2020

Event-Related Potential Correlates of Emotional Processing in a Rapid Picture-Viewing Paradigm

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EVENT-RELATED POTENTIAL CORRELATES OF EMOTIONAL PROCESSING IN A RAPID PICTURE-VIEWING PARADIGM

By

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A Thesis submitted to the Department of
Psychology
in partial fulfillment of the requirements for graduation with
Honors in the Major

Degree Awarded:

Fall, 2020

The members of the Defense Committee approve the thesis of Brianna Bucello defended on November 18, 2020.

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Abstract

Extensive research and evolutionary theory have shown that humans have evolved to selectively attend to and process emotionally evocative stimuli. In order to examine the underlying neurobiology of affective processing, researchers have examined the early posterior negativity (EPN) and the late positive potential (LPP), two event-related potentials (ERPs) reflecting, respectively, early visual processing and subsequent evaluative processing of salient affective stimuli. Externalizing proneness, dispositional tendencies towards negative behaviors to the outside world, is a commonly researched aspect in accordance with emotion regulation. This current study examined these ERPs within a rapid picture-viewing (RPV) paradigm to delineate how affective processing of emotionally evocative stimuli are impacted by the valence of prior and subsequent stimuli (i.e. serial affective processing). Additionally, the current study examined the relationship between externalizing proneness and these ERP indices of serial affective processing. More specifically, the RPV paradigm used in this study examined affective processing ERPs while participants passively viewed a series of 819 pictures from the International Affective Picture System (IAPS) displayed at a rate of 3 pictures per-second. Past research and a major focus of this study, have also suggested that ERPs derived from the rapid picture-viewing task relate to externalizing proneness and fear disorders such as PTSD and anxiety. Additionally, data analyses suggest a significant reduction in LPP responses and enhanced EPN responses in high externalizing prone individuals.

INTRODUCTION

In recent years, externalizing proneness has become an area of interest for many researchers, and this line of work has revealed that individuals high in externalizing proneness display dysregulated affective processing. More specifically, research examining the underlying neurological components of affective processing has revealed that high externalizing individuals tend to show impulsive behavior and a reduced ability to evaluatively process salient stimuli. (Krueger, Markon, Patrick, Benning, Kramer, 2007).

Event-related potentials (ERPs) provide researchers with a methodology for measuring brain activation with millisecond-level temporal resolution, allowing for measurement of temporally-distinct neural processes. In order to examine ERP indices of affective processing, previous studies have utilized picture-viewing tasks which present participants with a wide range of affective content that varies in valence (e.g. unpleasant vs. pleasant) and level of arousal (Olofsson, Nordin, Sequeiera, 2008). Studies utilizing these tasks commonly target two ERP components that are modulated by affective stimuli: the early posterior negativity (EPN) and late positive potential (LPP) (Schupp, Schamälzle, Flaish, Weike, Hamm, 2012).

Event-Related Potentials

Event-Related Potential (ERP) components are normally defined by their polarity, voltage, timing, and scalp topography (Woodman, 2010). Importantly, ERP's are characterized by millisecond-level temporal resolution, allowing for precise measurement of the temporal dynamics of emotional processing.

Initial Affective Processing and the EPN

The EPN is a negative-going ERP maximal at temporo-occipital sites, peaking between 150 and 350 milliseconds, and captures allocation of visual attention towards salient affective stimuli (Schupp et al., 2012). Emotionally charged visual stimuli (i.e. highly arousing positively and negatively valanced images) potentiate the EPN relative to neutral images (Schupp et al., 2012; Woodman, 2012; Olofsson, 2009; Dunning, Parvaz, Hajcak, 2011; Chen, 2018), suggesting that early affective processing guides visual attention towards more emotionally evocative stimuli (Schupp et al., 2012). However, it remains incompletely understood how serial affective processing impacts EPN amplitude. One study reported that preceding picture valence did not impact EPN amplitude (Schupp et al., 2012); however, this study did not examine the potential moderating effects of externalizing proneness.

Later Affective Processing and the LPP

The late positive potential (LPP) is a positive-going slow wave ERP maximal at centroparietal electrodes between 400-800 milliseconds following stimulus presentation, and reflects evaluative processing of salient affective stimuli (Brown, Van Steenbergen, Band, De Rover, Nieuwenhuis, 2012, Brown et al. 2012). The LPP is potentiated by highly arousing images (Brown et al., 2012), with negatively valanced stimuli eliciting a larger LPP compared to positively valanced images (Ito, Larsen, Smith, Cacioppo, 1998). These data suggest that negative stimuli elicit a greater degree of evaluative processing compared to both positive and neutral images.

