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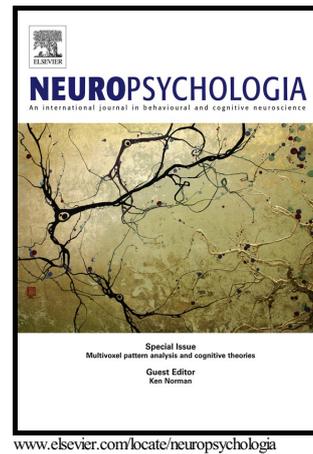Hemispheric Processing in Conventional Metaphor Comprehension: The Role of General Knowledge

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Hemispheric Processing in Conventional Metaphor Comprehension: The Role of General

Knowledge

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Abstract:

This study explored the relation between general knowledge and the hemispheric processing of

metaphoric expressions in college age students. We hypothesized that prior knowledge

influences how the hemispheres process metaphors in these individuals. In this study, 97 young

(college-aged) adults completed a general knowledge and vocabulary test, and were then divided

into high-knowledge/high-vocabulary and low-knowledge/low-vocabulary groups. Next,

participants viewed word pairs consisting of conventional metaphors, novel metaphors, word

pairs with a literal meaning, and unrelated word pairs. The first word in each pair was presented

centrally, and the second was presented to the right visual field-left hemisphere (rvf-LH) or the

left visual field-right hemisphere (lvf-RH), and participants indicated whether each pair was a

meaningful expression. Accuracy results showed an interaction between general knowledge and

visual-field hemisphere. Low-knowledge participants were more accurate for metaphors

presented to the rvf-LH than the lvf-RH, whereas high-knowledge participants showed no

accuracy differences between the hemispheres. We also found an interaction between vocabulary

and visual field-hemisphere for conventional metaphors. Specifically, low-vocabulary

participants showed a left-hemisphere accuracy advantage, but high-vocabulary participants

showed similar accuracy patterns in both hemispheres. These results suggest that young adult

readers who have more general knowledge process conventional metaphors similarly in both

hemispheres, whereas young adult readers who have less general knowledge may rely more

heavily on left-hemisphere processes during conventional metaphor comprehension.

1. Introduction

Language comprehension often requires readers to go beyond the literal meaning of a

word or phrase, and consider its figurative meaning. For example, in English, the common

metaphor "iron fist" refers to an individual who is very strict, rather than an individual who

literally possesses an iron hand. Because language comprehension often relies on understanding

figurative expressions, a more thorough understanding of how readers process these figurative

expressions is critical to our understanding of language and reading (Grossman & Noveck, 2015;

Hagoort & Levinson, 2014). Investigations of figurative language processing have given rise to

several studies on neurological functioning during figurative language comprehension (e.g.,

Eviatar & Just, 2006; Mashal & Faust, 2009), often focusing on the relative contributions of the

right and left hemispheres. In the current study, we explore how prior knowledge affects how

readers process metaphors, and the relative contributions of the right and left cerebral hemispheres in these comprehension processes.

Although the left cerebral hemisphere often dominates during a variety of language processes (Beeman & Chiarello, 1998), including word recognition (Ossowski & Behrmann, 2015) and phonological awareness (Ugolini, Wagley, Hsu, Arredondo, & Kovelman, 2016), many questions remain about how the brain processes figurative language. Some of the earliest neurological studies of figurative language suggested a right hemisphere processing advantage, as patients with damage to the right hemisphere often experience difficulty processing figurative meanings of phrases such as "face the music" (Myers & Linebaugh, 1981; Van Lancker & Kempler, 1987). However, recent findings suggest a more complex relation between the hemispheres and metaphor comprehension. Greater left hemisphere activity has been observed when readers were either judging the degree of figurative meaning in a text, or its positive/negative connotations (Rapp, Leube, Erb, Grodd, & Kircher, 2007). Similarly, when individuals read words with a metaphoric meaning (e.g., hot-cold-unfriendly), greater left-hemisphere activation is evident compared to when they read words with literal meanings (e.g., hot-cold-chilly) using functional magnetic resonance imaging (fMRI; Lee & Dapretto, 2007). Other studies have suggested bilateral activation during metaphor comprehension and production. For example, metaphor comprehension engages the left inferior frontal gyrus and both left and right regions of the inferior temporal cortex, as evidenced by fMRI (Eviatar & Just, 2006). Other fMRI research has demonstrated that the parietal cortex is bilaterally activated during metaphor comprehension (Obert et al., 2014). These findings are inconsistent with previous accounts of right hemisphere dominance during metaphor comprehension.

It is possible that the extent to which the right and left hemispheres are involved in metaphor processing depends partly on how familiar the reader is with the metaphorical phrase. For example, readers need less time to process highly familiar metaphors in a lexical decision task compared to less familiar metaphors (Blasko & Connine, 1993; Damerall & Kellogg, 2016). These behavioral differences are also reflected in how the hemispheres process familiar and less familiar metaphors. For example, fMRI evidence has shown increased right hemisphere activation when readers process novel metaphoric expressions (i.e., metaphors taken from poetry, which the participants were unlikely to have previously encountered), but increased left hemisphere involvement for familiar metaphoric expressions (Mashal, Faust, Hendler, & Jung-Beeman, 2007). The same pattern of results (i.e., a left hemisphere advantage for processing familiar metaphors and a right hemisphere advantage for processing novel metaphors) has also been observed using the divided visual field paradigm (Faust & Mashal, 2007). Interestingly, if participants are given repeated exposure to these novel metaphors, the hemispheric processing advantage shifts from the right to left hemisphere (Cardillo, Watson, Schmidt, Kranjec, & Chatterjee, 2012; Mashal & Faust, 2009). Further, repeated transcranial magnetic stimulation (rTMS) applied to the right hemisphere inhibits processing of novel metaphors, whereas rTMS applied to the left hemisphere disrupts processing of well-known (i.e., conventional) metaphors (Pobric, Mashal, Faust, & Lavidor, 2008). Taken together, these findings suggest that knowledge of metaphoric expressions can influence how the hemispheres process these phrases.

