

Online Resource 1 – Supplementary Methods and Experimental Setup

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

Psychological Research

Olivier Capra and Florent Berthaut

Corresponding author: olivier.capra@univ-catholille.fr

Supplementary Methods

Environmental and Setup Details

Room Conditions

The experiment took place in a temperature-controlled room at the first author's laboratory. Temperature and humidity were recorded continuously throughout each session using a calibrated digital hygrometer. Across all sessions, mean room temperature was 20.6°C (SD = 1.2°C) and mean relative humidity was 68.2% (SD = 4.8%). These variables were monitored because skin moisture and friction, both influenced by ambient conditions, affect grip force regulation (Johansson & Westling, 1984; Westling & Johansson, 1984). Their recording provides environmental documentation for the present paradigm and future replication attempts.

Participant Setup

Upon arrival, participants removed personal items — including powered-off mobile phones and jewelry — before being seated in front of the stimulus display. The grip force device was disinfected in their presence, and participants sanitized their hands with an alcohol-based gel to reduce uncontrolled variability in skin moisture and friction conditions across participants (Westling & Johansson, 1984, 1987). Headphones with disposable ear covers were provided; participants

adjusted playback volume to a comfortable level using a potentiometer. Chair height was adjusted so that the participant's eyes were aligned with a fixed marker at the center of the screen. Viewing distance was recorded for each participant ($M = 75$ cm, $SD = 7.5$ cm).



Figure 1: Experimental setup. The participant held the grip force sensor between thumb, index, and middle fingers, with the forearm resting on a cushioned support.

Posture and Device Orientation

Participants were instructed to adopt a standardized posture: forearm resting on a cushion placed on the desk, elbow bent at approximately 45° , and the grip force device held in the right hand between the thumb on one side and the index and middle fingers on the opposite side. The sensor was oriented with its cable extending horizontally, parallel to the table surface. Preliminary testing confirmed that this configuration exerted no measurable influence on grip force or device stability. All participants — including the three who were left-handed — used their right hand.

Experimenter Separation

Once the participant was positioned and the setup complete, a rolling partition was placed between the participant and the experimenter, who was seated to the left, concealing both the experimenter and the control screen for the duration of the experiment.

Individual Pretrial Target (IPT)

To establish a stable individual reference pressure, participants held the device and applied a natural, comfortable amount of force for approximately one



Figure 2: Grip force sensor. Close-up of the ATI Mini40 grip force sensor, mounted with two custom aluminum contact plates, held between thumb, index, and middle fingers.

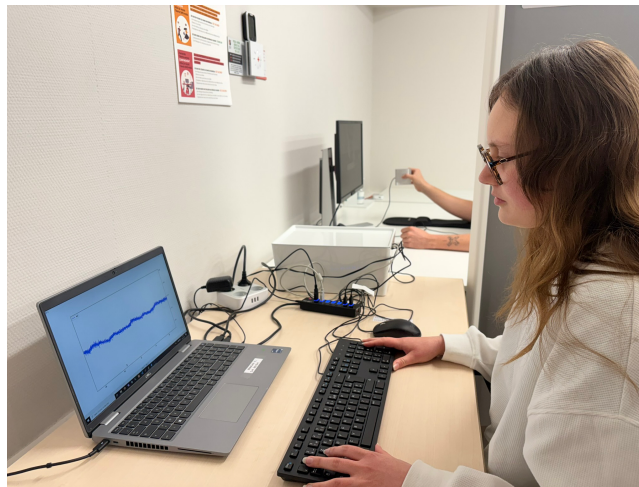


Figure 3: Experimenter station. The experimenter monitors the grip force signal. The participant, partially isolated behind a partition, observes a digital interaction.



Figure 4: Experimental space. The participant (right) and the experimenter (left) in the experimental space. At the center, the thermometer-hygrometer.

minute while the experimenter monitored the signal in real time. The average grip force over this period was computed as the Individual Pretrial Target (IPT), which served as the target pressure at the onset of each trial.

Whereas previous grip-force studies often used fixed target forces, this individualized approach was chosen to account for inter-individual variability in grip force and sensor-specific calibration. It is motivated by evidence that grip force is modulated by multiple factors including skin properties, friction, moisture, and tactile feedback (Westling & Johansson, 1984, 1987), and provides a participant-sensitive baseline that improves signal reliability.