Affective Processing and Externalizing Proneness

Externalizing proneness compromises dispositional tendencies towards negative behaviors that are directed at others or towards the outside world. This includes losing one's temper, excessive verbal aggression, substance abuse, physical aggression towards others, theft, and destruction of property. In a study utilizing a sample of abstinent and current substance-users, EPN amplitude was enhanced following presentation of both drug-related images and other positively valanced images without associated drug content, suggesting that early visual attention becomes biased towards drug-related stimuli in substance users (Dunning et al.). A bias towards cues in early processing and deficient evaluative processing was found in recent cocaine users; however, they also experience deficient processing of other emotional stimuli. (Dunning et al., 2011).

Current Study

Two components observed in this study are the EPN and LPP which modulate preferential emotional processing. Occurring between 150~300-ms after an onset stimulus, an EPN amplitude is measured as the relative negative difference in processing emotional pictures (pleasant and unpleasant) as compared to neutral images (Schupp et al., 2012). After initial visual processing, the LPP is measured over centro-parietal regions beginning as early as 300-ms and peaking between 400~1000-ms, (Hajcak & Nieuwenhuis, 2006; Schupp et al. 2012) as the LPP indicates stimulus evaluation and controlled attention processes (Schupp *et al.*, 2006; Hajcak *et al.*, 2009). This study analyzed affective processing of emotionally evocative stimuli and the impacts that valence of prior and subsequent stimuli have on EPN and LPP amplitudes. In addition, this study analyzed the interaction between externalizing proneness and

these ERP indices of externalizing proneness. Understanding the possible neurobiological differences one may have with externalizing proneness can be used as a possible biomarker for treatment. Assessing the rapid picture viewing paradigm in relation to varying ERP's will help better understand emotion regulation in externalizing prone individuals. Specifically, the overlap between later affective processing of one image and early affective processing of the next image. As the RPV task displays three images per second, there is an overlap of EPN and LPP responses, and this study is designed to assess if the early visual processing of the second image is affected by the valence of the later affective processing in the first image. This study utilized the RPV task and a 100-item version of the ESI to collect information about externalizing proneness and analyze how serial affective processing is affected by levels of externalizing.

Specific hypotheses for the current study were as follows:

1) I hypothesize that the amplitude of the EPN on the current trial will be reduced if the valence of the preceding image was pleasant or unpleasant as compared to neutral.
2) I hypothesize that pleasant and unpleasant affective images on the current trial will stimulate a larger LPP amplitude than neutral images, regardless of next trial valence.
3) I hypothesize that previous trial affective stimuli will evoke a larger EPN on the current trial as compared to neutral for high externalizing individuals.
4) I hypothesize that high externalizing individuals will have a more significant reduction in LPP responses on the current trial if the next trial valence is either pleasant or unpleasant as compared to neutral.

METHOD

Participants

The current study comprised 200 participants (99 females) were recruited from undergraduate psychology classes at Florida State University (n=124) and via Craigslist advertisements (n = 76) for this study (age M = 20.93, SD = 4.35). Each participant was screened for exclusionary criteria prior to participation (i.e. no major neurological conditions or visual impairments. Additionally, participants were required to be at least 18 years old during participation in the current study.

Measures

Externalizing Spectrum Inventory

The Externalizing Spectrum Inventory (ESI) is a widely used questionnaire used to comprehensively index externalizing psychopathology and personality (Southerland, Slade, Krueger, Markon, Partick, Kramer, 2017). The ESI assesses three higher-order dimensions of externalizing proneness: general disinhibition, callous-aggression, and substance abuse. These three dimensions are further subdivided into 23 lower-order facet scales that mark various expressions of externalizing proneness, including aggression, deceitfulness, sensation-seeking, and substance use/abuse (Patrick, Kramer, Krueger, Markon, 2013). The current study used an abbreviated 100-item version of the ESI designed to measure each dimension outlined in the full 415-item ESI.

Rapid Picture-Viewing Task

The rapid picture viewing paradigm utilized a series of 819 images from the International Affective Picture System (IAPS; Center for the Study of Emotion and Attention, 1999), where participants passively viewed a series of images displayed at 3 Hz. See figure 1 for an illustration of this task. The images were displayed at various valence and arousal levels and categorized by peasant, unpleasant, and neutral images. The valence of each image is rated on how positive or negative each image is, and the arousal level is rated on how evocative each image is. Pleasant images have high arousal and positive valence, while negative images have a high arousal and negative valence. The affective images contained three content categories each: erotic, nurturant, and adventure for pleasant, and mutilation, threat, and victim for unpleasant. Neutral images included average valence and arousal levels with depictions of neutral human faces, buildings, and various objects.

