The heart of the music: Musical tempo and cardiac response

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Introduction

- Musical tempo has been consistently linked with subjective arousal: faster tempos are perceived as more exciting than slow tempos.[1,2]
- Heart rate changes in response to tempo have been investigated for 125 years, but with inconsistent results.[3,4]
- Changes in HR, up until exercise levels, are primarily governed by the parasympathetic nervous system (PNS).[5] Thus, a more precise index of PNS activity may reveal significant effects that are masked when mean HR is examined.
- Because PNS influences on HR are rapid (millisecond level), measuring beat-to-beat variability in HR provides an measure of PNS activity.[6]
  - A simple time-domain index of Heart Rate Variability (HRV) is the square root of the mean of squared successive differences in inter-beat intervals (IBIs; the time in ms between successive heart beats).[7]
  - for *N* IBIs, rMSSD = $\sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(IBI_i - IBI_{i+1})^2}$
- Resting levels of HRV are associated with organism health and well-being; higher levels of HRV at rest are linked with:
  - Better physical health; HRV is an independent predictor of all-cause mortality,[8]
  - Lower levels of depression and anxiety,[9,10] and
  - Better accuracy and faster choice reaction times on working memory tasks.[11,12,13]

Current Study

- To investigate the role of tempo on subjective & physiological measures of emotion and the role of tempo in reaction time, and individual differences in these effects.
- These experiments utilized the same general stimulus set: computer-generated (MIDI) performances of 19th-century piano rags by Scott Joplin and Joseph Lamb.[14] MIDI permits the isolation and manipulation of a single musical variable of interest (here, tempo) without affecting other dimensions (pitches and pitch contours, rhythm, attack velocity, etc.).
- Three tempos: Slow, Medium, & Fast: 60, 90, 120 beats per minute (bpm)
- IBIs were recorded continuously throughout the experiment via a standard 3-electrode configuration, sampled at 1000 Hz. HRV was quantified as rMSSD
- In both experiments, an initial 2.5-min of IBI data was used to quantify each subject's resting HRV. A median split was performed on resting HRV to examine differences between individuals with "low" versus "high" resting HRV.

★**Experiment 1:** The impact of tempo on mean HR vs. HR variability

- Six 2.5-min excerpts alternated with six 2.5-min periods of silence. Subjects rated Valence and Arousal of the music on 7-point scales
- *Prediction:* Larger effect of tempo on HRV than mean HR

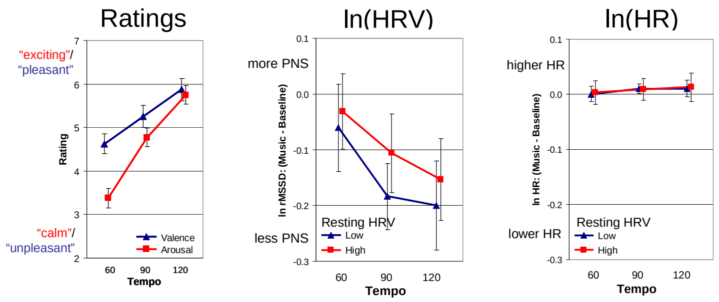
★**Experiment 2:** The impact of tempo on phasic HR

- Phasic HR: Ordinal IBIs following stimulus onset[15]
- *Rationale:* Larger phasic HR responses occur in response to high-arousal versus low-arousal pictures[16] and sounds[17]
- *Stimuli:* 54 12–16-s excerpts taken from Exp. 1 stimuli
- *Prediction:* Fast tempo (rated as more arousing) should yield larger orienting response than slow tempo

Experiment 1: Tempo and HRV

✓ 24 subjects divided into 12 "low" and 12 "high" based on resting HRV

✓ natural log of both HRV and mean HR compared



(all graphs: means ± 1 SE)

Tempo effect [$F_{lin}(1,11)$]:

Valence: F = 28.28, $p < .001$	Low: F = 10.40, p = .008	Low: F = 1.13, p = .311
Arousal: F = 103.36, $p < .001$	High: F = 10.53, p = .008	High: F = .74, p = .408

★ Result: Tempo impacts HR variability, but <u>not</u> mean HR

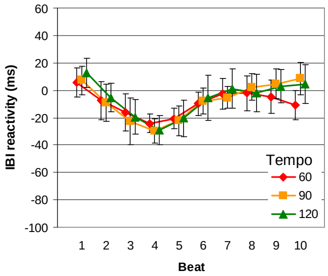
Experiment 2: Tempo and Phasic HR

✓ 18 subjects divided into 9 “low” and 9 “high” based on resting HRV

✓ “IBI reactivity”: mean of the 10 IBIs pre music onset subtracted from each post-music onset IBI

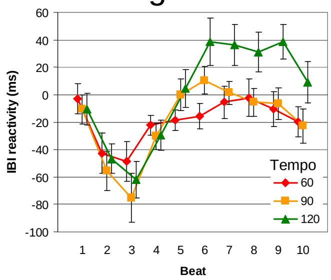
✓ Cubic trends [$F(1,8)$] in the 10-beat IBI series were calculated

Low HRV



60 bpm: F_{cub} = 5.71, $p < .05$
90 bpm: F_{cub} = 5.93, $p < .05$
120 bpm: F_{cub} = 3.01, $p < .20$

High HRV



60 bpm: F_{cub} = 3.90, $p < .10$
90 bpm: F_{cub} = 9.05, $p < .01$
120 bpm: F_{cub} = 15.25, $p < .01$

★ Result: Larger tempo effect on phasic HR in subjects with High HRV than Low HRV

Discussion

★ Experiment 1: Musical tempo (60, 90, 120 beats per minute) had a significant effect on heart rate variability (HRV), but not mean heart rate (HR). This difference could account for previous investigations reporting a null effect of tempo on mean HR. Fast music prompted the greatest parasympathetic withdrawal.

★ Experiment 2: Tempo differentiated patterns in phasic HR in subjects with high resting HRV, but not in subjects with low resting HRV. Tempo differentiated HR within a few moments of music onset.

These findings point to the importance of tempo on music’s ability to provoke changes in cardiovascular activity, and the evaluation of individual differences in physiological response.

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