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Research report

A preliminary investigation of dispositional affect, the P300, and sentence processing

Janahan Selvanayagam[a,1], Victoria Witte[a,2], Louis A. Schmidt[b], Veena D. Dwivedi[a,*]

[a] *Department of Psychology and the Centre for Neuroscience, Brock University, Niagara Region, 1812 Sir Isaac Brock Way, St. Catharines, ON L2S 3A1, Canada*
[b] *McMaster University, 1280 Main St W, Hamilton, ON L8S 4L8, Canada*

HIGHLIGHTS

- Dispositional affect modulates P300 amplitudes during reading.
- Less positive individuals are more sensitive to local, not global cues.
- These local cues are relevant for task relevance.

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ABSTRACT

We examined whether dispositional affect modulated the relation between sentence processing and the P300 Event Related Potential (ERP) component. We used sentence stimuli from our previous study, where sentences started with subject nouns that were quantified e.g., *Every kid…* or not, as in *The kid…*, and continued with a direct object which was either singular, as in *a tree,* or plural *the trees.* In this Stroop-like task, participants read sentences presented in 1- and 2-word chunks, and were asked to identify the number of words on the screen at the target word *tree(s)*, which was always presented alone (and never sentence-final). We replicated previous findings of a P300 effect, at the target *tree(s)*, however, actual by-condition effects differed from previous work. Of interest, clear individual differences were apparent. Participants with relatively lower Positive Affect scores (as measured by the Positive and Negative Affect Schedule; PANAS), showed differential P300 responses to the control condition, *Every/The kid climbed the tree*. Thus, the present ERP findings demonstrate that dispositional affect modulated P300 effects. These findings suggest that, rather than relying on global heuristic cues for sentence meaning interpretation, these participants may be differentially sensitive to local (grammatical) cues which signify task relevance. We discuss our results in terms of theories of positive affect, where less positive individuals are differentially sensitive to local (grammatical) information.

1. Introduction

In recent years, research in psychology has confirmed our common sense idea that people in different emotional moods perceive the world around them differently (e.g., is the glass half full or half empty). That is, the role that affect plays in cognition has come into prominence. Previous work has shown that more positive individuals perceive stimuli using more global features (that is, they see the forest rather than the individual trees), whereas those who are less positive tend to focus on more local information (they see individual trees rather than the forest; (Dale and Arnell, 2010; Fredrickson and Branigan, 2005; Gasper and Clore, 2002). It is unclear, at present, what sorts of implications these findings regarding affect and cognition would have for studies of language processing.

Relatedly, Event-Related Potential (ERP) language studies (Chwilla et al., 2011; Federmeier et al., 2001; Vissers et al., 2013, 2010) have examined mood and language processing. In previous work, emotional mood was induced in participants. For example, in studies by Chwilla et al., participants watched either happy or sad movies (short clips of either *Happy Feet* or *Sophie's Choice)* in order to induce mood. Their studies showed that participants in positive moods exhibited modulation of ERP effects of interest (i.e., either N400 or P600 components), whereas those in negative moods did not (mirroring effects reported in Federmeier et al., 2001).

* Corresponding author at: Psychology/Neuroscience, Brock University, Niagara Region, 1812 Sir Isaac Brock Way, St. Catharines, ON L2S 3A1, Canada.
E-mail address: vdwivedi@brocku.ca (V.D. Dwivedi).
[1] Present address: Western University, London, ON N6A 3K7, Canada.
[2] Present address: University of Heidelberg, Grabengasse 1, 69117 Heidelberg, Germany.

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We build on those findings here, investigating dispositional affect and language comprehension. Dispositional affect reflects the stability across time and situation of individuals to view their world with approach-oriented positive affect, or avoidance-oriented negative affect. The PANAS (Positive and Negative Affect Schedule, Watson et al., 1988) indexes these trait and state features of affect and mood. Given that it has been shown that there are individual differences in temperaments that can be more or less susceptible to affect induction (Brief et al., 1995; Larsen and Ketelaar, 1991, 1989), we examined whether dispositional affect, as measured by the PANAS, modulated neural responses to sentences. Specifically, we examined whether the P300, a response elicited in a previous ERP language study recently conducted in our laboratory, was influenced by affect.

We note that this ERP component (i.e., P300) is not typically associated with language experiments (vs. the N400, Kutas & Hillyard, 1980b, or the P600, Osterhout & Holcomb, 1992). In Dwivedi and Gibson (2017), we had participants read sentences, while also having them press a button regarding the number of words on the screen. In this dual-task experiment, participants read sentences starting with either *Every kid…* or *The kid…*, and at the appropriate target (direct object), had to identify whether one or two words were presented. We interpreted the resultant P300 effect as a response to target identification (Polich, 2007). Interestingly, this component also has been implicated in studies investigating emotion (see Angus and Harmon-Jones, 2019, for anger), and in the role of individual differences in personality. Cahill and Polich (1992; see also Polich & Martin, 1992) discussed the P300 with respect to introverted and extraverted individuals. They noted that extroverted individuals demonstrated stronger probability effects (via larger P300 amplitudes) than introverts (see also Daruna et al., 1985). Moreover, Cahill and Polich (1992) indicated that "P3 amplitude is not only different for extreme introverted and extraverted personality types, but evinces distinct patterns for changes in probability perhaps because these [participant] groups use their attentional resources differently when responding to the eliciting stimuli" (p. 31). Given that the Big Five trait of extraversion (Ilies & Judge, 2002; Watson & Clark, 1992) has been linked to positive affect, an exploratory investigation regarding the P300 and positive affect is warranted, and we do so here. On a related note, Hajcak et al. (2010) indicated that the P300 "appears to reflect the allocation of capacity-limited resources towards motivationally salient stimuli" (p. 131). We take this as our starting point, and ask how participants differing in positive affect attend to linguistic stimuli, while also responding to target words in the sentence. Following the work of researchers in cognition and emotion (Ashby et al., 1999; Gable and Harmon-Jones, 2010; Isen and Reeve, 2005; Talarico et al., 2009), we assumed that more positive individuals are more intrinsically motivated (i.e., goal directed behavior) with respect to the primary task of reading for sentence comprehension. Thus, variation in P300 amplitudes could be due to how more positive vs. less positive participants allocate their attention to stimuli, especially when having to identify and respond to targets (Kramer et al., 1987; Kramer and Strayer, 1988; Polich, 1987; Wickens et al., 1983).

1.1. Quantifier scope and number

Sentences of the form such as *Every kid climbed a tree* can have two possible meanings: either several kids climbed several trees, or just one tree was climbed by several kids. This ambiguity has been accounted for by philosophers and linguists, using logical notation and rules (May, 1985). Using that rule-based system (for further discussion, see Dwivedi, 2013) the plural interpretation is the preferred reading of such sentences. In Dwivedi and Gibson (2017), we tested for this plural preference (which was empirically observed in Kurtzman & MacDonald, 1993, among others). In our previous experiment, we borrowed a self-paced reading paradigm (see Berent et al., 2005; Patson and Warren, 2010), that had a Stroop-like task, and adopted it for use in ERP methods.

Whereas ERP language studies typically have participants read sentences presented one word at a time (at a single fixation point), we presented sentences in either one- or two-word chunks. If the word was in a blue font, participants had to identify whether one or two words were on the screen (by pressing either "1" or "2"). Based on findings in Patson & Warren (2010), and Berent et al. (2005), we hypothesized that if the word had overt plural marking (e.g., *trees*) and a "1" button press was required, interference from the plural marking would show an empirical effect. Furthermore, we expected that even in the absence of overt plural morphology, i.e., even if the word was *interpreted* as conceptually plural (as in quantifier scope sentences), the interference effect would be observed. Patson and Warren (2010) did observe increased reading times in their self-paced reading study which examined quantifier scope sentences such as *Each of the men carried a box* (vs. *Together the men carried a box*). That is, increased response times were observed when participants had to press "1" for *box* in *Each*-type sentences vs. *Together*-type sentences (moreover, increases were also observed for control sentences such as *Each of/Together the men carried some boxes).*

In our work, we expected to see differences for responses to *tree* in *Every kid climbed a tree* (vs. *The kid climbed a tree*); in addition, we expected to see interference effects for overt plurals such as *Every/The kid climbed the trees*. Next, we added an additional control *Every/The kid climbed the tree,* since the singular vs. plural conditions differed both in terms of plural morphology (*tree* vs. *trees)* as well as determiner type (*a* vs. *the*). The design of the previous experiment (and the one conducted here) is given in Table 1.