Prior knowledge may also play a role in metaphor comprehension. Kave and colleagues recruited young adults (mean age 25.4 years) and older adults (mean age 73.7 years) to participate in a study investigating the relation between aging and metaphor comprehension (Kave, Gavrieli, & Mashal, 2014). In this study, participants viewed word pairs and then pressed

a button to indicate whether the pair of words formed a meaningful expression. Although the

accuracy for the novel idioms was too low to interpret these response times, hemispheric

processing of conventional metaphors differed for older and younger participants. Younger

adults showed no significant difference between the hemispheres in terms of how accurately they

processed conventional metaphors, processing metaphors in either hemisphere with similar

accuracy. In contrast, older adults showed higher accuracy for conventional metaphors that were

presented to the left hemisphere compared to conventional metaphors in the right hemisphere.

Although this was an interesting finding, the difference between age groups disappeared when

controlling for vocabulary knowledge, suggesting that these age-related differences were due to

differences in vocabulary knowledge between the two groups. In fact, Kave et al. (2014) stated

that their findings showed evidence of "knowledge accumulation" in their older adults.

According to this knowledge accumulation hypothesis, older adults have acquired a greater

knowledge and understanding of the world (and of language) due to their greater life experience

compared to younger adults. In this hypothesis, greater amounts of general knowledge in the

older adults may have led to stronger links between individual words of the metaphors, which

were then processed by the left hemisphere. With repeated exposure to these metaphors, along

with the words and concepts related to those metaphors, close associations could more easily be

formed between the words in these metaphoric expressions. This account seems to be in

accordance with evidence that people may process and store well-known metaphors as if they are

one long, syntactically complex word (Gibbs, 1994; 2015). For example, individuals who are

very familiar with the "iron fist" metaphor may store the phrase similarly to how they might

store the single-word unit "controlling." In other words, for high knowledge readers, the

individual words in the metaphor may be linked so strongly via left-hemisphere connections that

they process these conventional metaphors as if they were one word. Such an explanation would

be consistent with the knowledge accumulation hypothesis, as greater knowledge of the

metaphor and its related concepts may lead to this different pattern of processing in the left

hemisphere compared to less knowledgeable individuals.

If the knowledge accumulation hypothesis is correct, one would expect that accuracy

scores for older and younger adults would be noticeably different in Kave et al.'s (2014) study.

Instead, the difference in left hemisphere accuracy scores for conventional metaphors seems

small (83.4% for younger adults vs. 86.7% for older adults). Accuracy differences between older

and younger adults were slightly greater when conventional metaphors were presented in the

right hemisphere (85.6 for younger vs. 80.1% for older adults). Thus, older adults do not seem to

be substantially outperforming their younger counterparts when conventional metaphors are

presented to the left hemisphere. Instead, the younger adults appear to be outperforming older

adults when conventional metaphors are presented to the right hemisphere. These results suggest

that the differences in how the hemispheres process conventional metaphors between younger

and older adults may be influenced by factors other than knowledge accumulation in older

adults.

The hemispheric differences evident between older and younger adults' processing of

conventional metaphors in the Kave et al. (2014) study may instead be due to a decline in right

hemisphere processing during language tasks in older adults. The older adults in Kave et al.'s

sample ranged in age from 69-85 years. These older participants fall well within the age range

during which most individuals begin experiencing cognitive decline (Singh-Manoux et al.,

2012). Of particular importance for the current study, cognitive decline is associated with

impairments in processing nonliteral language. For example, older adults with mild cognitive

impairment experience greater difficulty accessing and retrieving both figurative and literal

meanings during a language comprehension task when compared to younger adults (Cardoso,

Silva, Maroco, De Mendonca, & Guerreiro, 2014). Thus, it is possible that the greater reliance on

left hemisphere processes for metaphor comprehension in older adults may be due to difficulties

accessing semantic information in the right hemisphere, compared to younger adults.

The goal of the present study is to further examine how prior knowledge influences the

hemispheric processing of metaphors. Whereas Kave et al. (2014) were primarily interested in

age-related differences in the hemispheric processing of metaphors, the present study holds age

constant (i.e., all participants were college age students) and focuses on how different types of

knowledge (e.g., general knowledge and vocabulary) influence how the right and left cerebral

hemispheres process metaphors.

This experiment tests two competing hypotheses. First, if the "left hemisphere knowledge

hypothesis" based on the Kave et al. (2014) findings is correct, then we would predict that

individuals who have greater general knowledge will show a stronger pattern of left hemisphere

lateralization (i.e., higher accuracy scores compared to the right hemisphere) when

comprehending conventional metaphors compared to individuals who have less general

knowledge in the current study. Second, if the "bilateral knowledge hypothesis" based on models

of right hemisphere decline (Singh-Manoux et al., 2012) is correct, then we would predict that

individuals who have greater general knowledge will process conventional metaphors similarly

in both hemispheres, whereas individuals who have less general knowledge will demonstrate

greater accuracy for conventional metaphors presented to the left hemisphere compared to

conventional metaphors presented to the right hemisphere in the current study. Testing these two

hypotheses will allow us to understand the extent to which hemispheric differences in metaphor

processing observed in previous research (Kave et al., 2014) depends on prior knowledge while holding age constant.

2. Method

2.1. Participants

Ninety-seven participants (78 female, 19 male) from an urban university in the Midwest participated in exchange for course credit. These participants were all young adults falling with the normal age range of undergraduate college students (i.e., 18-22 years). All participants had normal or corrected-to-normal vision, were native speakers of English, and had no history of neurological damage or disorder. All participants were right-handed, as assessed by the Edinburgh Handedness Scale (mean laterality quotient: 0.87) (Oldfield, 1971).

