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Hemispheric asymmetries in "expert" processing of semantic relationships during reading

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Abstract

How does individual-level variation in experience and knowledge influence neural mechanisms recruited during real-time language comprehension? We used event-related brain potentials (ERPs) combined with lateralized visual presentations of critical sentence-final words to examine asymmetries in hemispheric processing as individuals who varied in their knowledge of the fictional world of Harry Potter (HP) read sentences about general topics / HP. HP sentence endings were either contextually supported, unrelated anomalies, or semantically related anomalies. Amongst HP "experts," both hemispheres were sensitive to contextual support, but only the right hemisphere (RH) was sensitive to the related anomaly manipulation. The exact pattern of results depended on the relationship (categorical vs event). Our findings are in line with accounts on which the left hemisphere (LH) activates narrow/specific semantic contents and the RH activates a broader range. We tentatively hypothesize that content experts may exploit these hemispheric differences in scope of activation.

Keywords: real-time language processing; ERPs; knowledge; individual differences; hemispheric asymmetries

Introduction

A major goal of cognitive science is to understand how experiences in the world interact with neural systems to shape human thinking and behavior. Critical to this aim is an understanding of how variation in experience may shape information processing, such as that in each of the two cerebral hemispheres. Despite the apparent import, little attention has been paid to how individual differences in experience and knowledge may shape the rapid, cascading processes involved in information processing, for example, during reading or listening to language in real time, in either hemisphere. The present study combines a detailed examination of individual differences in a knowledge domain with the study of how the two hemispheres contribute to meaning construction during real-time comprehension.

Access to world knowledge is a strong determinant of various aspects of sentence comprehension, with such knowledge guiding individuals as they process words in real time, incrementally and even anticipatorily (e.g., Kamide, Altmann, & Haywood, 2003; Hagoort, Hald, Bastiaansen, & Petersson, 2004). World knowledge, gleaned from experience, is likely to vary substantially from person to person. Investigations of language processing have largely neglected such variability, instead focusing on general cognitive abilities (reviewed in Boudewyn, 2015), such as working memory (e.g., Kim, Oines, & Miyake, 2018), cognitive control (e.g., Boudewyn, Long, & Swaab, 2015), and language proficiency (e.g., Pakulak & Neville, 2010).

Recent studies have aimed to fill this gap by focusing on a restricted domain of knowledge, the narrative world of Harry Potter, combined with event-related brain potential studies of reading. In Troyer and Kutas (2018), participants read sentences that were variously about general topics or about the narrative world of HP. The focus was on N400 amplitude (i.e., negative-going potentials peaking ~400 ms after the onset of a meaningful stimulus), which is notably sensitive to semantic manipulations, including the extent to which a word is supported by (or predictable from) a sentence context. Replicating a large number of studies (reviewed in Kutas & Federmeier, 2011), contextually supported words in control sentences elicited reduced N400 potentials compared to contextually unsupported words—regardless of individuals' degree of HP knowledge. By contrast, for HP sentences, the N400 effect of contextual support was dependent on individual-level HP knowledge, such that individuals with the greatest degree of knowledge showed the largest reductions in amplitude for contextually supported words, and individuals with little HP knowledge showed little to no difference between contextually supported vs. unsupported words. These findings provided the first empirical evidence that degree of domain knowledge can have a near-immediate influence on understanding contextually supported words in written sentences.

A subtler probe of the nature of the semantic contents involved in understanding language in real time has been the so-called related anomaly paradigm, in which individuals read sentences containing a word that is contextually inappropriate or anomalous but is somehow related to the sentence context or the most likely continuation. Federmeier and Kutas (1999a) used this paradigm to examine the extent to which individuals activate specific information that is shared between a predictable sentence continuation and another word from the same basic-level category. For example, in a sentence setting up an expectation for the word *palms*, participants might instead encounter *pines* (from the same category, trees) or *tulips* (from a different category, flowers). They found that N400 amplitudes were largest for between-category violations, smallest for expected continuations, and intermediate for within-category violations, supporting the claim that individuals rapidly (pre-)activate semantic features of the potentially upcoming predictable word.