Trial Onset and IPT Guidance

At the onset of each trial, the experimenter guided the participant back to their IPT level via verbal instructions while monitoring the signal in real time. Once the IPT was reached and maintained for 3 seconds, the video stimulus began automatically.

Artifact screening and exclusion

Following Nazir et al. (2017), grip force signals were screened for outlier patterns at the level of individual repetitions. To account for inter-individual differences in baseline grip force, the exclusion threshold for excessive mean variation was partially individualized using the Individual Pretrial Target (IPT). Specifically, the maximal allowed mean variation was defined as a weighted interpolation between a fixed 200 mN criterion and an IPT-scaled criterion, with a lower bound of 200 mN:

$$\text{MAX_VAR}_i = \max \left[\alpha_{\text{weight}} \left(\frac{\text{IPT}_i}{\overline{\text{GF}}_{\text{sample}}} \cdot 200 \text{ mN} \right) + (1 - \alpha_{\text{weight}}) \cdot 200 \text{ mN}, 200 \text{ mN} \right].$$

Here, IPT_i denotes the Individual Pretrial Target for participant i , $\overline{\text{GF}}_{\text{sample}}$ denotes the mean grip force computed across all participants before artifact rejection, and α_{weight} denotes the relative contribution of the individualized IPT-scaled criterion. In the present analyses, $\alpha_{\text{weight}} = 0.5$, corresponding to an equal weighting of the fixed and IPT-scaled criteria.

Repetitions were excluded if their mean variation exceeded MAX_VAR_i , or if rapid changes exceeded 100 mN within 100 ms. Trials with no valid repetitions were discarded. Participants with fewer than 80% valid trials were excluded from further analysis. From the initial sample ($n=49$), the IPT-weighted criterion excluded 31% of repetitions across all participants (84% of trials retained at least one valid repetition). Seven participants were then removed for having fewer than 80% valid trials. Within the resulting sample of 42 participants, 2,901 of 3,780 repetitions were retained, i.e., 23% repetition-level exclusion.

Grip Force Sensor

Force was measured using a six-axis load cell (Mini40, SI-40-2, ATI Industrial Automation, USA) mounted between two custom aluminum contact plates secured with double-sided tape, yielding a total apparatus weight of 68 g and dimensions of 8 cm (height) \times 8 cm (width) \times 2 cm (depth). Three force components were recorded: longitudinal F_x , radial F_y , and compressive F_z . Only the compressive component, F_z , corresponding to the force applied perpendicularly to the sensor surface, was retained for analysis.

Digital musical instrument configuration

A minimal digital musical instrument (DMI) was used to create a controlled real-time gesture–sound interaction. It consisted of a standard MIDI controller (Korg nanoKONTROL) connected to a laptop, which handled both sound synthesis and gesture-to-sound mapping implemented in Pure Data (Puckette, 1996). Sound synthesis relied on amplitude modulation (a 440 Hz sine wave amplitude-modulated at 40 Hz). The button registered presses as binary on/off events, independent of the force applied to it; each press triggered a change in sound volume, whose perceptual salience and temporal coupling to the press were manipulated to produce the three transparency levels (see main document Experimental Factors).

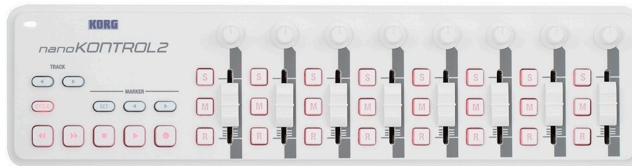


Figure 5: Korg nanoKONTROL digital controller

Acquisition and Synchronization Architecture

The sensor was connected to the acquisition computer via a National Instruments NI-6221 USB data acquisition card. Stimulus presentation was controlled by PsychoPy running on the acquisition computer, which also recorded grip force via a custom Python script at a sampling rate of 200 Hz. To synchronize stimulus events with force recordings, digital event markers were converted into analog pulses using an Arduino Uno microcontroller. In parallel, event markers and force data were streamed over a closed local network using the Lab Streaming Layer protocol (LSL; Kothe et al., 2025) and recorded via LabRecorder on a second computer, providing a redundant, software-timestamped verification path for temporal alignment. All data transfer occurred over a closed local network physically confined to the experiment room, ensuring that no participant data left the acquisition environment. A third computer was used solely for questionnaire administration at the end of each session.

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