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Implicit detection of poetic harmony by the naïve brain

Running title
Spontaneous recognition of poetry

Authors
Awel Vaughan-Evans , Robat Trefor , Llion Jones , Peredur Lynch , Manon W. Jones
and Guillaume Thierry

Affiliation
  School of Psychology, Bangor University, Bangor, Gwynedd, UK, LL57 2AS;
  School of Welsh, Bangor University, Bangor, Gwynedd, UK, LL57 2DG;
  Canolfan Bedwyr, Bangor University, Bangor, Gwynedd, UK, LL57 2DG.

Correspondence:
Guillaume Thierry
School of Psychology
Adeilad Brigantia
Penrallt Road
Gwynedd LL57 2AS
United Kingdom
Telephone +44 (0) 1248 388348
Email: g.thierry@bangor.ac.uk

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29   **Abstract**
30   The power of poetry is universally acknowledged, but it is debatable whether its
31   appreciation is reserved for experts. Here we show that readers with no particular
32   knowledge of a traditional form of Welsh poetry unconsciously distinguish phrases
33   conforming to its complex poetic construction rules from those that violate them. We
34   studied the brain response of native speakers of Welsh as they read meaningful
35   sentences ending in a word that either complied with strict poetic construction rules,
36   violated rules of consonantal repetition, violated stress pattern, or violated both these
37   constraints. Upon reading the last word of each sentence, participants indicated sentence
38   acceptability. As expected, our inexperienced participants did not explicitly distinguish
39   between sentences that conformed to the poetic rules from those that violated them.
40   However, in the case of orthodox sentences, the critical word elicited a distinctive brain
41   response characteristic of target detection –the P3b– as compared to the other
42   conditions, showing that speakers of Welsh with no expertise of this particular form of
43   poetry implicitly detect poetic harmony. These results show for the first time that before
44   we even consider literal meaning, the musical properties of poetry speak to the human
45   mind in ways that escape consciousness.
46
47   **Keywords:**
48   **Language, neuroaesthetics, poetry, event-related potentials, P3b**
49

Introduction

T.S. Eliot famously argued that "genuine poetry can communicate before it is understood" (Scofield, 1988; pp2). Was this an attempt to provoke controversy or can some aspects of poetry indeed be processed implicitly and independently of meaning? Poetry is a literary expression of feelings, thoughts and ideas, traditionally accentuated by metric constraints, rhyme, and alliteration. Recent scientific research looking into the effects of poetry has highlighted emotional responses to rhyme (Obermeier et al., 2013) and better memory recall as a result of alliteration (Hanauer, 2001; Lea et al., 2008). Rhyme violations, in particular, have been shown to increase pupillary responses (Scheepers et al., 2013) and modulate the amplitude of the N400, a brain potential index of semantic processing (Hoorn, 1996). Whilst there is little doubt that some poetic forms, often centuries old, impact human cognition (see Jacobs, 2015, for a recent review), we have yet to discover the extent to which such sensitivity may rely on automatic and implicit neural processing.

Here, we investigated event-related brain potentials (ERPs) elicited by the final word of sentences written in *Cynghanedd* ('harmony' in Welsh), an ancient poetic form that requires precise consonantal repetition (and/or internal rhyme) in conjunction with distinct stress patterns (Greene, 2012). In certain sub-types of Cynghanedd, consonants are repeated across the first and second parts of the line, and are always in the same order: *A daeth i ben | deithio byd* ('And it came to an end | travelling the world', as cited in Llwyd, 2010, critical consonants in bold). A line such as **A daeth i ben | deithio cwm* ('And it came to an end | travelling the valley') features a 'c' rather than a 'b', which constitutes a consonantal repetition violation. Traditional Cynghanedd rules also dictate a precise stress pattern: *Ein lluniaeth | a'n llawenydd* ('Our sustenance and joy', Llwyd, 2010, stress vowels underlined and critical consonants in bold). In contrast, the line **Ein lluniaeth | a'n llu newydd* ('Our sustenance and new host') violates traditional rules because 'n' in part one comes after the stress, but 'n' in part two precedes the final stress. Cynghanedd sentences thus consist of foregrounding features at the sublexical (phonological salience) and lexical (stress pattern) levels (Jacobs, 2015). Each of these features is known to independently influence aesthetic appreciation (e.g. Aryani, Jacobs & Conrad, 2013; Ch en, Zhang, Xu, Scheepers, Yang & Tanenhaus, 2016), but their interactive effect is unclear. In the present investigation, test sentences were constructed which either adhered to the rules of Cynghanedd, or violated its rules in terms of consonantal repetition, stress pattern, or both consonantal repetition and stress pattern (Table 1). Each condition was pseudo-randomly presented in equal proportion, resulting in an oddball paradigm with Cynghanedd-orthodox sentences occurring only 25% of the time.