Related anomaly paradigms coupled with ERP recordings have demonstrated that the brain is rapidly sensitive to

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different sorts of conceptual knowledge relevant for sentence processing (Kutas & Hillyard, 1984; Metusalem et al., 2012; Amsel et al., 2015; Rommers, Meyer, Praamstra, & Huettig, 2013). Metusalem and colleagues (2012), for example, examined the use of generalized knowledge about events in real-time sentence processing. People read short vignettes about various events, such as a hiking up a mountain, including sentence continuations that were linguistically expected (e.g., '*[The hikers] were awed by the view*'), anomalous but related to the event (e.g., *boots*), or anomalous and unrelated to the event (e.g., *scissors*). Results were similar to those of Federmeier & Kutas (1999a), with N400 potentials being largest for anomalous/unrelated words, smallest for expected words, and intermediate for anomalous but related words. Moreover, this pattern was similar in its timing and scalp distribution, being largest over central and parietal sites where N400 effects (e.g., of contextual support) are typically most prominent.

Troyer and Kutas (2020) combined the individual-differences approach (utilizing the narrative world of HP) with a related anomaly paradigm. They investigated HP sentences ending in contextually supported, unsupported but related, or unsupported and unrelated words. For half of the materials, words were from the same (fictional) category as the supported endings, and as a result, were believed to share a large number of semantic features (as in Federmeier & Kutas, 1999a). For the remaining half, words were related to the episode/event described by the sentence context (as in Metusalem et al., 2012). As expected, the degree to which related anomalies elicited reduced (i.e., more positive-going) N400 potentials was modulated by an individual's degree of HP knowledge. This held for both types of related anomalies (category- and event-related). These results provided strong evidence that the degree to which sentential contexts cue relevant knowledge (e.g., category- and event-related information) is rapidly modulated by differences in (in this case, fictional) world knowledge. In other words, world knowledge can have an immediate impact on word-by-word processing.

The ERP studies described above all used central visual presentation of words, one word at a time, to probe semantic processing during online language comprehension. As such, visual word-form information was available simultaneously to both cerebral hemispheres. However, it is well established that the hemispheres exhibit differences in processing of language and beyond. Perhaps most notably, the left hemisphere is critically (and perhaps even necessarily in typically-developing brains) involved in language production, while both hemispheres seem to be involved in language comprehension, including sensitivity to contextual support (e.g., Coulson, Federmeier, Van Petten, & Kutas, 2005). The left hemisphere (LH) has been linked to processing narrow, specific meanings, while the right hemisphere (RH) has been linked to weaker but broader activation of multiple meanings (the so-called "coarse semantic coding" hypothesis; Beeman et al., 1994). As for timing of information, LH has been argued to activate information in a more punctate fashion, while RH has been argued to keep information available for longer retention periods in a recognition memory paradigm (Federmeier & Benjamin, 1995). Within language comprehension, Federmeier (2007) has argued that the LH acts in a top-down, predictive fashion, rapidly anticipating likely upcoming words, while the RH acts in a more bottom-up, integrative fashion. To our knowledge, no prior studies have investigated how individual differences in world knowledge influence the relative contributions of the two cerebral hemispheres to word processing in written sentences in real time. In the current study, we aim to do just this.

To examine potential differences in how the two cerebral hemispheres contribute to real-time sentence comprehension, some researchers have used ERP reading studies combined with lateralized presentation of critical words. In this paradigm, individuals fixate centrally while critical words are presented ~2° to the right or left. Due to the contralateral organization of the human visual system, with the LH initially processing words from the right visual field (henceforth RVF), and the RH initially processing words from the left visual field (henceforth LVF), the lateralized word presentation paradigm results in initial stimulation of the contralateral hemisphere. This allows researchers to make inferences about potential differences between how the two cerebral hemispheres make sense of different types of meaningful information (reviewed in Banich, 2003).