Interestingly, we did not observe any difficulty associated with either overt plural marking (conditions (iii) and (iv) or covert plural interpretation (quantified singular condition (i) vs. non-quantified (ii)) (see Dwivedi & Gibson, 2017, for further details). In addition, although standard ERP language components (N400 and P600) were elicited for filler sentences, we did not observe these for critical conditions in Table 1.

Instead, all conditions elicited a P300 ERP component at the target word tree/trees, where significant differences (albeit in different directions) were observed in Singular and Plural conditions. That is, the Quantified Singular condition (i) showed decreased amplitude vs. the Non-quantified singular (ii), whereas the Quantified Plural condition (iii) showed increased amplitudes vs. the Non-quantified Plural (iv). Meanwhile, the control singular conditions (v) and (vi) did not differ at all from each other.

We recognize here, and in our previous work, that accounts regarding factors modulating P300 amplitudes lack a clear consensus. To our mind, there are at least two broad ways of thinking about the P300 effect: one is in terms of allocation of attentional resources in context updating, and another in terms of subjective probability of stimuli, as related to task (Donchin, 1981; Johnson, 1993; Luck, 1998; Polich, 2010, 2007). In our previous study, we interpreted the observed P300 amplitude differences using the first construct, that is, in terms of allocation of attentional resources as responses in a dual-task situation. That is, when sentences were

Table 1
Overview of experimental conditions.

Object Type		Quantified Subject Type				
Singular	(i)	***Quantified***				
		Every kid/	climbed **a**/	tree/	in the/	autumn./
				TW		
	(ii)	***Non-quantified***				
		The kid/	climbed **a**/	tree/	in the/	autumn./
				TW		
Plural	(iii)	***Quantified***				
		Every kid/	climbed **the**/	trees/	in the/	autumn./
				TW		
	(iv)	***Non-quantified***				
		The kid/	climbed **the**/	trees/	in the/	autumn./
				TW		
Control Singular	(v)	***Quantified***				
		Every kid/	climbed **the**/	tree/	in the/	autumn./
				TW		
	(vi)	***Non-quantified***				
		The kid/	climbed **the**/	tree/	in the/	autumn./
				TW		

Note: TW = target word position.

easier to interpret (the primary task), more attentional resources would be available for responding to the target word tree/trees (the secondary task). We hypothesized that sentences that switched in number during interpretation would be more difficult to interpret vs. those that did not, (for similar arguments regarding tense shifts, (see Dwivedi et al., 2006; Zwaan, 1996, 1999). For example in *Every kid climbed a tree,* the sentence starts with several participants in the scene (*Every kid*), and then switches to a singular item *a tree*. In contrast, there is no switch in number in *The kid climbed a tree*, where the sentence starts and ends with singular number. The switch in the previous sentence would increase the cost of interpreting it, resulting in fewer resources available for the secondary target identification task, manifesting as a smaller P300 amplitude (see Dwivedi & Gibson, 2017, for details regarding the Plural difference observed, as well as further theoretical discussion). We noted that participants were sensitive to the (global) heuristic cue of number during sentence interpretation, corroborating the model previously proposed in Dwivedi, 2013 (see also Dwivedi et al., 2010). Given the robustness of the P300 effect previously observed (i.e., present in all conditions) this experimental paradigm would be a good starting point to investigate whether dispositional affect would modulate this component.

1.2. Hypotheses and predictions

In the present exploratory study, we tested the following predictions:

First, we predicted that we would replicate the pattern of ERP findings in Dwivedi and Gibson (2017). Namely, we expected to find differences at the Singular condition, where P300 amplitudes are smaller for the non-quantified vs. quantified subject, whereas the quantified Plural should show greater amplitude than the non-quantified plural. In addition, we should not observe any evidence of difficulty for the Plural condition with this manipulation (manifested as smaller P300 amplitudes for Plural compared to Singular and Control Singular conditions).

Next, regarding dispositional affect and language, we note that the critical stimuli signal task relevance via local, grammatical cues (see Table 1). Local cues that are relevant for identifying and responding to targets in critical sentences include grammatical information such as subject type: quantified *Every* vs. non-quantified *The*, object type: indefinite *a* vs. definite *the*, as well as morphological marking of plural *–s* vs. no marking at all).

Synthesizing our previous work on language processing with work in cognition and participants' affective mood states, we hypothesize that individuals displaying more positive affect would be more motivated and engaged with global sentence meaning, whereas those less positive would be less motivated by the primary task of sentence interpretation and more motivated by the secondary task of target response.

There are at least two predictions regarding our previous study that elicited P300 effects: first, it could be the case that more positive participants (i.e., those displaying more positive affect), would show larger P300 differences in the same conditions as Dwivedi and Gibson (2017). This would be consistent with the idea that more positive participants would be sensitive to global cues regarding sentence interpretation, as argued previously.

Second, the findings might instead revolve around less positive participants, who would be using a strategy not about sentence interpretation relying on global heuristic cues but instead about local (grammatical) information. That is, less positive participants would be less concerned with overall sentence interpretation, and more motivated by local cues that are salient for the target response task and show relatively lower P300's.

2. Results

2.1. Behavioral analyses

2.1.1. Filler comprehension questions

Comprehension rates for questions at filler conditions were at 90.2% ($SD = 6.8\%$), indicating that participants were indeed paying attention to sentence materials.

2.1.2. Target identification response times and accuracy

As in previous work (Dwivedi and Gibson, 2017; Patson and Warren, 2010), these were only collected for correct trials. Mean response times for target identification were 366.9 ms ($SD = 29.3$ ms) for critical conditions and 373.4 ms ($SD = 26.0$ ms) for filler quantifier conditions. Participants were 75.5% ($SD = 12.9\%$) accurate at identifying that one word was on the screen for critical conditions, higher than the accuracy rate for corresponding filler quantifier conditions ($M = 69.0\%$, $SD = 17.0\%$) but in contrast with the high ceiling accuracy rate reported in previous work (Dwivedi and Gibson, 2017; Patson and Warren, 2010).

2.2. ERP analyses

Because the P300 effect has been reported with differing scalp distributions (Polich, 2007; Ruchkin et al., 1990, 1988), Dwivedi and Gibson (2017) performed separate repeated measure ANOVAs performed on medial and lateral ROIs, and for reasons of comparability, we adopted the same analytic approach here. All analysis of variance (ANOVA) and correlational analyses were conducted using SPSS (v.24, IBM Corp, 2016) statistical software. The Greenhouse-Geisser (Greenhouse and Geisser, 1959) non-sphericity correction was applied for effects with more than one degree of freedom in the numerator where Mauchly's Test of Sphericity was violated. Following convention, unadjusted degrees of freedom are reported, along with the Greenhouse–Geisser epsilon value (ε), adjusted p value and adjusted mean square error. Partial eta squared (η_p^2) is reported as a measure of effect size and post-hoc comparisons are Bonferroni corrected. Due to equipment failure leading to loss of trials, one participant's data were removed from the analyses, yielding 31 participants. Finally, only the first viewing of each trial was included in all analyses discussed below.

