How alliteration enhances conceptual–attentional interactions in reading

Egan, Ciara; Cristino, Filipe; Payne, Joshua; Thierry, Guillaume; Jones, Manon

Cortex

DOI:
10.1016/j.cortex.2019.11.005

Published: 01/03/2020

Abstract

In linguistics, the relationship between phonological word form and meaning is mostly considered arbitrary. Why, then, do literary authors traditionally craft sound relationships between words? We set out to characterise how dynamic interactions between word form and meaning may account for this literary practice. Here, we show that alliteration influences both meaning integration and attentional engagement during reading. We presented participants with adjective-noun phrases, having manipulated semantic relatedness (congruent, incongruent) and form repetition (alliterating, non-alliterating) orthogonally, as in "dazzling-diamond"; "sparkling-diamond"; "dangerous-diamond"; and "creepy-diamond". Using simultaneous recording of event-related brain potentials and pupil dilation (PD), we establish that, whilst semantic incongruency increased N400 amplitude as expected, it reduced PD, an index of attentional engagement. Second, alliteration affected semantic evaluation of word pairs, since it reduced N400 amplitude even in the case of unrelated items (e.g., "dangerous-diamond"). Third, alliteration specifically boosted attentional engagement for related words (e.g., "dazzling-diamond"), as shown by a sustained negative correlation between N400 amplitudes and PD change after the window of lexical integration. Thus, alliteration strategically arouses attention during reading and when comprehension is challenged, phonological information helps readers link concepts beyond the level of literal semantics. Overall, our findings provide a tentative mechanism for the empowering effect of sound repetition in literary constructs.

Keywords: neurocognitive poetics, phonology, semantics, event-related potentials, pupil dilation

1. Introduction

The question as to whether the phonological form of a word has any bearing on its meaning has intrigued scholars for millennia (cf. Plato's *Cratylus*). Mainstream opinion in the language sciences advocates no such relationship, claiming instead that phonological forms are arbitrarily associated with semantic concepts (de Saussure, 1916; Gasser, 2004; Lupyan & Winter, 2018). Nevertheless, proponents of sound symbolism (i.e., iconicity in natural language) have advocated that a word's phonology can and does reflect some of its semantic features, particularly in non-indoeuropean languages (cf. Perniss, Thompson, & Vigliocco, 2010; Monaghan, Shillcock, Christiansen, & Kirby, 2014; Kovic, Plunkett, & Westermann, 2010; Asano, et al., 2015; see also Culler, 1975; Jakobson, 1960), as is the case for onomatopoeic words (e.g., bang, pop, splash; Perniss & Vigliocco, 2014).

A natural extension to this question, then, is whether interactions between phonology and semantics extend beyond the level of intra-lexical iconicity, i.e., affect relationships between words at the phrasal level. In spoken language, comprehenders use prosodic patterns to structure the input and parse the speech stream which has an immediate impact on semantic processing (e.g., Breen, Dilley, McAuley, & Sanders, 2014; Brown, Salverda, Dilley, & Tanenhaus, 2015). But it is unclear whether and how phonological information derived during (silent) reading affects comprehension. Recent work in neurocognitive poetics suggests that stylistic prosodic features in phrases, such as phonological repetition, attract more attentional resources and that their neural representations are more strongly activated than those of neutral, declarative forms, as shown in behavioural (e.g. Carminati, Stabler, Roberts, & Fischer, 2006; Yaron, 2002; Tillmann & Dowling; Hanauer, 1996) and in event-related potential (ERP; Chen et al., 2016; Obermeier et al., 2013;, 2007; Vaughan-Evans et al., 2016) studies.

Here, we measured event-related brain potentials (ERPs) and pupil dilation (PD) changes in native English speakers reading adjective-noun phrases manipulated orthogonally for semantic relatedness and alliteration. We chose to study form-meaning relationships at the most elementary level of word combination in reading, i.e., two-word phrases, in order to (a) have full experimental control via counterbalancing of stimuli across conditions, and (b) remove an inherently 'poetic' attribute from the potentially biasing context of verse, thus providing an evaluation of form-meaning relationship as it occurs in natural language. Our choice of methods also allowed us to examine semantic processing in the context of attentional engagement: In ERP research, increased negativity in mean amplitudes of the N400 wave is associated with increased difficulty in accessing the meaning of a stimulus (Chwilla, Brown, Hagoort, 1995; Kutas & Federmeier, 2011). On the other hand, increased PD indexes the recruitment of attentional resources and task-related uncertainty (Kang, Huffer, & Wheatley, 2014; Geng, Blumenfeld, Tyson, & Minzenberg, 2015; Mathôt, 2018). Early dilation (<1000 ms) is associated with attentional orienting, relating to stimulus saliency or novelty, whereas later dilation (>1000 ms) is thought to reflect autonomic arousal, linked with mental effort or interest (Wang & Munoz, 2015; Wetzel, Buttelmann, Schieler, & Widmann, 2016; Mathôt, 2018).