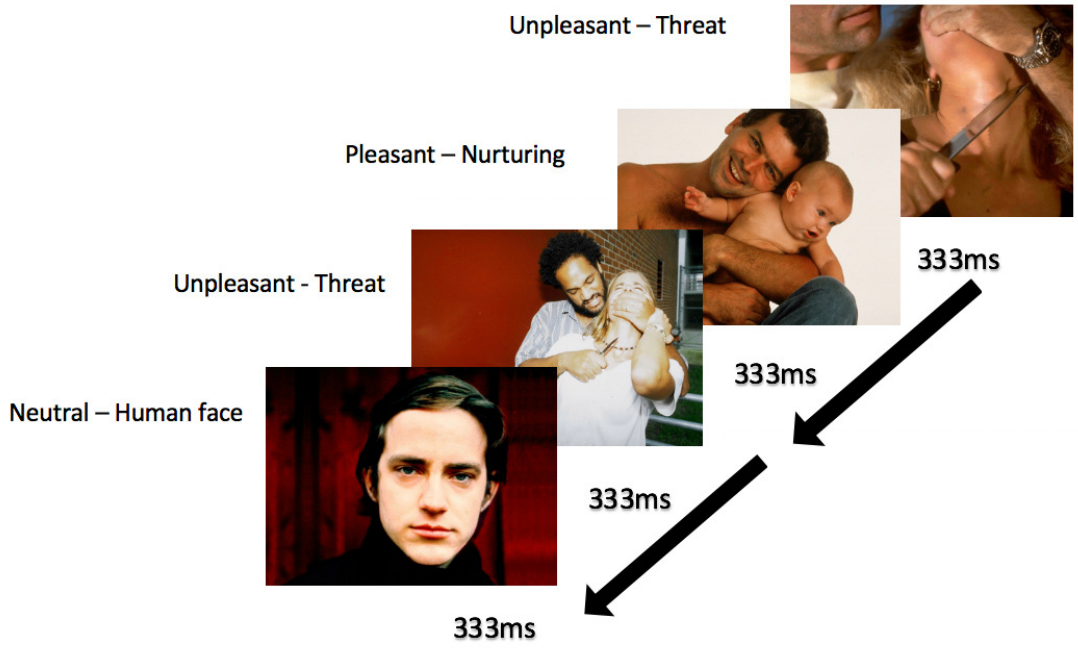

Figure 1. Illustration of the Rapid Picture-Viewing Task.

Psychological Data Acquisition

EEG activity was recorded using a 128-channel cap (Neuroscan Quik-Cap) containing Ag-AgCl electrodes positioned according to Neuroscan's nonstandard layout (NSL) system. Participants' EEG activity were recorded online using a Neuroscan's Synamps2 (Neuroscan, Inc.) amplifier. Vertical electrooculographic (VEOG) activity was monitored using electrodes placed above and below the left eye while horizontal electrooculographic (HEOG) activity was monitored using electrodes placed on the outer canthus of each eye. All Impedances were kept below 10 kΩ to ensure accurate recording, and all EEG data were re-referenced to an average of the left and right mastoids.

Data Reduction

Following EEG data collection, data epochs were extracted from -1000 to 2000 ms relative to the onset of each picture. Data epochs were then corrected for ocular artifacts utilizing an algorithm developed by Semlitsh, Anderer, Schuster, and Presslich (1986). Data were then imported to Matlab (Mathworks, Inc.) for subsequent data processing. EEG data were then downsampled to 128 Hz through application of an anti-aliasing filter. Following this step, epochs containing excessive artifacts were removed from subsequent analyses. Artifacts were defined as signal activity exceeding +75μV in either the pre-stimulus (-1000 to 0 ms) or post-stimulus (1 to 2000 ms) time window. Trial epochs for the EPN were then averaged separately for each combination of previous trial valence (pleasant, unpleasant, and neutral) with current trial valence (pleasant, unpleasant, and neutral), yielding nine trial types. Similarly, trial epochs for the LPP were averaged separately for each combination of current and next trial valence, yielding nine total trial types. Average EEG activity were then baseline-corrected by subtracting

average EEG activity during the 100 ms preceding picture onset. Following baseline correction, participants' component scores for the EPN were generated by averaging EEG activity between 230 and 310 ms following picture onset, while LPP component scores were generated by averaging activity between 450 and 750 ms relative to picture onset. These component windows were defined by examining grand average waveforms generated by averaging participants' LPP and EPN waveforms. Electrode clusters for each of these ERPs were then derived based on topographic maps of EEG activation within each component window (grand average waveforms and topographic maps are presented in Figure 2). The EPN was scored at an occipital electrode cluster (nsl electrodes 42, 43, 44, 45, 46, 68, 69, 70, 71, 72, 97, and 98) and the LPP was scored at a centroparietal electrode cluster (nsl electrodes 48, 49, 50, 64, 65, 66, 74, 75, and 76).