2.2. Materials

2.2.1. Stimuli.

For our experimental stimuli, we compiled a list of 100 word pairs, which were grouped into four conditions based on their semantic relatedness: literal (*messy room*), conventional metaphor (*iron fist*), novel metaphor (*glass river*), and unrelated (*wisdom wash*). Thus, we use the same conditions as previous studies (Kave et al., 2014; Mashal & Faust, 2007) with the exception that we created lists of word pairs in English instead of Hebrew (as was the case in the previous studies). Following previous studies of novel metaphors (Kave et al., 2014; Mashal & Faust, 2007; Pobric et al., 2008), the word pairs in the novel metaphor condition were taken from poetry. A full list of our stimulus items can be found in the Appendix.

To determine the degree of semantic relatedness for the word pairs in each condition, a pilot study was conducted in which 72 participants (who did not participate in the main experiment) judged each word pair based on the pairs' familiarity and plausibility. Following the

methods found in Pobric, Mashal, Faust, and Lavidor (2008), pilot participants rated the familiarity of each phrase on a scale of 1 (not familiar at all) to 5 (extremely familiar). Participants also indicated whether they believed each word pair to have a literal meaning, a figurative meaning, or no meaning. Descriptive statistics for these ratings can be found in Table 1. Results from the pilot study confirmed that our literal word pairs and our conventionally metaphoric word pairs were rated as being more familiar than the novel metaphoric pairs or the unrelated pairs. A oneway ANOVA revealed a significant difference between conditions in item familiarity scores, $F(3, 99) = 29.07$, $p < .001$. Follow-up Tukey post-hoc tests indicated comparable levels of familiarity between the conventional metaphor and literal conditions ($p = .992$). However, word pairs in the novel metaphor condition were rated as less familiar than pairs in the literal, conventional metaphor, and unrelated conditions. (all ps < .001).

A separate oneway ANOVA on the proportion of participants who rated each item as having a literal meaning also yielded significant differences, $F(3, 96) = 216.97$, $p < .001$. Tukey post-hoc analyses demonstrated that the proportion of items categorized as having a literal meaning was higher in the literal condition than in all other conditions (all ps < .001). However, there were no significant differences in proportion of items categorized as literally meaningful for the conventional metaphor, novel metaphor, or unrelated conditions.

Proportions of items categorized as having a figurative meaning were analyzed using a oneway ANOVA, which revealed significant differences between these conditions, $F(3, 96) = 118.99$, $p < .001$. Tukey post-hoc analyses indicated that the proportions for figurative meaning in each condition were all significantly different from each other (all ps < .001), with the conventional metaphor condition having the highest proportion of metaphoric meanings, followed by the novel metaphor condition, the control condition, and lastly, the literal condition.

Table 1: *Stimuli Pilot Study Results*

Condition	Familiarity	Literal Meaning Proportion	Figurative Meaning Proportion
Unrelated	1.82 (.04)	0.1 (.02)	0.38 (.02)
Literal Meaning	4.39 (.07)	0.85 (.02)	0.1 (.03)
Conventional Metaphor	4.35 (.10)	0.17 (03)	0.78 (.03)
Novel Metaphor	2.53 (.13)	0.15 (.02)	0.56 (.03)

All target word pairs were matched across conditions for word length, number of syllables, and word frequency.

Word concreteness was measured using a database of concreteness ratings of 40,000 English word lemmas (Brysbaert, Warriner, & Kuperman, 2014). Mean concreteness ratings were 3.89 (SE = .14) for the conventional metaphor pairs, 3.98 (SE = .11) for the literal pairs, 3.54 (SE = .13) for the novel metaphor pairs, and 3.46 (SE = .11) for the unrelated pairs. A one-way analysis of variance on mean concreteness ratings revealed a group difference $F(1,99) = 4.46$, $p = .006$, and a Tukey follow-up showed that pairs in the literal condition had higher concreteness ratings than the unrelated word pairs, $p = .016$. Importantly, however, the three experimental conditions (conventional metaphor, literal, and novel metaphor) did not differ in their concreteness ratings.

2.2.2. Individual Difference Measures

2.2.2.1. General Knowledge Measure.

Our primary measure for general knowledge was a set of 25 questions (e.g., "What is the capital of New York?") from Tauber (2013), which is an updated version of the general

knowledge question set developed by Nelson and Narens (1980). Correct responses for these

questions served as our operationalization of general knowledge (i.e., the number of correct

responses was used to measure each participant's level of general knowledge). We separated

participants into two groups: high knowledge (N = 44) and low knowledge (N = 53) using a mean

split of the number of correct responses. An independent samples t-test showed a significant

difference with a large effect size for number of questions answered in the high knowledge group

($M = 16.70$, $SE = .37$) and the low knowledge group ($M = 8.66$, $SE = .47$), $t(93.17) = 12.95$, $p <$

.001, $d = 2.68$.

2.2.2.2. Vocabulary Knowledge Measure.

Although our primary measure of knowledge consisted of the general knowledge

questions from Tauber et al. (2013), we also explored the impact of vocabulary knowledge on

metaphor comprehension (following Kave et al.'s 2014) study. To test vocabulary knowledge,

we administered the adult version of the Nelson-Denny Reading Test (Brown, Fischo, &

Hannah, 1993). The vocabulary section consisted of 80 multiple-choice items. Participants were

sorted into the low vocabulary ($N = 48$) and high vocabulary groups according to a mean split of

their number of correct answers. The low vocabulary group ($N = 48$) had an average score of

48.79 ($SE = 1.65$), and the high vocabulary group had an average score of 66.91 ($SE = .70$),

yielding a large difference in effect size, $t(63.41) = 10.09$, $p < .001$, $d = 2.06$.