We anticipated that semantic processing would be more difficult (and thus elicit greater N400 amplitudes) for incongruent adjective-noun pairs, and that alliteration would interact with semantic processing. We also expected that attention allocation would be boosted (and thus increase PD) in response to more effortful semantic processing, analogous to the N400 (Kuipers & Thierry, 2011; Wetzel et al., 2016), and that alliteration would also attenuate this response. We further expected these effects to occur during the later phase of pupil dilation (Mathôt, Grainger & Strijkers, 2017; Wetzel et al., 2016). Moreover, potential correlations between ERP amplitude and PD index offered an opportunity to empirically describe dynamic links between semantic integration and attentional engagement (cf. Kuipers & Thierry, 2011; 2013). In order to investigate whether semantic integration (occurring ~400 ms) further relates to early or later phases of attentional engagement, we examined the relationship between mean ERP amplitude in the classical N400 time window (300-5000 ms) and pupil dilation over the entire sequence of a trial.

2. Materials and Methods

2.1. Participants

The data of 20 native English speakers (16 females, mean age = 22, SD = 2.97) were included in the analysis (a further 5 were excluded owing to technical failures and/or excessive alpha contamination). This sample size was determined on the basis of recent similar studies (e.g., Chen et al., 2016; Vaughan-Evans et al., 2016). All participants had normal or corrected-to-normal vision and reported no past or present diagnosis of a learning difficulty. Ethical approval was granted by the School of Psychology, Bangor University and all participants provided written informed consent before taking part.

2.2. Stimuli and Procedure

In a two-by-two experimental design manipulating semantic congruency and alliteration orthogonally, a total of 416 adjective-noun word pairs were constructed, resulting in 104 pairs per condition. All stimuli, i.e., adjectives and nouns considered independently, were quasi-rotated across conditions (99.9%) and presented alongside 208 randomly interspersed filler trials. Stimuli were normed for semantic congruency in a separate study, in which 60 native English speakers rated each adjective-noun phrase on a 5-point Likert scale, answering the question “how likely would it be for the second word to follow the first in a normal sentence (ranging from 1: very unlikely to 5: very likely)". Congruent alliterating (M = 4.05, SD = 0.74) and non-alliterating (M = 3.96, SD = 0.78) phrases were both rated significantly more related than pairs from either the incongruent alliterating (M = 1.80, SD = 0.53) or incongruent non-alliterating (M = 1.66, SD = 0.53) conditions ($p < .05$). There was no significant difference between the ratings of the two congruent conditions ($p = .743$), or between the two incongruent conditions ($p = .364$). All stimuli were then resized using a mathematical algorithm in Matlab so that each word presented in white on a black background as a picture object contained the same number of lit pixels on the screen (i.e., words varied in size and length but luminance was kept constant from one stimulus to the next).

Participants sat at a distance of 100 cm from the monitor. Following setup of the EEG system and calibration of the eye-tracker, each trial began with a drift correction (single-point recalibration) also serving as fixation in the centre of the screen. Then, the adjective was presented for a random duration in the range of 330–550 ms in 20 ms increments. On 50% of the experimental trials the noun was then presented without an inter-stimulus interval for 500–600 ms in random 20 ms increments, whilst on the remaining 50% the noun was presented for 2000 ms, allowing for collection of PD data. Then, a response cue (#####) prompted the participant to indicate, using a counterbalanced, binary-decision button press, whether or not the two words were related in meaning (see **Figure 1**). Importantly, visually-presented fixation and response cues also had the exact same number of lit pixels as word stimuli, such that luminance was constant throughout experimental blocks. For data analysis, ERPs were analysed across all experimental trials, whereas PD data were analysed only on the longer presentation trials owing to the slow time-course of the pupil response (Mathôt et al., 2017).