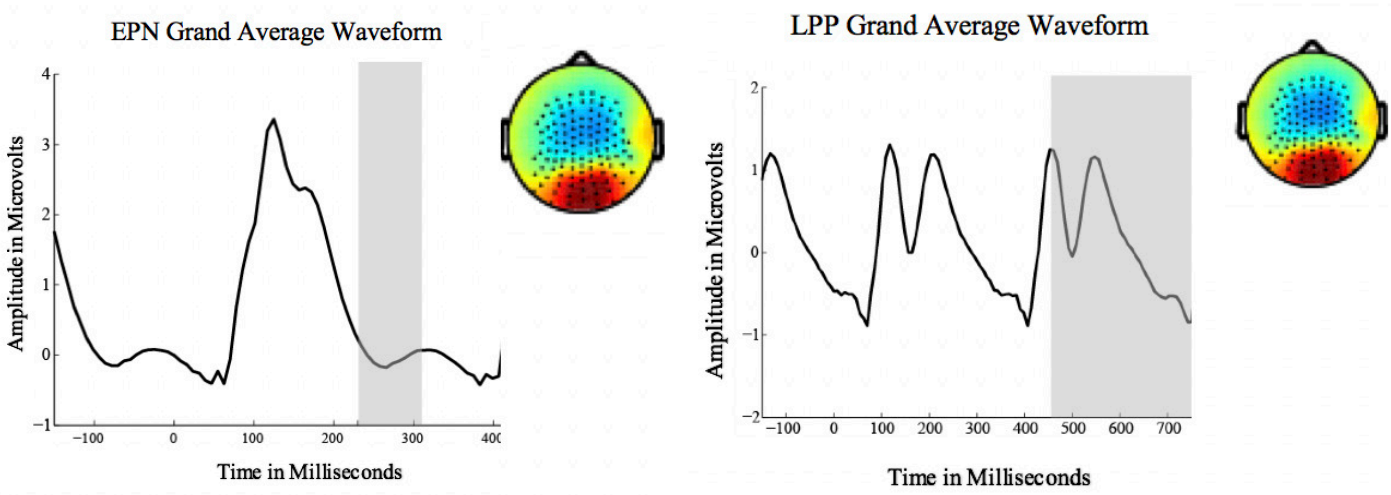

Figure 2. Grand average waveforms and topographic maps for the EPN and LPP

Procedure

Following informed consent, participants completed the 100-item version of the ESI. Next, the rapid picture-viewing (RPV) task was completed in a dimly lit, sound attenuated room.

Each portion of this study was completed in this controlled setting. Experimental stimuli were presented on a Dell high-definition CRT color monitor, at a viewing distance of 100-cm, using E-Prime version 1.1 (Psychology Software Tools Inc.).

Data Analysis

Univariate Normality and Outlier Correction

We utilized version 23 of the IBM SPSS Statistics package (IBM, Armonk, NY) for all statistical analyses. The EPN and LPP components derived from the rapid picture viewing task, were first evaluated for univariate normality by computing skewness (*s*) and kurtosis (*k*) statistics. To minimize outliers, a winsorization (Donoho & Huber, 1983) to the median ± 2.5 times the inter-quartile range, was used for any *s* or *k* values that exceeded -2 or 2. Following winsorization and outlier correction, descriptive statistics (*M*s, *SD*s) were computed for each ERP.

Hypothesis Testing

To test hypothesis 1, we ran a 3 (current trial valence; pleasant, unpleasant, and neutral) x 3 (previous trial valence; pleasant, unpleasant, and neutral) repeated measures ANOVA, utilizing EPN amplitude as the dependent measure. Similarly, a 3 (current trial valence; pleasant, unpleasant, and neutral) x 3 (next trial valence; pleasant, unpleasant, and neutral) repeated measures ANOVA was run for hypothesis 2 and is utilizing LPP amplitude as the dependent measure. To test hypothesis 3 and 4, similar ANOVAs were run for the LPP and EPN, respectively, but we also used overall externalizing proneness as a covariate measure. Significant

interactions were inspected by computing ERP difference scores for relevant affective differences, and examining correlations between difference scores and externalizing proneness.

