

## Online Resource 2

# Extended Statistical Analyses

Motor resonance in observed digital musical interactions: a time-resolved grip force study

Psychological Research

Olivier Capra & Florent Berthaut

`olivier.capra@univ-catholille.fr`

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This supplementary material provides extended statistical analyses of the main grip force effects reported in the manuscript. **Section 1** reports phase-by-phase one-sample tests on the global grip force signal averaged across all conditions. **Section 2** provides the full analysis pipeline for the Ancil vs. Direct contrast baselined at *fadeIn\_end*. **Section 3** reports the same pipeline after rebaselining the signal at *trigger\_start*, focusing on the post-trigger window shown in the main figure.

For each Ancil vs. Direct contrast, several complementary analyses are reported. Linear mixed models (LMMs) are fitted within pre-specified phase windows defined by the temporal structure of the interaction. Phase-by-phase descriptive statistics and nonparametric tests provide condition-level summaries of the same windows. A non-parametric permutation cluster test is reported as a mass-univariate reference. **The Time-resolved Bayesian Evidence Display (TBED)**  $H_1$  clusters are assessed against a sign-permutation null distribution; LMMs restricted to permutation-confirmed TBED  $H_1$  clusters provide a conventional mixed-effects characterization of these localized effects.

These analyses provide complementary views of the same grip force dynamics. Phase-level summaries characterize effects within theoretically defined interaction windows, whereas TBED and cluster-based analyses capture temporally localized deviations that may be diluted when averaged across broader phases.

## Note on table columns — Phase-by-phase analyses

The phase-by-phase tables report six descriptors per condition. Three pairs of measures are reported, each contrasting a **reference-event baseline-corrected** estimate with a **within-window baseline-corrected** estimate:

Column	Definition
Mean	Mean grip force over the phase window, expressed relative to the reference-event baseline ( <i>fadeIn_end</i> or <i>trigger_start</i> , as applicable).
Rel. Mean	Mean grip force over the phase window, after rebaselining to the first sample of the window.
Peaks	Mean of individual peak grip force values per participant within the phase window, expressed relative to the reference-event baseline ( <i>fadeIn_end</i> or <i>trigger_start</i> , as applicable).
Peaks Time	Mean latency of individual peaks per participant within the window, expressed in milliseconds from the beginning of the stimulus ( <i>stim_start</i> ).
Rel. Peaks	Mean of individual peak grip force values per participant within the phase window, after rebaselining to the first sample of the window.
Rel. Peaks Time	Mean latency of individual peaks after within-window rebaselining, expressed relative to the onset of the current phase window (ms from window start).

Amplitude measures are baseline-corrected; peak latencies are expressed either from stimulus onset or from the onset of the current phase window, as specified above.

Within each cell, the left value corresponds to the Ancil condition and the right value to the Direct condition (group mean  $\pm$  SD), followed by the statistic and p-value of the paired comparison between them. Highlighted cells indicate significance ( $p < .05$ , uncorrected). Phase windows were defined a priori by the temporal structure of the interaction; consistent with the main text, no correction for multiple comparisons was applied across these pre-specified windows.

# 1. Global grip force signal — all conditions

Analyses related to the global grip force signal averaged across all conditions and repetitions.

*Phase-by-phase descriptive statistics and frequentist tests comparing the grip force signal against baseline, averaged across all conditions and repetitions ( $n = 42$ ).  $p$ -values are uncorrected.*

One-sample t-test vs 0 — All					
Phase	$M$ (mN)	$SD$	$t$	$p$	$BF_{10}$
Stim Start - fade-In end	+2.77	4.42	+4.01	< .001***	105.1
Fade-in end - Mov. Start	+2.04	4.96	+2.63	0.012*	3.4
Mov. Start - Trigger Start	+1.28	10.52	+0.78	0.440	0.2
Trigger Start - Trigger End	+8.96	13.85	+4.14	< .001***	149.8
Trigger End - Mov. End	+12.44	18.02	+4.42	< .001***	328.8
Mov. End - Fade-out Start	+3.63	17.45	+1.33	0.190	0.4
Fade-out Start - Sound End + Stim End	-1.42	19.38	-0.47	0.642	0.2

