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Right hemisphere involvement for pun processing – Effects of idiom decomposition

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ABSTRACT

The present study investigated hemispheric processing of puns involving decomposable idioms (e.g. *Old skiers never die, they just **go downhill***) and non-decomposable ones (e.g., *Old cleaners never die, they just **bite the dust***) using a divided visual field paradigm. In two cross-modal priming experiments, participants listened to puns and made lexical decisions for targets presented either in the left or right visual fields. To investigate hemispheric asymmetries at different processing stages (early vs. late), the prime-target inter-stimulus interval was 0 ms in Experiment 1 and was increased to 750 ms in Experiment 2. The results from both experiments demonstrated a left hemisphere advantage for processing puns triggered by non-decomposable idioms; puns motivated by decomposable idioms were processed equally fast in both hemispheres, suggesting that this type of pun induced right hemisphere involvement and led to bilateral processing. We discuss the results in light of predictions derived from the 'graded salience' hypothesis and the 'fine-coarse coding' hypothesis and argue that the data are more consistent with the graded salience hypothesis.

1. Introduction

The left hemisphere (LH) is specialised for language processing, but there is a large body of research showing that the right hemisphere (RH) also contributes in an important and collaborative way (Beeman et al., 1994; Burgess & Chiarello, 1996; Chiarello & Beeman, 1998). The RH is often found to be involved in the processing of non-literal language. For example, RH involvement has been shown for *metaphors* (e.g., Bottini, Corcoran, Sterzi, Paulesu et al., 1994; Faust & Mashal, 2007; Klepousniotou, Gracco, & Pike, 2014; Mashal, Faust, Hendler, & Jung-Beeman, 2007; but cf. Stringaris, Medford, Giampietro, Brammer, & David, 2007 for an alternative view which holds that the RH is not specifically involved in metaphor processing); for *idioms* (e.g., Van Lancker & Kempler, 1987; Van Lancker-Sidtis, 2006); and for *jokes* (e.g., Coulson & Williams, 2005; Coulson & Wu, 2005; Marinkovic et al., 2011; Shammi & Stuss, 1999). Furthermore, RH processing preferences have been consistently observed for lexical ambiguity processing (Klepousniotou, Pike, Steinhauer, & Gracco, 2012; Peleg & Eviatar, 2008; Titone, 1998).

Given that puns are defined as intentionally ambiguous rhetorical devices (Coulson & Severens, 2007; McQuarrie & Mick, 1996) since they simultaneously invoke multiple meanings of words or phrases, it is surprising that the small body of research on pun comprehension points to LH preference for pun processing (Coulson & Severens, 2007; Goel & Dolan, 2001; Kana & Wadsworth, 2012). However, we recently found evidence that on-line pun comprehension is constrained by the semantic nature of the meanings that underpin the intentional ambiguity in puns. In a study that investigated the time course of meaning activation for puns motivated by idiomatic expressions (e.g., '*Old skiers never die, they just **go downhill***'), we found that decomposable idioms readily activated their

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figurative meanings whereas non-decomposable idioms showed delayed activation, thus suggesting that collaborative RH engagement may be observed only for some types of puns (i.e., those involving non-decomposable idioms) (Koleva, Ashton, & Klepousniotou, 2015). The current study aimed to explore the hemispheric asymmetries for puns motivated by decomposable and non-decomposable idioms and test the predictions of alternative hypotheses for right hemisphere involvement in non-literal language processing.

The *fine-coarse coding hypothesis* (Jung-Beeman, 2005) maintains that the two hemispheres activate semantic information in a qualitatively different way depending on the semantic relationships that exist in the mental lexicon among different words and the different meanings of the same word. The LH is suited for the activation of meanings that fall into a small/narrow semantic field (i.e., semantically closely-related meanings such as dominant meanings with central/core semantic features; e.g., the meaning of 'a piece of cutlery' when we process a word like 'fork'). Conversely, the RH is better suited for the activation of meanings belonging to a broad semantic field (i.e., semantically distant meanings such as subordinate meanings which represent peripheral/non-core features; e.g., the meaning of 'a road division' for the same word of 'fork').

The *graded salience hypothesis* (GSH; e.g., Giora, 1997; 2003; Giora, Zaidel, Soroker, Batori, & Kasher, 2000; Giora, 2012) makes similar predictions. In particular, within the GSH framework, hemispheric asymmetries are a function of language salience. Giora (1997; 2012) argue that language salience is a combination of variables, most importantly those of familiarity, conventionality and coded-ness in the mental lexicon with salient meanings being more familiar, more conventional and coded in long-term memory in comparison to non-salient meanings, which are less familiar, less conventional and are not coded in long-term memory (instead they are derived on-line during language comprehension). Giora et al. (2000) argue that the LH is engaged in the processing of salient meanings, whereas the RH is specialised in the processing of non-salient meanings. However, since less salient meanings (e.g., 'road division' for 'fork') also tend to fall into a broader semantic field and be less closely related to each other, evidence of RH involvement for non-literal language is normally consistent with predictions from both hypotheses (for a similar claim see Mashal, Borodkin, Maliniak, & Faust, 2015). We are not aware of a study that addresses the predictions of these two hypotheses in a single experimental design in order to tease them apart. Our study aimed to fill that gap.

Given that not all studies on non-literal language processing report RH involvement (e.g., Stringaris et al., 2007), Faust and Kenett (2014) proposed an even more generalised account of hemispheric asymmetries to account for those findings that suggest LH preference for non-literal language processing. The underlying assumption of the *cognitive continuum hypothesis* (Faust & Kenett, 2014) is that (figurative) language processing is a whole brain activity relying on the integration of processing that originates from both hemispheres. According to Faust and Kenett (2014), one end of the continuum exhibits LH processing that is defined as rigid and rule-based since it relies on highly salient, closely-related meanings, and the other end of the continuum exhibits RH processing which is chaotic and flexible as it relies on activation of broad semantic fields which contain very distantly related and/or less salient meanings. The cognitive continuum hypothesis maintains that findings of non-literal language processing may occupy different sections of the continuum ranging from LH-rigid to RH-chaotic depending on the internal semantic motivation of the non-literal language used in studies. Overall, the literature on hemispheric asymmetries for non-literal language claims that both more *distantly related meanings* and *less salient meanings* will engage RH resources, but so far no study has addressed the question which one of these two conditions (i.e., semantic relatedness vs. saliency) is a stronger predictor of RH involvement and/or why.

2. Pun processing

Previous pun processing studies suggest that puns are more likely to be processed in the LH (Coulson & Severens, 2007; Goel & Dolan, 2001; Kana & Wadsworth, 2012), but possible RH recruitment cannot be ruled out entirely if the internal motivation of puns is taken into account. In an event-related fMRI study, Goel and Dolan (2001) asked participants to listen to semantic jokes (e.g., *'What do engineers use for birth control?..Their personalities.'*) and phonological jokes that were in fact puns (e.g., *'Why did the golfer wear two sets of pants?..He got a hole in one.'*). All jokes showed common activation in the medial ventral prefrontal cortex and bilateral cerebellum, but only semantic jokes showed a bilateral pattern of activation in which the right posterior middle temporal gyrus was implicated. Phonological jokes (i.e., puns) showed predominantly LH involvement (activation in the posterior inferior temporal gyrus and the inferior frontal gyrus). In a more recent fMRI study, autistic and healthy control participants silently read sentences containing puns (e.g., *My advanced geometry class is full of squares*) or control sentences without puns (Kana & Wadsworth, 2012). The data from the healthy participants displayed significant left hemisphere dominance in the processing of puns (especially in areas such as the inferior frontal gyrus and the superior temporal gyrus).

In an EEG study, using a half-field cross-modal priming paradigm, Coulson and Severens (2007) asked participants to listen to puns (e.g., 'During branding cowboys have sore calves') and subsequently read highly related (e.g., 'cow') or moderately related (e.g., 'leg') probe words presented either in the right visual field (LH) or left visual field (RH). The results from Experiment 1 (ISI:0 ms) revealed that in the LH both probes led to priming effects in the N400 time window (indexing meaning access), whereas in the RH only the highly related probes showed N400 priming effects. The same results were found for the P600 time window (indexing meaning integration), showing that in both time-windows the RH was engaged only in the processing of the highly related probes. In Experiment 2 (ISI:500 ms), both highly related and moderately related probes led to priming in both hemispheres for both N400 and P600 time windows indicating that at a later processing stage the two hemispheres were equally involved in pun comprehension. Even though Coulson and Severens (2007) claimed that their study did not show evidence for RH involvement for puns, we argue that this conclusion can only be drawn for the results from Experiment 1. The findings from Experiment 2 showed that both hemispheres were equally engaged in the processing of the two meanings of the pun indicating an increase in RH involvement for puns.

In sum, then, it seems that the fMRI studies point to LH preferences for pun comprehension while the EEG study indicates that

there may be some RH involvement for puns (especially at later processing stages). Given the high temporal resolution of the EEG methodology (not characteristic for the slower hemodynamic response measured during fMRI scans) it is possible that RH pun effects are transitory and strictly time-locked to particular time-windows. Furthermore, if the motivating nature of jokes (semantic jokes vs. puns) could lead to hemispheric asymmetries for jokes, as evidenced by Goel and Dolan (2001), then it is logical to assume that the motivating nature of puns could also lead to hemispheric asymmetries. By not controlling for this variable, Coulson and Severens (2007) and Kana and Wadsworth (2012) may have obscured RH involvement for puns. In the present study, we will consider hemispheric asymmetries for puns which are motivated either by distantly related but salient meanings, or by semantically close but non-salient meanings.