2.2.2.3. Reading Comprehension Measure:

In addition to our general knowledge and vocabulary measures, we included a measure of

reading comprehension to test effects of reading skill. This was included to understand whether

any knowledge-related effects we observed in this experiment could be better explained by

reading skill rather than general or vocabulary knowledge. To test reading comprehension, we

used the comprehension section of the adult version of the Nelson-Denny Reading Test (Brown,

Fishco, & Hannah, 1993). This comprehension section consisted of seven passages with 38

corresponding multiple choice items. A mean split of the correct answers was used to divide the

participants into high comprehension ($N = 48$) and low comprehension ($N = 49$) groups. An

independent samples t-test on the number of correct answers indicated a significant difference

with a large effect size between the high comprehension group ($M = 33.18$, $SE = .23$) and the low

comprehension group, ($M = 22.51$, $SE = .65$), $t(58.32) = 11.10$, $p < .001$, $d = 2.26$.

2.3. Procedure

This experiment utilized the divided visual field paradigm, which allows stimuli to be

presented to either the right visual field-left hemisphere (lvf-RH) or the right visual field-left

hemisphere (rvf-LH) in isolation (Bourne, 2006). To run the experiment, we used E-Prime

software (Schneider, Eschman, & Zuccolotto, 2002).

Each participant was presented with 100 word pairs, with the first word presented

centrally and the second (target) word presented rapidly to the right visual field-left hemisphere

(rvf-LH) or the left visual field-right hemisphere (lvf-RH). Participants received instructions to

focus on a blue asterisk (*) in the center of the screen for 2,500 ms, which signaled the onset of a

trial. After the asterisk, participants saw the first word for 900 ms and read it silently to

themselves. This was followed by a fixation plus (+) for 200 ms in the center of the screen, with

participants focusing on the fixation plus for the entire time that it was on the screen. After the

fixation plus, participants were presented with the target word for 180 ms at 2.8 degrees to the

right or left of the center of the screen. After reading the target, participants indicated via button

press whether or not the first and second word formed a meaningful expression. Target word

presentation and hand use were counterbalanced across experimental versions (Bourne, 2006).

To familiarize themselves with the procedure, participants completed a practice session before the main experiment.

After completing the experimental task, participants completed the general knowledge, vocabulary, and reading comprehension measures. Participants received 10 minutes to complete the general knowledge test, 15 minutes for the vocabulary test, and 20 minutes for the comprehension test.

3. Results

For all three of our individual difference measures (general knowledge, vocabulary, and reading comprehension), we conducted repeated measures ANOVAs with the individual difference measure and visual field of presentation as the independent variables, and with response times and accuracy rates as the dependent variables. Prior to analyses, we removed the top 1% and bottom 1% of response to minimize the influence of outliers (Ratcliff, 1993). Descriptive statistics for response times to the target words and accuracy as a function of general knowledge and visual field-hemisphere are presented in Table 2. We present these results by condition (Conventional Metaphor, Literal, Novel Metaphor, and Unrelated).

Table 2: Means and Standard Deviations for Stimuli Response Time and Accuracy by General Knowledge

	Accuracy		Response Time	
Stimuli Condition	**High Knowledge**	**Low Knowledge**	**High Knowledge**	**Low Knowledge**
Conventional rvf-LH	.86 (.18)	.85 (.13)	837.82 (120.16)	894.48 (117.90)
Conventional lvf-RH	.87 (.14)	.79 (.16)	878.02 (125.05)	954.41 (144.22)
Literal rvf-LH	.94 (.16)	.92 (.08)	785.07 (121.78)	861.83 (122.75)

Literal lvf-RH	.91 (.16)	.90 (.10)	846.85 (132.82)	894.21 (143.56)
Novel rvf-LH	.19 (.18)	.23 (.23)	979.76 (169.11)	1039.71 (183.147)
Novel lvf-RH	.20 (.18)	.23 (.22)	1021.68 (169.74)	1032.03 (173.37)
Unrelated lvf-RH	.93 (.16)	.88 (.18)	967.70 (147.49)	991.78 (182.98)
Unrelated rvf-LH	.91 (.16)	.91 (.19)	971.14 (173.37)	1011.82 (184.64)

Note: rvf-LH refers to the right visual field-left hemisphere, and lvf-RH refers to the left visual field-right hemisphere. Numbers in parentheses represent standard deviations.

3.1. Conventional Metaphors

3.1.1. Accuracy.

See Figure 1 for a comparison of accuracy scores for conventional metaphors. A repeated measures ANOVA with general knowledge (high, low) and visual field-hemisphere (lvf-RH, rvf-LH) as the independent variables and accuracy as the dependent variable revealed no main effects for the presentation of hemisphere, $F(1,95) = 2.22$, $MSe = .14$, $p = .139$. However, we did observe a significant interaction between general knowledge and hemisphere, $F(1, 94) = 6.05$, $MSe = .14$, $p = .016$. Follow-up paired samples t-tests revealed that accuracy was lower in the right hemisphere than the left for low knowledge participants, $t(52) = 2.57$, $p = .013$. However, there was no difference in accuracy between the hemispheres for high knowledge participants, $p = .418$. Further, independent samples t-tests revealed that accuracy rates for the right hemisphere were higher in high knowledge participants compared to low knowledge participants, $t(95) = 2.78$, $p = .007$. We did not, however, observe significant differences between the high and low knowledge participants for accuracy rates of conventional metaphors presented to the left hemisphere, $p = .924$.
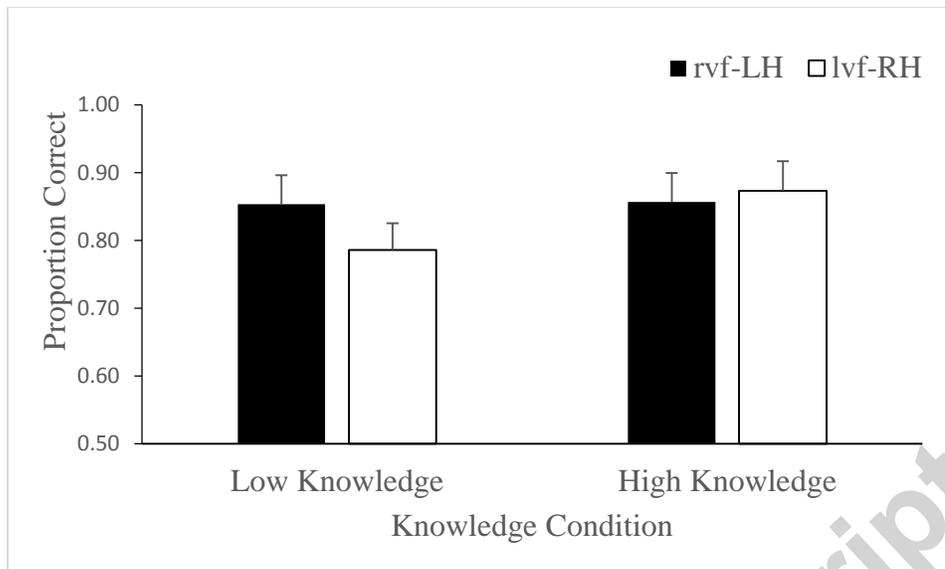
Figure 1. Proportion correct for conventional metaphor pairs. Note: rvf-LH refers to right visual field-left hemisphere; lvf-RH refers to left visual field-right hemisphere