## No reject (n=49)

*This pre-rejection analysis is reported as a descriptive robustness check only. The main inferential analyses are based on the artifact-cleaned sample. Phase-by-phase descriptive statistics and frequentist tests compare the grip force signal against baseline, averaged across all conditions and repetitions prior to artifact rejection ( $n = 49$ ).  $p$ -values are uncorrected.*

One-sample t-test vs 0 — All					
Phase	$M$ (mN)	$SD$	$t$	$p$	$BF_{10}$
Stim Start - fade-In end	+2.17	5.65	+2.66	0.011*	3.6
Fade-in end - Mov. Start	+3.55	6.37	+3.86	< .001***	75.8
Mov. Start - Trigger Start	+5.21	12.00	+3.01	0.004**	8.1
Trigger Start - Trigger End	+17.90	31.35	+3.96	< .001***	100.3
Trigger End - Mov. End	+18.12	30.30	+4.14	< .001***	172.0
Mov. End - Fade-out Start	+5.38	27.08	+1.38	0.175	0.4
Fade-out Start - Sound End + Stim End	+1.16	30.17	+0.27	0.790	0.2

## 2. Ancil vs. Direct (fadeIn\_end)

Analyses related to the comparison of the Ancil and the Direct conditions, baselined at *fadeIn\_end*.

### 2.1. LMM by interaction phase — Ancil vs. Direct

Mixed-effects model results fitted separately for each of the seven interaction phases ( $n = 42$ ). Estimates and SE in mN.  $p$ -values are uncorrected.

LMM — Ancil VS Direct				
Parameter	$\hat{\beta}$ (mN)	SE	$z$	$p$
<b>Stim Start - fade-In end (<math>n = 42</math>)</b>				
Intercept	+3.687	0.974	+3.78	< .001***
Direct	-2.011	1.320	-1.52	0.128
<b>Fade-in end - Mov. Start (<math>n = 42</math>)</b>				
Intercept	+1.986	0.945	+2.10	0.036*
Direct	+0.199	1.098	+0.18	0.856
<b>Mov. Start - Trigger Start (<math>n = 42</math>)</b>				
Intercept	+2.299	1.873	+1.23	0.220
Direct	-2.021	1.791	-1.13	0.259
<b>Trigger Start - Trigger End (<math>n = 42</math>)</b>				
Intercept	+11.058	2.399	+4.61	< .001***
Direct	-4.262	1.920	-2.22	0.026*
<b>Trigger End - Mov. End (<math>n = 42</math>)</b>				
Intercept	+14.567	3.091	+4.71	< .001***
Direct	-4.202	2.393	-1.76	0.079 <sup>†</sup>
<b>Mov. End - Fade-out Start (<math>n = 42</math>)</b>				
Intercept	+4.605	3.014	+1.53	0.127
Direct	-1.928	2.405	-0.80	0.423
<b>Fade-out Start - Sound End + Stim End (<math>n = 42</math>)</b>				
Intercept	-0.905	3.422	-0.26	0.791
Direct	-1.042	3.111	-0.34	0.738

Phase windows were defined a priori by the temporal structure of the interaction; no correction for multiple comparisons was applied across phases.

## 2.2. Frequentist analyses by phase — Ancil vs. Direct

Phase-by-phase descriptive statistics (mean  $\pm$  SD, mN) and frequentist tests. Highlighted cells: significant ( $p < .05$ , uncorrected).