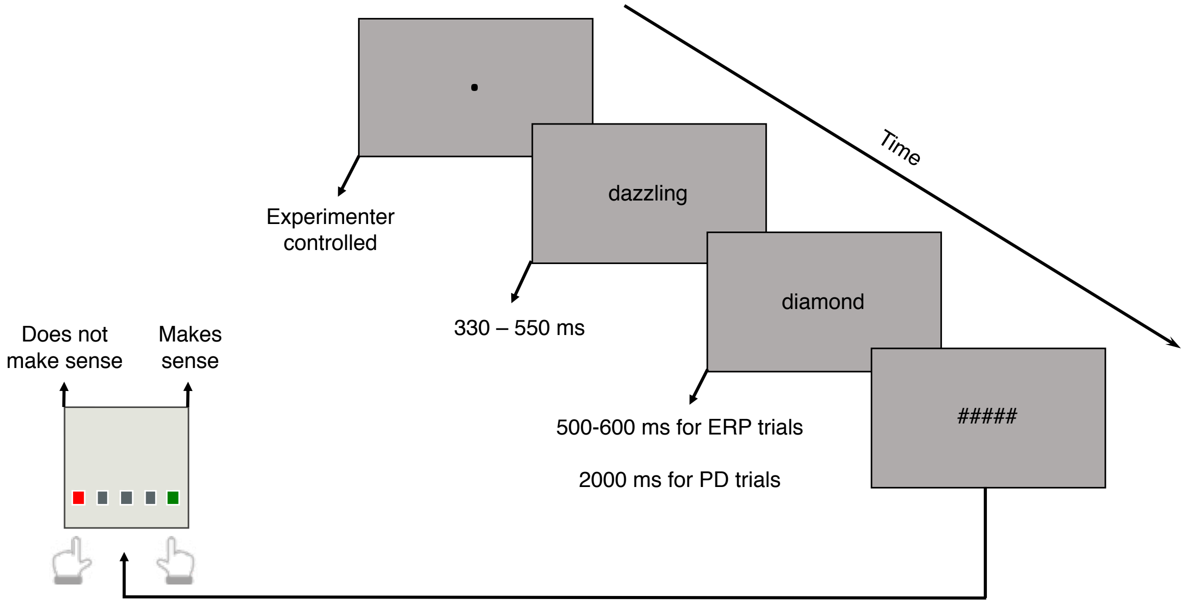

Figure 1. Schematic depicting the experiment procedure. Note that screen background was black and all stimuli were in white. Word size varied in order to keep the number of pixels constant, thus controlling luminance.

2.3. Pupillometry Recording

Pupil dilation was recorded using an Eyelink 1000 desktop mounted eye-tracker. Words were presented in white Arial font on a black background in the centre of a 62 x 34 cm monitor with a refresh rate of 60 Hz and a resolution of 1080 x 1920 pixels. Eye movements and pupil dilation were recorded from the participant's right eye, after a 9-point calibration. Baseline correction was performed using a subtractive, pre-stimulus baseline correction (based on the median dilation from the first 10 ms of each trial), as outlined in Mathôt, Fabius, Heusden, & Van der Stigchel (2018). Blinks, including small saccades, during a trial were identified and data was marked as missing. An extra 25 samples (25 ms) post blinks were also marked as missing, since pupil size takes time to recover upon opening the eyelid. In order to ensure minimal eye movements during a trial, all visual stimuli were less than 2 degrees of visual angle. Any data marked missing was interpolated using a basic linear interpolation.

2.4. ERP Recording

Electrophysiological data were recorded at 2048 Hz with a BioSemi system, using 128 active Ag/AgCl electrodes, positioned according to the 10-10 convention. Data were resampled to 1024 Hz prior to analyses. The common mode sense (CMS) active electrode and the driven right leg (DRL) passive electrode were used as reference and ground electrodes, respectively (www.biosemi.com/faq/cms&drl.htm). Horizontal and vertical electrooculograms (EOGs) were monitored using four facial bipolar electrodes placed on the outer canthi of each eye and in the inferior and superior areas of the left orbit.

Noisy electrodes were replaced by means of spherical interpolation. Data were re-referenced offline to the global average reference (average of all electrodes except for the EOGs) and filtered using a 30 Hz (48 dB/oct) low-pass and 0.01 Hz (12 dB/oct) high-pass zero phase shift filter. Data from a preliminary block in which participants were asked to make specific eye movements and blinks were visually inspected and non-ocular artefacts were discarded. Ocular correction was conducted using Independent Component Analysis (ICA, computed using the AMICA procedure; Palmer, Makeig, Kreutz-Delgado, & Rao, 2008). Data were then segmented into large epochs centred on noun onset starting from 200 ms before stimulus onset and until 800 ms after stimulus onset. Following this, EEG signals were visually inspected and remaining noisy epochs were discarded. After baseline correction relative to a 200 ms pre-stimulus interval, epochs were averaged in each of the four conditions (Mean number of trials = 75 +/- 15) and grand-averages were computed.

2.5. Experimental Design and Statistical Analyses

Behavioural accuracy was analysed using generalised linear mixed models, for which the fixed factors were centred and sum-coded (Nieuwenhuis, te Grotenhuis & Pelzer, 2017). Fixed factors were Congruence (Congruent, Incongruent) and Alliteration (Alliterating, Non-alliterating), and the interaction between them. The closest-to-maximal random effects structure with correlations was modelled, consisting of a between-participant intercept and within-participant slopes of Congruence, Alliteration, and their additive contribution (1 + Congruence+Alliteration | participant), plus an intercept for word pairs (1 | WordPair). Reaction times were not analysed, given that participants were asked to provide a delayed response.

ERP mean amplitudes were analysed using repeated measures ANOVA with the factors Congruency (congruent, incongruent) and Alliteration (alliterating, non-alliterating) in the N400 time-window (300–500 ms over 11 centroparietal recording sites, consistent with our a priori expectations given the usual N400 topography: Kutas & Federmeier, 2011). Simple main effects analyses were conducted to further examine the interaction effect.

For the pupillometry data, a procedure similar to that employed by Mathôt et al. (2017) was used: The timeseries was split into time-bins of 10 ms, and generalised linear mixed effects models were run for each bin. The dependent variable was the change in pupil size modelled according to the fixed effects and the interaction between them. As with the accuracy data, the maximal random effects structure was implemented ((1 + Congruence*Alliteration | participant) + (1 | WordPair)). We considered an effect to be significant based on the t-as-z approach where $t > 1.96$ (approx. $\alpha = .05$) in 20 or more contiguous time bins for a minimum effect duration of 200 ms.