Each Region of Interest (ROI) contained 4–5 electrodes (see also Gisladottir et al., 2015). The ROIs were defined as follows: Anterior Medial (AntMed): F3, Fz, F4, FC1, FC2; Central (Cent): C3, C1, Cz, C2, C4; Posterior Medial (PosMed): P3, Pz, P4, PO3, PO4; Left Anterior (LAnt): FT7, F5, F7, T7; Right Anterior (RAnt): FT8, F6, F8, T8; Left Posterior (LPos): CP5, P7, PO7, O1; Right Posterior (RPos): CP6, P8, PO8, O2. See Fig. 1.

Separate repeated measure ANOVAs were performed on medial and lateral ROIs, as defined above. For medial ROIs, the Anteriority factor was defined as Anterior, Central and Posterior (3 levels: Anterior Medial, Central, Posterior Medial). For lateral ROIs, factors included Anteriority (2 levels: Anterior vs. Posterior) and Hemisphere (2 levels: Left vs. Right).

To assess whether the paradigm resulted in any difficulty for plural conditions as compared to singular and control singular conditions, a repeated measure ANOVA was conducted at medial and lateral ROIs with the linguistic factor of Object Type (3 levels: Singular, Plural, Control Singular) for the relevant P300 time window of 300–500 ms (see Fig. 2 and Table 2). For ease of exposition, only significant main effects involving linguistic factors are reported, followed by interaction effects involving the non-linguistic factors of Anteriority and/or Hemisphere.

It is evident in Fig. 2 and Table 2 that the Plural Object Type displayed a smaller P300 amplitude as compared to the Singular and Control Singular conditions. Moreover, this effect was marginally significant at medial and lateral sites, and significant differences emerge at right posterior sites.

Next, following the analytic approach in Dwivedi and Gibson (2017), we now examine each Object Type by quantified vs. non-quantified condition. Separate repeated measures ANOVAs were conducted at each level of Subject Type (2 levels: quantified vs. non-quantified) at medial and lateral ROIs as defined above, for the relevant P300 time window of 300–500 ms Results are summarized in Table 3. Figs. 3–5 display waveforms for each Object Type at both quantified and non-quantified conditions at the medial ROIs as defined above.

For the Singular object type, *a tree* (see Fig. 3 and Table 3), no significant effect of Subject type was observed ($Fs < 2$). A significant interaction of subject type and anteriority was observed in medial analyses, $F(2, 60) = 4.68$, $MSE = 1.87$, $p = .027$, $\eta_p^2 = 0.135$). Visual inspection and pair-wise comparisons revealed that there was no difference between

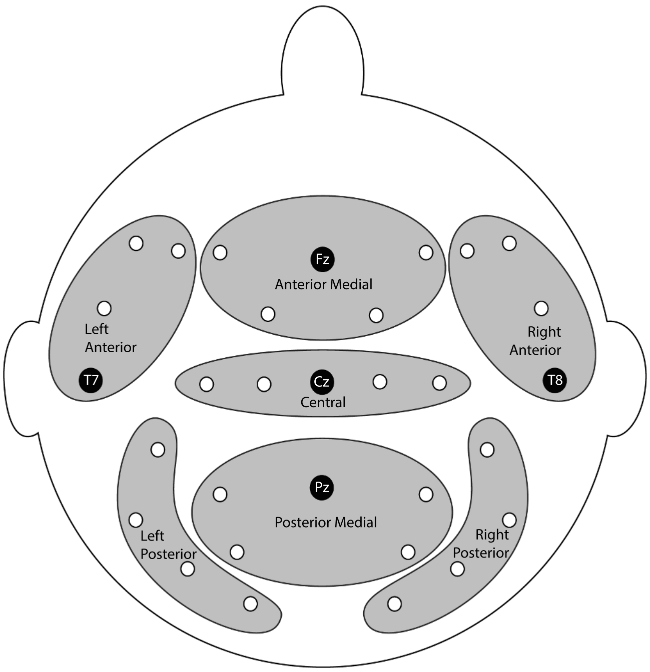

Fig. 1. Regions used for analyses of EEG data. Electrodes in dark circles included for orientation purposes.

quantified and non-quantified subjects in any region; this result simply reflects that within each subject type, voltages differed by region.

For the Plural object type *the trees*, (see Fig. 4 and Table 3), we see a similar pattern compared to the Singular condition (Fig. 3) where medial analyses revealed no effect of subject type (*Fs* < 2). Interestingly, the lateral analysis did reveal a three-way interaction between subject type, anteriority and hemisphere, F (1, 30) = 6.34, MSE = 0.368, p = .017, η_p^2 = 0.175). As in the Singular object type, this result simply reflects voltages differed by region within subject types.

Table 2
F-values for medial and lateral analyses of Object Type at target word for time window 300–500 ms using ROIs.

Analysis	Effect (*df*)	*F*	*p*	*MSE*	*eta-squared*
Medial	O (1, 30)	2.555	0.086†	13.118	0.078
	OxA (2, 60)	0.558	0.636	0.773	0.018
Lateral	O (1, 30)	2.725	0.074†	11.453	0.083
	OxA (1, 30)	2.13	0.133	1.159	0.066
	OxH (1, 30)	0.725	0.489	1.065	0.024
	OxAxH (1, 30)	3.879	0.037*	0.556	0.114

Note: O = Object Type; A = Anteriority; H = Hemisphere.
† $p < 0.1$.
* $p < .05$.

Finally, for the Control Singular object type, *the tree,* a main effect of subject type was revealed in medial, (F (1, 30) = 5.10, MSE = 16.08, p = .031, η_p^2 = 0.145), and lateral analyses, F (1, 30) = 5.90, MSE = 13.89, p = .022, η_p^2 = 0.164). As is evident in Fig. 5, sentences beginning with *Every kid* have higher amplitudes (over the whole head) as compared to sentences with non-quantified subjects *The kid.* As this was prevalent over the whole head, this did not interact with the ROIs (see Table 3).

2.3. Correlation analyses

Positive Affect (PA) scores ranged from 25 to 47 (M = 35.1, SD = 5.98).

To investigate the relation between P300 amplitude and PA scores at each Subject Type, difference scores were generated. That is, P300 amplitudes for *The kid….* conditions were subtracted from *Every kid….* conditions and these differences were correlated with PA.

Significant correlations were observed between PA and amplitude differences in Control Singular at all medial ROI's (all p's < 0.05) and marginally significant at all lateral ROIs except LPos (see Table 6; Fig. 6). This correlation showed that participants with low PA scores were driving the effect of Subject type seen in Fig. 5. To demonstrate this effect, the medial ROI sites are shown in Fig. 7 for low PA