Ancil VS Direct											
Mean		Rel. Mean		Peaks		Peaks Time		Rel. Peaks		Rel. Peaks Time	
<b>Stim Start - fade-In end</b>											
3.65 $\pm$ 5.77	1.66 $\pm$ 6.69	-0.76 $\pm$ 6.54	0.44 $\pm$ 7.75	8.54 $\pm$ 7.34	6.74 $\pm$ 10.08	205.83 $\pm$ 108.66	235.48 $\pm$ 124.87	4.13 $\pm$ 7.57	5.52 $\pm$ 11.75	205.83 $\pm$ 108.66	235.48 $\pm$ 124.87
300.00, $p = 0.06$ (wilcoxon)		429.00, $p = 0.79$ (wilcoxon)		311.00, $p = 0.08$ (wilcoxon)		331.50, $p = 0.20$ (wilcoxon)		444.00, $p = 0.93$ (wilcoxon)		331.50, $p = 0.20$ (wilcoxon)	
<b>Fade-in end - Mov. Start</b>											
1.98 $\pm$ 6.61	2.17 $\pm$ 5.65	1.91 $\pm$ 6.64	2.14 $\pm$ 5.95	9.54 $\pm$ 8.66	10.41 $\pm$ 8.49	1024.88 $\pm$ 301.40	968.33 $\pm$ 310.14	9.47 $\pm$ 8.66	10.38 $\pm$ 8.39	524.88 $\pm$ 301.40	468.33 $\pm$ 310.14
438.00, $p = 0.87$ (wilcoxon)		-0.20, $p = 0.84$ (t-paired)		380.00, $p = 0.38$ (wilcoxon)		379.50, $p = 0.37$ (wilcoxon)		375.00, $p = 0.35$ (wilcoxon)		379.50, $p = 0.37$ (wilcoxon)	
<b>Mov. Start - Trigger Start</b>											
2.35 $\pm$ 11.56	0.27 $\pm$ 12.70	1.16 $\pm$ 6.50	0.92 $\pm$ 4.22	7.39 $\pm$ 12.02	4.27 $\pm$ 12.91	1800.71 $\pm$ 129.63	1732.02 $\pm$ 121.42	6.21 $\pm$ 8.31	4.91 $\pm$ 6.13	290.71 $\pm$ 129.63	222.02 $\pm$ 121.42
346.00, $p = 0.19$ (wilcoxon)		411.00, $p = 0.62$ (wilcoxon)		1.59, $p = 0.12$ (t-paired)		247.00, $p = 0.01$ (wilcoxon)		380.00, $p = 0.38$ (wilcoxon)		247.00, $p = 0.01$ (wilcoxon)	
<b>Trigger Start - Trigger End</b>											
11.08 $\pm$ 14.65	6.82 $\pm$ 16.45	4.47 $\pm$ 6.41	6.97 $\pm$ 8.35	18.88 $\pm$ 17.15	15.44 $\pm$ 20.17	2450.71 $\pm$ 209.06	2478.93 $\pm$ 147.54	12.27 $\pm$ 11.14	15.59 $\pm$ 13.88	505.71 $\pm$ 209.06	533.93 $\pm$ 147.54
2.22, $p = 0.03$ (t-paired)		280.00, $p = 0.03$ (wilcoxon)		366.00, $p = 0.29$ (wilcoxon)		367.50, $p = 0.57$ (wilcoxon)		279.00, $p = 0.03$ (wilcoxon)		367.50, $p = 0.57$ (wilcoxon)	
<b>Trigger End - Mov. End</b>											
14.53 $\pm$ 18.97	10.35 $\pm$ 21.05	-0.18 $\pm$ 4.84	-0.56 $\pm$ 5.79	17.03 $\pm$ 19.48	13.62 $\pm$ 20.96	2803.05 $\pm$ 78.35	2805.83 $\pm$ 73.62	2.75 $\pm$ 5.89	2.71 $\pm$ 8.85	123.05 $\pm$ 78.35	125.83 $\pm$ 73.62
310.00, $p = 0.08$ (wilcoxon)		422.00, $p = 0.72$ (wilcoxon)		319.00, $p = 0.10$ (wilcoxon)		451.50, $p = 1.00$ (wilcoxon)		432.00, $p = 0.81$ (wilcoxon)		451.50, $p = 1.00$ (wilcoxon)	
<b>Mov. End - Fade-out Start</b>											
4.59 $\pm$ 18.66	2.67 $\pm$ 20.37	-8.18 $\pm$ 8.01	-6.98 $\pm$ 9.26	15.52 $\pm$ 19.86	13.79 $\pm$ 21.43	3443.45 $\pm$ 452.78	3430.71 $\pm$ 466.58	2.75 $\pm$ 6.60	4.14 $\pm$ 6.40	488.45 $\pm$ 452.78	475.71 $\pm$ 466.58
417.00, $p = 0.67$ (wilcoxon)		346.00, $p = 0.19$ (wilcoxon)		406.00, $p = 0.58$ (wilcoxon)		437.00, $p = 0.86$ (wilcoxon)		316.00, $p = 0.09$ (wilcoxon)		437.00, $p = 0.86$ (wilcoxon)	
<b>Fade-out Start - Sound End + Stim End</b>											
-0.90 $\pm$ 21.21	-1.95 $\pm$ 23.11	0.05 $\pm$ 5.83	-0.87 $\pm$ 5.83	4.47 $\pm$ 22.28	2.79 $\pm$ 22.80	4830.60 $\pm$ 155.41	4817.50 $\pm$ 158.42	5.43 $\pm$ 7.57	3.86 $\pm$ 5.09	310.60 $\pm$ 155.41	297.50 $\pm$ 158.42
0.34, $p = 0.74$ (t-paired)		392.00, $p = 0.46$ (wilcoxon)		449.00, $p = 0.98$ (wilcoxon)		395.50, $p = 0.65$ (wilcoxon)		1.09, $p = 0.28$ (t-paired)		395.50, $p = 0.65$ (wilcoxon)	
<b>Full Phase</b>											
4.55 $\pm$ 12.45	2.68 $\pm$ 13.46	0.14 $\pm$ 13.76	1.45 $\pm$ 19.21	25.22 $\pm$ 19.06	23.26 $\pm$ 19.80	2499.29 $\pm$ 1652.08	2456.19 $\pm$ 1490.09	20.80 $\pm$ 19.06	22.03 $\pm$ 25.43	2499.29 $\pm$ 1652.08	2456.19 $\pm$ 1490.09
1.11, $p = 0.27$ (t-paired)		440.00, $p = 0.89$ (wilcoxon)		395.00, $p = 0.49$ (wilcoxon)		382.50, $p = 0.71$ (wilcoxon)		430.00, $p = 0.79$ (wilcoxon)		382.50, $p = 0.71$ (wilcoxon)	