Finally, we correlated the N400 ERP amplitude with modulations in pupil size over time. For this analysis, we took mean N400 amplitudes for each participant per condition and correlated this value with changes in pupil size at each 20 ms time step over the course of the trial (2000 ms: i.e., longer presentation trials only).

Note that neither the study procedures nor the analyses were pre-registered prior to the research being conducted. We report how the sample size was determined, all data exclusions and inclusion/exclusion criteria, which were established prior to data analysis, all manipulations, and all measures in the study.

3. Results

3.1. Behavioural

Accuracy data revealed a significant fixed effect of congruency ($\beta = 1.54$, $SE = 0.19$, $z = 7.97$, $p < .001$), such that accuracy was lower for congruent ($M = 79.5$, $SD = 9.94$) than incongruent ($M = 94.58$, $SD = 10.37$) word pairs. We also found a significant main effect of alliteration ($\beta = 0.55$, $SE = 0.15$, $z = 3.62$, $p < .001$), with more errors for alliterating ($M = 84.83$, $SD = 11.79$) than non-alliterating pairs ($M = 89.25$, $SD = 13.18$). There was also an interaction between congruency and alliteration ($\beta = 1.48$, $SE = 0.15$, $z = 9.32$, $p < .001$), such that the difference between alliterating and non-alliterating stimuli was smaller for congruent than incongruent word pairs (**Figure 2**).

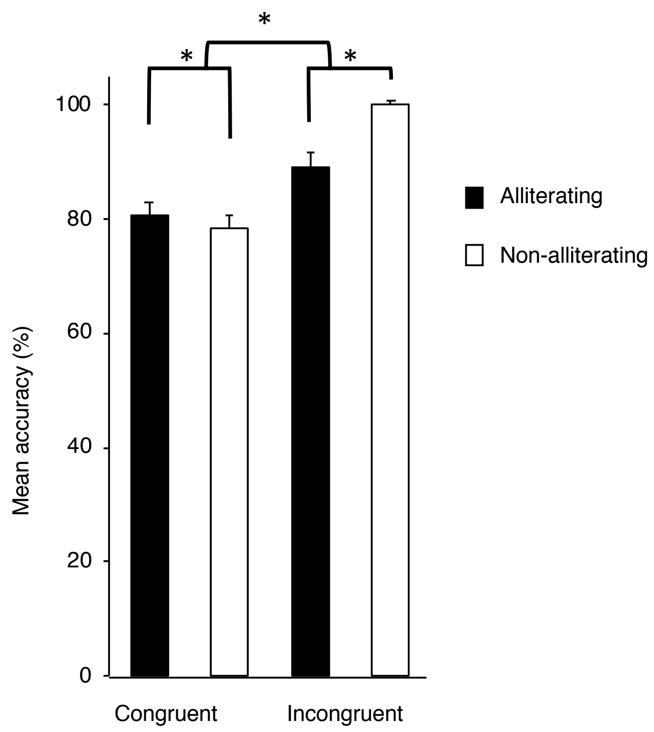

Figure 2. Behavioural accuracy, representing the mean number of trials upon which participants correctly reported that phrases 'made sense' or not. Error bars depict SEM.

3.2. ERP

In the N400 time-window there was a main effect of congruency ($F(1, 19) = 23.194$, $p < .001$, $\eta^2 = .55$), and of alliteration ($F(1, 19) = 9.116$, $p = .007$, $\eta^2 = .324$) on the mean ERP amplitudes, such that both congruency and alliteration tended to reduce N400 amplitude. A significant interaction between congruency and alliteration was also found ($F(1, 19) = 5.077$, $p = .036$, $\eta^2 = .211$), such that the effect of congruency for non-alliterating word pairs was significantly greater in magnitude than for alliterating word pairs (**Figure 3**).

3.3. Pupillometry

Congruency significantly modulated PD from 980–2000 ms, manifesting as a pupil size increase for congruent relative to incongruent word pairs (**Figure 3**). No other effects emerged.