3. Idiom decomposition

Idioms are fixed expressions (e.g., *go downhill*) that have an overall figurative meaning (*deteriorate*) that is different from the literal meanings of the words that form the expressions. The inherent ambiguity between figurative and literal meanings in idioms can be used to trigger the construction of puns (e.g., *Old skiers never die, they just go downhill*). Furthermore, idioms vary systematically in terms of decomposition, thus readily allowing us to tease apart effects of semantic relatedness (predicted to lead to RH processing preferences by *the fine-coarse coding hypothesis*) from effects of language salience (predicted to lead to RH preferences by *the salience graded hypothesis*). Gibbs, Nayak, and Cutting (1989) formulated the Decomposition Hypothesis which posited that (normally and abnormally) decomposable idioms have meanings that are closely related to the literal meanings of the individual words (*pop the question = pop (ask) + question (one particular type of question)*, whereas non-decomposable idioms have meanings that are completely unrelated to the individual word meanings (*kick the bucket ≠ kick + bucket*).

Gibbs et al. (1989) further argued that decomposable idioms are recognised faster than non-decomposable idioms. Subsequently, idiom decomposition effects have been reported in on-line priming studies (Caillies & Butcher, 2007; Cieslicka, 2013; Titone & Libben, 2014; Zhang, Yang, Gu, & Ji, 2013) as well as off-line judgement tasks (Libben & Titone, 2008 but cf. Tabossi, Fanari, & Wolf, 2008 who claimed that decomposition plays little role in idiom comprehension). Additionally, Titone and Connine (1999) argued that the differences in processing speed for decomposable and non-decomposable idioms reflect differences in their mental representations. On the one hand, non-decomposable idioms have semantically unrelated literal and idiomatic meanings, but on account of the existing semantic dissimilarity, these idioms code their idiomatic meanings in the mental lexicon, thus making them salient. On the other hand, decomposable idioms have semantically related literal and idiomatic meanings, which can explain the redundancy of keeping coded idiomatic meanings of this type of idiom. Therefore, the idiomatic meanings of decomposable idioms are non-salient (decomposable idioms are underspecified for their idiomatic meanings). In sum, idioms can dissociate semantic relatedness and saliency in a novel way showing that meanings can be simultaneously semantically unrelated and salient as well as semantically related and non-salient.

Cieslicka (2013) further demonstrated that decomposable and non-decomposable idioms were processed differently in the two hemispheres. In two half-field lexical decision experiments investigating the time-course of idiom activation, the two types of idioms were embedded in neutral and idiomatic contexts and were centrally presented as primes. Lateralised targets were presented with no delay or with a delay of 400 ms to native speakers of Polish and Polish second language learners. The results for the native speakers group revealed that decomposable idioms did not activate their idiomatic meanings at all with no delay, and the RH processed these meanings only in neutral contexts with a delay of 400 ms. On the other hand, the RH was engaged in the processing of the idiomatic meanings of non-decomposable idioms with no delay (in both neutral and idiomatic contexts) and with a delay of 400 ms (in idiomatic contexts). These findings are consistent with the fine-coarse coding hypothesis which predicts that non-decomposable idioms will show stronger RH involvement compared to decomposable idioms on account of having idiomatic meanings that are distantly related to the literal meanings.

4. The present study

The present study expanded previous findings by focusing on a different context type, namely double-meaning consistent pun contexts, in order to investigate whether the RH advantage in processing non-decomposable idioms is still evident when processing pun contexts. We used decomposable (e.g. *go downhill*) and non-decomposable idioms (e.g., *bite the dust*) in idiomatic single-meaning consistent sentences (e.g. *Old painters never die, they just **go downhill*** and *Like it or not, we all **bite the dust***) and double-meaning consistent pun sentences (e.g., *Old skiers never die, they just **go downhill*** and *Old cleaners never die, they just **bite the dust***) to investigate the extent to which the RH is involved in the processing of puns. Similarly to Coulson and Severens (2007), we conducted two cross-modal half-field priming experiments in which participants performed lexical decisions for targets that followed the sentence primes. The targets were: (i) related to the idiomatic meaning, (ii) related to the literal meaning, or (iii) unrelated. To investigate hemispheric asymmetries at two processing stages (early and late), we presented targets immediately at the end of the priming sentence in Experiment 1 (ISI:0 ms), while in Experiment 2 we presented them with a delay of 750 ms (ISI:750 ms). This design allowed us to investigate hemispheric asymmetries for pun processing stemming from the simultaneous processing of two semantically related meanings (i.e., decomposable puns) and two semantically unrelated meanings (i.e., non-decomposable puns). According to the fine-coarse coding hypothesis we would expect decomposable puns to be processed in the LH due to the close semantic similarity between the literal and idiomatic meanings entering in the pun, whereas the non-decomposable puns would recruit the RH due to the semantic dissimilarities between the two meanings. In contrast, the graded salience hypothesis predicts the opposite pattern. Since the idiomatic meanings of decomposable idioms are not coded in the mental lexicon, they are considered to be non-salient which would

predict RH involvement for decomposable puns; conversely, since the idiomatic meanings of non-decomposable idioms are coded, they are considered salient (similar to the literal meanings of these idioms) hence no RH involvement is predicted for non-decomposable puns.

5. Methodology

5.1. Participants

Twenty native speakers of English (11 female, mean age = 22.2 years, age range 19–32, mean years in education = 14.9) took part in the experiment. All participants were right-handed (assessed according to the Handedness Inventory, Briggs & Nebes, 1975), with normal or corrected to normal vision and no history of either neurological or language impairments. The experiment received approval from the Ethics Committee of the School of Psychology, University of Leeds.

5.2. Design and materials

The study had a within-participant design with four factors for each ISI: Visual Field (left vs. right); Idiom type (decomposable idioms vs. non-decomposable idioms); Context (single-meaning consistent vs. double-meaning consistent/puns); and Target type (idiomatically-related vs. literally-related vs. unrelated). The materials consisted of 240 sentences varying between 8 and 11 words in length. The experimental sentences (120 in total) consisted of 60 single-meaning consistent sentences and 60 double-meaning consistent sentences (i.e., puns). Half of the sentences ended in decomposable idioms, and half ended in non-decomposable idioms. For example, *'Old painters never die, they just **go downhill**'* is a single-meaning consistent sentence ending in a decomposable idiom, while *'Old skiers never die, they just **go downhill**'* is the double-meaning consistent sentence counterpart. Conversely, *'Like it or not, we all **bite the dust**'* is a single-meaning consistent sentence ending in a non-decomposable idiom and *'Old cleaners never die, they just **bite the dust**'* is the double-meaning consistent counterpart. The pun sentences were (i) taken from Internet sites (http://bit.ly/2nuPuUY), (ii) adapted from books about jokes (Alexander, 2006; Moger, 1992), or (iii) designed following the underlying principles in (i) and (ii). We consulted five native speakers of English who all agreed that in all double-meaning consistent pun sentences the two meanings were evoked and a humorous effect was achieved.

We conducted three pre-tests to control and validate our experimental stimuli. Firstly, to control for semantic relatedness effects, we asked native speakers of English (N = 8) to read each single-meaning consistent sentence and indicate on a Likert scale (1–7) how much the literal meanings of the individual content words in the idiom contributed to the overall idiomatic meaning as used in the sentence (1 = meanings do not contribute at all; 7 = original meanings of the words are apparent in the meaning of the idiom). The average relatedness score of the decomposable idioms was 4.12 (SD = 0.69) and that of the non-decomposable idioms was 2.24 (SD = 0.63); decomposable idioms had a statistically higher degree of semantic relatedness between their meanings (i.e. higher degree of decomposition) than non-decomposable idioms [t (29) = 11.075, $p < .001$, $\eta_p^2 = 0.809$].

Secondly, since we wanted to use only idioms that are clearly understood as idiomatic, and thus not unduly ambiguous, we asked a different group of native speakers of English (N = 17) to indicate on a Likert scale (1–7) how strongly they associated an idiom with its idiomatic meaning and with its literal meaning (1 = 'very rarely'; 7 = 'very often'). For idiomatic meanings, for decomposable idioms, the average association score was 5.11 (SD = 1.2) and for non-decomposable idioms it was 4.95 (SD = 1.3); there was no difference between the two [t (29) = 0.59, p = .56, $\eta_p^2 = 0.012$]. This result suggests that both types of idioms are associated with their idiomatic meaning to an equal degree. To show that for each idiom type, the association score for the idiomatic meanings was significantly higher than the association score for the literal meanings (making idioms clearly biased towards their idiomatic meanings), we conducted further t-tests. For decomposable idioms, the association score for the idiomatic meanings was significantly higher than the association score for the literal meanings 2.23 (SD = 0.91) [t (29) = -9.02, p < .0001, $\eta_p^2 = 0.737$]. For non-decomposable idioms, the association score for the idiomatic meanings was also significantly higher than that for the literal meanings 1.9 (SD = 0.5) [t (29) = -11.53, p < .0001, $\eta_p^2 = 0.821$]. The association scores for the literal meanings of the decomposable idioms (2.23) and non-decomposable idioms (1.9) did not differ significantly [t (29) = 1.609, p < .12, $\eta_p^2 = 0.082$]. Thus, these tests show that both decomposable and non-decomposable idioms are significantly more strongly associated with their idiomatic meanings with no differences across idiom type. The two types of idiom did not differ in length either. Decomposable idioms were, on average, 3.93 words long (SD = 1.11), and non-decomposable idioms, were, on average, 3.8 words long (SD = 0.99) [t (29) = 0.465, p = .645, $\eta_p^2 = 0.007$].