In a lateralized presentation version of the Federmeier & Kutas (1999a) paradigm, the categorical related anomaly effect was evidenced only with RVF/LH presentation (Federmeier & Kutas, 1999b) whereas the event-related anomalies observed in Metusalem et al. (2012) were found only in the LVF/RH (Metusalem, Kutas, Urbach, & Elman, 2016). The lateralized studies therefore suggest that the category-related and event-related anomaly effects, respectively, might stem from neural mechanisms which involve (at least in part) different hemispheres.

These findings seem to square with aspects of the literature on differences between hemispheric processing: LH has been hypothesized to predictively process specific semantic features (of the sort shared by category members) whereas the RH is argued to activate a broader range of semantic content—information that is perhaps less directly related to the moment of processing at hand, as in the event-related anomalies. If the hemispheres can indeed be said to have such different "modes" of processing, there may be circumstances in which the "mode" of one hemisphere is more useful or appropriate.

We hypothesized that the two hemispheres might therefore be recruited during sentence processing to different degrees as a function of each individual's degree of knowledge. To our knowledge, no prior study has investigated this. We did not have particular hypotheses about the precise outcomes with respect to degree of knowledge. Perhaps content experts, reading materials they know a great deal about, and with knowledge of many facts, are more likely to recruit LH "predictive" mechanisms, anticipating only very specific

information, and ignoring other information. Or, by contrast, experts, with their vast array of knowledge, may exploit the RH for its broad and flexible processing. It might also be the case that experts can make better use of both the hemispheres' abilities simultaneously, with LH showing fine-grained prediction of only the most appropriate or predictable continuations, and RH being sensitive to (potentially a great deal of) information.

To begin to explore these hypotheses, we combined the HP individual differences approach with a lateralized/visual hemifield paradigm, providing an extension of Troyer and Kutas (2020). Participants who varied in their knowledge of the narrative world of HP read pairs of sentences about HP which variously ended in contextually supported (i.e., correct), unsupported but related, or unsupported and unrelated words. They also read control sentences about general topics ending in contextually supported or unsupported words. In each case, the final (critical) word was presented laterally to the RVF or to the LVF, thus initially stimulating the LH or RH, respectively, yielding approximately a 10 ms advantage to the hemisphere initially stimulated. This difference, though small, can have processing consequences lasting several hundreds of milliseconds or more (as reviewed, in part, above).

Across participants, and especially within HP experts, we expected to extend findings that both hemispheres would be similarly sensitive to contextual support for sentences about general topics, leading to reduced N400 amplitudes for Supported relative to Unsupported endings. That is, we expected that this pattern also would obtain for sentences from a fictional narrative world.

With central presentation, Troyer and Kutas (2020) did not observe statistical differences in ERPs as a function of the type of related anomaly; the pattern of timing and morphology of each was consistent with the patterns observed in both Federmeier and Kutas (1999a) and Metusalem et al. (2012). However, paradigms using lateralized visual presentation suggest hemispheric asymmetries in processing these two semantic relationships (Federmeier & Kutas, 1999b; Metusalem et al., 2016). We therefore asked whether, either across all individuals, or perhaps just across high-knowledge individuals, the same asymmetries would obtain for categorical and event relationships in a fictional world. That is, we might expect to see related anomaly effects (i.e., reduced N400 amplitude for related anomalies compared to unrelated words, though not as reduced as for contextually supported words; i.e., a three-way difference between conditions) in only the RVF/LH for categorically-related words and in only the LVF/RH for event-related words.

We also asked whether there would be any changes in hemispheric asymmetries as a function of degree of knowledge. For the present purposes, we examined ERPs in subgroups of individuals with high and low HP knowledge, respectively. High-knowledge individuals might exhibit the pattern described above, with the LH being more sensitive to categorically-related information and the RH being more sensitive to event-related information, whereas lower-knowledge individuals might show weaker asymmetries for related anomalies (or no related anomaly effects, at all). Regardless of the exact pattern, any reliable differences in how more vs. less knowledgeable individuals recruit the cerebral hemispheres would be a novel finding, and would begin to elucidate how variation in knowledge shapes neural processing during word-by-word sentence reading.

Methods

Participants

48 right-handed students participated in the study for partial course credit and some monetary compensation.

