Neural signatures of perceptual transitions for a novel bistable auditory stimulus

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Introduction:

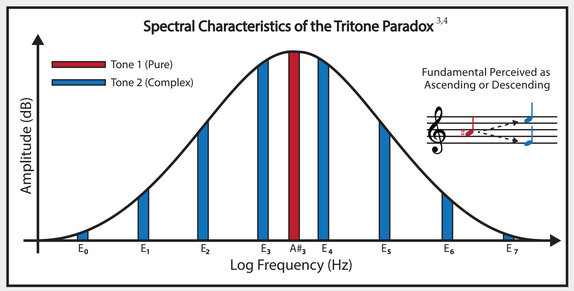
Previous Research:

- Multistable figures allow the investigation of neural processes associated with conscious perception while holding the stimulus constant.[1]
- The intermittent stimulus presentation paradigm allows time-locking of event-related potentials (ERPs) to the onset of images or sounds.
- Previous experiments have consistently reported two components associated with perceptual transitions of bistable visual stimuli (e.g. Necker cube, face-vase), the "reversal negativity" (RN) and the "late positive complex" (LPC).[2]

Current Investigation:

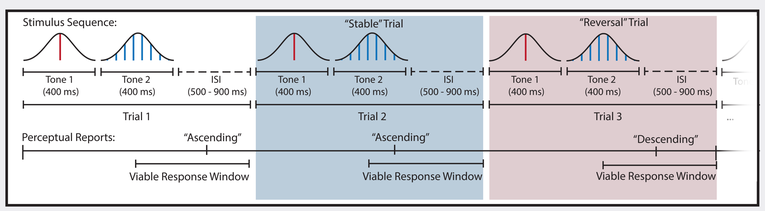
- A novel auditory bistable stimulus based on Shepherd Tones was presented intermittantly while subjects reported their percepts.
- The goal was to determine whether similar ERP components index perceptual reversals in the auditory domain as in the visual domain.

Stimuli:



Stimuli consisted of pairs of tones: a pure tone, presented for 400 ms followed by a complex Shepherd tone, also for 400 ms.

Methods:



Participants:

- 21 Reed College students and recent alumni,
- (ages 18 - 30, 52% female).

Trials

- 780 - 1040 total tone-pairs per subject (until minimum trials per condition > 150)
- 65 tone-pairs per block
- 12 - 16 blocks total

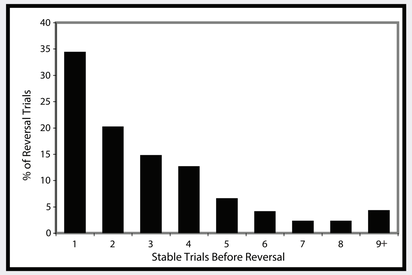
Task:

- respond after each stimulus pair indicating ascending or descending perception
- trials sorted into "reversal" and "stable" conditions by comparing perceptual reports across adjacent trials

EEG methods

- 96 equidistant channels: 500 Hz sampling rate: Average Mastoid reference
- ERPs timelocked to the onset of tone 1.

Behavioral Data:



Reversal rates were highly similar to those previously reported for visual bistable stimuli.[5]

- Reversals took place on average every 2.92 trials (4.38 sec).
- Reversals were inevitable.
- Reversal intervals approximate a lognormal distribution.

Trials per Condition (T/C):

	Stability	Reversal
% T/C:	65.42%	34.58%
Minimum T/C:	186	102
Average T/C:	294.0	157.1
SD T/C:	134.3	87.1

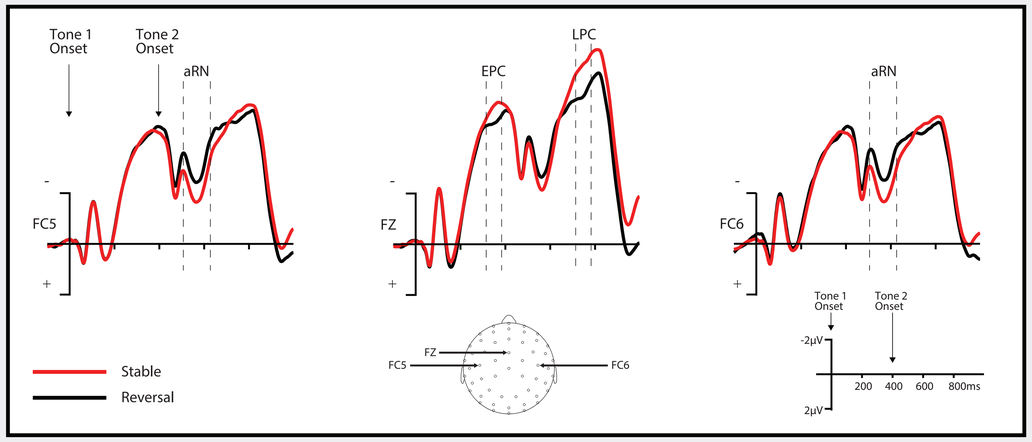
% Response:

Ascending:	51.2 %
Descending:	48.8%

Reaction Times (ms):

M:	832.2
SD:	146.1

Event Related Potentials:



Auditory Reversal Negativty (aRN) observed from 520- 620 ms (120- 220 ms after tone 2 onset) over bilateral fronto-central scalp.

