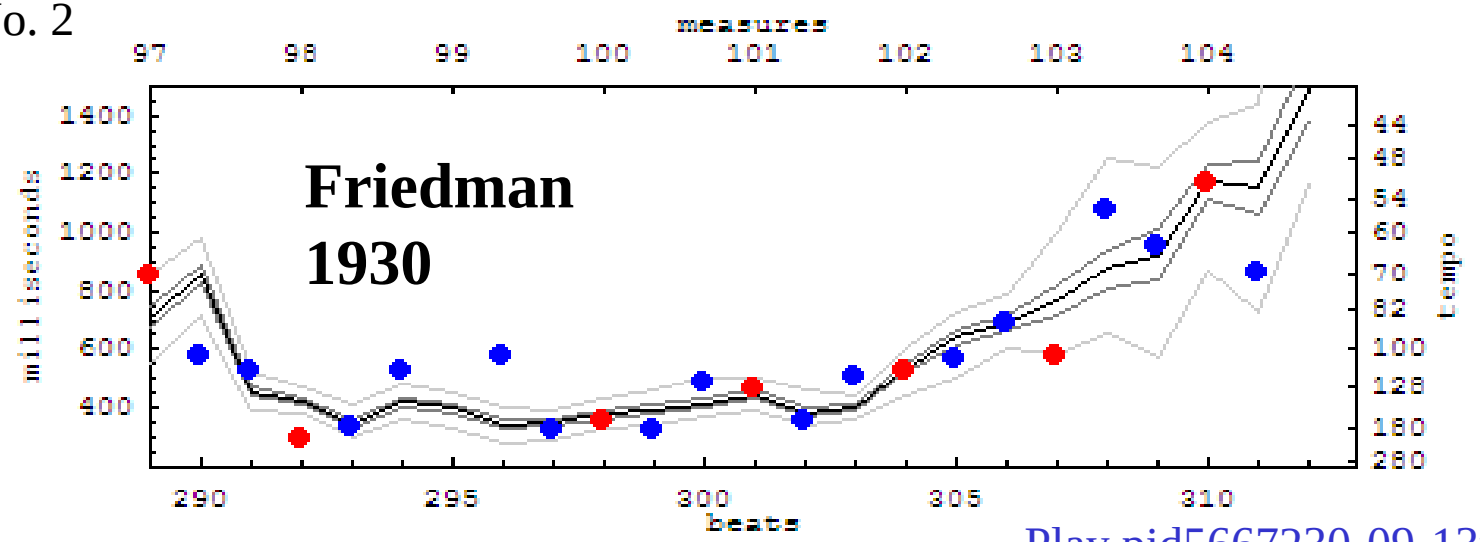


Play pid9048-06-02m

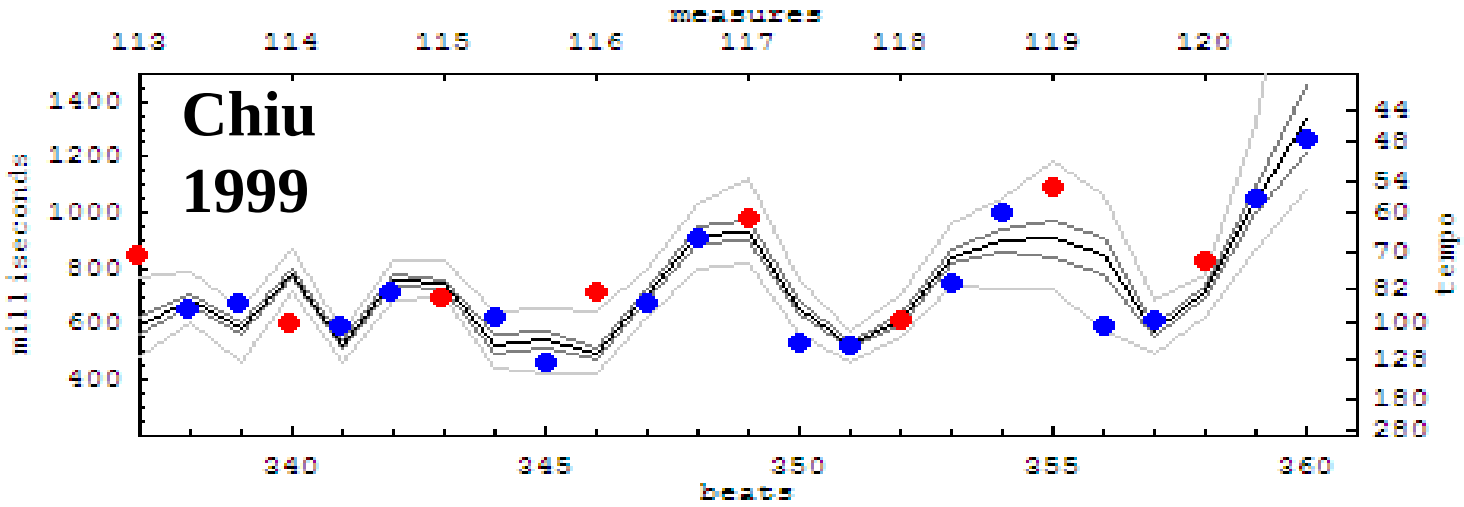
Tempo Plots Op. 7, No. 2 (2)