Materials

80 Control sentence pairs (a subset of the 108 Control sentence pairs in Troyer & Kutas, 2018) described commonplace scenarios and ended in a contextually Supported or Unsupported (albeit plausible) word; e.g., '*We had been watching the blue jay for days. The bird laid her eggs in the* <u>*nest*</u> (Supported) / <u>*yard*</u> (Unsupported).'

156 HP sentence pairs (identical to those in Troyer & Kutas, 2020) described events and entities from the HP series and ended in a contextually Supported, unsupported but semantically Related, or unsupported and Unrelated word. For half, the Related word was from the same (fictional) category as the Supported word (as in Federmeier & Kutas, 1999a,b). For the other half, it was related via the episode/event being described by the sentence pair (as in Metusalem et al., 2012, 2016). Category example: '*Sybill Trelawney is a Hogwarts professor. She teaches* <u>*Divination*</u> (Supported) / <u>*Transfiguration*</u> (Related) / <u>*basilisk*</u> (Unrelated).' Event example: '*Harry has a patronus. It takes the form of a* <u>*stag*</u> (Supported) / *dementor* (Related) / *Sectumsempra* (Unrelated).' See Troyer & Kutas (2020) for more examples and details on how HP sentences were constructed and normed using cloze production, behavioral ratings, and measures from distributed models of semantics trained directly on the text of the HP books.

Experimental procedures

Participants silently read pairs of sentences for comprehension, first about general topics and next about Harry Potter. The first sentence appeared in its entirety in the center of the screen. Participants pressed a button to advance to the second sentence, which was presented one word at a time with a 500 ms SOA (200 ms on, 300 ms off). Words flashed in the center of the screen, except for the final word, which was presented ~2° to the left or right of center. Following the ERP study, participants completed a 10-question HP trivia quiz and a questionnaire about HP experience (see Troyer & Kutas, 2018, for details). We also collected measures of general reading experience and general knowledge.

ERP recording and data analysis

The electroencephalogram (EEG) was recorded from 26 tin electrodes geodesically arranged in an ElectroCap, with impedances kept below 5 KΩ. Recordings were referenced online to the left mastoid and re-referenced offline to an average of the left and right mastoids. EEG was recorded by Grass bio-amplifiers with a bandpass of .01-100 Hz at a sampling rate of 250 Hz. Trials contaminated by artifacts (e.g., eye movements or blinks) were discarded.

Grand average ERPs to sentence-final words were computed across all 26 recording sites for each experiment and by Visual Field (Left Visual Field/LVF, Right Visual Field/RVF) and Ending Type (Supported, Related, Unrelated). For statistical analyses, our dependent variable was mean amplitude in a region of interest (ROI) during a canonical N400 time period (250-500 ms) relative to a 100 ms pre-stimulus baseline. This ROI comprised 15 channels across central and parietal scalp locations, where N400 effects are typically largest: LMFr, RMFr, LDFr, RDFr, LMCe, RMCe, LDCe, RDCe, MiCe, LDPa, RDPa, MiPa, RMOc, LMOc, MiOc. For most analyses, we used repeated measures ANOVA. For investigations of individual differences in HP knowledge, we used mixed-effects linear regression models with random intercepts by participant.

Results

Behavior: HP knowledge scores

HP trivia quiz scores (out of 10) ranged from 1 to 10 (M = 7; SD = 2.26), For subgroup analyses, a median (=7) split was used, leading to a "high-HP-knowledge" group of 20 participants who scored above the median (M = 9.1, SD = .85) and a "low-HP-knowledge" group of 17 participants who scored below it (M = 4.53, SD = 1.46).

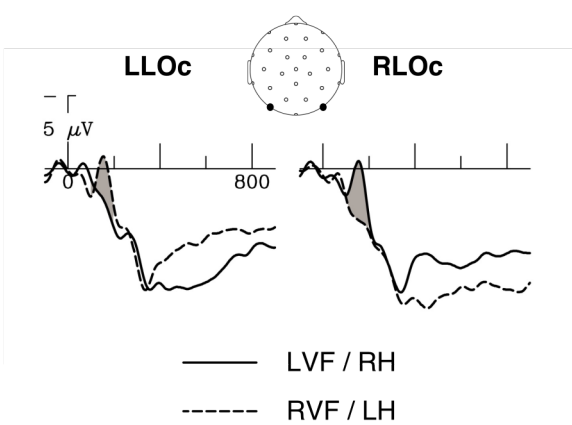

Fig 1. Visual N1 (100-200 ms, shaded) to Supported words in Control sentences at lateral occipital sites.