- Main effect of condition: $F(1,20) = 15.2$, $p < 0.001$
- Hemisphere x Condition interaction: $F(1,20) = 0.017$, $p = 0.9$

Late Positive Complex (LPC) observed from 720 - 820 ms (320 - 380 ms after tone 2 onset) over fronto-central scalp.

- Main effect of condition: $F(1,20) = 6.2$, $p = 0.02$

Early Positive Component (EPC) observed from 320 - 380 ms (-80 - -20 ms before tone 2 onset) over fronto-central scalp.

- Main effect of condition: $F(1,20) = 2.93$, $p = 0.1$

Conclusions:

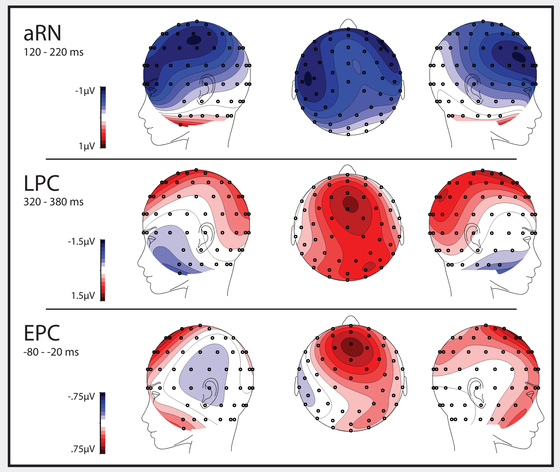
Auditory components similar in time and polarity to the visual RN and LPC were evident.

These auditory reversal components showed a more frontal distribution and slightly earlier timing relative to their visual analogs, commensurate with a contribution from auditory brain regions.

The characteristics of the auditory RN are consistant with its interpretation as reflecting the transition between neural representations that form the moment-to-moment contents of conscious perception.

The LPC observed here is likely to reflect similar post-perceptual processes as its visual counterpart, such as updating of working memory.

Difference Maps (Reversal - Stable):



Future Directions:

Investigate the visual modality using a matched stimulus with the same two-part design.

Manipulate attention, effort and voluntary control of reversals to investigate the pre-stimulus interval.

Manipulate the location of ambiguity in the paradigm by presenting a complex tone before a pure tone.

References:

1. G. M. Long and T. C. Toppino (2004). Enduring Interest in Perceptual Ambiguity: Alternating Views of reversible Figures. *Psychological Bulletin*, 130(5):748 - 768.

2. M. A. Pitts, J. L. Nerger, T. J. Davis (2007). Electrophysiological correlates of perceptual reversals for three different types of multistable images. *J. Vision*, 7(1):6, 1–14.

3. R.N. Shepard (1964). Circularity in judgments of relative pitch. *The Journal of the Acoustical Society of America*, 36:2346.

4. D. Deutsch (1986). A musical paradox. *Music Perception*. 3(3): 275–280.

5. J. W. Brascamp et. al. (2009). Intermittant Ambiguous Stimuli: Implicit memory causes periodic perceptual alternations. *J. Vision*. 9(3):3: 1 - 23.

Original Abstract:

Multistable figures allow the investigation of neural processes associated with conscious perception while holding physical characteristics of a stimulus constant. Using an intermittent stimulus presentation paradigm, previous event-related potential (ERP) experiments have consistently reported two components associated with perceptual transitions of bistable visual stimuli (e.g. Necker cube, face vase), the "reversal negativity" (RN) and the "late positive complex" (LPC). The RN, which appears over the occipital parietal scalp at ~250msec post stimulus is thought to reflect changes in perceptual representations in the ventral stream, while the LPC (~400msec) is likely to index working memory updating. Because prior research has focused exclusively on visual stimuli, it was unclear whether analogous neural signatures might exist in other sensory modalities. The present experiment utilized a novel bistable auditory stimulus based on Shepherd Tones. Pairs of complex tones with ambiguous pitch relationships were presented while subjects reported whether they perceived the tone pairs as ascending or descending in pitch. ERPs elicited by the tones were compared between trials in which perceived pitch motion changed direction relative to the previous trial versus trials in which perceived pitch motion remained the same across trials. An auditory RN component was evident at similar latencies as the visual RN (~210msec) over fronto-central scalp locations, suggesting sources in auditory brain regions. An auditory LPC component was also evident at subsequent latencies (~330msec). These results suggest an auditory analog of the RN which bolsters the claim that this ERP component may reflect transitions between neural representations that form the moment to moment contents of conscious perception.

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