## 2.3. Permutation cluster test — Ancil vs. Direct

Nonparametric permutation cluster test (10,000 permutations,  $|t| = 1.96$ , two-tailed). No clusters reached significance ( $p < .05$ ).

Permutation Cluster Test — Ancil VS Direct				
Cluster	Start (ms)	End (ms)	Size (samples)	$p$
1	1890	2250	73	0.286
2	180	285	22	0.714

## TBED permutation null distribution

The TBED  $H_1$  clusters were evaluated with a sign-permutation cluster procedure adapted from nonparametric cluster-based testing (Maris & Oostenveld, 2007). Whereas the classical procedure operates on a  $t$ -statistic, here the same logic is applied to the time-resolved Bayesian evidence trace ( $dBF_{10}$ ). Clusters were defined as runs of contiguous time points exceeding the moderate-evidence threshold ( $dBF_{10} > 5$  dBan for  $H_1$ ; the symmetric criterion  $dBF_{10} < -5$  dBan defines  $H_0$  clusters, not tested here). For each cluster, its temporal extent—the number of contiguous time points above threshold—served as the cluster-level statistic.

The null distribution was generated by randomly flipping the condition labels within each participant and recomputing the full  $dBF_{10}$  trace; the maximum cluster extent across the trace was retained for each of 2000 permutations. Retaining the maximum controls the family-wise error rate, so that each observed cluster—including short ones—is evaluated against the largest cluster expected under the null. The empirical  $p$  value was computed as  $(b + 1)/(n + 1)$ , where  $b$  is the number of permutations whose maximum cluster extent equalled or exceeded the observed extent and  $n$  the number of permutations (Phipson & Smyth, 2010); this ensures that  $p$  is never zero. Clusters with  $p < .05$  were considered validated and entered the follow-up mixed model.