ERPs: All participants

We examined ERPs to Supported Endings for Control Sentences at left and right occipital sites (Fig 1). As expected, we observed larger visual N1 potentials to words presented contralaterally compared to ipsilaterally, consistent with central fixation and contralateral visual processing.

Control Sentences Across participants, we observed a main effect of Ending Type for control sentences ($p < .0001$), with Supported endings leading to reduced N400 amplitudes compared to Unsupported endings, replicating many studies in the literature. There was no main effect of Visual Field nor interaction between Visual Field and Ending Type (Fig. 2, Control Sentences, top line).

HP Sentences Across participants, as expected, we observed a main effect of Ending Type for HP sentences ($p < .0001$), with the largest N400 amplitude for Unrelated, smallest N400 amplitude to Supported, and intermediate N400 amplitude to Related endings (all pairwise differences $p < .01$). These findings are similar to the pattern observed for central presentation. There was no main effect of or interaction with Visual Field (Fig. 2, HP Sentences, top line).

ERPs and individual differences in HP knowledge

Control Sentences To verify that individual participants would show canonical effects of contextual support for control sentences about general topics regardless of any differences in HP knowledge, we used nested linear mixed-effects model comparisons to ask whether HP knowledge had any non-additive influence on effects of Visual Field or Ending Type. As expected, there was no influence of HP knowledge ($p = .41$).

HP Sentences Model comparison of nested linear mixed effects models including Visual Field, Ending Type, and HP knowledge revealed that HP knowledge did have a non-additive influence on N400 effects ($p < .05$).

To rule out the possibility that other individual differences (we had measured) could better account for individual subject-level variability in N400 ERPs to critical words in HP sentences, we also tested a model that incorporated fixed effects of ending type, visual field, HP domain knowledge, general knowledge scores, and aggregate reading experience scores along with all possible interaction terms for each individual differences measure, ending type, and visual field. We compared this model and a nested model that included Visual Field, Ending Type, HP knowledge, and their interactions but omitted any effects of general knowledge or aggregate reading experiences, and found that the more complex model did not explain additional variance ($p = .25$).

We explored the influence of HP knowledge on effects of Visual Field and Ending Type more closely by focusing on subgroups (see below).

ERPs: Individuals with high HP knowledge

For individuals with high HP knowledge, we observed both a main effect of Ending Type ($p < .0001$) and a marginal ($p = .07$) interaction of Ending Type and Visual Field: high-knowledge individuals showed the three-way difference between Supported, Related, and Unrelated words in the LVF/RH (all ps < .01), but only a two-way difference (with Supported words leading to reduced N400 amplitudes compared to Related and Unrelated words, ps < .0001) in the RVF/LH (Fig. 2, HP Sentences, second line).

Because we had specific hypotheses about how each subset of materials might be influenced by visual field of presentation, we next examined items containing category-related and event-related anomalies separately (Fig. 3).

For the category-related items, in the RVF/LH, the pattern of results resembled that for the entire set of items, with Supported endings eliciting reduced N400 potentials compared to Unrelated/Related endings (ps < .01). In the LVF/RH, however, there was a different pattern. For category-related materials, there was no difference in amplitude between Supported and Related endings ($p = .18$), both reduced compared to Unrelated endings (ps < .01).

For the event-related items, in the RVF/LH the pattern of results also resembled that for the entire set of items, with Supported endings eliciting reduced N400 potentials compared to Unrelated/Related endings (ps < .001). In the LVF/RH, however, the pattern differed somewhat from that observed across all the items, with Supported items eliciting reduced N400 amplitude compared to both Related and Unrelated Items (ps < .0001), which did not differ significantly from each other ($p = .14$).

