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You may now kiss the bride: Interpretation of social situations by individuals with right or left hemisphere injury

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ABSTRACT

While left hemisphere damage (LHD) has been clearly shown to cause a range of language impairments, patients with right hemisphere damage (RHD) also exhibit communication deficits, such as difficulties processing prosody, discourse, and social contexts. In the current study, individuals with RHD and LHD were directly compared on their ability to interpret what a character in a cartoon might be saying or thinking, in order to better understand the relative role of the right and left hemisphere in social communication. The cartoon stimuli were manipulated so as to elicit more or less formulaic responses (e.g., a scene of a couple being married by a priest vs. a scene of two people talking, respectively). Participants' responses were scored by blind raters on how appropriately they captured the gist of the social situation, as well as how formulaic and typical their responses were. Results showed that RHD individuals' responses were rated as significantly less appropriate than controls and were also significantly less typical than controls and individuals with LHD. Individuals with RHD produced a numerically lower proportion of formulaic expressions than controls, but this difference was only a trend. Counter to prediction, the pattern of performance across participant groups was not affected by how constrained/formulaic the social situation was. The current findings expand our understanding of the roles that the right and left hemispheres play in social processing and communication and have implications for the potential treatment of social communication deficits in individuals with RHD.

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1. Introduction

The left hemisphere (LH) of the brain has long been known to be generally dominant with respect to language processing, particularly regarding morpho-syntactic processing and the comprehension of the literal aspects of language (Binder, 1996; Broca, 1861; Caplan et al., 1996; Friederici, 2011; Geschwind, 1965; Griffiths et al., 2012; Risse et al., 1997; Wada and Rasmussen, 1960). However, there is now evidence that the right hemisphere (RH) plays a relatively more critical role in producing and interpreting global or pragmatic aspects of language, particularly using linguistic and social cues to understand communicative intentions and contextually appropriate meaning (Brownell et al., 1983, 1986; Champagne-Lavau and Joanette, 2009; Cutica et al., 2006; Ferre et al., 2011; Fournier et al., 2008; Martin and McDonald, 2006; Tompkins, 2012; Van Lancker and Kempler, 1987; Wapner et al.,

1981; Winner and Gardner, 1977). For example, the RH appears to play a special role in processing affective prosody, drawing inferences from discourse, and comprehending various forms of figurative language (Cheang and Pell, 2006; Giora et al., 2000; Kaplan et al., 1990; Lundgren et al., 2011; McDonald, 2000; Shamay-Tsoory et al., 2005b; Shammi and Stuss, 1999; Wapner et al., 1981).

This contrast between RH and LH functioning with respect to language processing has been discussed and supported across a variety of domains and conditions such as autism, schizophrenia, and dementia (Eslinger et al., 2007; Rapp et al., 2013; Sabbagh, 1999; Sidtis, 2012), but is most well-documented by comparing individuals with RH damage (RHD) versus LH damage (LHD). Notably, individuals with RHD exhibit impairments on both spontaneous and experimental measures of pragmatic language (Mackenzie and Brady, 2004; Myers, 2005; Weed, 2011). In contrast, individuals with LHD may have overt speech and language difficulties with respect to word-finding, grammaticality, etc., but social aspects of their communication remain relatively preserved

(Cutica et al., 2006; Dronkers et al., 1998; Shamay-Tsoory et al., 2005b).

A critical aspect of pragmatic communication involves the ability to appreciate social, contextual, and emotional cues (Tompkins, 2012). Individuals with RHD have been shown to be impaired in this domain with respect to the expression and comprehension of such social cues, both with and without accompanying verbal content (Adolphs et al., 2000; Baum and Pell, 1999; Blonder et al., 2012; Martin and McDonald, 2003; Pell, 2006; Weed et al., 2010). For example, RHD individuals may fail to interpret a speaker's intonation or facial expression as indicating sarcasm or humor, often make socially unsuitable remarks, and have difficulty interpreting others' mental states (i.e., impaired theory of mind; Champagne-Lavau and Joanette, 2009; Fournier et al., 2008; Griffin et al., 2006; Joanette et al., 1990; Klonoff et al., 1990; Yeh and Tsai, 2014).