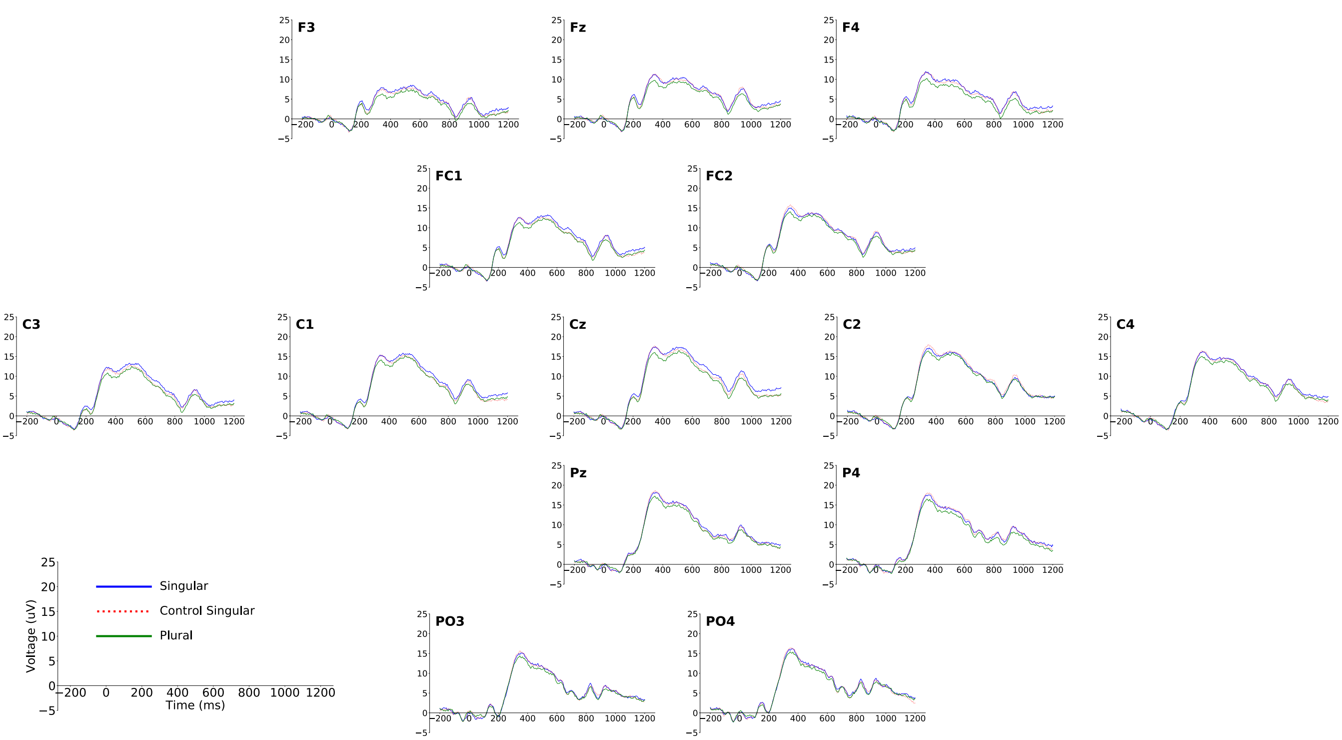

Fig. 2. Grand average ERP waveforms for Object Type conditions: Singular, Plural, Control Singular. Averages are time-locked to the onset of the target word *tree(s)*.

Table 3
F-values for Singular, Control Singular and Plural Object Types at target word for time window 300–500 ms using ROIs.

Condition	Analysis	Effect (*df*)	*F*	*p*	*MSE*	*eta-squared*
Singular	Medial	Q (1, 30)	1.441	0.239	20.544	0.046
		QxA (2, 60)	4.676	0.027*	1.870	0.135
	Lateral	Q (1, 30)	0.565	0.458	11.572	0.018
		QxA (1, 30)	0.402	0.531	1.503	0.013
		QxH (1, 30)	0.215	0.646	1.911	0.007
		QxAxH (1, 30)	< 0.001	0.990	0.833	< 0.001
Plural	Medial	Q (1, 30)	0.996	0.326	13.898	0.032
		QxA (2, 60)	1.185	0.293	1.706	0.038
	Lateral	Q (1, 30)	2.034	0.164	12.434	0.064
		QxA (1, 30)	0.040	0.843	2.481	0.001
		QxH (1, 30)	0.215	0.646	0.853	0.007
		QxAxH (1, 30)	6.344	0.017*	0.368	0.175
Control Singular	Medial	Q (1, 30)	5.097	0.031*	16.076	0.145
		QxA (2, 60)	0.053	0.873	1.541	0.002
	Lateral	Q (1, 30)	5.869	0.022*	13.893	0.164
		QxA (1, 30)	0.422	0.521	1.816	0.014
		QxH (1, 30)	0.666	0.421	0.709	0.022
		QxAxH (1, 30)	1.936	0.174	0.612	0.061

Note: Q = Quantified subject; A = Anteriority; H = Hemisphere.
* $p < .05$.

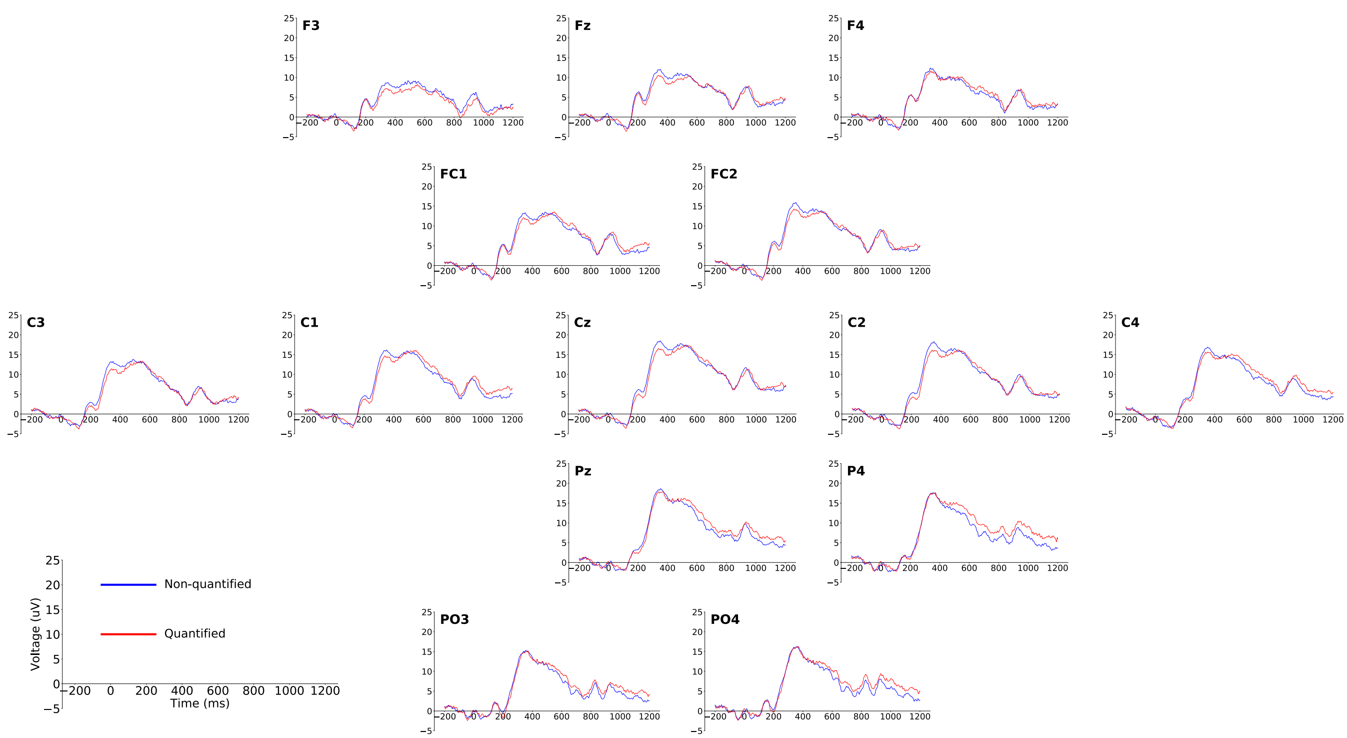

Fig. 3. Grand average ERP waveforms for Quantified versus Non-quantified Singular condition. Averages are time-locked to the onset of the target word tree.

participants (N = 16, PA less than 35) and Fig. 8 for high PA participants (N = 15, PA greater than median score of 35). No other significant correlations were observed (see Tables 4–6).[3]

3. Discussion

We investigated whether dispositional affect modulated P300 amplitudes, using the paradigm from our previous ERP language work (Dwivedi and Gibson, 2017). We note that we did not replicate the pattern of P300 effects seen previously. Notably, we did observe difficulty at the Plural condition; P300 amplitudes were smaller here overall, indicating that the interference between the plural morpheme *-s* and the 1-button press resulted in fewer resources available at this condition. Next, we found a strong negative correlation with positive affect and P300 amplitudes, such that lower dispositional PA yielded greater P300 amplitude differences in Control Singular conditions. We interpret the cognitive significance of this effect, below.