In sum, for these so-called HP "experts," incorrect words (i.e., words that were contextually unsupported, inappropriate continuations) presented to the RVF/LH seemed to be processed similarly regardless of semantic relationship to the correct completion. By contrast, the LVF/RH was sensitive to the influence of semantic relatedness, albeit to different degrees for category vs. event relations.

ERPs: Individuals with low HP knowledge

For the subgroup of individuals with low HP knowledge, there was a main effect of Ending Type (with a three-way difference: Supported < Related < Unrelated, ps < .05) and no effect of or interaction with Visual Field (see Fig. 2, HP Sentences, third line). Within each related anomaly type (category, event), this pattern was the same, except for a marginal difference between the Unrelated and Related conditions (ps < .10).

In sum, the subgroup of participants with the lowest HP knowledge showed a contextual support effect and a (small) related anomaly effect. However, there was no statistical evidence of hemispheric asymmetries for these participants.

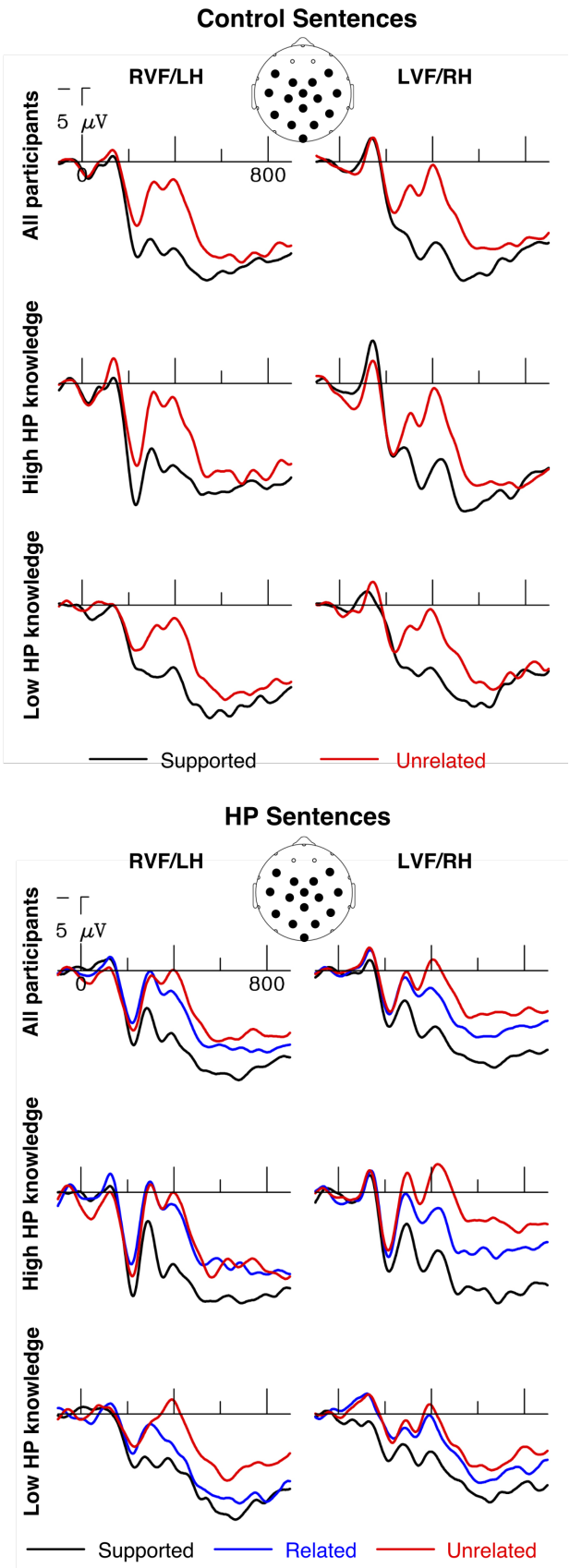

Fig 2. ERPs to critical words averaged across the ROI.