Lastly, we designed a norming study to rate the idioms for familiarity. Native English speakers (N = 19) read each of the single-meaning consistent sentences and indicated on a Likert-scale (1–7) how familiar they were with each idiom (1 = 'not familiar at all'; 7 = 'very familiar'). The average familiarity score for the decomposable idioms was 4.97 (SD = 0.84) and that for the non-decomposable idioms was 4.1 (SD = 0.96). The difference was found to be statistically significant [t (29) = 4.283, $p < .001$, $\eta_p^2 = 0.387$]. Libben and Titone (2008) argued that decomposition and familiarity are highly correlated (i.e., the more decomposable an idiom is, the more familiar it is considered). However, the correlation between decomposition and familiarity did not affect the results of the current study, as that assumption would lead to the prediction that decomposable idioms are processed faster on account of being more familiar; our results (see Results section below) do not support this assumption.

All experimental sentences were paired with three target words (idiomatic, literal, unrelated). Each target word was presented after both single-meaning consistent and double-meaning consistent sentences. Target words were selected with the help of an on-line

Table 1
Example of experimental materials.

Idiom type	Decomposable idioms		Non-decomposable idioms	
Context	**Single-meaning consistent**	**Double-meaning consistent (pun)**	**Single-meaning consistent**	**Double-meaning consistent (pun)**
	*Old painters never die, they just **go downhill.***	*Old skiers never die, they just **go downhill.***	*Like it or not, we all **bite the dust.***	*Old cleaners never die, they just **bite the dust.***
Idiomatic Target	***decline***	***decline***	***grave***	***grave***
Literal Target	***slide***	***slide***	***dirt***	***dirt***
Unrelated Target	***soup***	***soup***	***wire***	***wire***

thesaurus (accessed at http://bit.ly/1aB0ByF) and verified as unrelated using established associative norms (Nelson, McEvoy, & Schreiber, 1998). In particular, idiomatic-related target words were synonymous to the figurative expressions (i.e. the idioms) and were selected with the help of the on-line thesaurus to match the idiomatic meaning of the idiom (e.g., for the idiom 'go downhill' a synonym to the idiomatic meaning is 'decline'). Literal-related target words were synonymous/related to the literal meaning of one of the key content words comprising the idiom (e.g., for the idiom 'go downhill' a synonym to the literal meaning is 'slide'). The third target word was unrelated to either the idiomatic meaning or the literal one and did not appear as a synonym in the thesaurus or associative norms (Nelson et al., 1998). Based on measurements obtained from the MRC Psycholinguistic Database (http://bit.ly/2n3yt3P), the Irvine Phonotactic Online Dictionary (IPhoD; http://www.iphod.com/) and the CLEARPOND Database (http://clearpond.northwestern.edu/index.php), all target words were matched for *familiarity* [F (2,129) = 0.827, p = .44] (idiomatic: mean = 540 (SD = 37); literal: mean = 539 (SD = 53); unrelated: mean = 526 (SD = 60); *frequency* [F (2, 177) = 0.19, p = .83] (idiomatic: mean = 26 (SD = 15); literal: mean = 27 (SD = 17); unrelated: mean = 28 (SD = 17); *neighbourhood density* [F (2,177) = 2.31, p = .10] (idiomatic: mean = 13.93 (SD = 16.84); literal: mean = 19.93 (SD = 12.27); unrelated: mean = 16.81 (SD = 16.39); and *bigram frequency* [F (2,177) = 1.16, p = .32] (idiomatic: mean = 0.009 (SD = 0.004); literal: mean = 0.009 (SD = 0.004); unrelated: mean = 0.008 (SD = 0.003) (see Table 1 for an example of the experimental stimuli).

The non-experimental filler sentences (120) were also between 8 and 11 words long. Half of them were double-meaning consistent puns and the other half were not. Each filler sentence was followed by three different non-words respecting the phonotactics of English (legal English pseudo-words) (see Appendix A).

We used the cross-modal semantic priming paradigm in which primes were presented aurally and the targets were presented visually on a computer screen. Auditory materials were read by a female native speaker of British English and were recorded using 'Audacity' at 44.1 KHz.

5.3. Procedure

Experiment 1 (ISI:0 ms) and Experiment 2 (ISI:750 ms) were run in parallel; the order was counterbalanced across participants. The stimuli within each experiment were counterbalanced in three lists; the order of the lists was also counterbalanced. Participants attended three sessions (separated by at least a week) to complete the study. During each session, participants completed two lists of stimuli (one list from Experiment 1 and a different list from Experiment 2) with a 5-min break between the two lists. Within each list, stimuli were pseudo-randomised so that no three items of the same type occurred consecutively. Participants were tested individually at all times and the presentation of the stimuli and recording of the reaction times and the error rates were controlled by E-Prime2. Participants were seated in a comfortable position in front of the computer monitor approximately 57 cm away from the screen. They received oral instructions that were reinforced in written form at the beginning of the experiment. The instructions informed them that they would use headphones to listen to sentences which would be followed by a word presented visually on the computer screen. They were also informed that the word would flash very quickly either to the right-hand side or to the left-hand side of a fixation cross that remained in the centre of the screen throughout the experiment. Participants were trained to fixate on the cross and were asked to listen carefully to each sentence. At the end of the sentence, they had to decide whether the word was a real word in English or not. Lexical decisions were indicated by clicking the relevant mouse-buttons as quickly and as accurately as possible. The experiment began with a practice block of 11 sentences to train participants to keep their eyes fixated on the cross and refrain from moving. Each trial began with the presentation of a fixation cross for 500 ms at the centre of the screen which remained visible for the entire experiment. Fixation time was followed by the audio presentation of the priming sentence. Immediately at the end of the sentence (with an inter-stimulus interval of 0 ms, ISI:0 ms), or with a delay of 750 ms (ISI:750 ms) the target word appeared either in the left or right visual field. Targets were visually presented for 150 ms with 2.0° foveal eccentricity from the fixation cross. As soon as participants responded, or at the end of 1700 ms if they failed to indicate any decision, the next trial started automatically after a delay of 200 ms.

6. Results: experiment 1 (ISI:0 ms)

Non-experimental stimuli (all filler sentences followed by non-words) were removed from the analyses. Prior to statistical

analyses, errors (7%) and outliers (3.6%) (± 2 *SD* from each participant's mean per condition) were removed. Data were then subjected to a 2(Idiom type: decomposable idioms vs. non-decomposable idioms) x 2(Context: single-meaning consistent vs. double-meaning meaning consistent, puns) x 3(Target type: idiomatically-related vs. literally-related vs. unrelated) x 2(Visual Field: left visual field vs. right visual field) repeated measures ANOVA for subjects (F1) and items (F2). The process was repeated for both reaction time (RT) and accuracy (ACC) data. Significant main and interaction effects were explored further using the Newman-Keuls ($p < .05$) post-hoc tests (see Appendix B for a table summarising the results).

6.1. Response latencies

The Idiom type x Context x Target type x Visual Field ANOVA carried out with reaction time (RT) data revealed significant main effects of Visual Field [$F1$ (1,19) = 29.212, MS = 32556, $p < .0001$, $\eta_p^2 = 0.606$; $F2$ (1,29) = 42.88, MS = 52762, $p < .0001$, $\eta_p^2 = 0.597$] showing that targets presented in the right visual field-LH (584 ms) produced significantly faster responses than targets in the left visual field-RH (601 ms, $p < .0002$), which is consistent with the LH advantage for language processing. There was also a significant main effect of Target type [$F1$ (2,38) = 10.423, MS = 13071, $p < .0001$, $\eta_p^2 = 0.354$; $F2$ (2,58) = 4.49, MS = 18195, $p < .01$, $\eta_p^2 = 0.134$] showing that literal targets (582 ms) were significantly faster than unrelated ones (598 ms, $p < .0006$) while idiomatic targets (597 ms) were as fast as unrelated ones ($p = .804$).

A significant two-way interaction between Idiom type x Target type [$F1$ (2,38) = 12.528, MS = 8013, $p < .0001$, $\eta_p^2 = 0.397$; $F2$ (2,58) = 3.01, MS = 13439, $p < .057$, $\eta_p^2 = 0.094$] revealed that the idiomatic targets of non-decomposable idioms (589 ms) were significantly faster than the unrelated ones (603 ms; $p < .01$) suggesting facilitation, whereas the idiomatic targets of decomposable idioms (607 ms) were significantly slower than the unrelated ones (598 ms, $p < .049$) suggesting interference effects. The literal targets of both types of idioms showed priming effects (for decomposable idioms, 579 ms, $p < .0003$; for non-decomposable idioms, 588 ms, $p < .008$) (see Fig. 1).