3.1. Low positive affect, probability and local cues

The present finding that individuals with low positive affect scores respond differently at the Control singular condition is consistent with the hypothesis that less positive participants would be sensitive to local vs. global cues in sentences. That is, participants with Low PA scores showed

[3] Out of exploratory interest, we did also ran correlations with these P300 amplitude differences scores and Negative Affect (NA) scores (*Mean* = 16.0, *SD* = 5.35). No significant correlations were observed with NA.

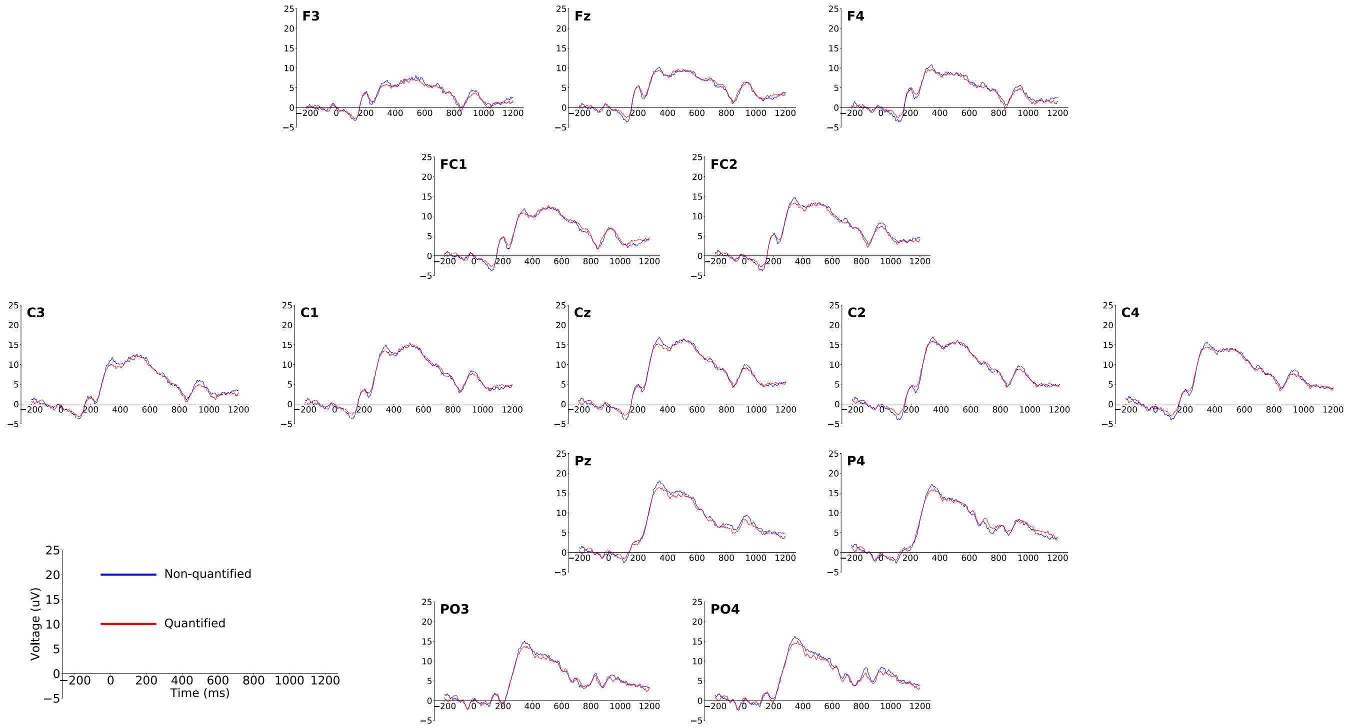

Fig. 4. Grand average ERP waveforms for Quantified versus Non-quantified Plural condition. Averages are time-locked to the onset of the target word trees.

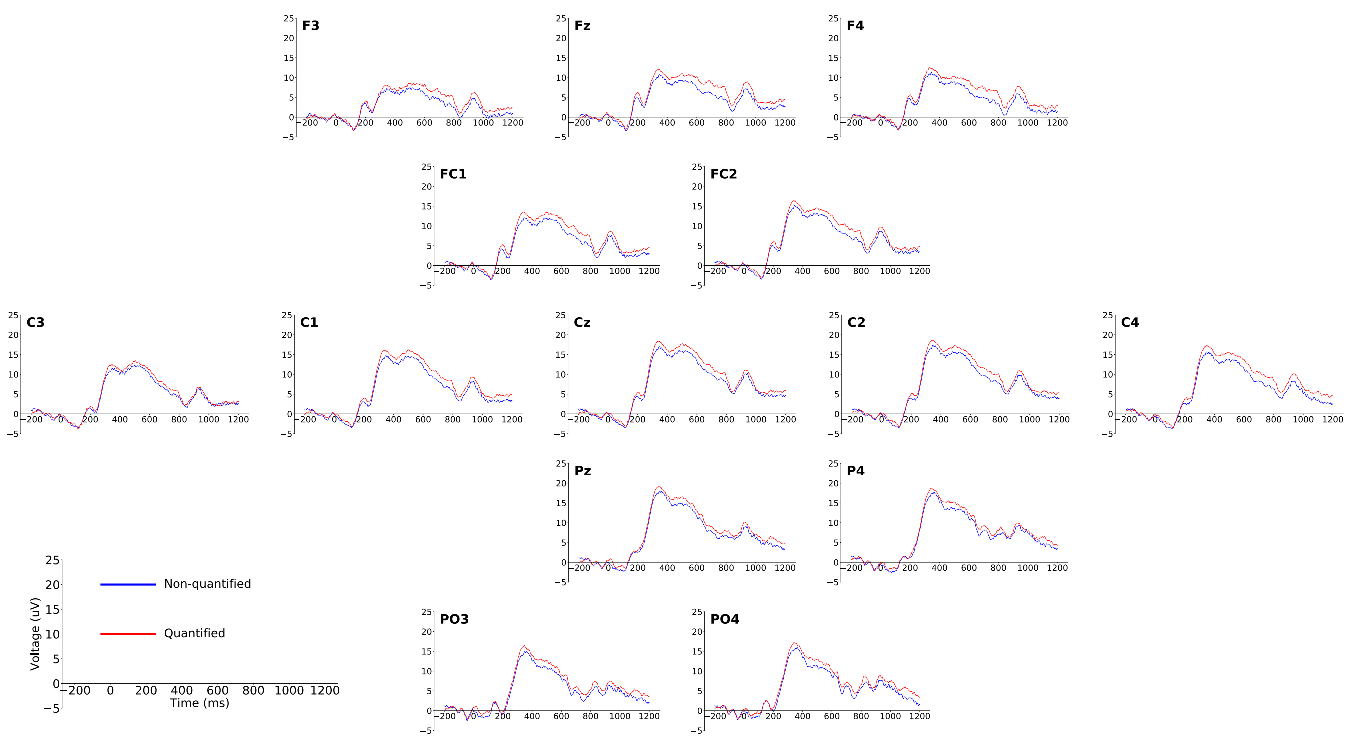

Fig. 5. Grand average ERP waveforms for Quantified versus Non-quantified Control Singular condition. Averages are time-locked to the onset of the target word tree.

greater P300 amplitude differences to sentences such *The kid climbed the tree,* vs. *Every kid climbed the tree.* These differences were not observed elsewhere. We note that the non-quantified Control singular condition begins with *The…,* in subject position, which is the case for half of critical trials (the other ½ start with *Every*) and several filler trials, too[4]. The definite determiner '*the*' is also present at the direct object position in the control singular *the tree*, as it is for the Plural *the trees*, as well as filler conditions, adding up to about 40% of trials (vs. 22% for indefinite '*a*'*)*. Finally, the target noun *tree* is also present in the Singular condition *a tree* but not in the Plural (*the trees*); once filler conditions are included, 72% of trials have singular targets. Thus, is it clear that *The kid climbed the tree* has the most common features, and is thus the least informative regarding task probability. The other conditions, Singular and Plural, do not have these common features for their non-quantified counterparts; as a result, the difference observed for high vs. low PA individuals is not observed there.