The ability to accurately process social situations is particularly important for another aspect of pragmatics that also involves RH processes, the generation of contextually appropriate formulaic expressions (Sidtis et al., 2009; Sidtis, 2012). Formulaic language accounts for a surprisingly large percentage of everyday communication, about 25% according to some estimates (Pawley, 2007; Sidtis, 2012; Van Lancker and Rallon, 2004). Formulaic expressions include (though are not limited to) rote or stereotyped utterances such as idiomatic expressions (*How time flies!*), salutations (*How's it going?*), overlearned expressions (*I thought so*) and curse words (fill in your preferred word of choice here). Although such utterances are "fixed and unitary," they go beyond the sum of their lexical content to convey complex meanings "rife with nuance and connotations" and thus rely heavily on the proper processing of social information (Sidtis, 2012, p. 63).

Interestingly, aphasiologists have long noted the relative preservation of such formulaic or overlearned speech in LHD individuals, including those with severe aphasia (Broca, 1861; Van Lancker Sidtis, 2010; Wray, 2008). In contrast, individuals with RHD produce a relative paucity of formulaic language (Sidtis and Postman, 2006) and are relatively poor at processing formulaic expressions (Van Lancker and Kempler, 1987). For example, Van Lancker and Kempler (1987) compared LHD and RHD individuals' comprehension of novel sentences versus formulaic expressions. They found that RHD individuals were relatively impaired at matching auditorily-presented formulaic expressions to the correct image (e.g., *He's turning over a new leaf*), while LHD were relatively impaired on novel sentences (e.g., *He's sitting deep in the bubbles*). With respect to production, Sidtis and colleagues (Sidtis and Postman, 2006; Sidtis et al., 2009; Van Lancker Sidtis, 2010) recently analyzed spontaneous speech samples for the presence of formulaic expressions and showed that RHD individuals uttered fewer such expressions relative to both LHD individuals as well as controls. In contrast, LHD individuals exhibited a greater proportion of such automatic utterances than both RHD individuals and controls. Such findings have been used to argue that the LH is more critical for generating novel utterances, while the RH mediates more formulaic expressions (but see Goldberg and Costa, 1981; Goldberg et al., 1994, for an opposing view).

Although RHD individuals have generally been found to generate fewer formulaic expressions as described above, very little research has examined the extent to which this phenomenon interacts with the type of social context (Achim et al., 2013). Previous work in both healthy and brain-injured individuals suggest that the RH is preferentially involved in processing more ambiguous, difficult or complex contexts, particularly cases that involve understanding non-literal language and inferring information that has not been explicitly stated (Briner et al., 2012; Klepousniotou and Baum, 2005; Leigh et al., 2013; Mashal and Faust, 2008; Myers, 2005; Prat et al., 2012; but see Blake, 2009a,b; Ferstl et al.,

2002; Keil et al., 2005; Leonard and Baum, 2005). Indeed, a recent, notable study by Tompkins et al. (2012) showed that providing a linguistic context to training stimuli led to improved narrative discourse comprehension in an individual with RHD. These and other findings are thought to indicate that the RH processes more distantly related aspects of meaning and maintains their activation longer than the LH, even when those aspects may not be relevant for a given context (Ben-Artzi et al., 2009; Cardillo et al., 2012; Copland et al., 2002; Faust et al., 2006; Goel et al., 2007; Jung-Beeman, 2005; Kacinik and Chiarello, 2007; Peretz and Lavidor, 2013; Tompkins et al., 2008; but see Gouldthorp and Coney, 2011; Kandhadai and Federmeier, 2008; Peleg et al., 2012).

Since the hypothesized broader meaning activation processes of the RH are assumed to be disrupted in RHD individuals, we wanted to investigate the extent to which RHD and LHD individuals would be facilitated when the social situations had more constrained/predictable contexts. By "more constrained/predictable contexts," we mean social situations with relatively prescribed schemes and expected expressions based on stored, general knowledge about the social context (see framework by Achim et al., 2013), such as saying "Congratulations" to a new graduate at a graduation ceremony or saying "Happy Birthday" to someone celebrating their birthday (see Table 1 for examples from this study). Such social situations stand in contrast to more ambiguous situations in which a prescribed utterance is less predictable, for example a man and woman talking or two people hugging (again, see Table 1; Forgas, 1985).