RESULTS

Early Posterior Negativity (EPN)

Figure 3 illustrates condition differences for the EPN based on current and previous trial valence within waveform plots and a line plot comparing mean differences. For the first ANOVA examining EPN amplitude, we found a significant main effect for current trial valence $F(2,198) = 123.60$, $p < .001$, where EPN amplitude was significantly more negative following pleasant images compared to unpleasant and neutral images; neutral and unpleasant images did not differ significantly from one another. We also found an overall significant main effect for previous trial valence $F(2,198) = 14.86$, $p < .001$, where the EPN amplitude was more negative following neutral images compared to unpleasant and pleasant; unpleasant and pleasant images did not differ significantly from one another. As expected from previous research and our hypothesis, affective images produced an enhanced EPN relative to neutral images with a more pronounced negative-going modulation for pleasant images compared to unpleasant on the current trial. The opposite effect was evident on the previous trial as affective content, pleasant and unpleasant trials, reduced the amplitude of the EPN on the current trial. We also found a significant interaction between previous and current trial $F(4,196) = 3.69$, $p = .006$, where the previous trial valence significantly impacts the EPN modulation in the current trial. If the previous trial was pleasant or unpleasant, pleasant trials are the only valence category that differs from the other two. If the preceding trial was neutral in valence, significant differences in EPN

amplitude are evident on the current trial: pleasant trials have a greater amplitude than unpleasant, and unpleasant trials have a greater amplitude than neutral.