For the *trigger\_start* rebaselining (Section 3), the null was computed over the full time course, but only clusters falling within the theoretically interpretable post-trigger window are reported; evaluating a windowed cluster against the global maximum is conservative.

### 2.4. TBED permutation null distribution — Ancil vs. Direct

One  $H_1$  cluster (52 samples, 260 ms) was validated against the sign-permutation null distribution ( $p = .004$ ); a short subsequent cluster (4 samples, 20 ms) was not ( $p = .058$ ) and was not interpreted further.

TBED permutation null distribution — Ancil VS Direct				
Cluster	Window	Statistic (samples)	$p$	Rank
Global null: $n = 2000$ permutations, mean $\pm$ SD = $1.0 \pm 5.2$ samples, 95th pct = 6.0 samples				
H1 cluster 1	1920–2175 ms	52 samples (821.2 dBan)	0.004**	top 0%
H1 cluster 2	2215–2230 ms	4 samples (20.6 dBan)	0.058 <sup>†</sup>	top 6%

Paired sign-permutation. BF threshold: 5 dBan. Cluster statistic: size (samples  $> 5$  dBan). Null: max cluster size per permutation.

### 2.5. LMM on TBED $H_1$ cluster — Ancil vs. Direct

Follow-up LMM fitted on the permutation-confirmed TBED  $H_1$  cluster ( $> 5$  dBan, 1920–2175 ms).

LMM on TBED $H_1$ clusters — Ancil VS Direct				
Cluster 1: 1920–2175 ms ( $n = 42$ , 52 samples, mean BF = 15.8 dBan)				
Parameter	$\hat{\beta}$ (mN)	SE	$z$	$p$
Intercept	—	—	—	—
Direct	-6.930	1.863	-3.72	$< .001$ ***

Reference: Ancil; estimates express the Direct–Ancil difference in GF.

### 3. Ancil vs. Direct (trigger\_start)

Analyses related to the comparison of the Ancil and Direct conditions after rebaselining at button contact (*trigger\_start*). Statistical summaries focus on the post-trigger window from *trigger\_start* to *mov\_end*, matching the zoomed time course shown in the main figure. Full-course time series are provided in the Appendix for descriptive inspection.

#### 3.1. LMM by interaction phase — Ancil vs. Direct (*trigger\_start*–*mov\_end*)

Mixed-effects model results fitted separately for two interaction phases ( $n = 42$ ). Estimates and SE in mN.  $p$ -values are uncorrected.

LMM — Ancil VS Direct					
Parameter	$\hat{\beta}$ (mN)	SE	$z$	$p$	
<b>Trigger Start - Trigger End (<math>n = 42</math>)</b>					
Intercept	+4.700	1.129	+4.16	< .001***	
Direct	+2.062	1.009	+2.04	0.041*	
<b>Trigger End - Mov. End (<math>n = 42</math>)</b>					
Intercept	+8.177	2.191	+3.73	< .001***	
Direct	+2.142	1.597	+1.34	0.180	

Phase windows were defined a priori by the temporal structure of the interaction; no correction for multiple comparisons was applied across phases.

#### 3.2. Frequentist analyses by phase — Ancil vs. Direct

Phase-by-phase descriptive statistics (mean  $\pm$  SD, mN) and frequentist tests. Highlighted cells: significant ( $p < .05$ , uncorrected).