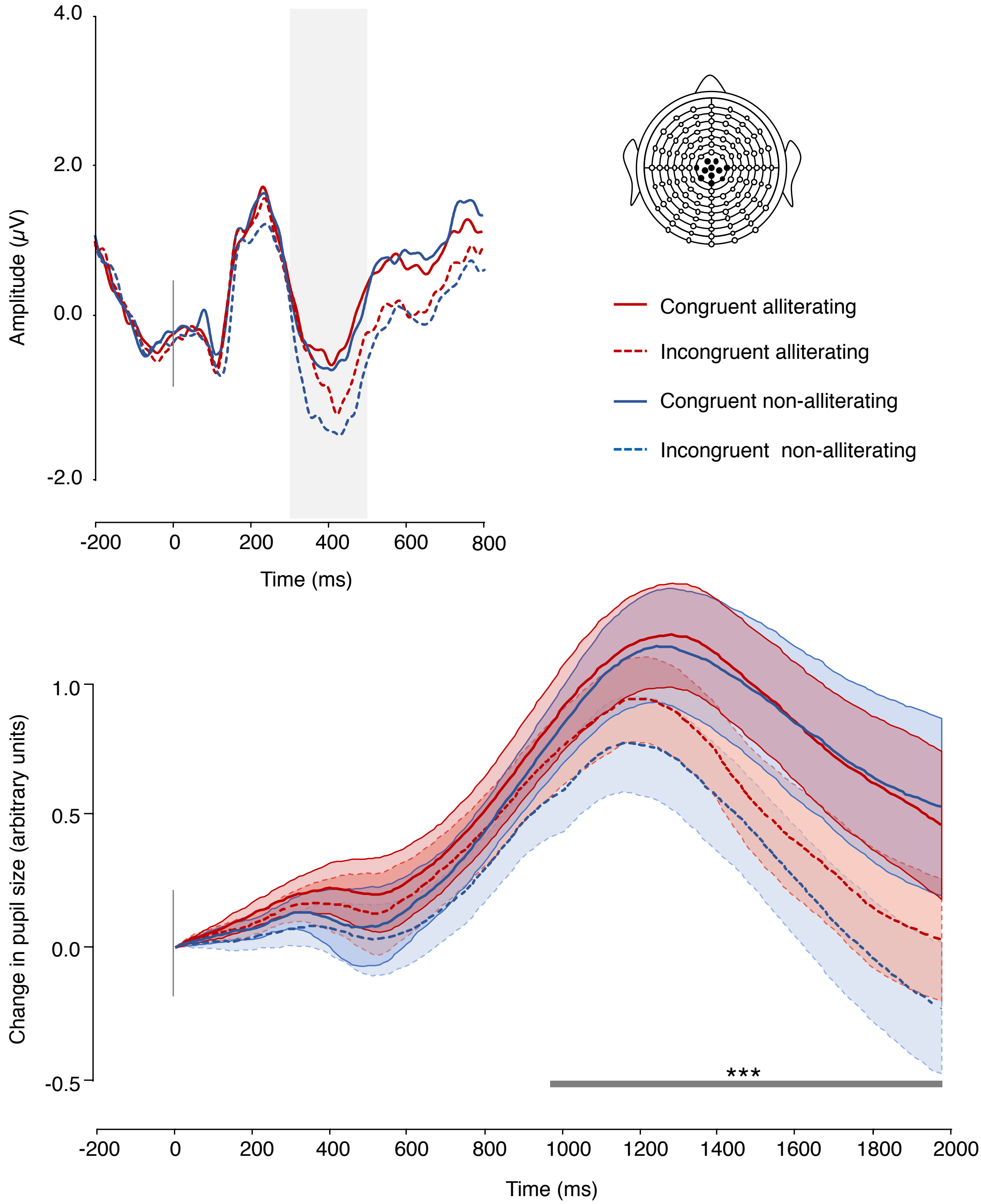

Figure 3. *Top*: Mean ERP amplitudes, the shaded bar representing the area of analysis; *Bottom*: mean pupil dilation change over time. SEM is indicated by the shaded areas for the pupil dilation data, as per usual convention. The grey line indicates the time-window in

which the main effect of congruency was significant. In both graphs, 0 ms on the time line represents noun onset.

3.4. Correlation analysis

We next examined the relationship between online semantic processing in the ERP signal and different stages of attentional engagement, reflected in the pupil dilation measure. Mean N400 value significantly correlated negatively with pupil size for incongruent non-alliterating trials between 400–800 ms (early time window), and beyond 800 ms for congruent alliterating trials (late time window) after the former ceased to be significant.

