BEAT COMPLEXITY AND VARIABILITY MAY OPTIMIZE THE EFFECTS OF RHYTHMIC AUDITORY CUEING ON THE PARKINSONIAN WALK

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Introduction

1. *Rhythmical cueing* improves the spatio-temporal gait parameters of patients with Parkinson's Disease (PD) [1].
2. A particular statistical parameter (the α-exponent that describes the self-affinity of a noisy series and is used to quantify its auto-correlation, or long-range correlation) has been proposed as an index of healthy variability in physiological control and is known to decrease with PD [2].
3. Music can be more powerful than simple metronomes in entraining human rhythmical behavior.

Hypothesis: A combination of musical complexity and long-range correlated variability at the main metrical level is going to optimize the cueing effect. Peak response is expected for musical stimuli with $1/f$ variability in the inter-beat-intervals.

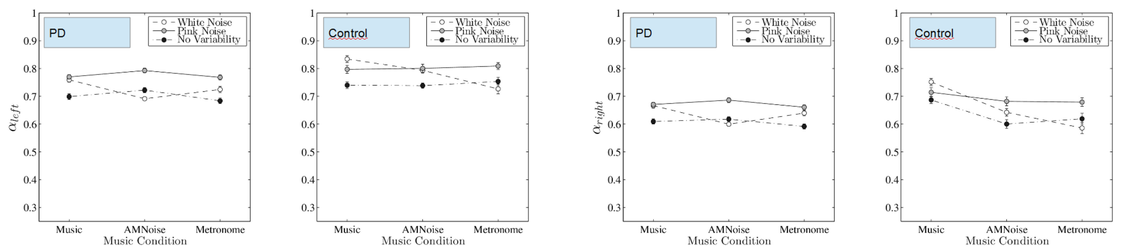
Methods

Design: 3 (Music, Amplitude-Modulated Noise, and Metronome) x 3 (White Noise, Pink Noise, and No Variability in the inter-beat-intervals) within-subject x 2 (PD and Control).
Stimuli: prepared in advance from manipulated midi piano renditions of classical marches; Average tempo = +10% the participant-preferred; CV = 2% (in white and pink) and 0% (in no variability conditions).
Data collection: 18 walking trials plus pre-test, (3+1)-minute-long, on a small track inside the hospital rehabilitation hall, spread over two days. IMUs were used to detect gait events and extract gait parameters (MobilityLab, APDM).
Synchronization: The phase of the step cycle, linearly-interpolated from the foot-falls, was sampled at the time of the beats implicit in the auditory stimulus. Circular statistics were applied to this relative phase to obtain a measure of synchronization (vector length *R*, which is inversely related to the circular variance). Participants did not receive any instruction with respect to synchronization.
Long-range correlation: α (detrended fluctuation analysis).
Participants: (in progress) 11 PD (early motor symptoms) and 6 control.

Results

A sequence of linear statistical models applied to the right foot inter-step-interval α values.

	Model A	Model B	Model C	Model D	Model E	Model F	Model G
Intercept	0.64 *	0.61 *	0.58 *	0.57 *	0.66 *	0.67 *	0.70 *
Trial	0.00	0.00	0.00	0.00	0.00	0.00 *	0.00 *
Music		0.06 *	0.06 *	0.04	0.08 *	0.00	0.00
AMNoise		0.02	0.02	0.02	0.04	0.02	0.02
White Noise			0.03	0.03	0.01	0.00	-0.01
Pink Noise			0.06 *	0.07 *	0.04	0.04	-0.04
Group				0.02	-0.03	-0.05	-0.06
Group*Music				0.06	-0.02	0.05	0.05
Group*AMNoise				-0.01	-0.03	-0.03	-0.02
Group*White Noise				0.00	0.02	0.02	0.03
Group*Pink Noise				-0.01	0.01	0.01	0.07
Synchronization					-0.22 *	-0.28 *	-0.32 *
Synchronization*Music						0.16 *	0.16 *
Synchronization*AMNoise						0.05	0.05
Synchronization*White Noise							0.03
Synchronization*Pink Noise							0.18 *
AIC	-282.82	-287.26	-294.14	-287.69	-331.18	-341.77	-362.45
BIC	-268.00	-265.04	-264.51	-239.54	-279.32	-282.51	-295.79
Log Likelihood	145.41	149.63	155.07	156.85	179.59	186.89	199.23
Deviance	-290.82	-299.26	-310.14	-313.69	-359.18	-373.77	-398.45
Num. obs.	300	300	300	300	300	300	300
Num. groups: PP	17	17	17	17	17	17	17
Variance: PP(Intercept)	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Variance: Residual	0.02	0.02	0.02	0.02	0.01	0.01	0.01
χ^2		8.44	10.88	3.55	45.48	14.60	24.68
df (χ)		2	2	5	1	2	2
p		0.015	0.004	0.616	0.000	0.001	0.000



Conclusion

1. Music and $1/f$ variability are associated with an increase in α (consult the coefficients in the linear models table, Model B and C).
2. PD and controls respond similarly to the auditory cueing stimuli (Model D).
3. These effects are also mediated by synchronization with the stimuli (Model F and G).
4. PD patients with early motor symptoms do benefit from the optimized cueing inasmuch as the given statistical coefficients can be interpreted as markers of a healthy control system.

References

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