Ancil VS Direct											
Mean		Rel. Mean		Peaks		Peaks Time		Rel. Peaks		Rel. Peaks Time	
<b>Trigger Start - Trigger End</b>											
4.72 $\pm$ 6.36	6.79 $\pm$ 8.21	4.47 $\pm$ 6.41	6.97 $\pm$ 8.35	12.52 $\pm$ 11.22	15.41 $\pm$ 13.80	2450.71 $\pm$ 209.06	2478.93 $\pm$ 147.54	12.27 $\pm$ 11.14	15.59 $\pm$ 13.88	505.71 $\pm$ 209.06	533.93 $\pm$ 147.54
310.00, $p = 0.08$ (wilcoxon)		280.00, $p = 0.03$ (wilcoxon)		295.00, $p = 0.05$ (wilcoxon)		367.50, $p = 0.57$ (wilcoxon)		279.00, $p = 0.03$ (wilcoxon)		367.50, $p = 0.57$ (wilcoxon)	
<b>Trigger End - Mov. End</b>											
8.18 $\pm$ 13.01	10.32 $\pm$ 15.30	-0.18 $\pm$ 4.84	-0.56 $\pm$ 5.79	10.85 $\pm$ 13.64	13.59 $\pm$ 16.77	2803.05 $\pm$ 78.35	2805.83 $\pm$ 73.62	2.75 $\pm$ 5.89	2.71 $\pm$ 8.85	123.05 $\pm$ 78.35	125.83 $\pm$ 73.62
359.00, $p = 0.25$ (wilcoxon)		422.00, $p = 0.72$ (wilcoxon)		335.00, $p = 0.15$ (wilcoxon)		451.50, $p = 1.00$ (wilcoxon)		432.00, $p = 0.81$ (wilcoxon)		451.50, $p = 1.00$ (wilcoxon)	
<b>Full Phase</b>											
-1.80 $\pm$ 6.54	2.64 $\pm$ 9.01	0.14 $\pm$ 13.76	1.45 $\pm$ 19.21	18.86 $\pm$ 12.95	23.22 $\pm$ 20.49	2499.29 $\pm$ 1652.08	2456.19 $\pm$ 1490.09	20.80 $\pm$ 19.06	22.03 $\pm$ 25.43	2499.29 $\pm$ 1652.08	2456.19 $\pm$ 1490.09
199.00, $p < .01$ (wilcoxon)		440.00, $p = 0.89$ (wilcoxon)		317.00, $p = 0.09$ (wilcoxon)		382.50, $p = 0.71$ (wilcoxon)		430.00, $p = 0.79$ (wilcoxon)		382.50, $p = 0.71$ (wilcoxon)	

### 3.3. Permutation cluster test — Ancil vs. Direct (*trigger\_start–mov\_end*)

Nonparametric permutation cluster test (10,000 permutations,  $|t| = 1.96$ , two-tailed). No clusters were detected in the *trigger\_start–mov\_end* window.

### 3.4. TBED permutation null distribution — Ancil vs. Direct (*trigger\_start–mov\_end*)

Within the theoretically interpretable post-trigger window, one  $H_1$  cluster (32 samples, 160 ms; 2480–2635 ms) was validated against the sign-permutation null distribution ( $p = .015$ ). The null was computed over the full time course.

TBED permutation null distribution — Ancil VS Direct				
Cluster	Window	Statistic (samples)	$p$	Rank
Global null: $n = 2000$ permutations, mean $\pm$ SD = $1.9 \pm 9.3$ samples, 95th pct = 11.0 samples				
H1 cluster 1	2480–2635 ms	32 samples (332.7 dBan)	0.015*	top 1%

Paired sign-permutation. BF threshold: 5 dBan. Cluster statistic: size (samples  $> 5$  dBan). Null: max cluster size per permutation.

### 3.5. LMM on TBED $H_1$ cluster — Ancil vs. Direct (*trigger\_start–mov\_end*)

Follow-up LMM fitted on the permutation-confirmed TBED  $H_1$  cluster ( $> 5$  dBan, 2480–2635 ms).

LMM on TBED $H_1$ clusters — Ancil VS Direct				
Cluster 1: 2480–2635 ms ( $n = 42$ , 32 samples, mean BF = 10.4 dBan)				
Parameter	$\hat{\beta}$ (mN)	SE	$z$	$p$
Intercept	—	—	—	—
Direct	+4.633	1.416	+3.27	0.001**

Reference: Ancil; estimates express the Direct–Ancil difference in GF.

## References

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- Phipson, B., & Smyth, G. K. (2010). Permutation P-values should never be zero. *Statistical Applications in Genetics and Molecular Biology*, 9(1), Article 39.