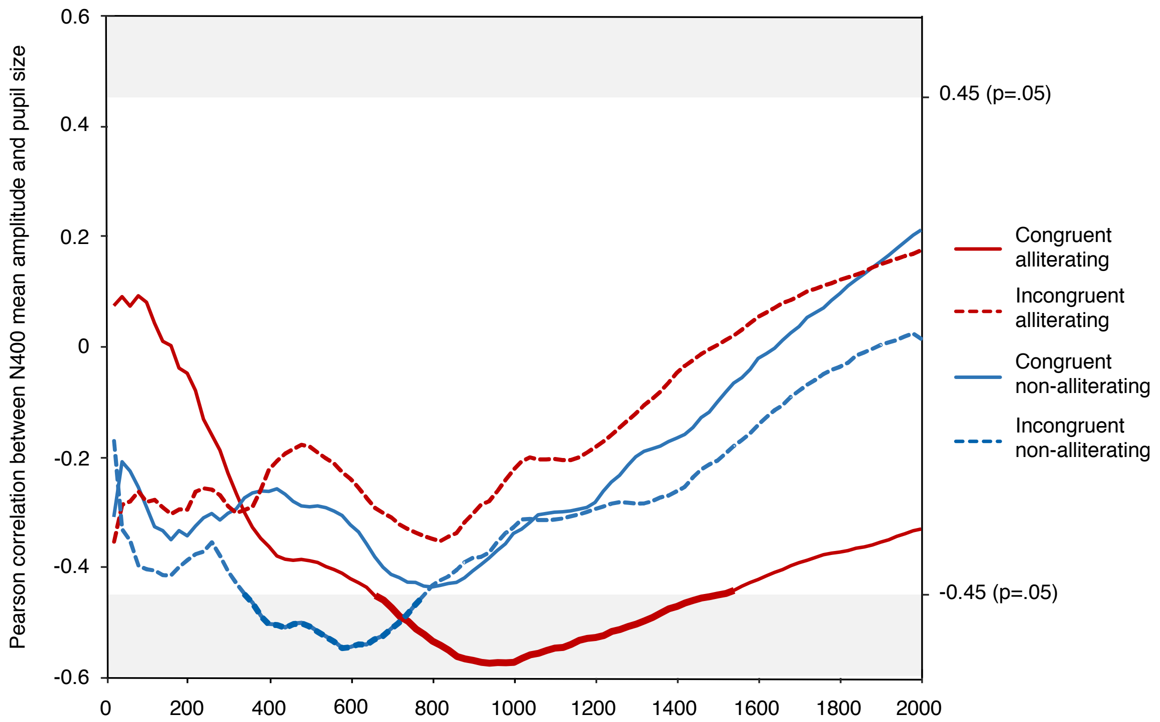

Figure 4. ERP-pupil dilation correlations at 20 ms time bins indicating Pearson correlation coefficients. Thicker lines indicate statistical significance (r > -0.45). Significance thresholds are indicated along the righthand Y-axis.

4. Discussion

Here, we examined how alliteration influences the interplay of semantic and attentional processes during reading as indexed by brain potentials and pupil dilation. We show that (a) alliteration tends to decrease N400 amplitude in the case of unrelated words, (b) semantic relatedness increases PD, and (c) alliteration and semantic relatedness interact such that PD increase is particularly sustained for related words within a phrase.

In the behavioural data, participants were highly accurate in rejecting incongruent phrases (e.g., *creepy-diamond*), as it is easier to assess two concepts as being unrelated than verifying a link between them, this has been previously shown in similar studies (Wu, Athanassiou, Dorjee, Roberts, & Thierry, 2011; Boutonnet, McClain, & Thierry, 2014). However, accuracy was reduced when incongruent phrases were also alliterating (e.g., *dangerous-diamond*), suggesting that alliteration compromised participants' ability to judge a phrase as incongruent. ERP data showed that this uncertainty in the behavioural judgement was underpinned by semantic-level evaluation rather than superficial meta-cognitive judgement. Consistent with a large body of ERP literature detailing the N400 effect (Kutas & Federmeier, 2011), our results showed a generally reduced N400 amplitude for congruent compared with incongruent pairs. However, incongruent alliterating pairs (e.g., *dangerous-diamond*) elicited a reduced N400 amplitude compared to incongruent non-alliterating pairs (e.g., *creepy-diamond*). Thus, when phrases were difficult to understand, repetition of the word-initial phoneme led the reader to consider the pairs as more congruent.

Surprisingly, the pupil dilation data showed the opposite pattern to the ERP data. Indeed, we observed significantly *larger* dilations for congruent than incongruent phrases, peaking at around 1200 ms post stimulus onset. Bearing in mind that the course of pupil dilation manifests as a biphasic pattern, reflecting partially separable processes, this suggests that semantically congruent pairs elicited greater autonomic arousal compared with incongruent pairs (Mathôt, 2018; Hess & Polt, 1960). Whilst no other effects were statistically significant, visual inspection of the data presented in **Figure 3** suggests a trend in which incongruent alliterating phrases were again distinguished from their non-alliterating counterparts.[1]

Together, ERP and PD data suggest that alliteration modulates online semantic processing, with repercussions for participants' ability to accurately judge whether or not phrases were congruent. Our findings therefore lend support to the controversial idea that "similarity in sound can reflect similarity in meaning" (Hanauer, 1998; see also Jakobson, 1960), and also suggest that repetition of sound can lead to an *illusory* impression of meaning relatedness. Moreover, whilst Chen et al. (2016) recently showed that repetition of sound can boost access to meaning for congruent sentences in poetry, we show that it can influence semantics even in the case of absolute minimal phrasal constructions (see also Acheson & MacDonald, 2011 for a similar consideration in the case of declarative sentences).

In order to investigate how semantic integration further relates to attentional engagement, we examined the relationship between mean N400 amplitude and pupil dilation over the entire sequence of the noun duration. Incongruent non-alliterating trials (e.g., *creepy – diamond*) showed early, pronounced negative correlations, which likely reflect an early attentional orienting response to the most semantically challenging condition (Mathôt, 2018; Wetzle et al., 2015). In a second phase, a negative correlation for congruent alliterating stimuli (e.g., *dazzling-diamond*) peaked at ~1000 ms. We tentatively interpret this sustained effect as an indication that semantically and phonologically congruent pairs heighten arousal and interest beyond semantic and phonological links considered separately.

[1] Given that we recorded EEG and pupil dilation simultaneously, we could not impose head restraint – which would have improved PD measures' reliability – without compromising EEG data quality. Thus, a number of trends in the PD data possibly did not reach statistical significance because of the ensuing variance.