When using vocabulary (high, low) and visual field-hemisphere (rvf-LH, lvf-RH) as independent variables, we detected a main effect of vocabulary for conventional metaphor accuracy, where higher vocabulary participants were more accurate ($M = .89$, $SD = .12$) than low vocabulary participants ($M = .79$, $SD = .18$), $F(1, 95) = 16.53$, $p < .001$. The main effect for visual field-hemisphere was not significant, $p = .09$. There was no an interaction between vocabulary and visual field-hemisphere, however, the results were in the same direction as those for the general knowledge, in other words, low vocabulary participants showed more left-hemisphere lateralization than high vocabulary participants, $p = .127$.

We also explored conventional metaphor accuracy using Reading Comprehension (high, low) and visual field-hemisphere (lvf-RH, rvf-LH) as independent variables. However, no main effects of reading comprehension or interactions between comprehension and visual field-hemisphere emerged from this analysis.

3**.1.2. Response Time.**

See Figure 2 for a comparison of conventional metaphor response times. We used a repeated

measures ANOVA with general knowledge (high, low) and visual field-hemisphere (lvf-RH, rvf-

LH) as the independent variables and response time for conventional metaphors as the dependent

variable. We detected a main effect of visual-field hemisphere, such that individuals processed

conventional metaphors more quickly when presented to the left hemisphere, regardless of prior

knowledge, $F(1, 95) = 24.68$, $p < .001$, $MSE = 120548.83$. Further, we detected a significant

main effect of general knowledge, with high knowledge participants processing conventional

metaphors more quickly than low knowledge participants regardless of hemisphere of

presentation, $F(1, 95) = 7.67$, $p = .007$, $MSE = 212789.01$. However, we did not observe an

interaction between general knowledge and visual field-hemisphere, $p = .33$.
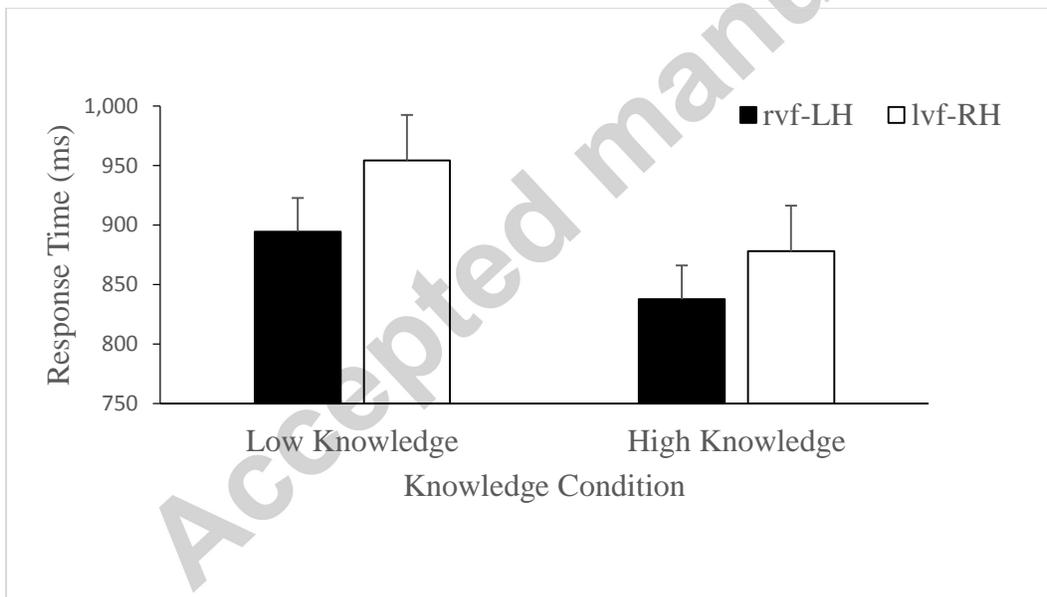

Figure 2. Response times (in milliseconds) for conventional metaphor pairs. . Note: rvf-LH

refers to right visual field-left hemisphere; lvf-RH refers to left visual field-right hemisphere.

We also tested response time for conventional metaphors as a function of vocabulary and

visual field-hemisphere, and a separate analysis using reading comprehension and visual-field

hemisphere as independent variables. These analyses did not indicate any significant main effects or interactions for these two individual differences.

3.2. Novel Metaphors

Accuracy for novel metaphors was generally low, and we did not observe any main effects or interactions when using general knowledge as an individual difference measure. Because accuracy was well below chance ($M = .21$, $SD = .21$) we elected to not analyze response times further for novel metaphors (Pobric et al., 2008), nor did we explore any other individual differences.