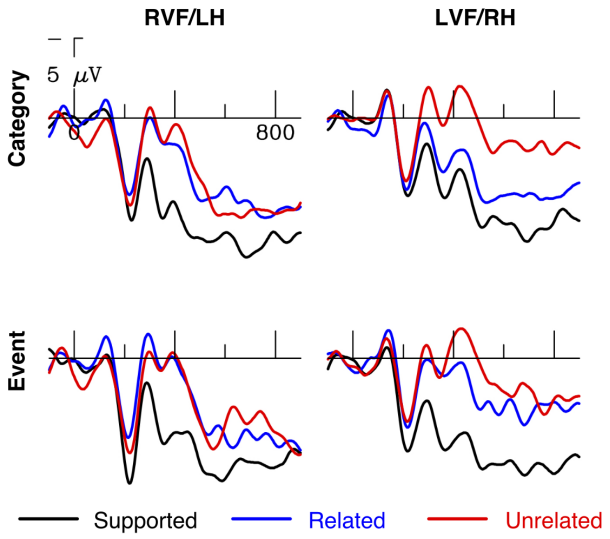

Fig 3. ERPs (in the ROI) to critical words by related anomaly type, for the high-HP-knowledge subgroup.

ERPs: Difference waves

We computed difference ERPs for related anomaly effects (Unrelated minus Related endings) to provide a clearer visualization of the size of such effects for each hemisphere by related anomaly type and HP knowledge subgroup (Fig. 4). For the high-knowledge group, this visualization shows the presence of a hemispheric effect (larger related anomaly effect for LVF/RH compared to RVF/LH) across both types of related anomalies. By contrast, for the low-knowledge group, the statistics indicated no significant effect of hemisphere. However, the visualization provided in Fig. 4 suggests the presence of the reversed effect (i.e., larger related anomaly effect for RVF/LH compared to LVF/RH) amongst the event-related anomalies. Future studies could investigate this further by focusing solely on event (as opposed to event+category) relations, increasing the number of event-related items and thereby increasing the power to detect individual differences effects.

Discussion

The present study was designed to investigate hemispheric differences in real-time semantic processing during word by word reading as a function of fine-grained differences in domain knowledge and different types of semantic relationships. Across participants, for sentences about general topics and sentences about the (fictional) world of Harry Potter, we observed large effects of contextual support on N400 amplitudes, regardless of the visual field of critical word presentation. That is, in the N400 time period, both hemispheres were sensitive to the contextual information about "real-world" and "fictional" situations in the sentences. Extending previous results with central presentation, the size of the effect of contextual support was modulated by degree of HP knowledge for HP sentences only.

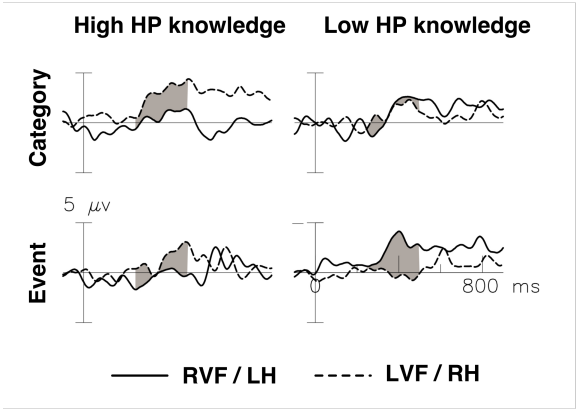

Fig 4. Difference waves for related anomaly effects by subgroup, related anomaly type, and visual field. Shaded region represents N400 time period (250-500 ms).

One primary goal was to ask whether we would observe different hemispheric asymmetries for the different types of related anomalies in our materials. Based on the literature, we expected the LH to be more sensitive to categorical relationships and the RH more sensitive to event relationships. Second, we assessed whether hemispheric asymmetries, regardless of their exact nature, differed as a function of individuals' degree of knowledge.

We observed hemispheric asymmetries in processing of related anomalies in fictional sentences about HP, but only for the most knowledgeable individuals (scoring 80% or above on the HP trivia quiz). By contrast, individuals less knowledgeable about HP showed smaller related anomaly effects which were statistically indistinguishable across hemispheres. In the present study, we examined such effects on N400 amplitudes, due to their theoretical interest; however, we do plan to examine other time periods in exploratory analyses.

