Catching the Visual System in Action: A Modified Event-Related Potential Paradigm for Dynamic Stimuli

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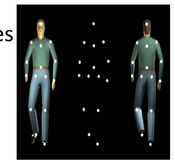
Introduction



- Understanding the biological motion (BM) performed by other living entities has both ecological and sociological significances. Point-light displays (PL-BM) are commonly used to study biological motion.
- To investigate the timing order of how our brain processes such a dynamic stimulus requires a temporally sensitive method.
- Many literature (Hirai et al., 2003, 2005; Hirai et al. 2009; Krakowski et al., 2011) used Event-Related Potential (ERP) paradigm to study the underline temporal mechanism of BM perception. However, time-locking at the onset of a temporally-unfolding stimulus does not capture its dynamic nature.
- The goal of this study is to develop a variant of the ERP method, aiming to visualize brain activities at a frame level.

Innovation: the Sparse Pulse ERP (spERP)

- Conventional ERP on dynamic stimulus (Fig 1a.)
  - Time-locking at the first frame of the display, treat the dynamic stimulus as if it's a static picture.
  - One trial will contribute to at most one single ERP.
  - Analysis could only be performed at the trial level.
- Sparse Pulse ERP on dynamic stimulus (Fig 1b.)
  - Changing the contrast of the stimulus at individual frames ("pulse frames") could elicit VEPSs at different time points along with the unfolding of the stimulus temporally.
  - Time-locking at the "pulse frames".
  - One trial of display could produce multiple ERPs, increasing SNR.
  - Analysis could be performed at frame-level.

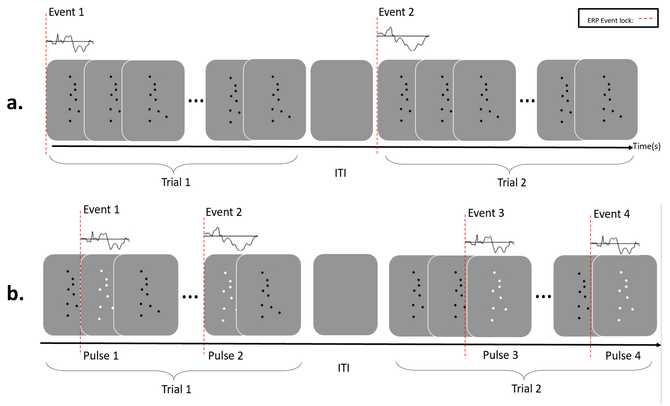


Figure 1. Still frames depicting PL-BM stimuli and the conventional ERP and the modified spERP paradigms. **a**. Conventional ERP would time-lock the EEG at the onset of display of each PL-BM stimulus (i.e., one event within one trial). **b**. spERP paradigm would time-lock to the pulse (here, white) frames within the PL-BM stimuli, such that there are multiple events within each trial.

Method

- N = 17
- Condition: 2 (left vs. right) * 2 (biological vs. scramble)
- Pulse Probability = 0.1 (Each trail consist of 60 frames of a display, containing two complete 30-frame cycles. Each frame of the display has a probability of 10% to undergo a contrast reversal, meaning on average 6 pulse frames per trial).
- Pulse frames are assigned pseudo-randomly across each display with a control of no pulse frame at the beginning, the ending, as well as the adjacent 2 frames.
- Subjects were asked to perform a keypress if they detect a single dot changes its color to yellow. The task serves as attention control, and it not the main interest of the experiment.

Experimental Results

- Overall Componentry and Latencies
  - spERP shows similar componentry to the conventional ERP (time-lock to the onset frame), including typical P1, N1, P2, and N2.
  - spERP components have overall smaller amplitudes, earlier peak onsets.

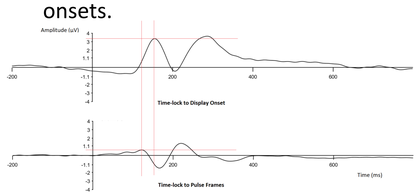


Figure 2. ERPs averaged across conditions and subjects using different event-lock. Upper: time-lock to the display onset frame; Lower: time-lock to the pulse frames.

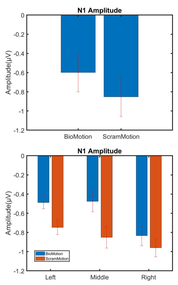


Figure 4. N1 Component. **Upper**. Stimulus type; **Lower**. stimulus type plotted separately at electrodes locations.