3.3. Literal Word Pairs

3.3.1. Accuracy.

See Figure 3 for a comparison of accuracy scores for literal word pairs. A repeated measures ANOVA with general knowledge (high, low) and visual field-hemisphere (lvf-RH, rvf-LH) as the independent variables and literal word pair accuracy as the dependent variable revealed a main effect of hemisphere; literal pairs were processed more accurately in the left than the right hemisphere, $F(1, 95) = 6.19$, $MSe = .04$, $p = .015$. However, we did not observe a main effect of general knowledge, $p = .53$, nor did we observe an interaction between prior knowledge and hemisphere of presentation, $p = .60$.
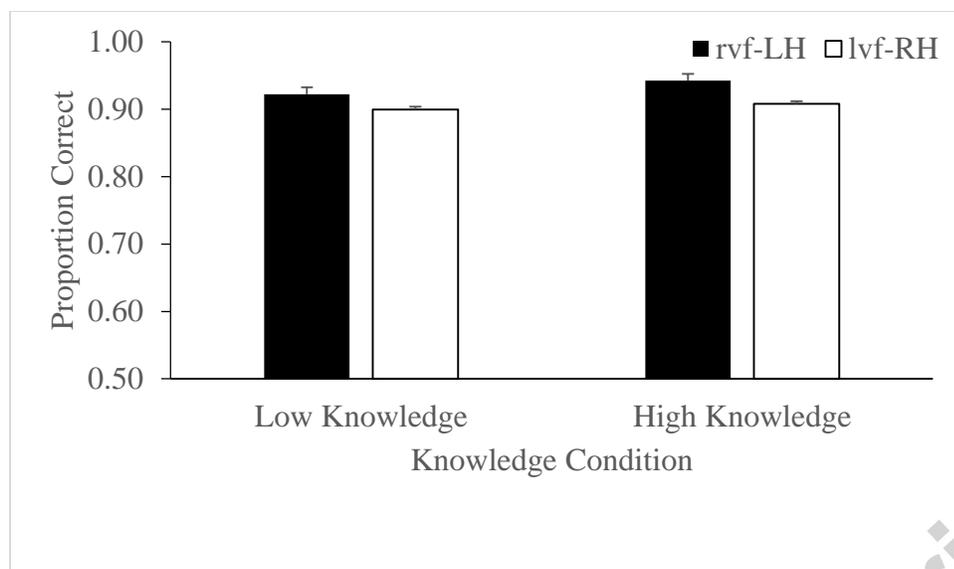
Figure 3. Proportion correct for literal word pairs. Note: rvf-LH refers to right visual field-left hemisphere; lvf-RH refers to left visual field-right hemisphere

Using vocabulary (high, low) and visual field-hemisphere (lvf-RH, rvf-LH) as independent variables, we observed a significant main effect of hemisphere, with accuracy being higher in the rvf-LH (*M* = .93, *SD* = .12) than the lvf-RH (*M* = .90, *SD* = .13), *F*(1, 95) = 5.97, *MSe* = .006, *p* = .016.   There was also a main effect for vocabulary: accuracy was higher for high vocabulary participants (*M* = .94, *SD* = .08) than for low vocabulary participants (*M* = .89, *SD* = .15), *F*(1, 95) = 4.01, *MSe* = .024, *p* = .048. There was no interaction between vocabulary and visual field-hemisphere. *p* = .745.

We also conducted an ANOVA with reading comprehension (high, low) and visual field-hemisphere (rvf-LH, lvf-RH) as independent variables, but found no significant effects.

3.3.2. Response Time.

See Figure 4 for a comparison of response times for literal world pairs. A repeated measures ANOVA with general knowledge (low, high) and visual field-hemisphere (rvf-LH, lvf-RH) as independent variables revealed a main effect for visual field-hemisphere, as literal pairs were

processed more quickly when presented to the left hemisphere than the right, $F(1, 95) = 27.64$,

$MSe = 106565.51$ $p < 001$. We also observed a main effect for general knowledge, as high

knowledge participants processed literal pairs faster than low knowledge participants, $F(1, 95) = 6.10$, $MSe = 30370.62$, $p = .015$. We did not detect an interaction between knowledge and visual

field-hemisphere, $p = .10$.

When exploring the influence of vocabulary (high, low) and visual field-hemisphere (rvf-LH, lvf-RH) on response time for literal word pairs, we observed no effects of vocabulary or

interactions between vocabulary and visual field. Similarly, in a separate analysis, we found no

main effects of reading comprehension or interactions between reading comprehension and

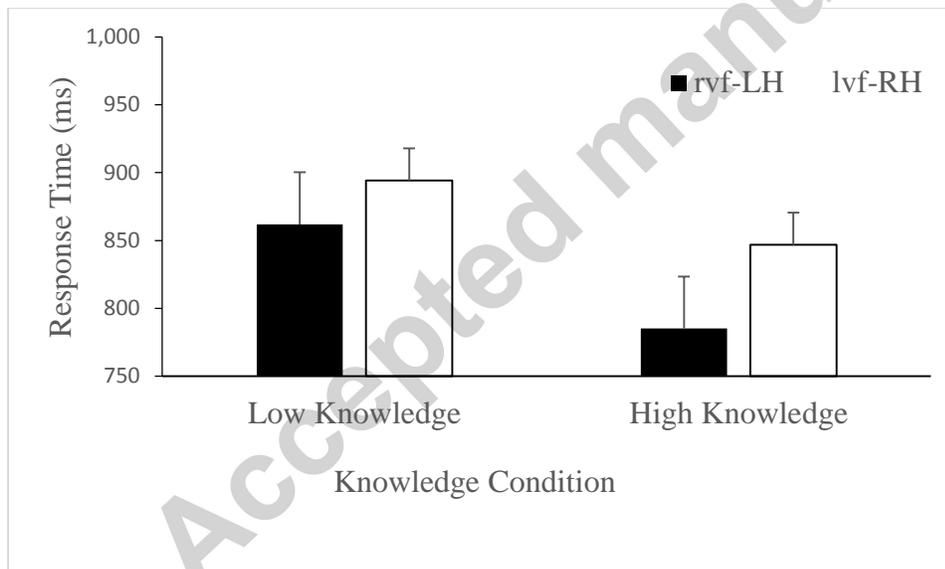visual field on responses times for literal word pairs.