Mazurka in A minor
Op. 7, No. 2

(Third beats red)

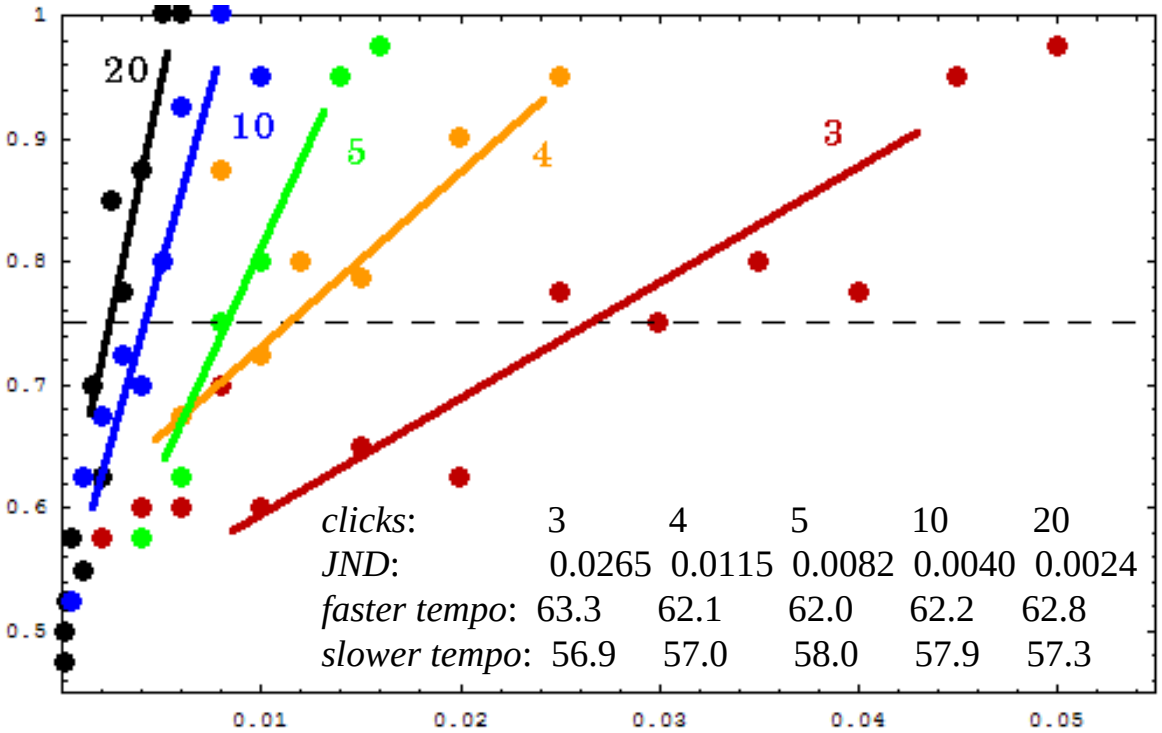


Play pid5667230-09-13m



Play pid9048-06-15m

Tempo Perception Experiment



clicks:	3	4	5	10	20
JND:	0.0265	0.0115	0.0082	0.0040	0.0024
faster tempo:	63.3	62.1	62.0	62.2	62.8
slower tempo:	56.9	57.0	58.0	57.9	57.3

10 clicks; 60 MM

JND * 10

JND * 4

JND

JND/4

JND/10