The P3b is an ERP component commonly observed during oddball paradigms thought to reflect a context-updating process whereby a comparison is made between the currently processed stimulus, and the previous representation held in working memory (see Polich, 2007, for a review*)*. We anticipated that participants would show greater P3b amplitudes when singling out the infrequent target combination of consonantal repetition and stress pattern conforming to Cynghanedd from the other three non-Cynghanedd conditions. We were keen to know, however, whether such potential detection of the Cynghanedd-orthodox targets would be accompanied by signs of conscious evaluation as indexed by behavioral data and at debriefing.

Materials and methods
102   **Participants**
103   Twenty-five fluent native speakers of Welsh (9 males; 16 females), with no prior
104   knowledge of the rules of Cynghanedd, were included in the analysis. Of the initial
105   participant pool, one participant was excluded due to prior knowledge of Cynghanedd
106   and its underlying rules; two participants were excluded as they had too few
107   uncontaminated epochs per condition; and a further four participants were removed as a
108   result of overall excessive noise in the data. All participants possessed normal or
109   corrected-to-normal vision. Ethical approval was granted by the School of Psychology,
110   Bangor University ethics committee, and participants gave written consent before the
111   experiment session started.
112
113   **Stimuli and procedure**
114   Experimental sentences belonged to 36 sets each consisting of four sentences, resulting
115   in a total of 144 sentences. Twenty-five percent of the experimental sentences followed
116   the rules of Cynghanedd whilst the remaining 75% violated the Cynghanedd rules in
117   terms of consonantal repetition (25%), stress pattern (25%), or both consonantal
118   repetition and stress pattern (25%; see Table 1). The experiment thus conformed to a
119   classical oddball paradigm with Cynghanedd as the target condition. Where possible,
120   sentence final words were rotated across conditions. However, due to the strict rules of
121   Cynghanedd, it was not possible to fully rotate all items between conditions. Word
122   frequency (from the *Cronfa Electroneg o Gymraeg*; Ellis et al., 2001) and length did not
123   differ significantly between conditions ($F(3,140) = 1.86$, $p = 0.14$; $F(3,140) = 0.76$, $p =$
124   0.52).
125
126   *IInsert Table 1 about herel*
127
128   Participants viewed all 144 sentences in three sections, segmented such that they
129   adhered to the natural rhythm of the Cynghanedd line, with the final, critical word
130   presented in isolation. On each trial, the first two segments were presented for 500ms
131   each, with an inter-stimulus interval (ISI) of 300ms. A varying ISI (ranging between
132   400-700ms) was used between the second segment and the sentence final word, which
133   remained on the screen for a maximum of 2000ms, or until a response was made,
134   whichever was the shortest (Figure 1). Presentation order was pseudorandomized, such
135   that sentences from the same sentence set never appeared in the same experimental
136   block. Upon presentation of the final word, participants were asked to indicate as
137   quickly and as accurately as possible, whether or not the sentence sounded 'good' by
138   pressing designated buttons on a serial response box. Upon completion of the
139   experimental task, participants were presented with a list of the 36 sentence sets and
140   were asked to rank the sentences in each set in a decreasing order of preference (1 =
141   most preferred; 4 = least preferred).
142
143
144   *| Insert Figure 1 about here |*
145
146
147   **ERP recording**
148   Electrophysiological data was recorded from 32 Ag/AgCl electrodes set according to
149   the extended 10-20 convention at a rate of 1 kHz in reference to the left mastoid. The
150   electroencephalogram (EEG) activity was filtered online with a band-pass filter between
151   0.1-200 Hz and again offline with a band-pass zero-phase shift filter set between 0.1-