The significant interaction of Idiom type x Context x Target type [$F1$ (2,38) = 4.178, MS = 1821, $p < .022$, $\eta_p^2 = 0.180$; $F2$ (2,58) = 3.14, MS = 4075, $p < .05$, $\eta_p^2 = 0.099$] showed context effects for targets after non-decomposable idioms. In the single-meaning consistent (i.e., idiomatic) contexts, these idioms primed both literal (587 ms, $p < .006$) and idiomatic targets (584 ms, $p < .001$), while in the double-meaning consistent puns, neither the literal (586 ms) nor idiomatic targets (593 ms) showed priming effects ($p = .275$ and $p = .637$ respectively). Conversely, in both contexts, decomposable idioms primed only the literal targets (in single-meaning contexts 580 ms, $p < .05$; in puns 576 ms, $p < .0004$) and the idiomatic targets behaved similarly to the unrelated ones (in single-meaning contexts 606 ms, $p = .09$; in puns 606 ms, $p = .378$).

Visual Field entered into a significant three-way interaction of Idiom type x Context x Visual Field [$F1$ (1,19) = 6.327, MS = 13919, $p < .0001$, $\eta_p^2 = 0.462$; $F2$ (1,29) = 27.79, MS = 25366, $p < .0001$, $\eta_p^2 = 0.471$] which showed that the two hemispheres processed the two types of puns differently depending on the type of idiom motivating the pun. Decomposable puns were processed equally fast by the two hemispheres (LH = 594 ms, RH = 596 ms, $p = .728$) indicating bilateral processing, whereas non-decomposable puns were processed significantly faster in the LH (577 ms) than the RH (608 ms, $p < .0006$) suggesting a LH advantage. This pattern was reversed in the single-meaning, non-pun, contexts. Decomposable idioms were processed significantly faster in the LH (581 ms) than the RH (607 ms, $p < .002$); non-decomposable idioms were processed equally fast by the two hemispheres (LH = 589 ms, RH = 598 ms, $p = .310$) (see Fig. 2).

The factor Visual Field entered into another 3-way interaction of Context x Target type x Visual Field (by subjects) [$F1$ (2,38) = 3.734, MS = 3057, $p < .033$, $\eta_p^2 = 0.164$; $F2$ (2,58) = 2.96, MS = 4656, $p = .06$, $\eta_p^2 = 0.093$] showing that, in the LH, there was only priming for the literal targets after puns (566 ms, $p < .001$), while in the RH, there was only priming for the literal targets after single-meaning contexts (611 ms, $p < .04$), thus indicating further pun-related hemispheric asymmetries.

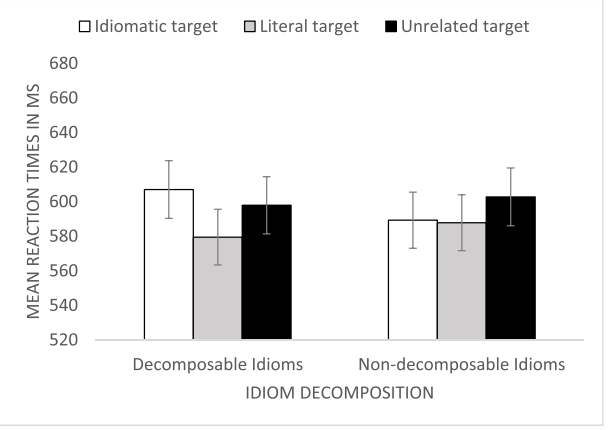

Fig. 1. Mean RTs (ms) for the idiomatic, literal and unrelated targets for decomposable and non-decomposable idioms collapsed across the two contexts at the short ISI. Error bars indicate the standard error.

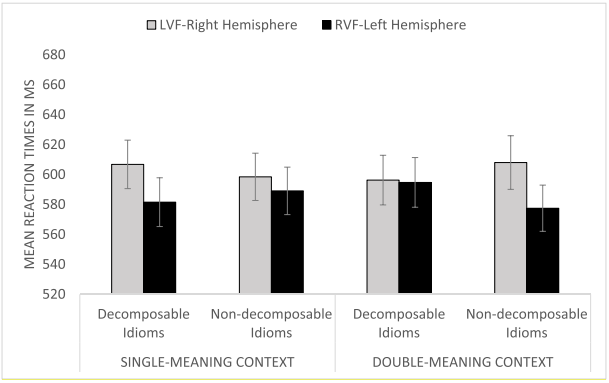

Fig. 2. Mean RTs (ms) for decomposable and non-decomposable idioms in single-meaning and double-meaning pun contexts in the two hemispheres at the short ISI. Error bars indicate the standard error.

6.2. Accuracy rates

The Idiom type x Context x Target type x Visual Field ANOVA carried out with accuracy (ACC) data revealed a significant two-way interaction of Idiom type x Target type [$F1$ (2,38) = 9.39600, MS = 15.152, $p < .0005$, $\eta_p^2 = 0.331$; $F2$ (2,58) = 3.42693, MS = 10.101, $p < .039$, $\eta_p^2 = 0.106$]. The Newman-Keuls post-hoc tests showed that after decomposable idioms, errors neither for idiomatic (2.37%) nor for literal targets (1.87%) differed from the unrelated targets (1.97%; $p = .128$ and $p = .621$ respectively); after non-decomposable idioms, errors for idiomatic targets (1.77%) were significantly lower than the unrelated targets (2.48%, $p < .012$), while errors for the literal targets (2.29%) did not differ from the unrelated targets ($p = .583$). The main ANOVA also revealed a significant three-way interaction of Idiom type x Context x Visual Field [$F1$ (1,19) = 9.29451, MS = 14.700, $p < .007$, $\eta_p^2 = 0.328$; $F2$ (1,29) = 6.80176, MS = 9.800, $p < .014$, $\eta_p^2 = 0.189$] but the post-hoc tests did not show any further significant differences.

7. Discussion

This experiment investigated hemispheric asymmetries for decomposable and non-decomposable puns during early stages of processing (ISI:0 ms). Consistent with the predictions of the Graded Salience Hypothesis (Giora et al., 2000), the results showed that non-decomposable puns (motivated by two salient/coded meanings) were processed predominantly in the LH, while decomposable puns (partly motivated by non-salient/non-coded meanings) recruited some RH resources leading to bilateral processing. Given that we used unambiguous idioms that have dominant idiomatic meanings and subordinate literal meanings, the Graded Salience Hypothesis receives further support from the finding that in the single-meaning consistent/idiomatic contexts (irrespective of semantic relatedness) the literal meanings of idioms showed RH processing most probably due to being the less frequently used (non-salient) meanings for the set of unambiguous idioms we used in our study. Finally, there was clear evidence of decomposition effects in that the idiomatic meanings of non-decomposable idioms showed strong facilitation effects, while those of decomposable idioms showed strong interference effects (indicating processing disadvantages). Given the evidence from Coulson and Severens (2007) that the RH became involved in the processing of puns only when participants were given more processing time (Experiment 2; ISI:500 ms), our second experiment investigated whether the RH would show even stronger involvement in the processing of decomposable puns when the prime-target interstimulus-interval increased to 750 ms.

8. Results: experiment 2 (ISI:750 ms)

Non-experimental stimuli (all filler sentences followed by non-words) were removed from the analyses. Prior to statistical analyses, errors (6.3%) and outliers (3.9%) (± 2 *SD* from each participant's mean per condition) were removed. Data were then subjected to a 2(Idiom type: decomposable idioms vs. non-decomposable idioms) x 2(Context: single-meaning consistent vs. double-meaning meaning consistent, puns) x 3(Target type: idiomatically-related vs. literally-related vs. unrelated) x 2(Visual Field: left visual field vs. right visual field) repeated measures ANOVA for subjects (F1) and items (F2). The process was repeated for both reaction time (RT) and accuracy (ACC) data. All significant main and interaction effects were explored further using the Newman-Keuls ($p < .05$) post-hoc tests.

8.1. Response latencies

The Idiom type x Context x Target type x Visual Field ANOVA carried out with reaction time (RT) data revealed significant main effects of Visual Field [$F1$ (1,19) = 17.276, MS = 32647, $p < .0005$, $\eta_p^2 = 0.476$; $F2$ (1,29) = 63.16, MS = 46003, $p < .0001$, $\eta_p^2 = 0.685$] indicating that responses made in the right visual field-LH (604 ms) were significantly faster than responses made in the left

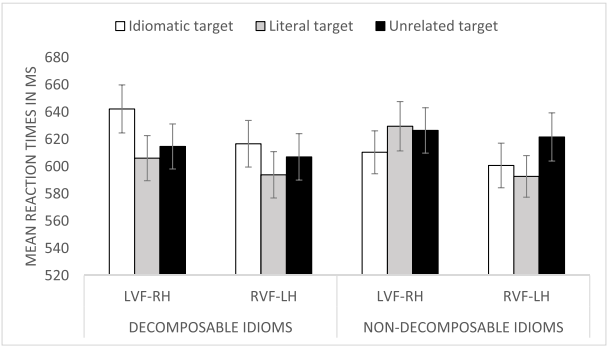

Fig. 3. Mean RTs (ms) for the idiomatic, literal and unrelated targets for decomposable and non-decomposable idioms in the two hemispheres at the long ISI. Error bars indicate the standard error.

visual field-RH (621 ms, $p < .0006$), as well as a significant main effect of Target type (by subjects) [$F1$ (2,38) = 13.027, MS = 7424, $p < .0001$, $\eta_p^2 = 0.407$; $F2$ (2,58) = 2.00, MS = 46003, $p = .144$, $\eta_p^2 = 0.065$] showing that, even at this late processing stage, only the literal targets (605 ms) were faster than the unrelated ones (616 ms, $p < .0001$) while the idiomatic targets (616 ms) did not differ from the unrelated ($p = .961$).

