Cognitive processing of auditory rhythmic structure and novel stimuli

“Knowing is not thinking so much.”

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Abstract

We hypothesized that the novelty and complexity of auditory rhythmical structures would have a direct affect on a persons cognitive capacity to process rhythmic structure. We found that there was s significant difference (p=.025) between regularly occurring auditory stimuli, and oddball stimuli in the amplitude of the P200, and significant latency difference (p=.006) in the P200. Our other trials included a structured rhythmical pattern which included off beats at different percentages, but unexpected like the oddball (UAS). As the percentage of off beats went up the difference between the regularly occurring auditory stimuli and UAS went down. This would indicate that as the percent of off beats went up, the brain had an easier time processing the individual stimuli in those trial blocks. This was possibly due to the higher percentage representing a more common stimulus.

Introduction

Across cultures worldwide, rhythmic events are an important part of daily life. The ability to recognize the temporal structure of events is at least advantageous and at most necessary for success. In this experiment we explored the brain’s ability to distinguish between different temporal structures. Using electrodes to register the activity of neurons we examined brain potentials connected to certain events. These event-related potentials (ERP) were averaged into components time locked with the trial stimuli. The components were examined in connection with the oddball paradigm and with unexpected additional stimuli (UAS) of different percentages. The control was an entrainment of regular stimuli without any additional sounds.

Based upon theoretical models of perception of metrical hierarchies (Krumhansl, 2000) and evidence that more attention is paid to novel stimuli (Hannon & Trehub, 2005) we predict that cognition will be easier for the regular stimuli compared to unexpected. This difference in brain activity and time in processing should be seen in comparisons of amplitude and latency following the respective stimuli.

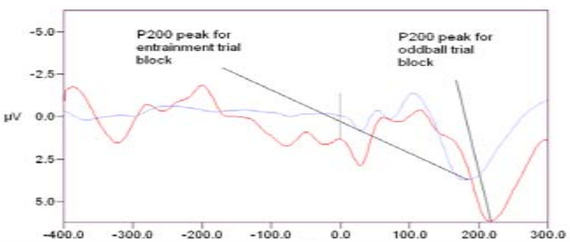
Methods

An experiment designed in E-Prime was used to capture ERPs time locked to specific auditory stimuli (a single drum kick beat). The stimuli were presented in three different trial type blocks: entrainment, oddball, and UAS (unexpected additional stimuli). Entrainment trial blocks consisted of a regularly occurring auditory stimulus at a rate of one every 1000 milliseconds. The oddball trial block consisted of 80% regularly occurring 1000 millisecond beats, and 20% off beats which were 379 milliseconds after a regularly occurring beat, and randomly distributed throughout the overall rhythmical structure. The UAS trial block consisted of differing percentages of beats and off beats (20%, 30%, 40%, and 50% off beats). However, unlike with the oddball trial block, the off beats were in a regular occurring pattern inside of the overall rhythmical structure.

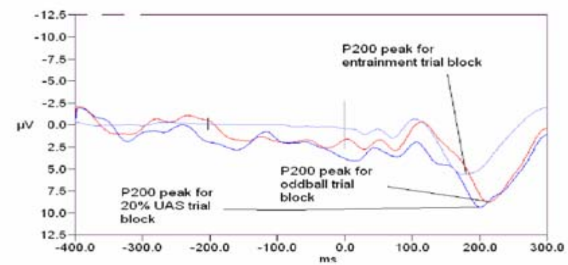
A 32 electrode cap was used to capture the study participant’s ERPs. The data was sent to Scan 4.2 where it was epoched, filtered, baseline corrected, and artifact rejected. The data was analyzed using SPSS to determine inter and intra trial significance and variability. An ANOVA statistical test was performed followed by post hoc LSD analysis for latency and amplitude differences at the CPZ electrode. The CPZ electrode was chosen due to maximal component values being present at that site.

Participants were 14 college students recruited through personal connection or in-class recruitment.

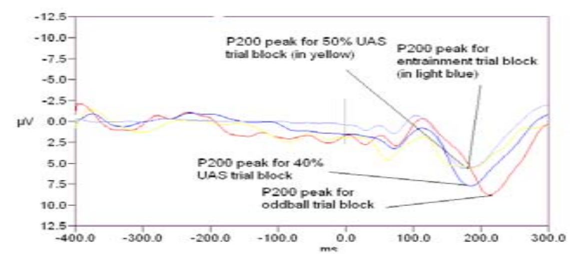
Comparison picture of the entrainment and oddball trial blocks at the CPZ electrode. These had significant differences in amplitude and latency.



Comparison picture of grand averages for entrainment, 20% UAS, and oddball trial blocks at the CPZ electrode. This represents all of the trials that had a significant difference compared to the entrainment trial block in amplitude.



Comparison picture of the grand averages for entrainment, oddball, 40% UAS, 50 UAS trial blocks at the CPZ electrode. These represent all the trial groups that had significant differences as compared to the oddball trial block for latency



Results

Two one-way ANOVAs of the 6 conditions (regular, oddball, UAS20, UAS30, UAS40, UAS50) suggested there might be differences in amplitude, F(5,67)=1.57 and p=.178 and latency F(5,67)=2.30, p=.054. These were followed up based on a priori hypotheses.

A significant difference was found in the maximum amplitude of a positive component at 200ms a post hoc LSD analysis between regular vs. oddball showed: MeanDiff=3.095, StdError=1.35 p=.025. Analysis of amplitudes of regular vs. UAS 20% significant difference was also found: MD= -2.817, SE=1.35, p=.041.

Comparing the specific latency of the positive component across trials produced significant difference for an analysis between regular vs. oddball (MD= -34.5, SE=12.273 p=.006). Significant difference between the oddball and the two highest percentage UAS was also found. Oddball vs. UAS40% (MD=29.17, SE=12.035, p=.018) and Oddball vs. UAS50% (MD=28.98, SE=12.549, p-.024).

In addition to the significant differences between trials, a trend in the differences in amplitude across trials was suggested by lower significant difference to the regular stimuli as the UAS percentages rose. Comparing regular stimuli with UAS30, UAS40 and UAS50 gave p=.110, p=.149 and p=.606 respectively.

Discussion

The difference between the p200 in the regular and oddball trials lends support to our hypothesis that less brain processing goes into processing regular stimuli as opposed to novel stimuli. The regular stimuli had been entrained according to a metrical structure and after entrainment the brain no longer needed to categorize the sounds as rigorously. However, with the unexpected stimuli, additional processing was needed because of the lack of precedence. In addition to the significant difference found between regular and unexpected stimuli, an interesting general trend was found as the percentages of the UAS rose from 20% to 50%. The difference in amplitude and latency between the regular stimuli and UAS fell corresponding to the percentage rise. This suggests that as the UAS became more common the brain recognized the unexpected stimulus with greater ease.

Further research is needed into the area of rhythmic structure organization and the perception of novel vs. regular stimuli. Specifically more research is needed in the brain’s ability to predict the UAS and the effect specific structures have on predictions.

References

Krumhansl, Carol. (2000) “Rhythm and Pitch in Music Cognition” Psychological Bulletin, 126(1) 159-179

Hannon, Erin E and Trehub, Sandra E. (2005) “Metrical Categories in Infancy and Adulthood” Psychological Science, 16 (1), 48-55.

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