152 20Hz. Eye blink artifacts were modeled and mathematically corrected (Gratton et al.,
153 1983) and remaining artifacts were removed manually. Epochs ranging from -100 to
154 1,000ms after the onset of the target word were extracted from continuous EEG
155 recordings. Epochs with activity exceeding ±75µV at any electrode site were
156 automatically discarded. There was a minimum of 30 epochs per condition for every
157 participant. Baseline correction was performed in reference to pre-stimulus activity, and
158 individual averages were digitally re-referenced to the algebraic mean of the left and
159 right mastoids.
160
161 **Data analysis**
162 For the online categorization task, the percentage of 'good' responses was analyzed by
163 means of a one-way repeated measures analysis of variance (ANOVA) with 'Sentence
164 Type' (Cynghanedd, Consonantal violation, Stress violation, Double violation) as an
165 independent variable. Reaction times were analyzed by means of a two (Categorization:
166 'good', 'not good') -by-four (Sentence Type: Cynghanedd, Consonantal violation,
167 Stress violation, Double violation) repeated measures ANOVA.
168
169 For the offline ranking task, responses were scored such that they were given a 1 if they
170 correctly ranked Cynghanedd sentences as the 'best' sentence, and a 0 if they did not.
171 Responses were then analyzed by means of a one-sample t-test.
172
173 For the ERP data, P3b mean amplitude was predictively extracted between 240-340ms
174 at six electrodes where the P3b is known to be maximal in amplitude (CP3, CPz, CP4,
175 P3, Pz, P4) and maximal sensitivity was verified by inspecting the global field power
176 produced across the scalp in the Cynghanedd condition. P3b mean amplitudes were
177 analyzed by means of a one-way repeated measures ANOVA with 'Sentence Type'
178 (Cynghanedd, Consonantal violation, Stress violation, Double violation) as an
179 independent variable. Post-hoc tests were conducted using Bonferroni corrections.
180
181 <div align="center">**Results**</div>
182 **Behavioral results**
183 **Online categorization task.**
184 We found a significant main effect of Sentence Type; $F(3,72) = 8.63$, $p < 0.001$, $n^2_p =$
185 .26 (Figure 2.a.). Pairwise comparisons revealed that Cynghanedd sentences were more
186 likely to be categorized as 'good' ($M = 65\%$; 95% CI [60, 70]) compared with
187 Consonantal violation sentences ($M = 58\%$; 95% CI [51, 65]; $p = 0.005$) and Stress
188 violation sentences ($M = 55\%$; 95% CI [50, 60], $p < 0.001$), but not Double violation
189 sentences ($M = 63\%$; 95% CI [58, 69], $p = 0.38$). Furthermore, Double violation
190 sentences were more likely to be categorized as 'good' than Consonantal violation
191 sentences ($p = 0.04$) and Stress violation sentences ($p = 0.001$). Comparisons of
192 categorization score against chance revealed that responses significantly differed from
193 chance for Cynghanedd, the Double violation condition, and the Consonantal violation
194 condition ($t(24) = 2.325$, p = .029), but not the Stress violation condition ($t(24) = 1.905$,
195 p = .069). Critically, whereas the greater than chance performance in the Cynghanedd
196 condition was felicitous (these were the Cynghanedd-orthodox sentences), it was
197 infelicitous in the Double violation and the Consonantal violation conditions.
198
199 For the reaction time data, a main effect of Categorization was found ($F(1,24) = 33.58$,
200 $p < .001$, $n^2_p = .58$; Figure 2.b.): Sentences that were perceived as 'good' were
201 responded to faster ($M = 653$ms, 95% CI [568, 738]) than sentences perceived as 'not
202 good' ($M = 774$ms, 95% CI [678, 869]). There was also a main effect of Sentence Type