Target type interacted significantly with Visual Field [$F1$ (2,38) = 5.445, MS = 3249, $p < .008$, $\eta_p^2 = 0.223$; $F2$ (2,58) = 4.33, MS = 5940, $p < .018$, $\eta_p^2 = 0.130$] showing priming effects only for the literal targets in the LH (593 ms, $p < .0001$). Target type also interacted significantly with Idiom type [$F1$ (2,38) = 17.388, MS = 18504, $p < .0001$, $\eta_p^2 = 0.478$; $F2$ (2,58) = 4.75, MS = 28173, $p < .012$, $\eta_p^2 = 0.141$] mirroring the findings from Experiment 1. The idiomatic targets of non-decomposable idioms (604 ms) showed priming effects relative to the unrelated targets (623 ms, $p < .02$), while the idiomatic targets of decomposable idioms (629 ms) were significantly slower than the unrelated targets (610 ms, $p < .004$) indicating that at later stages of processing these targets still showed interference effects. The literal targets of non-decomposable idioms showed priming effects (604 ms, $p < .004$), while those of decomposable idioms (599 ms) were similar to the unrelated ones (610 ms, $p = .09$). There was also a significant two-way interaction of Idiom type x Context (by subjects) [$F1$ (1,19) = 4.555, MS = 2369, $p < .046$, $\eta_p^2 = 0.193$; $F2$ (1,29) = 2.25, MS = 2587, $p = .145$, $\eta_p^2 = 0.072$] but the post-hoc tests did not reveal any additional significant differences.

A significant 3-way interaction of Idiom type x Target Type x Visual Field [$F1$ (2,38) = 3.785, MS = 3912, $p < .032$, $\eta_p^2 = 0.166$; $F2$ (2,58) = 4.90, MS = 7166, $p < .01$, $\eta_p^2 = 0.144$] revealed that the interference effects were related to processing decomposable idiomatic targets in the RH. For decomposable idioms, the idiomatic targets (642 ms) were significantly slower than unrelated targets ($p < .007$) in the RH. No other effects in either hemisphere were found for these idioms. For non-decomposable idioms, in the LH, responses both to the idiomatic (601 ms) and literal targets (593 ms) showed priming effects relative to the unrelated targets (622 ms; $p < .042$ and $p < .008$ respectively). No priming was found in the RH (see Fig. 3).

Most importantly, there was a significant three-way interaction of Idiom type x Context x Visual Field [$F1$ (1,19) = 24.327, MS = 11659, $p < .0001$, $\eta_p^2 = 0.561$; $F2$ (1,29) = 10.05, MS = 15696, $p < .003$, $\eta_p^2 = 0.257$] which showed the same asymmetric hemispheric processing of decomposable and non-decomposable puns as in Experiment 1. Decomposable puns were processed equally fast in the two hemispheres (LH = 615 ms, RH = 617 ms, $p = .562$) indicating bilateral processing, while non-decomposable puns were processed significantly faster in the LH (599 ms) than the RH (624 ms, $p < .0002$) suggesting a LH advantage. The pattern was reversed in the single-meaning condition: decomposable idioms were processed significantly faster in the LH (597 ms) than the RH (625 ms, $p < .0002$), while non-decomposable idioms were processed equally fast in the two hemispheres (LH = 610 ms,

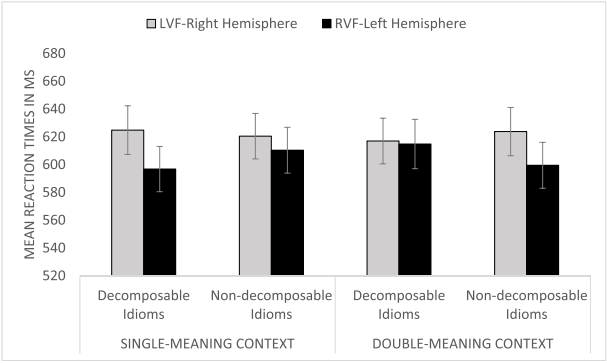

Fig. 4. Mean RTs (ms) for decomposable and non-decomposable idioms in single-meaning idiom contexts and double-meaning pun contexts in the two hemispheres at the long ISI. Error bars indicate the standard error.

RH = 620 ms, $p = .06$) (see Fig. 4).

Additionally, the 3-way interaction of Context x Target type x Visual Field [*F1* (2,38) = 4.817, MS = 3084, $p < .013$, $\eta_p^2 = 0.202$; *F*2 (2,58) = 3.01, MS = 3918, $p < .057$, $\eta_p^2 = 0.094$] was significant. The post-hoc tests revealed that in double-meaning consistent contexts (i.e., puns) the literal targets (588 ms) showed priming effects when processed in the LH ($p < .0002$). No other effects were found.

8.2. Accuracy rates

The Idiom type x Context x Target type x Visual Field ANOVA carried out with accuracy (ACC) data revealed only a significant two-way interaction of Idiom type x Target type [*F*1 (2,38) = 7.72790, MS = 12.915, $p < .001$, $\eta_p^2 = 0.289$; *F*2 (2,58) = 3.09945, MS = 8.610, $p < .05$, $\eta_p^2 = 0.097$] indicating that after decomposable idioms, errors for neither the idiomatic (2.2%) nor the literal targets (1.53%) differed from the unrelated ones (1.93%; $p = .206$ and $p = .222$ respectively). In contrast, after non-decomposable idioms, errors for idiomatic targets (1.57%) were significantly lower compared to the unrelated targets (2.25%, $p < .02$); literal targets (1.93%) and unrelated targets did not differ from each other ($p = .430$).

9. Discussion

In this experiment we investigated the hemispheric asymmetries for decomposable and non-decomposable puns at later processing stages. The main results show that the hemispheric differences for the two types of puns we observed in Experiment 1 persist under conditions in which participants were given more processing time. In particular, both experiments revealed that non-decomposable puns engage predominantly the LH, while decomposable puns recruited both hemispheres leading to increased RH involvement. Furthermore, the decomposition effects from Experiment 1 were also maintained in Experiment 2: the idiomatic meanings of non-decomposable idioms showed clear priming effects (facilitation), whereas the idiomatic meanings of decomposable idioms were processed significantly more slowly than the unrelated targets (interference). In the General discussion below we explore the possibility that greater processing costs associated with decomposable puns led to the recruitment of RH resources (while the lack of processing costs for the non-decomposable puns did not necessitate the recruitment of RH resources).

10. General discussion

The study aimed to investigate the hemispheric asymmetries for decomposable and non-decomposable puns at different processing stages. The complete data set is consistent with the cognitive continuum hypothesis (Faust & Kenett, 2014) as it revealed that the two types of puns occupy different places of the LH-RH processing continuum: across both ISIs, non-decomposable puns were processed faster in the language-dominant LH, whereas decomposable puns were processed equally fast in the two hemispheres, suggesting increased RH involvement for this type of puns only. Given that decomposable puns are partly motivated by non-salient meanings (i.e., their secondary meanings are underspecified and assumed to be computed on-line), unlike non-decomposable puns which are motivated entirely by salient meanings (i.e., meanings that are already stored in the mental lexicon), our results are consistent with the predictions of the *graded salience hypothesis* (Giora et al., 2000) according to which the RH is preferentially involved in processing non-salient meanings. On the basis of these data we argue that, for pun processing, meaning salience (indexed here by coded-ness in the mental lexicon) predicts hemispheric asymmetries more accurately than semantic relatedness (predicted by the coarse-coding hypothesis). Given the evidence that cognitively more complex linguistic stimuli engage RH resources (Vigneau et al., 2011), we argue that the use of non-salient meanings to motivate decomposable puns makes these puns harder to process, thereby leading to RH involvement. Non-decomposable puns, on the other hand, are motivated by salient/stored meanings making them easier to process and explaining the LH preference for this type of puns.

One source of the processing costs for decomposable puns is likely associated with activating the idiomatic meanings motivating this pun type. Evidence suggesting processing costs for decomposable idioms comes both from previous literature and the current data set. For example, compared to non-decomposable idioms (*'to kick the bucket'*), decomposable ones (*'to go downhill'*) show a slower time course of activation (Cieslicka, 2013), more negative N400 amplitudes (Zhang et al., 2013) and weaker priming effects (Titone & Libben, 2014). Results from the current study further indicate processing costs only for decomposable idioms: across both ISIs these idiomatic meanings showed strong interference effects (i.e., reaction times significantly slower than the unrelated targets) whereas the idiomatic meanings of non-decomposable idioms showed strong facilitation effects. Titone and Connine (1999) argued that such decomposition effects reflect representational differences between the two types of idioms: non-decomposable idioms have a separate mental representation for the idiomatic meaning, whereas decomposable idioms are underspecified for the idiomatic meanings - prompting Holsinger and Kaiser (2013) to hypothesise that decomposable idioms realise their idiomatic meaning through the literal ones.