[4] That is, 259/ 456 trials, or 57% start with *The …,* compared to just 17% starting with *Every….*

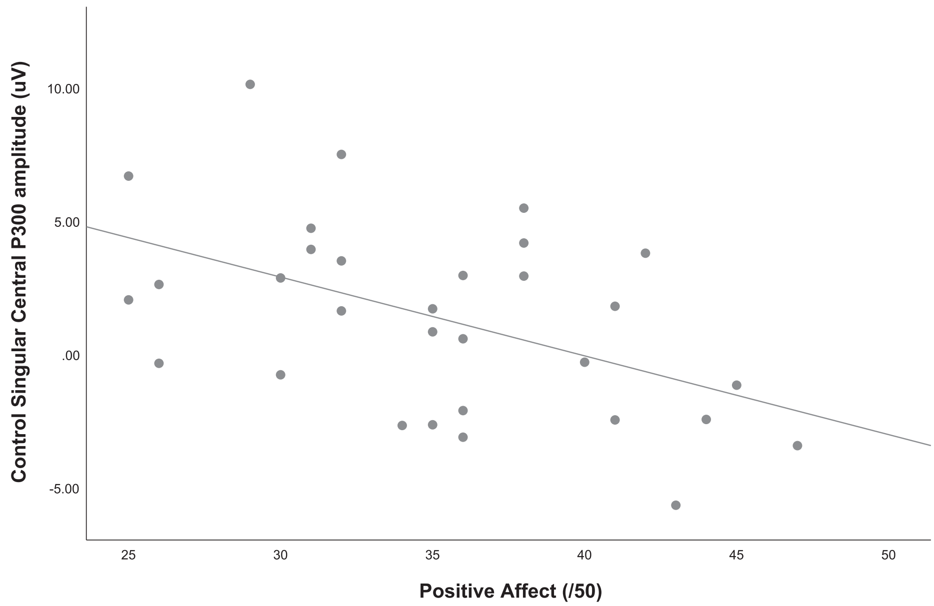

Fig. 6. Scatterplot of mean P300 amplitude difference scores (Quantified minus Non-quantified) and PA for the Control Singular condition at the Central ROI.

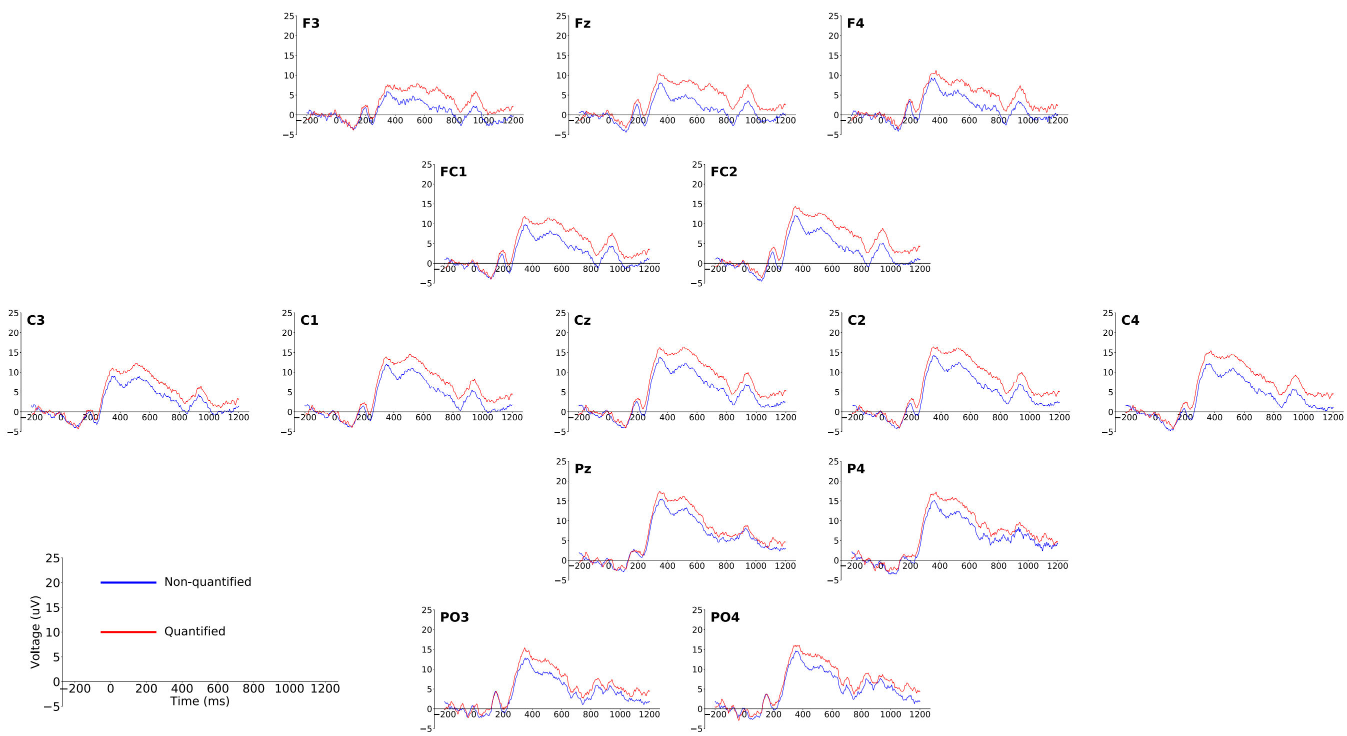

Fig. 7. Grand average ERP waveforms for low PA participants (PA $<$ median 35; N = 16) for Quantified versus Non-quantified Control Singular condition. Averages are time-locked to the onset of the target word tree.

3.2. Limitations

Here we note that although we did replicate the P300 neural effect in this experiment, the pattern was not the same. Significantly, this sample of participants[5] was indeed sensitive to the plural morphology of *trees,* and did in fact show an interference effect at the plural.[6] Furthermore, they did not show differences previously observed at the Singular vs. Plural conditions. In addition, overall this group was less accurate at the Number Response task, that is they differed at both

[5] We did not derive an a priori estimate of sample size (and instead relied on comparable samples in related ERP language studies, as cited above). We did do a post hoc analysis regarding sample size using (freely available) G*Power software (Faul et al., 2007). Using recommended settings of alpha = 0.05, and power =0.80 for a strong correlation of r = 0.5 (Cohen, 1992) between Positive Affect scores and P300 amplitude, a sample size of N = 26 would be appropriate. Given that our N= 31, we had adequate power to detect an effect.

[6] Because we did not expect to find difficulty, we had no predictions regarding this and PA. For exploratory purposes, we did compute correlations for P300 amplitudes (difference scores for P300 amplitudes were computed for Plural minus Singular, and Plural minus Control Singular for relevant ROIs. No correlations were found; see Supplementary Materials).