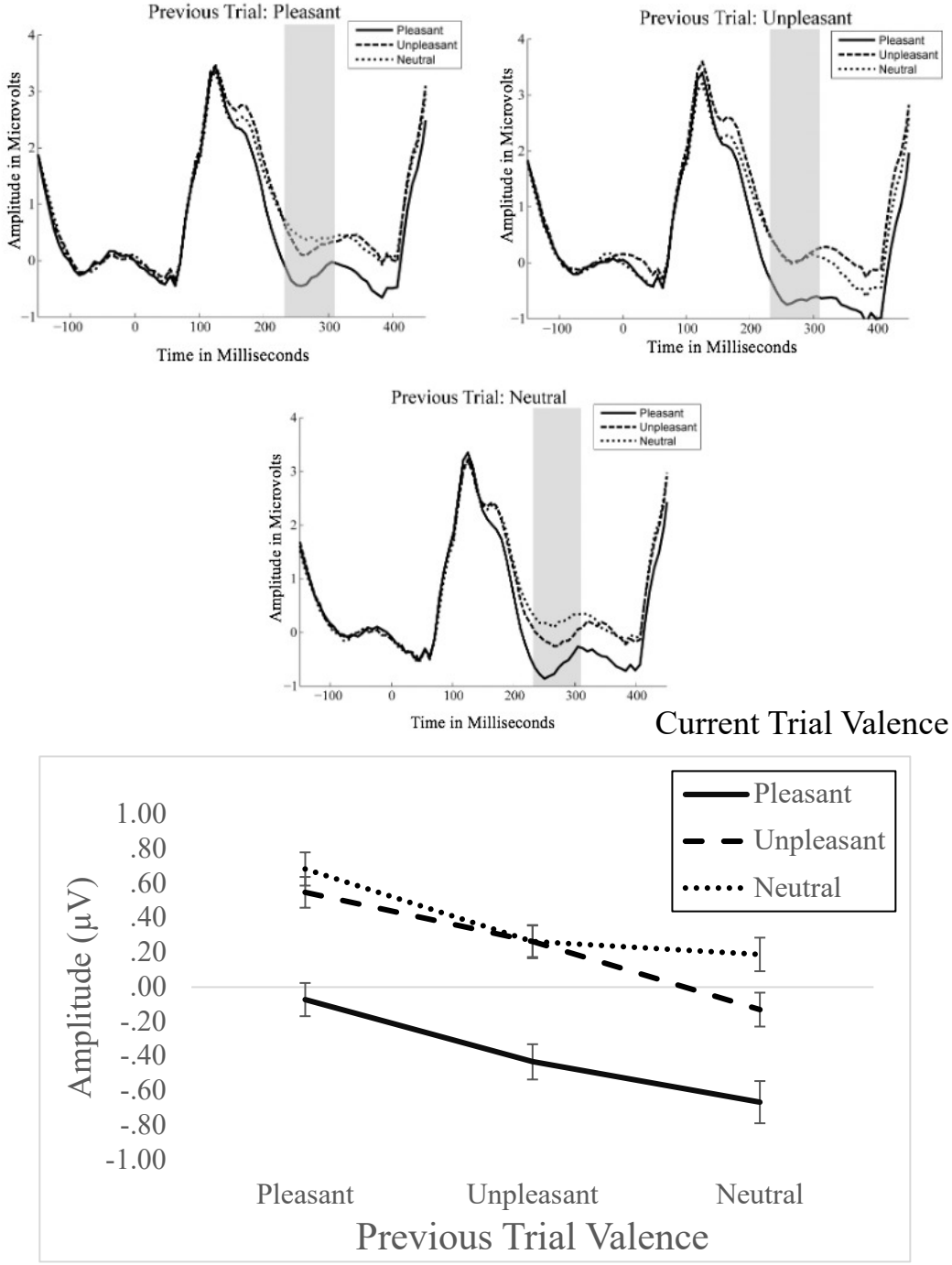

Figure 3. Condition differences for the EPN based on current and previous trial valence within waveform plots and a line plot comparing mean differences

Late Positive Potential (LPP)

Figure 4 illustrates condition differences for the LPP based on current and next trial valence within waveform plots and a line plot comparing mean differences. For the second ANOVA examining LPP amplitude, we found a significant main effect for current trial valence $F(2,198) = 7.02$, $p = .001$, where the LPP amplitude was greater following a pleasant and unpleasant picture as compared to neutral; pleasant and unpleasant images did not differ from one another. There was also an overall significant effect for next trial valence $F(2,198) = 134.57$, $p < .001$, where the LPP amplitude following a pleasant image is greater than an unpleasant image and a neutral image. Supporting previous research, results suggest that the LPP is potentiated by highly arousing images. A significant interaction was found between previous and current trial $F(4,196) = 4.93$, $p = .001$. If the next trial is pleasant, the data suggests that the current trial valence categories unpleasant and pleasant do not differ from one another. Conversely, regardless of the current trial valence, the LPP does significantly differ from one another when the next trial is unpleasant or neutral. If the next trial is unpleasant or neutral, the LPP is significantly larger when the current trial valence is pleasant or unpleasant as compared to neutral.