203 (F(3,72) = 3.24, p = 0.03, n^2_p = .12), but none of the corrected pairwise comparisons
204 reached significance.
205
206 **Offline sentence ranking task.**
207 A one sample t-test revealed that participants did not rank Cynghanedd sentences as the
208 best option significantly better than chance ($M_{accuracy}$ = 28%; t(24) = 1.87, p = 0.07).
209 Since this result was approaching significance, we further tested whether participants
210 showed any inclination to rank Cynghanedd sentences in the top two choices by coding
211 the response as 1 if Cynghanedd sentences were ranked 1st or 2nd, or as 0 if Cynghanedd
212 sentences were ranked 3rd or 4th. In this case, a one sample t-test revealed that
213 participants did perform significantly greater than chance on this task ($M_{accuracy}$ = 62%;
214 t(24) = 6.93, p < 0.001).
215
216 | *Insert Figure 2 about here* |
217 | *Insert Figure 3 about here* |
218
219 **Electrophysiological data.**
220 We found a significant main effect of Sentence Type; F(3,72) = 3.149, p = 0.03, n^2_p =
221 .12; with Cynghanedd sentences eliciting greater mean amplitudes (M = 5.93, 95% CI
222 [4.86, 7.01) than Consonantal violation sentences (M = 5.01, 95% CI [3.92, 6.10]; p =
223 0.01), Stress violation sentences (M = 4.88, 95% CI [3.58, 6.17]; p = 0.002), and Double
224 violation sentences (M = 5.00, 95% CI [3.90, 6.09]; p = 0.007), respectively (Figure 3).
225 Analyses in earlier time windows (P1 & N1) did not show any significant differences as
226 a result of the experimental conditions. As expected the distribution of the effect was
227 centroparietal (Figure 4). Furthermore, the topographic maps show that participants
228 were not sensitive to the consonantal repetition and stress pattern rules when presented
229 independently; rather, they were only sensitive to constructions that complied with *both*
230 consonantal repetition and stress pattern rules.
231
232 Upon visual inspection, the topography of the P3 appeared to be right-lateralized, whilst
233 the experimental effect seemed more left-lateralized. In order to determine whether the
234 interaction was significant, we conducted an additional ANOVA, with Sentence Type
235 (Cynghanedd, Consonantal violation, Stress violation, Double violation) and
236 'Laterality' (Left [CP3;P3], Right [CP4;P4]) as independent variables. We found a
237 significant effect of Laterality; F(1,24) = 27.66, p < .001, n^2_p = .54, with greater P3b
238 mean amplitudes elicited on the Right (M = 6.05, 95% CI [5.01, 7.09]) than on the Left
239 (M = 4.37, 95%CI [3.39, 5.36]). The Sentence Type * Laterality interaction did not
240 reach significance (F(1,24) = 1.05, p = .377, n^2_p = .04), however, indicating that the
241 experimental effect was not modulated by electrode site.
242
243 | *Insert Figure 4 about here* |
244
245   **Discussion**
246 Here we investigated whether naïve readers of a traditional form of Welsh poetry are
247 able to unconsciously distinguish phrases conforming to its poetic construction rules
248 from those that violate them. In line with our predictions, words correctly completing a
249 sentence in Cynghanedd elicited significantly greater P3b mean amplitudes than words
250 completing other sentence types, indicating a shift of attention associated with target
251 recognition (Polich, 2007).
252

253 The P3b modulation observed here had a typical centroparietal distribution and a time-
254 range comparable to that observed in simple target detection tasks, consistent with the
255 classic P3b effect (Knight, 1996). Thus, participants' brains treated correct completion
256 words as targets and implicitly categorized Cynghanedd-orthodox sentences as
257 sounding 'good' compared to sentences violating its construction rules. Strikingly,
258 however, and in contrast with ERP results, participants showed no overt knowledge or
259 conscious awareness of Cynghanedd rules in the online categorization task since (a)
260 they failed to discriminate between Cynghanedd and Double Violation sentences, and
261 (b) their performance was either at chance level (Stress violation condition) or
262 infelicitous with regard to Cynghanedd rules in the other violation conditions. There
263 was some differentiation between sentence types, with participants rating Cynghanedd
264 sentences as sounding better than those from single violation conditions. It is possible
265 that this difference occurred due to participants perceiving the rule violations in these
266 conditions, however this interpretation cannot account for the fact that participants did
267 not consider Cynghanedd sentences as sounding better than Double violation sentences.
268 Participants did, however, demonstrate a preference towards Cynghanedd sentences
269 during the offline judgement task. Given that the ranking task was of a very different
270 nature to the online task (involving direct comparison between the different alternatives
271 of each sentence) and that it was not time constrained, it is highly likely that participants
272 changed cognitive strategy in this task, and focused on elements of the stimuli that were
273 not attended to during the online categorization task.
274
275 Interestingly, the results of the online decision task are somewhat incongruent with
276 recent research emphasizing the influence of foregrounded features on aesthetic
277 appreciation (Aryani, Jacobs & Conrad, 2013). For example, Aryani et al., (2013)
278 demonstrated, via use of a text analysis tool, that the salience of particular sublexical
279 features (e.g., phonological repetition) correlates with the semantic and aesthetic
280 properties of poetic phrases. Given that a 'sound good' judgment could be influenced by
281 such foregrounding properties, Cynghanedd and Stress violation sentences should be
282 judged as 'good' more than the other two sentence types, but this was not the case in our
283 data. Whilst participants considered Cynghanedd sentences as sounding better than
284 those from single violation conditions, they did not consider Cynghanedd sentences as
285 sounding better than Double violation sentences. This finding could be interpreted in
286 one of two ways; 1) the consonantal repetition manipulation was too subtle to influence
287 participants' explicit judgments, or 2) the 'sound good' decision task implemented in
288 this study did not depend on the affective qualities of the repeated phonemes. In
289 addition, the ERP results suggest that appreciation of Cynghanedd depends on a
290 combination of subtle consonantal repetition *and* stress pattern, rather than consonantal
291 repetition alone.
292
293 The P3b effect observed here may be considered counter-intuitive, since P3b amplitude
294 is classically reduced with repeated occurrences of stimuli. Here, the presence of
295 consonantal repetition patterns in the Cynghanedd condition may have been expected to
296 reduce the amplitude of the P3b rather than increase it. Thus, the enhanced P3b response
297 to Cynghanedd appears to indicate a kind of attentional orienting response, specifically
298 when both the stress pattern and consonantal repetition rules are observed, thus making
299 this particular sentence a target. This is congruent with recent electrophysiological
300 evidence showing that lyrical stanzas that contain consistent meter *and* rhyme facilitate
301 processing compared with those that contain only one, or neither of these patterns
302 (Obermeier et al., 2016). Another recent study has shown that electrophysiological
303 responses to poetry can be modulated by prosodic elements (e.g., rhyme) alone (Chen,