4.1. Conclusion

In sum, we show that stylistic manipulation of written phrases not only affects semantic processing and attentional orienting, but leads to dynamic interaction between the two. When semantic processing is difficult, inter-word alliteration can incur the illusion of meaning relatedness, which leads to attenuated online processing effort and more errors. And when semantic processing is relatively easy – as in the case of congruent pairs – increased depth of semantic processing leads to sustained cortical arousal. Our findings are consistent with recent evidence for substantial effects of sound symbolism in language comprehension (e.g., Perniss et al., 2010; Monaghan et al., 2014; Asano, et al., 2015), but they also demonstrate for the first time that form-meaning interactions can occur between as well as within words. These data elucidate a key mechanism in neurocognitive poetics: Previous studies examining the cognitive effects of stylized text have reported increased reader engagement as shown separately by slower reading times on the one hand (e.g., van den Hoven, Hartung, Burke, & Willems, 2016) and larger pupil dilation on the other (Scheepers, Mohr, Fischer, & Roberts, 2013). However, our study is the first to show that extracting meaning from stylized text is crucial in engaging the reader's interest, providing empirical explanation for why stylistic prose is 'savoured' (Jacobs, 2015).

Disclosure of interest

The authors declare no competing financial interests.

Acknowledgments

MWJ is an associate member of the Welsh National College (colegcymraeg.ac.uk).

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix A. Supplementary material

Research data, code and digital materials for this article:
https://osf.io/c8n93/?view_only=9e0d54a66ff24d7682df081691b2d8e4

References

Acheson, D. & MacDonald, M. (2011). The Rhymes that the Reader Perused Confused the Meaning: Phonological Effects during On-line Sentence Comprehension. *Journal of memory and language.* 65(2), 193-207. DOI: 10.1016/j.jml.2011.04.006

Asano, M., Imai, M., Kita, K., Kitajo, K., Okada, H. & Thierry, G. (2015). Sound symbolism scaffolds language development in preverbal infants. *Cortex.* 63, 196-205, https://doi.org/10.1016/j.cortex.2014.08.025.

Boutonnet, B., McClain, R. & Thierry, G. (2014). Compound words prompt arbitrary semantic associations in conceptual memory. *Frontiers in Psychology.* DOI: https://doi.org/10.3389/fpsyg.2014.00222

Breen, M., Dilley, L. C., McAuley, J. D., & Sanders, L. D. (2014). Auditory evoked potentials reveal early perceptual effects of distal prosody on speech. *Language, Cognition and Neuroscience.* 29, 1132–1146.

Brown, M., Salverda, A. P., Dilley, L. C., & Tanenhaus, M. K. (2015). Metrical expectations from preceding prosody influence perception of lexical stress. *Journal of Experimental Psychology: Human Perception and Performance.* 41, 306–323.

Carminati, M., Stabler, J., Roberts, A., Fischer, M. (2006) Readers' responses to sub-genre and rhyme scheme in poetry. *Poetics.* 34: 204–218. DOI: 10.1016/j.poetic.2006.05.001.

Chen, Q., Jingjing, Z., Zu, X., Scheepers, C., Yang, T. & Tanenhaus, M. (2016). Prosodic expectations in silent reading: ERP evidence from rhyme scheme and semantic congruence in classic Chinese poems. *Cognition.* 154, 11-21.

Chwilla, D., Brown, C. & Hagoort, P. (1995). The N400 as a function of the level of processing. *Psychophysiology.* 32(3), https://doi.org/10.1111/j.1469-8986.1995.tb02956.x

Culler, J. (1975). *Structuralist poetics: Structuralism, linguistics and the study of literature*. London: Routledge.

Gasser, M. (2004). The Origins of Arbitrariness in Language. *Proceedings of the Annual Meeting of the Cognitive Science Society,* 26(26).

Geng JJ, Blumenfeld Z, Tyson TL and Minzenberg MJ (2015). Pupil diameter reflects uncertainty in attentional selection during visual search. *Front. Hum. Neurosci*. 9:435. doi: 10.3389/fnhum.2015.00435

Hanauer, D. (1998). The genre-specific hypothesis of reading: Reading poetry and encyclopedic items. *Poetics.* 26(2), 63-80. https://doi.org/10.1016/S0304-422X(98)00011-4

Hess, E. & Polt, J. (1960). Pupil size as related to interest value of visual stimuli. *Science.* 132(3423), 349-350.

Jacobs, A. (2015). Neurocognitive poetics: methods and models for investigating the neuronal and cognitive-affective bases of literature reception. *Frontiers in Human Neuroscience.* 9(186), doi: 10.3389/fnhum.2015.00186

Jakobson, R. (1960). Linguistics and poetics. In T. Sebeok (Ed.), *Style in language* (pp. 350–377). Cambridge, MA: MIT Press.

Kang, O., Huffer, K. & Wheatley, T. (2014). Pupil Dilation Dynamics Track Attention to High-Level Information. *PLOS ONE.* 9(8), https://doi.org/10.1371/journal.pone.0102463

Kovic, V., Plunkett, K. & Westermann, G. (2010). The shape of words in the brain. *Cognition.* 114(1). 19-28, doi: 10.1016/j.cognition.2009.08.016.