For example, in order to understand the non-coded idiomatic meaning of '*to go downhill*', we activate aspects of the literal meanings of '*to go*' and '*downhill*' which will then function as the building blocks upon which the idiomatic meaning of '*deteriorate*' could be constructed on-line (i.e., serial processing). On the other hand, the literal meanings of non-decomposable idioms are unlikely to be instrumental in the same way, and activating these meanings cannot function as building blocks during the comprehension process. For instance, to understand the idiomatic meaning of *'to kick the bucket'*, the language processor cannot benefit in any way from the initial activation of the literal meanings of *'to kick'* and *'bucket'*, hence these idiomatic meanings develop their own mental

representation which can be retrieved holistically (see Caillies & Butcher, 2007; Gibbs et al., 1989; Swinney & Cutler, 1979 who also argue that deriving meaning on-line is cognitively more taxing than retrieving pre-existing lexical representations). Thus, the idiomatic meanings of decomposable idioms require greater processing costs (indicated by slower-time rise, more negative N400 effects and interference effects) because they are not coded and rely on a serial process of meaning activation, leading to RH involvement only for the decomposable puns. It appears that having to compute online the idiomatic meaning of decomposable puns slows down the LH and, at the same time, it invokes the assistance of the RH. Analogously, processing the two salient meanings of non-decomposable puns does not involve any extra cognitive demands which in turn does not necessitate recruiting RH resources (or at least not to the same extent) to complement those of the language dominant LH. Instead, the LH can process the two salient meanings of non-decomposable puns speedily and efficiently.

Another source of the processing costs of decomposable puns could be the semantic similarity that exists between the literal and idiomatic meanings that motivate this pun type. Processing costs for semantically related stimuli are often observed in picture-word naming tasks, for example where participants have to name a picture displayed alongside a distractor word. In such tasks, participants take longer to name the picture when the distractor word is semantically closely related to the picture (i.e., semantic interference effects) compared to conditions in which the distractor word is semantically unrelated to the picture (i.e., semantic facilitation effects) (e.g., Costa, Alario, & Caramazza, 2005). Furthermore, the phonological similarity effect (e.g., Caylak, 2010) also suggests that processing similarities is cognitively costly by revealing superior recall levels for sounds that are phonetically dissimilar compared to rhyming sounds (i.e., phonetically similar). Analogous findings are also observed at the level of orthography (i.e., transposed-letter effects). For instance, according to Grainger (2008), non-words such as *caniso* (closely resembling yet different from *casino*) are more likely to lead to classification errors compared to non-words such as *caviro* (more distantly resembling *casino*). Lastly, in a previous semantic priming study on pun processing conducted in our lab, we found significant costs (i.e., slower response latencies) related to puns triggered by two semantically related meanings. In that study semantic similarities were captured through motivating puns with polysemes (i.e., ambiguous words that have two semantically related senses; e.g., *The prince with a bad tooth got a **crown***) and semantic distance through motivating puns with homonyms (i.e., ambiguous words that have two semantically distant meanings; e.g., *A cross-eyed teacher can't control his **pupils***). That study revealed that polysemous puns were processed significantly more slowly than homonymous puns (Koleva, Mon-Williams, Weighall, Havelka, & Klepousniotou, 2016). Overall, then, there is compelling evidence in the psycholinguistic literature to suggest that processing similarities (in meaning, sounds and letters) is cognitively more costly compared to processing semantic, phonological and orthographic dissimilarities.

Therefore, we argue that the RH is involved only in the processing of decomposable puns - partly because, being motivated by two semantically similar meanings, these puns require greater cognitive resources relative to non-decomposable puns which are motivated by two semantically distant meanings. Our design cannot differentiate between costs stemming from the activation of non-coded meanings and those stemming from processing linguistic similarities because these two sources are conflated in the case of the idiomatic meanings of decomposable puns. Nevertheless, our study significantly contributes to the pun processing literature by demonstrating that the internal motivation of puns is an important predictor of hemispheric asymmetries. In particular, our findings showed that processing non-salient meanings leads to RH involvement (unlike processing salient meanings) - confirming the predictions of the *graded salience hypothesis* (Giora et al., 2000).

The co-occurrence of greater processing costs and RH involvement has been reported in the experimental literature on non-literal language processing. As discussed in the Introduction, Kana and Wadsworth (2012) investigated pun comprehension for a group of autistic participants as well as healthy controls. The clinical data revealed greater activation in the language areas in the pun condition (compared to the healthy control group in the same condition) accompanied by RH involvement for pun comprehension only for the clinical population. The same relationship of processing costs-RH involvement has also been observed for other types of non-literal language such as metaphors, irony and sarcasm. For example, in an EEG/ERP set up, Arzouan, Goldstein, and Faust (2007) investigated the processing of literal expressions, conventional and novel metaphors. The authors reported a gradually increasing N400 amplitude (literal < conventional < novel) which showed right-based scalp distribution only in the case of novel metaphors. In the irony literature, less salient ironic interpretations consistently show slower time-course of meaning activation compared to salient literal expressions (indicating processing costs) (e.g., Giora & Fein, 1999; Giora, Fein, & Schwartz, 1998) and fMRI studies indicate RH involvement for ironic language too (e.g., Shibata, Toyomura, Itoh, & Abe, 2010). Similarly, sarcasm-related processing costs, compared both to literal baseline controls and metaphors, were reported (Olkoniemi, Ranta, & Kaakinen, 2016) as well as RH facilitation for sarcastic texts (Briner, Joss, & Virtue, 2011). Our study further strengthens the relationship between greater processing costs and RH involvement for non-literal language by showing that the same relationship holds for puns in young healthy adult populations.

Our results also have implications for the literature on idiom decomposition effects and hemispheric asymmetries for decomposable and non-decomposable idioms. In particular, in accordance with Titone (1998), we found that in single-meaning unambiguous idiomatic contexts during both early and late processing stages, decomposable idioms were processed faster in the LH, whereas non-decomposable idioms were processed equally fast in both hemispheres. Furthermore, we replicated and strengthened the finding that decomposable idioms show processing disadvantages compared to non-decomposable ones (consistent with Cieslicka, 2013; but cf. Gibbs et al., 1989). We showed for the first time that both during early and late processing stages the idiomatic meanings of decomposable idioms showed consistent interference effects (responses significantly slower than unrelated baseline controls). Further research needs to address the possibility that suppression mechanisms may be responsible for these effects. Moreover, and irrespective of decomposition effects, our study also provides evidence that the RH is involved in the processing of the literal meanings of all idioms because they are deemed to be the non-salient ones for unambiguous idiomatic expressions (for similar results see Mashal, Faust, Hendler, & Jung-Beeman, 2008; also Cieslicka, 2013 for decomposable idioms in the native Polish block).

Given that we only used unambiguous idioms that were clearly biased towards the idiomatic meanings, the literal meanings of such idioms are considered the less salient ones (saliency being indexed by means of familiarity/meaning dominance). Our findings, thus, provide further evidence that the RH is preferentially engaged in the processing of non-salient meanings (Giora et al., 2000).

In sum, our study provides support for the cognitive continuum hypothesis (Faust & Kenett, 2014) by revealing that non-decomposable puns are predominantly processed in the language dominant hemisphere (LH) while decomposable puns recruit RH resources leading to bilateral processing for this type of pun. More importantly, however, the study contributes to the wider literature on non-literal language and RH processing by suggesting that language (non)-salience (Giora, 2012) can predict more accurately RH involvement than semantic distance (Jung-Beeman, 2005), when these two variables are examined within a single experimental design. We argued that the RH is necessary only for decomposable puns because they are partly motivated by non-salient meanings which are cognitively more costly to process compared to salient meanings. We suggested that the extra cognitive demands could stem from two sources: (i) activating non-coded meanings following a process of on-line meaning computation (rather than meaning retrieval), and/or (ii) simultaneously processing two semantically similar meanings (rather than two dissimilar ones). The present study used a relatively small number of participants; yet the results were robust in capturing processing differences between decomposable and non-decomposable puns motivated by idioms. These findings pave the road for future studies. Further research with increased participant numbers on pun processing should disentangle the separate costs stemming from each of these sources.

Acknowledgments

We would like to thank Lucy Ferguson and Lucy Morris for help with data collection.