With respect to the exact pattern in hemispheric asymmetries for the high-HP-knowledge subgroup, we found that the LVF/RH showed a three-way distinction between contextually supported, related, and unrelated words. This is the pattern reported for event-related anomalies in sentences about generalized events drawing on common world knowledge (Metusalem et al., 2016). By contrast, in these same individuals, the RVF/LH showed only a two-way distinction: N400 amplitudes were reduced for contextually supported words but large for both types of unsupported words, whether they were related or unrelated to the context/supported word.

The exact pattern depended on the nature of the semantic relations, although not as attested in the literature, as both were limited to LVF/RH presentations. For category relationships, the related anomaly effect was similar in magnitude to the contextual support effect, with no difference between supported and related words, both eliciting reduced N400 amplitudes relative to unrelated words. For event relationships, there was a three-way difference between ending types, though the difference between related and unrelated words was marginal.

There are many differences between the sentence materials in the current study and those in published reports including related anomalies which may account for the apparent discrepancy in findings. Notably, the HP sentence materials are fictional "facts"; i.e., the sentence pairs in the Supported condition constitute true statements about people, places, things, and events in the narrative world of HP. By contrast, previous studies of category-related anomalies (e.g., Federmeier et al., 1999a,b) used short story-like descriptions of people, places, things, and events that are possible based on real-world knowledge, but do not draw on verification of facts to understand the critical words (e.g., '*They wanted to make the hotel look more like a tropical resort. So along the driveway, they planted rows of palms.*').

Given that our HP sentence materials were designed to have a single best completion, i.e., a correct ending, it may be that, for these materials, the semantic expectations of highly knowledgeable individuals were quite specific and fine-grained. We tentatively suggest that we may have observed a two-way distinction between Supported vs. Related/Unrelated words in RVF/LH presentation because HP "experts" could rapidly use their knowledge to narrowly activate (and perhaps pre-activate) the word best completing the sentence—in this case, the correct word to complete the fictional "fact." At the same time, the reduction in "experts'" N400 amplitudes to Related words of both types (category, event) suggests that multiple types of semantic relationships may be active during sentence processing and are more available with LVF/RH presentation. Future research could more closely examine the precise influences of text style (i.e., descriptive stories vs. facts) and more carefully compare the influence of expertise within individuals (e.g., by examining those who have differing degrees of knowledge among multiple domains) to test these hypotheses.

Other likely differences between our sentence materials and those of Federmeier and Kutas (1999a,b) are the age and modality of acquisition as well as frequency of input. Thus, the discrepancy between the RH sensitivity to category-related anomalies we observed in the current study and LH sensitivity observed in prior work may be due to a number of differences between real-world and fictional materials. Examining category relations of the two types within the same set of individuals would allow for teasing apart these issues and might provide insight into the organization of knowledge gleaned from the real world vs. fiction alone.

We speculate that our results are in line with accounts of hemispheric processing asymmetries (Beeman, 1994; Federmeier, 2007), suggesting that the left hemisphere (LH) (pre-)activates narrow/specific semantic contents and the right hemisphere (RH) activates broader semantic contents. Tentatively, we suggest that, as individuals become content experts, they may exploit these different functional characteristics of the two cerebral hemispheres, such that the LH is more involved in semantic verification of facts while the RH remains available for flexible recruitment of (a potentially vast amount of) variously related semantic content.

Individual differences in domain knowledge have been used to study various aspects of cognition (reviewed in Ericsson et al., 2006). However, only a few recent studies have made use of the knowledge variability that is naturally present among language users to examine the immediate impacts it has on *processing*. The current findings add to this literature, showing for the first time that degree of knowledge can interact with the relative contributions of the two cerebral hemispheres during real-time word reading. Such variation in knowledge provides a window onto variation in processing that may otherwise be difficult to attain. To extend and generalize these findings, future studies would do well to examine hemispheric contributions to real-time processing as a function of individual differences in knowledge both across multiple domains of knowledge as well across different types of meaningful relations among words in sentences.

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