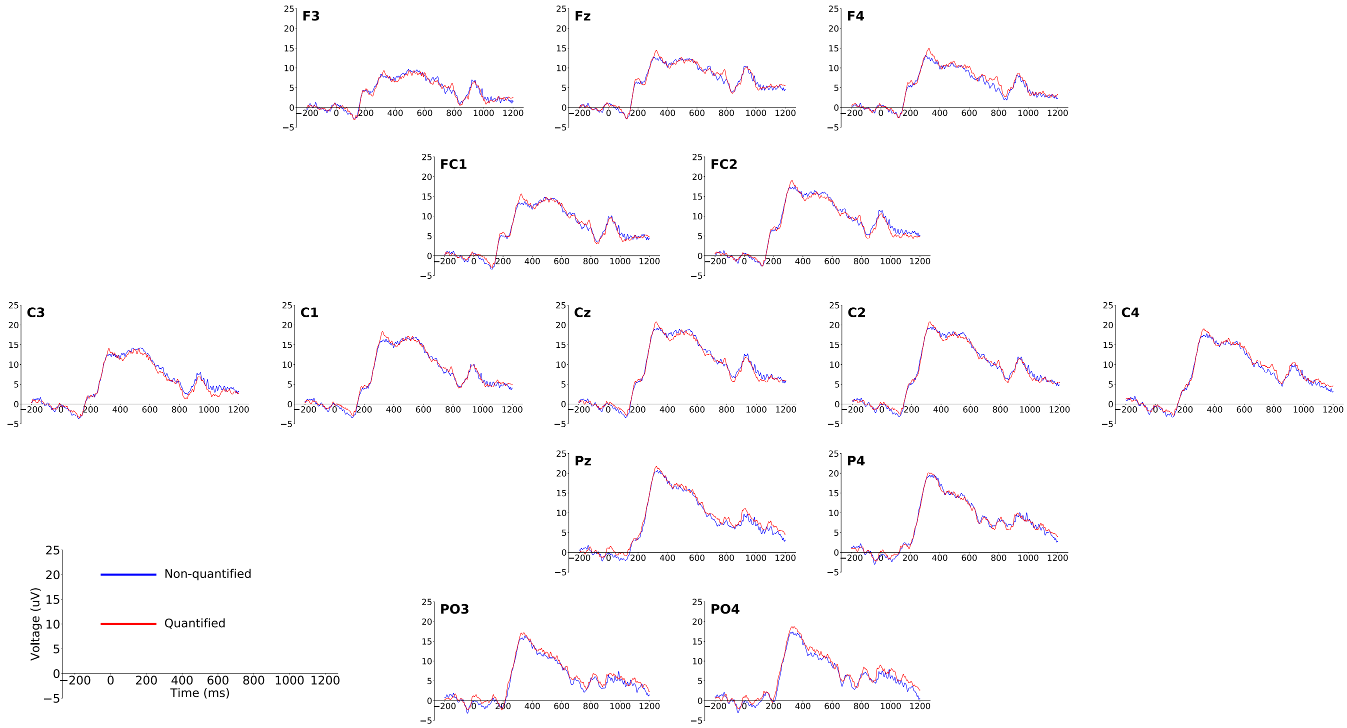

Fig. 8. Grand average ERP waveforms for high PA participants (PA > median 35; $N = 15$) for Quantified versus Non-quantified Control Singular condition. Averages are time-locked to the onset of the target word tree.

Table 4
Pearson correlations for P300 amplitude differences in the Singular condition (Quantified – Non-quantified) with PA.

		AntMed	Cent	PosMed	LAnt	RAnt	LPos	RPos
PA	*r*	0.073	0.117	0.290	0.014	−0.179	0.232	0.156
	p	0.697	0.531	0.113	0.942	0.334	0.208	0.403

Table 5
Pearson correlations for P300 amplitude differences in the Plural condition (Quantified – Non-quantified) with PA.

		AntMed	Cent	PosMed	LAnt	RAnt	LPos	RPos
PA	*r*	0.118	0.103	0.088	0.048	0.041	0.098	−0.044
	p	0.526	0.582	0.639	0.796	0.827	0.601	0.815

Table 6
Pearson correlations for P300 amplitude differences in the Control Singular condition (Quantified – Non-quantified) with PA.

		AntMed	Cent	PosMed	LAnt	RAnt	LPos	RPos
PA	*r*	−0.411	−0.491	−0.439	−0.354	−0.352	−0.238	−0.310
	p	0.022*	0.005**	0.014*	0.051†	0.052†	0.197	0.090†

* $p < .05$.
** $p < .01$.
† $p < 0.1$.

behavioral and electrophysiological measures (see Supplementary Materials for further analysis).

It is unclear why undergraduates at the same institution should differ with respect to the experiment. We acknowledge that university students consist of less- and more-skilled readers, where these readers are known to use qualitatively different processing strategies (Daneman et al., 2007; Hannon and Daneman, 2004, 2001; see also Budd et al., 1995; Lee-Sammons and Whitney, 1991). Specifically, less-skilled readers are less able to maintain necessary information in an active state. It could be the case that the 24 participants we tested years ago vs. the 32 participants we tested in the past 12 months represent different cohorts of readers. This could certainly be the case due to changes in reading patterns over the past few years, as well as the fact that our current sample mostly consisted of first year Psychology students, whereas our previous sample consisted of mostly upper year students. The fact that this group is less-skilled is certainly corroborated

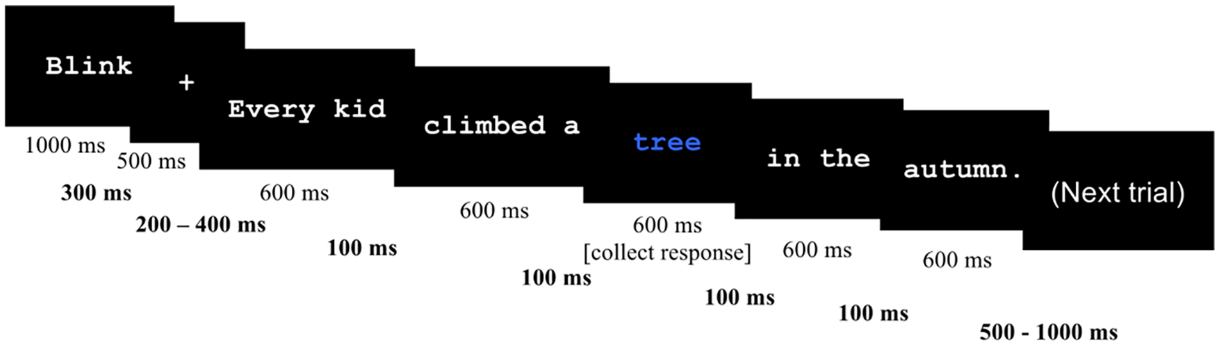

Fig. 9. *Sample trial procedure*. Number judgments were made at the critical word (here, *tree*), which was presented in blue font as indicated in the figure. Time values in bold represent inter-stimulus intervals, and time values in regular font represent the duration of stimulus presentation on the screen.

by the fact that this group was significantly less able to perform the task, as compared to the previous group.[7]

3.3. Conclusion

The current work suggests that dispositional affect, like other personality measures found previously (see Cahill & Polich, 1992; Polich & Martin, 1992) can account for individual differences in P300 waveforms during a target response task while participants read sentences. This is the first study to show that dispositional affect can modulate P300 magnitude, furthering our understanding of individual differences associated with this component. Furthermore, the findings are consistent with studies in affect and other domains of cognition that suggest that less positive individuals are sensitive to local, not global cues.

4. Experimental procedures

4.1. Participants

Thirty-two Brock University undergraduates (25 female, mean age 20.25 years, range 18–26 years) were recruited and either paid for their participation or received partial course credit. All participants were native, monolingual speakers of English, had normal or corrected-to-normal vision and were right handed, as assessed by the Handedness Inventory (Briggs and Nebes, 1975). No participants reported any neurological impairment, history of neurological trauma, or use of neuroleptics.

This study received ethics approval from the Brock University Bioscience Research Ethics Board (BREB) prior to the commencement of the experiment (REB 13-282). Written, informed consent was received from all participants prior to their participation in the experiment.

4.2. Materials

The experimental stimuli consisted of 156 sentence scenarios for the six conditions described in Table 1. In order to reduce repetition effects, the stimuli were divided into six counterbalanced lists, such that each participant saw an equal number of sentence pairs from each condition, resulting in 26 trials per experimental condition per list. Each experimental list consisted of 456 sentences (156 critical trials and 300 filler trials) divided into one and two-word chunks. Across each list, there was an approximately equal number of one- and two-word chunks, and each participant made approximately equal numbers of one and two-word judgments throughout the task. Each list was pseudo-randomized using the Mix utility (van Casteren and Davis, 2006) such that no two sentences of the same condition appeared consecutively, no two experimental sentences appeared consecutively, and the first five sentences of each list were filler sentences. See Dwivedi & Gibson (2017) for a full list of experimental and filler items.