Appendix A

A list of all materials used in the experiments; the bolded words indicate the ambiguous phrases.
Decomposable idioms – double-meaning consistent contexts (puns):

Old bankers never die, they just **pass the buck.**
The young musician tried hard but couldn't **steal the show.**
Old colanders never die they just can't **take the strain.**
Progressive neurosurgeons always **keep an open mind.**
The artist wanted a cube but **had a mental block.**
I considered becoming a mountaineer but I couldn't **make the grade.**
We never get anywhere in geometry – only **go round in circles.**
I was a milkman but everything **turned sour.**
Old skiers never die, they just **go downhill.**
They kept their ballet dancers **on their toes.**
I was a balloonist but it didn't **get off the ground.**
I studied electrical engineering but I am still **in the dark.**
I can master Braille once **I've got a feel for it.**
I was a sprinter but I was **on the wrong track.**
Money for kitchen sink detergent is just money **down the drain.**
Life's like a shirt button – it only **hangs by a thread.**
I was destined for osteology – I could **feel it in my bones.**
I was a transplant surgeon, but **my heart wasn't in it.**
Toreadors resign when they can't **take the bull by the horns.**
I know a lingerie buyer who **gave his wife the slip.**
The careless lion-tamer let the cat out of the bag.
When a boxer practises in winter, he may be **out cold.**
Maths teachers are boring – they always **go off on tangents.**
The hair stylist knew she would **make waves.**
The old crab's relationship is **on the rocks.**
Life's like showers – one wrong turn and you're **in hot water.**
The cannibals gave the latecomers **the cold shoulder.**
This butcher does not seem to **mince his words.**
He couldn't fix the washing machine and **threw in the towel.**
The pilot's career is **up in the air.**

Decomposable idioms – single meaning consistent contexts:

It is never too tempting to pass the buck.
When we had guests children would never steal the show.
The transport service does not let us take the strain.

To progress we should keep an open mind.
When they referred to statistics I had a mental block.
Only a small minority of the students couldn't make the grade.
We can't decide today – we seem to go round in circles.
Soon after the accident their relationship turned sour.
Old painters never die, they just go downhill.
They kept their new employees on their toes.
Without enough money, the new company couldn't get off the ground.
I attended the seminar but I am still in the dark.
You can master anything if you've got a feel for it.
My tutor told me yesterday I was on the wrong track.
Money spent on fancy trinkets is just money down the drain.
Life is all very precious – it only hangs by a thread.
I was destined for greatness – I could feel it in my bones.
I was a good mechanic but my heart wasn't in it.
Managers resign when they can't take the bull by the horns.
The police followed him but he gave them the slip.
Unfortunately my little sister let the cat out of the bag.
A single slap from him can immediately knock you out cold.
Bookish people are boring – they always go off on tangents.
The new student knew she would make waves.
Sadly, her second marriage is on the rocks.
All those complaining e-mails can easily land you in hot water.
The pupils gave the newcomer the cold shoulder.
A frank person never tries to mince their words.
He couldn't do his maths homework and threw in the towel.
His career plans are up in the air.

Literal Targets	Idiomatic Targets	Unrelated Targets
cash	dodge	smoke
perform	capture	bird
drain	suffer	wing
brain	flexible	bowl
cone	halt	media
slope	attain	fluid
sphere	static	stove
lemon	spoil	essay
slide	decline	soup
stretch	anxious	plastic
sky	succeed	demon
star	ignorant	trend
finger	skill	match
trail	error	snake
pour	waste	shake
needle	risk	bath
joint	perceive	crouch
chest	dislike	tree
cow	brave	cream
skirt	chase	shell
feline	reveal	arrow
ice	smack	sauce
algebra	digress	hen
ocean	fascinate	spasm
stone	split	bureau
wet	worry	kid
blade	avoid	foam
meat	honest	loud
wipe	defeat	code
fly	dim	pat

Non-decomposable idioms – double-meaning consistent contexts (puns):

I was a carpenter but it **went against the grain.**
In medical matters it's the nurses who **call the shots.**

I wasn't a yachtsman as I didn't **know the ropes.**
To commit suicide at sea is to **go overboard.**
The chef has to make sure he doesn't **cook the books.**
To communicate with a fish, you need to **drop a line.**
The young jockey resigned because he couldn't **hold his horses.**
Babies don't like baths because they **get them into a lather.**
The success of the new bank is **on the cards.**
Management at the post office always **push the envelope.**
When he was sentenced to the guillotine he **lost his head.**
I fired my masseuse because she **rubbed me the wrong way.**
Old cleaners never die they just **bite the dust.**
The arts students decided to **paint the town red.**
The lumberjack wanted advice from someone with **no axe to grind.**
The stuck-up chef was left with **egg on his face.**
A bunch of meteorologists got together to **shoot the breeze.**
The lady threatened to take the laundrette to the cleaners.
The suicide bomber said the explosion **blew his mind.**
A bad shoemaker's assistant **was given the boot.**
He didn't pay his orchestra and had to **face the music.**
The crooked greengrocer found himself **in a pickle.**
Two surgeons joking about operations will **have each other in stitches.**
I worked in a delicatessen but I couldn't **cut the mustard.**
The swimmer quit as he would **go off the deep end.**
Old owls never die, they just don't **give a hoot.**
Sailing is a sport that does not **float my boat.**
Butchers' cutting remarks can **get customers in a stew.**
Old gardeners never die they **kick the bucket.**
Chemistry students are never **out of their element.**

Non-decomposable idioms – single meaning consistent contexts:

I worked on Sundays but it went against the grain.
I wanted to trade but I didn't know the ropes.
It's easy for primary school pupils to go overboard.
He looks for accountants who are unlikely to cook the books.
To stay in touch with the family, just drop a line.
The young manager resigned because he couldn't hold his horses
Couples don't like quarrels because they get them into a lather.
The success of the new play is on the cards.
Management at work always push the envelope.
When he won the national lottery he completely lost his head.
I fired my assistants because they rubbed me the wrong way.
Like it or not we all bite the dust.
Yesterday the boys decided to paint the town red.
She acted solely out of concern with no axe to grind.
The non-attendance left the boss with egg on his face.
A bunch of students got together to shoot the breeze.
He wished he could take his company to the cleaners.
The story I told her absolutely blew her mind.
After the scandal he was given the boot.
He didn't submit his essay and had to face the music.
The crooked policeman found himself in a pickle.
Two friends joking about puns will have each other in stitches.
I wanted to do research but I couldn't cut the mustard.
After a few drinks he'd go off the deep end.
We all need to learn not to give a hoot.
Watching horror movies before sleep does not float my boat.
Cutting remarks can always get customers in a stew.
Old farm animals never really kick the bucket.
Guests should never feel out of their element.

Literal Targets	Idiomatic Targets	Unrelated Targets
circle	odd	coat
inject	reign	lend
knot	knack	paddock
dinghy	excess	tissue
meal	alter	pocket
string	mail	lamp
ride	calm	wash
soap	tense	dish
earn	feasible	mud
stamp	grow	mile
sword	panic	pearl
muscle	anger	ought
dirt	grave	wire
brush	fun	text
chop	profit	priest
yellow	stupid	screen
wind	gossip	cloth
broom	trick	fleet
gale	shock	glimpse
lace	sack	knit
sing	blame	mixture
jar	dilemma	visual
thread	laugh	wisdom
seed	expert	gang
jump	yell	ankle
shout	ignore	pub
row	joy	drama
boil	hurt	tunic
barrel	coffin	modest
atom	comfort	slug

Filler sentences with puns:

Employers like their mechanics to be geared up.
The fine print is usually a clause for suspicion.
People who like yoghurt are well-cultured.
After the test drive, the car salesman drove home his point.
The size a dieter would like to get to is the sighs of relief.
The astronauts stopped dating because they needed their space.
Strippers are bad investors as they tend to lose their shirts.
Patients usually feel better after receiving hand transplants.
Their business plan for a flower shop was cut and dried.
Two duchess arguing about their husbands decided to duke it out.
In the old days a suspended sentence was hanging.
Those who make sinks often feel washed out.
She was given a violin lesson for free, with no strings attached.
He bought a donkey just to get a kick out of it.
They are a fastidious couple – she is fast, he is tedious.
They hid in a sauna where they could sweat it out.
After dating the goalie for a while, she realised he is a real keeper.
Those who experiment with thin ice will achieve a breakthrough.
He slipped into a manhole with a loaded gun, but then blew his cover.
Six is afraid of seven because seven eight nine.
Erasable pens were a good idea on paper.
Molecules boiling points vary to some degree.
The farmer brought some milk to church to be pastorized.
It's hard for a depressed turtle to come out of its shell.
The decision to shoot more wolves caused howls of protest.
A horse is a very stable animal.
Straw hats are no longer in their hay day.
I used to be a tap dancer until I fell in the sink.
People think that writing long stories is a novel idea.
I didn't know which hammer to get, But I think I nailed it.

We didn't know she had a dental implant until it came out in a conversation.
A tight-rope walker enjoys being on-line.
On Valentine's day many people take heart.
People in medieval days were always hanging out by the gallows.
When his ship ran aground, he couldn't fathom why.
If money talks, we do not really need bank tellers.
The skeleton went to a party but had no body to dance with.
The railway constructions are on track.
The average ghost is mean spirited.
Old deans never die, they just lose their faculties.
The science teacher says the globe means the world to her.
A thief who stole a calendar got twelve months.
I used to hate maths before I realised that decimals have a point.
A new type of broom is sweeping the nation.
Using fingers to count is a digital calculator.
If you give managers an inch, they think they are a ruler.
He took a gun to his watch because he wanted to kill time.
I usually take steps to avoid elevators.
Maths teachers call retirement the aftermaths.
He was stealing from a blood bank, but he was caught red-handed.
Contacts are easy to lose, so keep your eyes on them.
The job to die for comes with a killer boss.
Graveyard workers should really dig their jobs.
When the elevator broke I was downcast.
My job at the concrete plant seems to get harder and harder.
He has been a jogger for three years running.
To some marriage is a word, to others – a sentence.
Don't trust people who do acupuncture, they are back-stabbers.
Old mediums never die – they just give up the ghost.
Noteworthy musicians are very composed.