Figure 4. Response time (in milliseconds) for literal word pairs. Note: rvf-LH refers to right

visual field-left hemisphere; lvf-RH refers to left visual field-right hemisphere

3.4. Unrelated Word Pairs.

We did not detect any main effects or interactions in terms of either response time or

accuracy for processing unrelated word pairs.

3.5. Contrasting Conventionally Metaphoric and Literal Word Pairs

To contrast response times and accuracy rates for items in the conventional metaphor condition and the literal condition, we conducted a 2x2x2 Mixed ANOVA with knowledge (high, low) as the between-subjects factor, and visual field-hemisphere (rvf-LH, lvf-RH) and condition (conventional metaphor, literal) as the within-subjects factors.

3.5.1. Accuracy.

With accuracy as the dependent variable, the Mixed ANOVA revealed a significant interaction between knowledge, visual field-hemisphere, and condition, $F(1, 95) =4.88$, $p = .049$. We then used a series of paired-samples t-tests to explore the interaction, using a Bonferroni correction to adjust the alpha level to .0125. For low knowledge participants, accuracy scores were higher when stimuli were presented to the rvf-LH than the lvf-RH, regardless of condition (all ps < .01). However, for high knowledge participants, there was no difference in accuracy scores between conventional metaphors and literal pairs in the lvf-RH ($p = .10$), but accuracy was higher for literal pairs compared to conventional metaphors when presented to the rvf-LH, $p < .001$.

3.5.2. Response Time.

With response time as the dependent variable, the Mixed ANOVA revealed a significant interaction between knowledge, visual field-hemisphere, and condition, $F(1, 95) = 3.71$, $p = .038$. We then used a series of paired-samples t-tests to explore the interaction, using a Bonferroni correction to adjust the alpha level to .0125. Low knowledge participants processed all items more quickly when presented to the rvf-LH than the lvf-RH, regardless of stimulus condition (all $ps < .001$). High knowledge participants showed the same trend for faster processing of literal than conventionally metaphoric items in the rvf-LH (all $ps < .01$), although

the difference between conditions tended to be smaller for high knowledge participants

(31.18ms) compared to low knowledge participants (60.21ms).

3.6. Item Difficulty

Although a direct comparison of metaphoric to literal items is not the primary goal of this

study, the longer response times for conventionally metaphoric items relative to literal items

raises the possibility that the conventional metaphors may be more difficult to process than the

literal items. Indeed, we observed positive correlations between response time and accuracy for

both the conventionally metaphoric condition ($r = .87$, $p < .001$) and the literal condition ($r = .73$,

$p < .001$). This positive correlation reflects a speed-accuracy tradeoff, a well-known

phenomenon in response time research (see Heitz, 2014, for a review). Because response times

tended to be longer in the conventionally metaphoric condition than in the literal condition, one

potential concern is that the pattern of accuracy differences for the two conditions in either

hemisphere may be due to item difficulty rather than to the figurativity.

To test for the possibility of difficulty as a confounding influence, we calculated

difference scores by subtracting accuracy in the lvf-RH from accuracy in the rvf-LH for each

item in the literal and conventional metaphor conditions. Positive scores indicate greater relative

accuracy for rvf-LH presentation, and negative scores reflect greater accuracy for lvf-RH

presentation. These difference scores were then compared to response times using a Pearson

bivariate correlation. There was a slight positive correlation between literal items and the

difference score, suggesting that longer response times were associated with greater accuracy in

the rvf-LH, however, this correlation was not significant, $r(25) = .174$, $p = .41$. There was a

slight negative correlation between conventional metaphors and the difference score, suggesting

that longer response times were associated with greater accuracy in the lvf-RH, but again, the

correlation was not significant, $r(25) = -.265$, $p = .211$. Because response times are not significantly correlated with accuracy difference scores for items in either condition, we do not find any evidence that the observed hemispheric differences in accuracy between literal and conventionally metaphoric items were due to greater difficulty of the conventional metaphors.

4. Discussion

The results of our experiment present several intriguing findings about how prior knowledge influences the hemispheric processing of conventional metaphors. We observed that, when processing conventional metaphors, high knowledge participants showed similar accuracy levels regardless of the hemisphere to which the word pairs were presented. In contrast, low-knowledge participants showed hemispheric asymmetry when processing conventional metaphors. Specifically, accuracy for conventional metaphors was lowest for low knowledge participants during the left visual field-right hemisphere trials compared to all other conditions. This interaction between knowledge level (high vs. low) and visual field-hemisphere supports the hypothesis that general knowledge may influence how the hemispheres process common English metaphors. Further, a lack of effects related to reading comprehension help to ensure that these effects for metaphor processing reflected differences in knowledge rather than differences in reading skill.

The current results suggest that individuals with more knowledge may process conventional metaphors differently in their right hemisphere compared to less knowledgeable individuals. This individual difference may help explain why some prior research has found no special role for the right hemisphere in processing conventional metaphors (e.g., Rapp et al., 2007) while other research has suggested bilateral involvement in conventional metaphor processing (Eviatar & Just, 2006). Perhaps some participants in these prior studies may have

been more knowledgeable than participants in other studies, which may explain why right hemisphere has shown more evidence for involvement in some studies than in others.

Why would high and low knowledge participants show similar processing patterns for conventional metaphors in the left hemisphere, but not the right? The accuracy differences observed may reflect differences in how semantic information is stored in the right and left hemispheres. According to the Coarse Coding Hypothesis (Jung-Beeman, 2005), the right and left hemispheres carry out qualitatively different functions during text comprehension. According to this hypothesis, neuronal connections in the language areas of the left hemisphere are densely connected to a few neighboring neurons. In contrast, right hemisphere areas associated with language comprehension tend to have more connections to more distant neurons, but these connections are less dense than in the corresponding left-hemisphere areas. Beeman theorizes that during text comprehension, the left hemisphere is more likely to activate semantic information that is semantically "close" to the word or phrase being processed, while the right hemisphere is more likely to activate semantically "distant" information. These processes are important when readers process metaphors, as metaphor comprehension often involves integrating knowledge from various domains (Bowdle & Gentner, 2005; Cacciari & Glucksberg, 1994). As such, it may be the case that high-knowledge readers, who possess more information about the world, can better process the figurative meaning of novel metaphors using distant semantic relations compared to low-knowledge readers. There is currently a dearth of research testing interactions between prior knowledge and fine-coarse semantic coding (with the exception of Kave et al., 2014), however, our findings point to the possibility that general knowledge may influence how the hemispheres process figurative language.