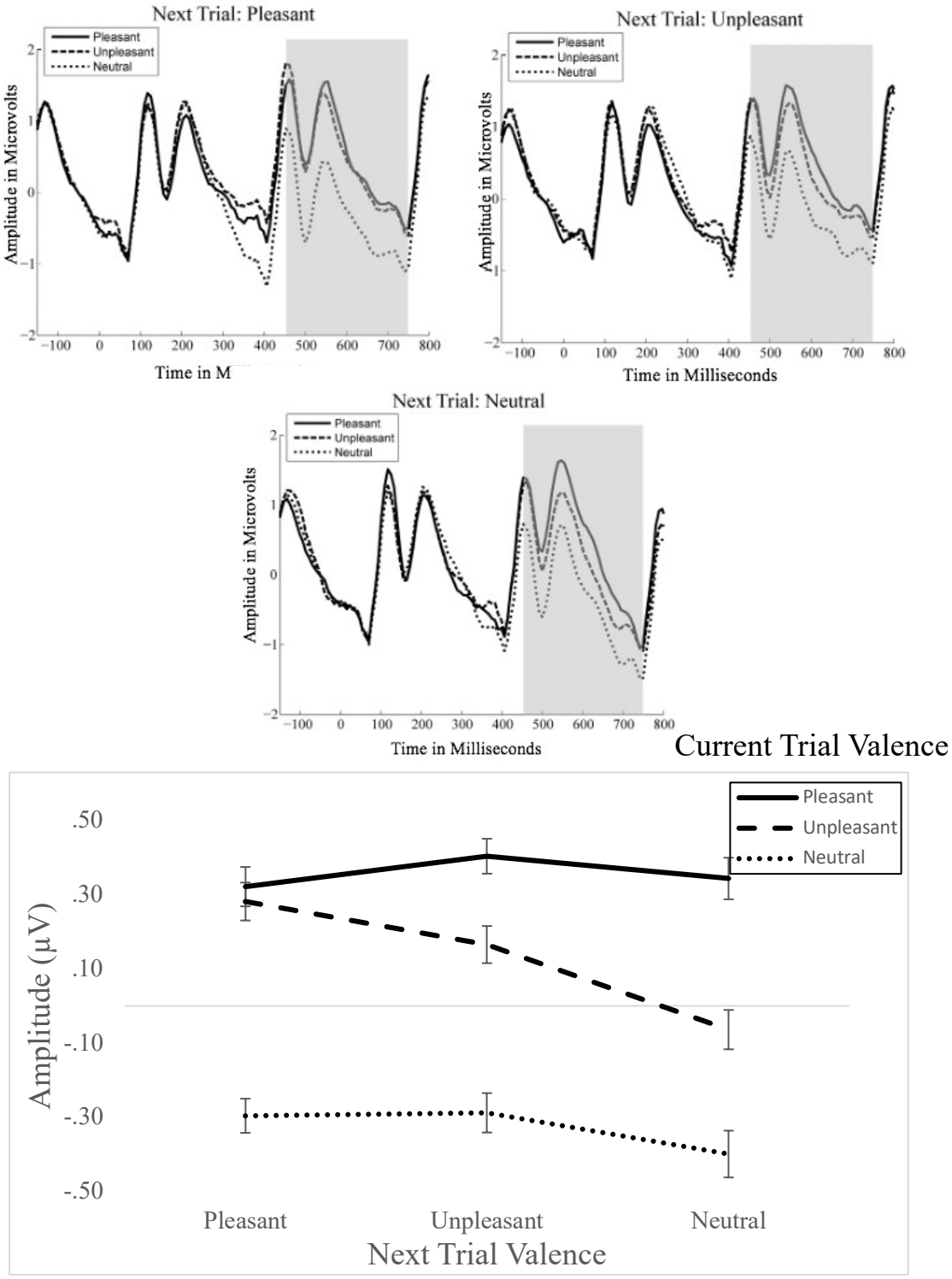

Figure 4. Condition differences for the LPP based on current and next trial valence within waveform plots and a line plot comparing mean differences

Affective Processing ERPs and Externalizing Proneness

EPN and Externalizing Proneness

For the third ANOVA examining EPN amplitude with externalizing proneness as a covariate, results for this analysis are presented in Figure 5. Briefly, this analysis revealed significant main effects for both previous and current trial valence, but no effect of externalizing proneness on either category. There was neither a main effect for externalizing, nor was there an interaction effect between externalizing proneness or any of the other categories in the ANOVA ($p > .05$).

	***F*(2-4,196-198)**	***p***
Previous Trial Valence	**20.51**	**<.001**
Previous Trial x Externalizing	**1.00**	**.37**
Current Trial Valence	**57.34**	**<.001**
Current Trial x Externalizing	**1.31**	**.27**
Current Trial x Previous Trial	**1.73**	**.14**
Current x Previous x Externalizing	**1.03**	**.39**

Figure 5. Multivariate test showing main effects for previous trial valence, current trial valence, and interaction effects with externalizing proneness and EPN trial valences.

LPP and Externalizing Proneness

For the third ANOVA examining LPP amplitude with externalizing proneness as a covariate, results for this analysis are presented in Figure 6. This figure illustrates a significant interaction between next trial valence and externalizing proneness, and overall next trial valence. When analyzing next trial difference scores, results indicate that high externalizers exhibit no

significant difference between processing pleasant - neutral and unpleasant - neutral. However, the difference between categories gets smaller the more externalizing an individual is (figure 7).

	F(2-4,196-198)	*p*
Current Trial Valence	2.53	.08
Current Trial x Externalizing	1.30	.28
Next Trial Valence	**64.55**	**<.001**
Next Trial x Externalizing	**4.18**	**.02**
Current Trial x Next Trial	2.42	.05
Current x Next Trial x Externalizing	.45	.77

Figure 6. Multivariate test showing main effects for current trial valence, next trial valence, and interaction effects with externalizing proneness and LPP trial valences.

	r(198)	*p*
LPP Next Trial Difference Scores		
Pleasant - Unpleasant	.03	.71
Pleasant - Neutral	**-.17**	**.02**
Unpleasant - Neutral	**-.18**	**.01**

Figure 7. LPP Next trial difference scores. Significant differences exist for pleasant-neutral and unpleasant-neutral.

DISCUSSION

This current study evaluated two previously studied concepts: (1) ERP indices of affective processing in succeeding trials that utilized a rapid picture viewing paradigm and (2) the relationship between externalizing proneness and these ERP indices of serial affective processing. There is sparse literature pertaining to previous and current trial evaluations of the early posterior negativity (EPN) and late positive potential (LPP). However, results from this current study replicate and expand on previous findings from a research study focusing on affective prime and targets (Flaisch, 2008). The expansion in this study observes the effects of next trial valence on the post perceptual processing of the LPP for high externalizing individuals.