Filler sentences without puns:

A small amount of this paint goes a long way.
Give your brother my regards when you see him.
We have to get to the root of the problem.
Prevention plays a central role in traditional medicine.
She managed to calm him down and seek help.
Both candidates spent last month courting the media.
She has very modern ideas about educating her children.
The delay is due simply to the volume of traffic.
We take the view that it would be wrong to interfere.
In case of emergency, break the glass and press the button.
It was a performance of verve and vitality.
The money was collected for a specific purpose.
There's no point getting into a panic about the exams.
Two regiments were sent to garrison the town.
For certain personal reasons I shall not be able to attend.
He passed the rope around the post three times to secure it.
Each student's points were totalled and entered in a list.
He still has a cloud of suspicion hanging over him.
The treatment they gave him did him more harm than good.
I think you should go back to your original plan.
She towers over other dancers of her generation.
His savings were a comfortable cushion against financial problems.
Classical dance in its purest form requires symmetry and balance.
The land is used by local people to graze their animals.
I showed my pass to the security guard and he waved me through.
The survivors were adrift in a lifeboat for days.
She has a remarkable inner strength.
We had to stop for breath before we got to the top.

Remove the skins by soaking the tomatoes in hot water.
Their latest single represents a new departure for the band.
They were able to share their common joys and griefs.
They'll be offended if you do not go to their wedding.
I had a flick through the catalogue while waiting.
The meeting was hyped up in the media as an important event.
He's been on the computer all morning, chatting to his friends.
The injured were carried away on stretches.
I am really concerned about my spiritual welfare.
She was charged with credit card fraud.
I was pinched for dangerous driving.
You must have wiped off that programme I recorded.
A lecture from my parents now would just finish me.
She always wears her hair pinned back.
The big corporations are bleeding some of the small countries dry.
There is not a grain of truth of what she says.
He travelled from town to town selling his wares.
He caught a whiff of perfume as he leaned towards her.
The story was reported in the press and on television.
He was very insecure about his appearance.
I believe you have a complaint against one of our nurses.
Their marriage was trumpeted as the society marriage of the year.
This dictionary gives phonetic transcriptions of all headwords.
The Army is auctioning off a lot of surplus equipment.
Below him was nothing but a black void.
He called her the foulest names imaginable.
We cannot guarantee adequate supplies of raw materials.
The star of the show was a young Italian singer.
We spent the whole evening discussing domestic trivia.
Now she had him in her clutches, she wasn't going to let go.
A group of kids started a pick-up game of basketball.
A welcoming fire was burning in the fireplace.

Non-Words	Non-words	Non-Words
lerps	smoob	drine
vuct	claivs	swuff
norve	fruzz	clulls
jamped	plines	psyth
nurf	daves	wogged
clyst	shabes	bloys
owse	kril	flib
landge	derse	vuked
spugs	braff	smool
jadge	flized	sharn
sproil	zurp	yeel
bruint	slarfs	gloals
polks	plaped	shruff
klus	scalvs	cleald
bungal	crarc	daught
pendge	gevved	pheech
brenge	stask	bliche
glact	blit	pigued
crus	clis	spleese
smenth	snace	phuv
dorce	twans	glells
yarks	stuilt	flodd
chich	dored	deaned
ganks	wronk	seffed
phecks	stends	hurns
cabes	nuds	reace
gleut	prese	frope
hapes	vames	tib
ments	pheem	blinch
malps	whamp	thobs
scrons	klupes	rolds

zamped	klou	gnoped
crogue	vaives	phreen
vonce	snibs	slonce
spabe	gect	gopse
dake	draff	crong
beags	woffed	crumed
durnt	pheek	soast
coved	zouls	carce
slafe	wat	prith
momps	smase	cloams
brive	treng	tweigh
kib	plause	peph
nirm	mawk	stusk
flaum	glaul	nirs
droles	croafs	fusk
clift	lods	flane
bymn	skarc	plev
stiest	skop	stad
klense	frilks	drarps
foafs	swalt	snuth
jitts	dondge	folge
crined	crench	stib
neets	mave	flerm
drungs	cype	plonn
vild	slobes	neidge
zumf	flell	spance
blufts	ribed	gluse
hule	shales	rond
lault	chole	farch

Appendix B

Experiment & Analyses	Significant Effect	ANOVA By Participants	ANOVA By Items
0 ISI: Response Latencies	Visual Field	$F1$ (1,19) = 29.212, MS = 32556, $p < .0001$, $\eta_p^2 = 0.606$	$F2$ (1,29) = 42.88, MS = 52762, $p < .0001$, $\eta_p^2 = 0.597$
	Target type	$F1$ (2,38) = 10.423, MS = 13071, $p < .0001$, $\eta_p^2 = 0.354$	$F2$ (2,58) = 4.49, MS = 18195, $p < .01$, $\eta_p^2 = 0.134$
	Idiom type x Target type	$F1$ (2,38) = 12.528, MS = 8013, $p < .0001$, $\eta_p^2 = 0.397$	$F2$ (2,58) = 3.01, MS = 13439, $p < .057$, $\eta_p^2 = 0.094$
	Idiom type x Context x Target type	$F1$ (2,38) = 4.178, MS = 1821, $p < .022$, $\eta_p^2 = 0.180$	$F2$ (2,58) = 3.14, MS = 4075, $p < .05$, $\eta_p^2 = 0.099$
	Idiom type x Context x Visual Field	$F1$ (1,19) = 6.327, MS = 13919, $p < .0001$, $\eta_p^2 = 0.462$	$F2$ (1,29) = 27.79, MS = 25366, $p < .0001$, $\eta_p^2 = 0.471$
	Context x Target type x Visual Field	$F1$ (2,38) = 3.734, MS = 3057, $p < .033$, $\eta_p^2 = 0.164$	$F2$ (2,58) = 2.96, MS = 4656, $p = .06$, $\eta_p^2 = 0.093$
0 ISI: Accuracy Rates	Idiom type x Target type	$F1$ (2,38) = 9.39600, MS = 15.152, $p < .0005$, $\eta_p^2 = 0.331$	$F2$ (2,58) = 3.42693, MS = 10.101, $p < .039$, $\eta_p^2 = 0.106$
	Idiom type x Context x Visual Field	$F1$ (1,19) = 9.29451, MS = 14.700, $p < .007$, $\eta_p^2 = 0.328$	$F2$ (1,29) = 6.80176, MS = 9.800, $p < .014$, $\eta_p^2 = 0.189$
750 ISI: Response Latencies	Visual Field	$F1$ (1,19) = 17.276, MS = 32647, $p < .0005$, $\eta_p^2 = 0.476$	$F2$ (1,29) = 63.16, MS = 46003, $p < .0001$, $\eta_p^2 = 0.685$
	Target type	$F1$ (2,38) = 13.027, MS = 7424, $p < .0001$, $\eta_p^2 = 0.407$	$F2$ (2,58) = 2.00, MS = 46003, $p = .144$, $\eta_p^2 = 0.065$
	Target type x Visual Field	$F1$ (2,38) = 5.445, MS = 3249, $p < .008$, $\eta_p^2 = 0.223$	$F2$ (2,58) = 4.33, MS = 5940, $p < .018$, $\eta_p^2 = 0.130$
	Target type x Idiom type	$F1$ (2,38) = 17.388, MS = 18504, $p < .0001$, $\eta_p^2 = 0.478$	$F2$ (2,58) = 4.75, MS = 28173, $p < .012$, $\eta_p^2 = 0.141$

	Idiom type x Context	$F1$ (1,19) = 4.555, MS = 2369, $p < .046$, $\eta_p^2 = 0.193$	$F2$ (1,29) = 2.25, MS = 2587, $p = .145$, $\eta_p^2 = 0.072$
	Idiom type x Target Type x Visual Field	$F1$ (2,38) = 3.785, MS = 3912, $p < .032$, $\eta_p^2 = 0.166$	$F2$ (2,58) = 4.90, MS = 7166, $p < .01$, $\eta_p^2 = 0.144$
	Idiom type x Context x Visual Field	$F1$ (1,19) = 24.327, MS = 11659, $p < .0001$, $\eta_p^2 = 0.561$	$F2$ (1,29) = 10.05, MS = 15696, $p < .003$, $\eta_p^2 = 0.257$
	Context x Target type x Visual Field	$F1$ (2,38) = 4.817, MS = 3084, $p < .013$, $\eta_p^2 = 0.202$	$F2$ (2,58) = 3.01, MS = 3918, $p < .057$, $\eta_p^2 = 0.094$
750 ISI: Accuracy Rates	Idiom type x Target type	$F1$ (2,38) = 7.72790, MS = 12.915, $p < .001$, $\eta_p^2 = 0.289$	$F2$ (2,58) = 3.09945, MS = 8.610, $p < .05$, $\eta_p^2 = 0.097$

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