304 Zhang, Xu, Scheepers, Yang & Tanenhaus, 2016). Our findings are somewhat
305 incongruent with this conclusion, since stress pattern alone failed to generate a main
306 effect on P3b mean amplitudes.
307
308 Recent eye-tracking studies have also shown that literary stylistic features in sentences
309 increase attentional engagement (see Jacobs, 2015, for a review). Our data crucially
310 show that this attentional orienting effect occurs as early as 240ms, and is therefore
311 likely to reflect implicit processing. Recall that participants were unable to overtly
312 identify the Cynghanedd forms, and we found no correlation between reaction times and
313 P3b mean amplitudes, contra previous findings (Conroy & Polich, 2007; Ramchurn et
314 al., 2014; but see McCarthy & Donchin, 1981). Thus, whereas previous studies have
315 shown that the explicit, aesthetic appreciation of poetry can be linked to implicit
316 responses (e.g. Jacobs, 2015; Obermeier et al., 2016), the current findings provide the
317 first tangible evidence that this link is permeable: our participants were able to *implicitly*
318 detect correct poetic forms, even though they could not *explicitly* differentiate between
319 conditions (cf. Renault, Signoret, Debruille, Breton & Bolgert, 1989).
320
321 Furthermore, despite the relatively complex nature of the processes underlying the
322 decision task, the observed P3b had a latency akin to that typical of simple shape-
323 matching tasks (Kok, 2001), occurring much earlier than typical responses to linguistic
324 stimuli (Kutas & Hillyard, 1980). This suggests that spontaneous recognition of poetic
325 harmony is a fast, sublexical process, and is not strategic nor cognitively effortful.
326 Finally, our findings show that the brain responds to *combinations* of poetic – or
327 foregrounding - features at the sublexical (phonological salience) and the lexical (stress
328 pattern) levels (cf. Jacobs' 2015 4x4 model of neurocognitive poetics). That is, our data
329 suggest that the interactive effects of poetic features are more potent than that of
330 features presented in isolation.
331
332 Taken together, our results demonstrate the ability of the human brain to process poetic
333 forms spontaneously, quickly, and implicitly, in the absence of any formal knowledge
334 or instruction regarding underlying construction rules. This study shows for the first
335 time that before we even consider literal meaning, the musical properties of poetry
336 instinctively speak to the human mind in ways that escape consciousness.
337

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Tables

405

Table 1. Experimental conditions

Sentence	Rule adherence	Condition label
Y geiriau brwd ger y bryn	Consonantal repetition+ Stress pattern+	Cynghanedd
Y geiriau brwd ger y bont	Consonantal repetition– Stress pattern+	Consonantal violation
Y geiriau brwd ger y border	Consonantal repetition+ Stress pattern–	Stress violation
Y geiriau brwd ger y clawdd	Consonantal repetition– Stress pattern–	Double violation

English translation: The fervent words near the hill / trees / border / bank

408

Figure legends

410
411 **Figure 1.** Structure of an experiment trial and response required from participants

412
413 **Figure 2.** Online categorization results. **(a)** Sentence categorization performance.
414 **(b)** Reaction times.

415
416 **Figure. 3** ERP results. P3b mean amplitudes elicited by all four sentence types were computed
417 and compared between 240-340 ms after the onset of the final word (grey box).

418
419 **Figure 4.** Topographic maps of ERP difference waves in the P3b analysis window (240-340ms
420 after the onset of the final word). *Cynghanedd* topographies depict differences between Double
421 violation and Cynghanedd conditions. *Correct stress patterns* topographies depict differences
422 between Double violation and Consonantal violation conditions. *Correct consonantal repetition*
423 topographies depict differences between Double violation and Stress violation conditions.