Kuipers, J. & Thierry, G. (2011). N400 amplitude reduction correlates with an increase in pupil size. *Frontiers in human neuroscience*, 5(61). doi:10.3389/fnhum.2011.00061

Kuipers, J. & Thierry, G. (2013). ERP-pupil size correlations reveal how bilingualism enhances cognitive flexibility. *Cortex.* 49(10), doi: 10.1016/j.cortex.2013.01.012.

Kutas, M., & Federmeier, K. (2011). Thirty years and counting: finding meaning in the N400 component of the event-related brain potential (ERP). *Annual review of Psychology.* 62, 621-47. doi: 10.1146/annurev.psych.093008.131123.

Lupyan, G. & Winter, B. (2018). Language is more abstract than you think, or, why aren't languages more iconic? *Philosophical Transactions of the Royal Society B: Biological Sciences,* 373(1752). https://doi.org/10.1098/rstb.2017.0137

Mathôt, S. (2018). Pupillometry: Psychology, Physiology, and Function. *Journal of Cognition.* doi:10.5334/joc.18

Mathôt, S., Fabius, J., Heusden, E., & Van der Stigchel, S. (2018). Safe and sensible preprocessing and baseline correction of pupil-size data. *Behavior Research Methods.* doi:10.3758/s13428-017-1007-2

Mathôt, S., Grainger, J., & Strijkers, K. (2017). Pupillary responses to words that convey a sense of brightness or darkness. *Psychological Science.* doi:10.1177/0956797617702699

Monaghan, P., Shillcock, R. C., Christiansen, M. H., & Kirby, S. (2014). How arbitrary is language? *Philosophical Transactions of the Royal Society B: Biological Sciences,* 369(1651), https://doi.org/10.1098/rstb.2013.0299

Nieuwenhuis, R., Grotenhuis, M., te, & Pelzer, B. (2017). Weighted Effect Coding for Observational Data with wec. *The R Journal*, 9(1), 477. https://doi.org/10.32614/RJ-2017-017

Obermeier, C., Menninghaus, W., von Koppenfels, M., Raettig, T., Schmidt-Kassow, M., Otterbein, S. & Kotz, S. (2013). Aesthetic and emotional effects of meter and rhyme in poetry. *Frontiers in Psychology.* 4(10), doi: 10.3389/fpsyg.2013.00010

Palmer, J., Makeig, S., Kreutz-Delgado, K. & Rao, B. (2008). Newton method for the ICA mixture model. ICASSP, IEEE *International Conference on Acoustics, Speech and Signal Processing - Proceedings.* 1805-1808. 10.1109/ICASSP.2008.4517982.

Perniss, P. & Vigliocco, G. (2014). The bridge of iconicity: from a world of experience to the experience of language. *Philosophical Transactions of the Royal Society B: Biological Sciences.* 369, https://doi.org/10.1098/rstb.2013.0300

Perniss, P., Thompson, R. L., & Vigliocco, G. (2010). Iconicity as a general property of language: evidence from spoken and signed languages. *Frontiers in Psychology,* 1, 227. doi:10.3389/fpsyg.2010.00227

Saussure, F. (1916). *Course in General Linguistics.* London: Duckworth.

Scheepers, C., Mohr, S., Fischer, M. & Roberts, A. (2013). Listening to Limericks: a pupillometry investigation of perceivers' expectancy. *PLoS One.* 8(9), doi:10.1371/journal.pone.0074986.

Sedley, D. N. (2003). *Plato's Cratylus.* Cambridge, UK: Cambridge University Press.

Tillmann, B. & Dowling, W. (2007). Memory decreases for prose, but not for poetry. *Memory & Cognition.* 35(4), 628-639.

van den Hoven, E., Hartung, F., Burke, M. & Willems, R. (2016). Individual Differences in Sensitivity to Style During Literary Reading: Insights from Eye-Tracking. *Collabra.* 2(1), 25. DOI: http://doi.org/10.1525/collabra.39

Vaughan-Evans, A., Trefor, R., Jones, L., Lynch, P., Jones, M. & Thierry, G. (2016) Implicit Detection of Poetic Harmony by the Naïve Brain. *Frontiers in Psychology.* (7)1859. doi: 10.3389/fpsyg.2016.01859

Wang, C. & Munoz, D. (2015). A circuit for pupil orienting responses: implications for cognitive modulation of pupil size. *Current Opinion in Neurobiology.* 33, 134-40. doi: 10.1016/j.conb.2015.03.018.

Wetzel N, Buttelmann D, Schieler A, Widmann A. (2016). Infant and adult pupil dilation in response to unexpected sounds. Dev Psychobiol. 58(3):382-92. doi: 10.1002/dev.21377

Wu, y., Athanassiou, S., Dorjee, D., Roberts, M. & Thierry, G. (2011). Brain Potentials Dissociate Emotional and Conceptual Cross-Modal Priming of Environmental Sounds. *Cerebral Cortex.* 22(3), 577-583. DOI: 10.1093/cercor/bhr128

Yaron, I. (2002). Processing of obscure poetic texts: Mechanisms of selection. *Journal of Literary Semantics.* 31(2), 133-170, DOI: https://doi.org/10.1515/jlse.2002.013.