Although the accuracy patterns for conventional metaphors demonstrated an interaction between general knowledge and visual field-hemisphere, the novel metaphors show a less clear pattern. Because accuracy rates for the novel metaphors in our study were well below chance, we did not interpret this data. These low accuracy rates may be surprising given that participants in our pilot study rated the novel metaphors as being more meaningful than our unrelated word pairs, but previous researchers have also noted low accuracy rates for novel metaphors (e.g. Pobric et al., 2008). Similarly, when Kave et al, (2014) presented novel Hebrew metaphors to Hebrew-speaking participants, accuracy rates were also low. However, other studies using novel metaphors in Hebrew have yielded higher accuracy rates (Mashal & Faust, 2007). One possibility is that processing novel metaphors may be very difficult in English without proper context (Clark, 1992; 1996). Presenting novel metaphors with a greater amount of context may improve participants' understanding that these novel metaphors are meaningful phrases (as opposed to the unrelated pairs in our control condition). Further, it may be that novel metaphor comprehension requires a greater amount of time than the present study and Kave et al. (2014) used. If so, this could help explain why participants in our pilot study found more meaning in the novel metaphors (i.e., our pilot study was not constrained by time and thus allowed participants ample opportunity to comprehend the novel metaphors). It may be useful for future studies to systematically vary the stimulus onset asynchrony between the two stimuli words in each pair to better understand the time course of novel metaphor comprehension. It is also possible that readers may need more context to make sense of novel metaphor word pairs. Future studies could explore this by including preceding context which would help the reader understand the intended meaning.

Since our materials and methods were based closely on Kave et al.'s (2014) study on metaphor processing and aging, our results may shed more light on their previous findings. In Kave et al.'s study, younger participants showed similar patterns of activation in their right and left hemispheres during a divided visual field task, but older adults had lower accuracy rates in their right compared to their left hemispheres. As these age-related accuracy differences seemed to be negated when vocabulary knowledge was accounted for, Kave et al. suggested that a "knowledge accumulation hypothesis" could explain the differences between the older and younger adults. Our current findings support a role for prior knowledge in metaphor processing, but it seems as if high levels of knowledge are associated with bilateral metaphor processing, and asymmetric processing of metaphors is associated with low knowledge levels. Thus, it is possible that the left hemisphere asymmetries demonstrated by Kave et al.'s older participants may be due not to knowledge accumulation, but rather due to processing changes associated with cognitive decline, especially considering the advanced age of Kave et al.'s older participants. For example, cognitive decline may result in semantic information becoming less accessible to right hemisphere processes, a view that is compatible with the right-hemisphere decline model of aging (Orbelo et al., 2005). Future research may wish to test older adults who are cognitively typical vs. those who show evidence of cognitive decline to better understand what role (if any) cognitive decline may play in metaphor comprehension.

In summary, our results provide evidence that general knowledge may play a role in metaphor comprehension, with greater amounts of general knowledge being associated with more bilateral processing for conventional metaphors, and less general knowledge being associated with hemispheric asymmetries during metaphor processing. These results demonstrate the critical role of prior knowledge in understanding figurative language. Our results also provide

further evidence that the extent to which the hemispheres process conventional metaphors depends on the readers' prior knowledge, with high knowledge leading to more accurate processing in the right hemisphere.

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Appendix

Experimental Word Pair Lists

Conventional Metaphor Word Pairs

sunny	disposition
sly	fox
smoking	gun
iron	fist
moral	compass
half	baked
bitter	end
cabin	fever
butter	fingers
boiling	mad
wet	blanket
rug	rats
couch	potato
melting	pot
angry	sea
cold	feet

blind	eye
dark	thoughts
lightning	reflexes
smooth	sailing
bubbly	personality
foggy	memory
broken	heart
bright	student
warm	welcome

Novel Metaphor Word Pairs

fresh	courage
impatient	machinery
shivering	life
icy	clean
fragrant	shadow
nuclear	anger
unkempt	afternoon
happy	dawn
blank	sleep
sharp	scent
tender	sky
nodding	leaves

stiff	noise
braided	freeway
mad	slap
hungry	mind
crooked	math
burning	moment
dry	buzz
lonely	oval
molten	sound
rotting	education
gentle	art
glass	river
silent	wound

Literal Word Pairs

salty	food
lazy	cats
damp	soil
spring	flower
sticky	glue
red	apple
fragile	statue
tiny	speck

soft	coat
dull	knife
white	snow
yellow	sun
messy	room
wooden	spoon
unjust	law
cloudy	weather
corrupt	politician
shiny	metal
old	ruins
hot	fire
depressed	teenager
new	computer
friendly	dog
fast	car
plastic	bag

Unrelated Word Pairs

guilt	current
funny	acid
young	budget
polite	bay

unfair	beef
evil	ticket
joint	tire
divine	node
financial	smell
radical	dock
worried	pan
high	organ
southern	release
fair	jacket
instrument	island
automatic	slab
petty	balloon
result	rice
wisdom	wash
intern	knight
aware	base
success	carpet
prime	train
eager	trophy
humble	lock

Highlights:

-We used the divided visual field technique to present metaphors to the right and left hemispheres

-Participants were divided into high- and low-knowledge groups

-High knowledge groups showed similar accuracy for metaphors in both hemispheres

-Low knowledge group showed left-hemisphere bias for metaphor accuracy

-Results suggest relationship between general knowledge and hemispheric processing of metaphors