- N1 Component
  - Analysis: 2 (Stimulus type: BioMotion, ScramMotion) by 3 (Electrode location: Left Mid, Right) repeated measure ANOVA
  - No main effect of stimulus type and electrode location. No significant interaction.

- P1 Component
  - Analysis: 2 (Stimulus type: BioMotion, ScramMotion) by 3 (Electrode location: Left, Mid, Right) repeated measure ANOVA
  - At occipital and occipital parietal sites, biological motion pulse frame create a significant larger P1 peak comparing to scrambled motion. ($F(1,101) = 15.56$; $p = <0.001$).
  - Main effect of electrode location and interaction between stimulus type and electrode location was not significant.

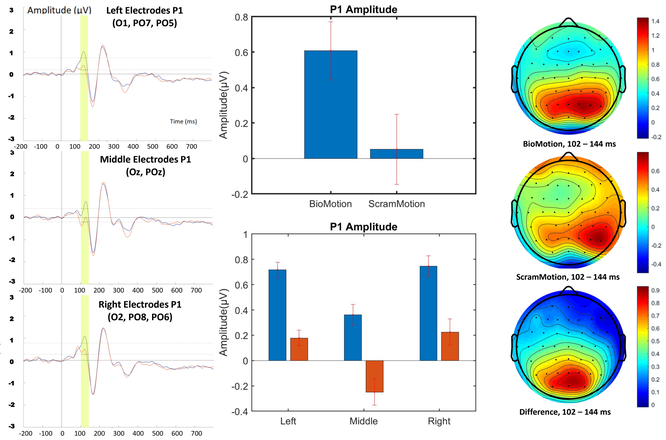


Figure 3. P1 Component. **Left column:** ERP waveforms time-locked to pulse frames for the two conditions (orange: BM; blue: SM) at left, midline and right electrodes. The shaded areas is the analysis window to compute mean amplitude (+/-20 ms of the mean peak latency); **Middle column: Upper**. Main effect of stimulus type; **Lower**. stimulus type plotted separately at electrodes locations. **Right column:** The scalp topography plots illustrating the topographic distribution of the mean component amplitudes of different conditions and their difference during the selected time window.

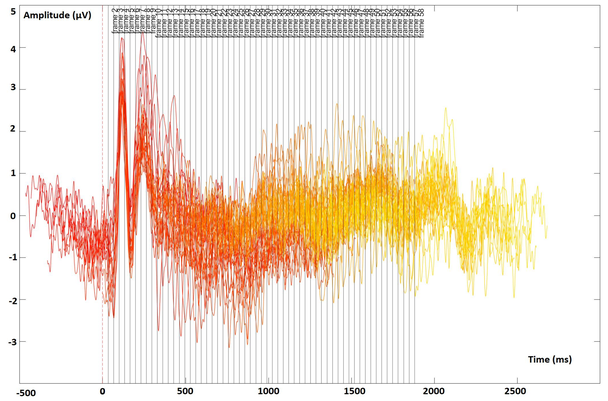


Figure 4. Overlay of spERPs of each frame under BioMotion condition (from frame 2 to frame 58). X-axis represents the time of one entire trial of display. The time of each frame is marked as vertical black line.

- Frame-Level Visualization
  - Even thought the pulse frames are distributed randomly along with the display, with enough subjects, it is still able to have a sufficient number of trials for every single frame (except the first and last two frames) to get a relatively clean ERP.
  - By overlaying the pulse ERPs on the time scale of the display (one "trial" with 60 frames), it is visible that the early frames are largely dominated by the "onset" ERP elicited by the first frame of the display.

General Summary

- spERP
  - The contrast reversal of a single frame is sufficient to evoke a VEP, which allows us to actively probe different stages of processing and increase the applicability of the ERP paradigm on dynamic stimuli.
  - The frame-level visualization illustrates that the onset issue still exists in the current manipulation. Distributing pulse frames randomly will not entirely solve the onset issue. Different designs are required to entirely solve the issue to answer questions about the early stage of processing.
- P1
  - P1 amplitude was modulated by stimulus type, with a larger amplitude for biological motion condition compared to spatially scrambled control.
  - The sensitivity of P1 to dynamic biological motion is likely not a function of the presence of motion cues per se, considering the early stage this component reflects. This finding echoed with previously reported P1 modulation by a static point-light figure (Buzzell et al. 2013; White et al. 2014) and may serve as evidence for the 'snapshot' neurons suggested by a computational model of biological motion (Giese & Poggio, 2003) as well as neurophysiological studies (Vangeneugden et al., 2014)

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