Event Related Potential Indices of Serial Affective Processing

EPN

The EPN, indicative of early affective processing, was evident over occipital electrode sites from 230-310ms. (Schupp et al., 2004). When analyzing the effects of various valence categories in relation to the EPN, we referenced the valence of previous trials to the valence of current trials. This study showed main effects for current and previous trials. It was evident that affective images produced an enhanced EPN relative to neutral images, where a more pronounced modulation occurred for pleasant images compared to unpleasant on the current trial. The EPN amplitude on the previous trial suggested that neutral images elicited a larger EPN than unpleasant images, and unpleasant images elicited a larger amplitude than pleasant images. This implies that affective content on the previous trial may reduce the amplitude on the current trial. In analyzing the interaction effect of previous and current trial valence, our data suggests that on current trials, there is a significant difference between pleasant, unpleasant, and neutral if the

preceding trial was neutral. If the preceding trials are pleasant or unpleasant, then the pleasant trials are the only valence category that differ from unpleasant and neutral. The differentiation of all three content categories are evident when the previous trial was neutral. This finding supports previous research and my first hypothesis where it was found that the posterior negativity on the current image was reduced when the previous image was emotional (i.e., pleasant or unpleasant Flaisch, 2008). This finding suggests that the previous trials valence served as a function of the EPN magnitude on the current trial. One interpretation of this finding is that the early affective processing of salient stimuli, pleasant or unpleasant images, blunt the ability to affectively process the succeeding image.

LPP

The LPP, reflecting post-perceptual elaborative processing of visual stimuli, was evident over centroparietal electrode sites from 450 to 750ms. The late positive potential complex was indexed by current trial valence to next trial valence. The valence of the current trial and next trial were observed to see how the amplitude of the LPP on the current trial would vary dependent on the valence of the next trial. There were significant main effects for the amplitude of the LPP on the current and next trial. Supporting my second hypothesis, it was evident that pleasant and unpleasant affective images on the current trial stimulated a larger LPP amplitude than neutral images; however, their effects were not significantly different from one another. On the next trial, the LPP amplitude was larger for pleasant images than unpleasant images and the LPP amplitude for unpleasant images was larger than neutral. There was also a significant interaction effect between current and next trials. The valence categories do not significantly differ from one another in amplitude when the next trial is pleasant, but do differentiate when the

next trial is unpleasant or neutral. In the neutral next trial valence category, we see that there is the greatest difference in significance, which could be due to parallel processing. This is the idea that the participant is able to simultaneously engage in elaborative processing of multiple images.

ERP Indices and Externalizing Proneness

EPN

The effects of externalizing proneness and EPN amplitude were analyzed and results showed evidence for significant effects on the previous and current trial valence independently. However, there were not any interaction effects with externalizing scores from the ESI and either trial category. This implies that high externalizing individuals do not have any difficulty processing the affective nature of the picture regardless of its valence category. These results are somewhat consistent with my third hypothesis because there was no difference in modulation of the EPN based on externalizing proneness. Those who are higher in externalizing have an intact ability to engage in this initial component of affective processing.

LPP

The effects of externalizing proneness and LPP amplitude were analyzed and revealed significant effects for next trial valence and an interaction effect with next trial valence and externalizing proneness. One interpretation of these results surrounds the idea of parallel processing. As individuals engage in elaborative processing of multiple images at the same time, the LPP is being attenuated at the onset of a new stimulus. In other words, regardless of the valence on the next trial, high externalizers are sufficient in engaging at post perceptual processing but are more likely to have interference occur due to the next picture being presented.

Results suggest that immediate affective stimulus in the next trial inhibits continued processing of the prior affective stimuli. These results support my fourth hypothesis that individuals will have a more significant reduction in LPP responses on the current trial if the next trial valence is either pleasant or unpleasant as compared to neutral.

Limitations

There were a few notable limitations from this current study. One limitation was the variety of individuals in the sample. The study aimed to recruit based on boldness and disinhibition scores; however, the group selected for this study were only comprised of undergraduate students and community members. The variety of individuals in this sample size is quite limited, and future studies should consider including a prison sample and replicating this work with more variability in the top quartile for externalizing. In addition, we limited our power to detect some of the interaction effects when analyzing ERP amplitudes on current, previous, and next trial valence. Future studies could consider averaging the pleasant and unpleasant categories into an affective category in order to detect significant effects more easily.

Conclusions

This study aimed to investigate ERPs within a rapid picture-viewing (RPV) paradigm to delineate how affective processing of emotionally evocative stimuli are impacted by the valence of prior and subsequent stimuli (i.e. serial affective processing). In addition, this study investigated rapid affective processing in individuals who varied on levels of externalizing proneness. A key component to this study was distinguishing initial affective processing and later post-perceptual processing using time-domain filtering, but also understanding that parallel

processing is occurring during the successional image display. Results displayed that individuals with higher externalizing proneness are sufficient in selectively attending to stimuli and engaging at post perceptual processing, but are more likely to have interference occur due to the next picture being presented. This idea that immediate affective stimuli in the next trial are inhibiting continued processing of the prior affective stimuli, may be consistent with individuals who have dysregulated behavior and maladaptive decision making.

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