4.2.1. Critical conditions

4.2.1.1. Subject noun phrase type.. The subject noun phrase was either quantified or not. Quantified subjects always used the universal quantifier *Every*, in contrast to Non-quantified subjects, which always used the (non-quantified) definite article *the*[8].

4.2.1.2. Object noun phrase type. The direct object noun phrase was of three types: singular, as in *a tree*; control singular, as in *the tree*; or plural, as in *the trees.* Thus, this 2 × 3 design resulted in 6 conditions, as outlined in Table 1.

4.2.1.3. Sentence structure. All experimental sentences consisted of simple declarative sentences (e.g., SUBJECT^VERB^OBJECT), modified from (Dwivedi et al., 2010) for the current experiment. In each sentence, the subject was always an animate noun (e.g., *kid, jeweller, etc.*). The remainder of the sentence consisted of an active verb in the past tense (e.g., *climbed, appraised, etc.*) followed by an inanimate object noun (e.g., *tree, diamond, etc.*) and a three-word prepositional phrase (e.g., *in the autumn, before being certified*, etc. See Dwivedi & Gibson (2017) for further details.

4.2.2. Filler conditions

The experiment included 300 distractor sentences in addition to the critical sentences to reduce predictability, incorporate number judgments for pairs of words, and elicit standard ERP components. Word pairs always consisted of determiner-noun or adjective-noun combinations as in (Patson and Warren, 2010).

4.2.2.1. Filler quantifier sentences. Eighty sentences that began with subjects other than *Every* were included. Of these 80 sentences, 40 began with a plural quantifier (e.g., *many, most, etc.*) and 40 began with *the*. Number judgments were always made on word pairs (resulting in a "2" button press), and, as in the critical conditions, the target word pairs were always the third chunk of the sentence presented on the screen. Sample sentences for this condition include *Many investors lost a* ***small fortune*** *during the depression*, and *The newscaster announced the*

[7] As per a reviewer's recommendation, we split our participants into High vs. Low accuracy groups in order to examine whether a subset of the current participants would show a similar pattern as in Dwivedi and Gibson (2017). We did not have an independent measure of reading skill, and surmised that this higher accuracy on the task would be a marker of a more skilled reader. We did see voltage patterns for high accuracy participants that were numerically in a similar direction (despite being quite small) as our previous group (where differences emerged in the same direction as previously for Singular and Plural conditions). See Supplementary Materials for this analysis, as well as a further analysis recommended from the reviewer, to speculate how affect scores might correlate with ERP results for the small high accuracy group.

[8] Technically, *the* can be termed non-quantificational, or referential. For ease of exposition, we will be referring to it as non-quantified.

***winning numbers** in the evening.*

4.2.2.2. Standard ERP language component sentences. A total of 160 sentences were included to elicit standard ERP language components and to introduce variability into the task. Forty sentences (from Dwivedi et al., 2010) with grammatical violations were included to elicit the P600, a marker of syntactic anomaly (e.g., *The nurse was/*were dressing a wound*). Forty sentences (from Connolly, Phillips, & Forbes, 1995) with anomalous words were also included to elicit a standard N400 effect (Kutas and Hillyard, 1980a; Kutas and Van Petten, 1994) using semantically anomalous sentences (e.g., *Ned has a daughter and a #cloud*). Finally, 80 coherent, unambiguous sentences were included to provide a baseline for the ungrammatical and anomalous sentences. There were no number judgments made on any of these fillers. These produced the expected components and will not be discussed further.

4.2.2.3. Other filler sentences. An additional 60 sentences were included to balance the number of judgments made on single words and word pairs and to vary the location of the targets to reduce predictability (note that word judgments were always made for the third chunk presented in critical trials and quantifier filler conditions).

Finally, in order to ensure that participants paid attention to the sentences, forced-choice content questions were asked (true/false; yes/no) on all of these fillers, and half of the filler quantifier sentences. The two alternative answers were shown on the left- and right-hand side of the screen. The position of the correct answer was counterbalanced across trials. For example:

After | **repeated losses** | the gambler | was | very unhappy.
The gambler was excited.
(1) True (2) False

4.3. Electrophysiological recordings

Electroencephalographic recordings were obtained using the 64-channel ActiveTwo BioSemi system (BioSemi, Amsterdam). The sampling rate of the data was 512 Hz and was digitized using a 24-bit analog-to-digital converter. The 64 Ag-AgCl electrodes were arranged in the international 10–20 system (Jasper, 1958). Eye movements and blinks were monitored by use of an electrooculogram (EOG) via 3 electrodes, one located by the outer canthus of each eye and one below the right eye, placed out of the participant's peripheral vision. All recordings were obtained against a common mode sense (CMS) electrode located adjacent to Pz and amplified by the ActiveTwo system.

All recordings were filtered and analyzed using EMSE data editor v5.5.1 (Cortech Solutions, 2013). To remove artifactual trends such as linear drift or non-linear interference from power sources, polynomial detrend was applied to the data at order 3 across the entire time series. The electrodes (excluding EOG electrodes) were re-referenced offline to the linked mastoids. Two infinite impulse response filters were applied at 12 db/octave to all electrodes. The first was a bandpass of 0.1–100 Hz to remove low and high frequency noise, and the second was a bandstop of 59–61 Hz to remove 60 Hz noise. Eye movement and blink artifacts were corrected via a spatial ocular artifact correction algorithm (Pflieger, 2001) from the EMSE v5.5.1 software (Cortech Solutions, 2013). Due to equipment malfunction, data from electrode Fp1 was lost in some participants. A spatial interpolation filter (Cortech Solutions, 2013) was applied for this electrode, for all participants. Average ERPs were computed for each participant time-locked from stimulus onset to 1200 ms with a pre-stimulus baseline of 200 ms. ERPs were averaged for each participant at the direct object *tree/trees* for all critical conditions in Table 1.

4.4. Procedure

Participants were tested individually in one session of approximately three hours. In each session, participants completed a short questionnaire regarding reading habits, a handedness inventory (Briggs and Nebes, 1975), and the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988)[9] before the application of the electrodes. Following a practice session of eight trials, each participant completed the experimental trials in six blocks of 76 trials per block with rest periods between each block. See Fig. 9 for a sample trial procedure.

All words were presented in light grey, 19-point Courier New font on a black background in the centre of the computer monitor. Participants pressed the response pad when they were ready to begin. Each participant was then presented with the word “Blink” for 1000 ms, followed by a fixation marker (+) for 500 ms to indicate the beginning of a new trial. Following a variable inter-stimulus interval of 200 to 400 ms, the participant was presented with each sentence in one- and two-word chunks in the centre of the screen. Each word or word pair was presented at a fixed rate of 600 ms per word followed by an inter-stimulus interval of 100 ms. The target word in critical trials (always the third chunk on screen) or pair of words in filler trials (the location of the critical word pairs varied; refer to section Filler conditions.) was presented in blue font. Participants were instructed that blue font was a cue to make the number judgment and pressed pre-specified keys with their dominant hand to indicate whether one or two words were on the screen. The word remained on the screen for 600 ms regardless of when the response was made, although participants were taken to a feedback error screen if they responded incorrectly or failed to respond within 600 ms. The trial was always repeated in the event of any type of error (note that ERP analyses were only conducted on the first presentation of the target). Once a correct response was obtained, the sentence continued. Participants were presented with a two-choice comprehension question (true/false; yes/no) following 110 filler trials (24% of all trials) and responded using the response pad. Following a variable inter-trial interval of 500–1000 ms, the next trial began.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brainres.2019.146309.

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[9] Because this study was the first of its kind, participants were tested on both the PANAS and Circumplex questionnaire (Feldman Barrett and Russell, 1998), where order of questionnaire testing was counterbalanced. The pattern of results obtained using Circumplex were analogous to those found with PANAS; for ease of exposition, results are reported only in terms of the latter.

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