In the current study, we asked groups of RHD, LHD, and control participants to interpret what a character in a cartoon-drawing was thinking or saying. The goal of this research was to more precisely examine the appropriateness, typicality, and formulaicity of responses in RHD and LHD individuals, as well as the extent to which performance was affected by more or less constrained social contexts. Our first prediction was that RHD individuals would produce less appropriate responses overall relative to LHD and control individuals, based on previous work linking the RH to the ability to produce socially appropriate and relevant language. The data were also analyzed for the proportion of formulaic expressions present in participants' responses as well as the typicality of their responses (i.e., the degree to which other individuals in the sample produced the same responses). Our prediction here was that RHD individuals would generate a lower proportion of formulaic expressions in their overall output and less typical responses than LHD participants and controls, based on previous research and theoretical claims that RH processes are preferentially involved in the comprehension and production of formulaic language (Sidtis, 2012; Sidtis and Postman, 2006; Sidtis et al., 2009). Finally, we were also interested in testing the extent to which RHD and LHD individuals would be facilitated in their performance when the social situation depicted in the cartoons had a more predictable context associated with a more formulaic utterance (e.g., a priest speaking to a bride and groom vs. a man looking down as a woman speaks to him, respectively). Here, we predicted that all groups would provide more appropriate, typical, and formulaic responses in the more predictable context but that RHD individuals would show a greater discrepancy between the more versus less constrained contexts compared to LHD individuals. This prediction is based on findings that the RH is specialized for processing more ambiguous and less specific contexts (Grindrod, 2012; Klepousniotou and Baum, 2005; Leigh et al., 2013; Peretz and Lavidor, 2013). Given that participants with LHD can rely on RH processes to a greater extent than RHD individuals, they were expected to generate better responses in the less constrained situations.

Table 1
Examples of less and more constrained cartoon stimuli and sample responses.

Cartoon		Group	Individual responses
	Less constrained social context	Controls	"About that assignment." "I won't do it again." "I'm sorry."
		LHD	"I'm sorry." "Sorry I forgot to study." "I'm sorry—I won't do it again."
		RHD	"OK lady. What kind of shoes did you buy?" "Nice shoes." "Uh really honey—I didn't mean to pee on the couch."
	Less constrained social context	Controls	"Boy, she's cute." "She's pretty." "My lucky day!"
		LHD	"She's cute." "Wow, I haven't seen her all summer. She looks great." "You're beautiful."
		RHD	"I wonder how big her allowance is." "Let's arm-wrestle." "Should I touch her hand?"
	More constrained social context	Controls	"I now pronounce you man and wife." "Do you take this woman to be your lawfully wedded wife?" "Kiss the bride."
		LHD	"I now pronounce you man and wife." "And do you promise, blah blah blah." "Do you take this man to be your husband?"
		RHD	"Nice to meet your bride." "Do you take Sharon to be your wife forever through sickness, health, and finances? OK folks, the ring." "I now pronounce you man and wife. Or, as a licensed gynecologist, you may need my services."
	More constrained social context	Controls	"This is our proudest day." "Congratulations, son." "We're so proud of you."
		LHD	"Congratulations." "Congratulations, son–your graduation." "Congratulations, Son."
		RHD	"Now, my boy, you're a college graduate. Now you're out to meet the world. Go out and learn how to make a dollar." "Will you be paying back your loans soon, honey?" "Congratulations. You finally graduated. May you make your mark in your business life now."

2. Methods

2.1. Participants

We tested 22 individuals with a documented history of stroke in the right or left hemisphere: Eleven individuals (9 men and 2 women) with RHD and 11 individuals (9 men and 2 women) with LHD. The RHD and LHD groups did not differ with respect to age, $p > .05$ (RHD mean=68.3 years, SD=16.2, range 27–88; and LHD mean=65.8 years, SD=11.0, range 44–86); or education, $p > .05$ (RHD mean=14.9 years, SD=2.7, range 12-20; and LHD mean=15.8 years, SD=2.7, range 11–20). All individuals were tested at least 1 year post-stroke, except for two RHD and two LHD individuals who had more recent strokes (< 6 months).

The LHD individuals all tested within normal limits (score > 93.7) on the Western Aphasia Battery (Kertesz, 1982), although they still had mild clinical symptoms of aphasia, such as word-finding problems. The RHD individuals and controls had no symptoms of aphasia. All participants except for 2 RHD individuals were tested on a line bisection task and were found to exhibit no or minimal visuospatial distortions. The average deviation of line bisection in RHD individuals was −1.0% (SD=4.2, range −7.5% to 6.2%) and in LHD individuals, −2.3% (SD=2.0, range=−5.6% to 0.0%), where negative numbers represent a leftward bias. Symptoms of visual neglect were reported in the medical record of just one of the RHD individuals who had a recent stroke, but removing him from the data analysis below did not change the pattern or significance of the findings.

RHD and LHD individuals' lesions were reconstructed from T1 MRI scans and then normalized to MNI space (see Fig. 1). Brain imaging was not available for one RHD individual, but his VA medical records reported a RH stroke with left-sided weakness. Two patients had non-cortical lesions: one LHD individual had a left cerebellar stroke and one RHD individual had a right pontine
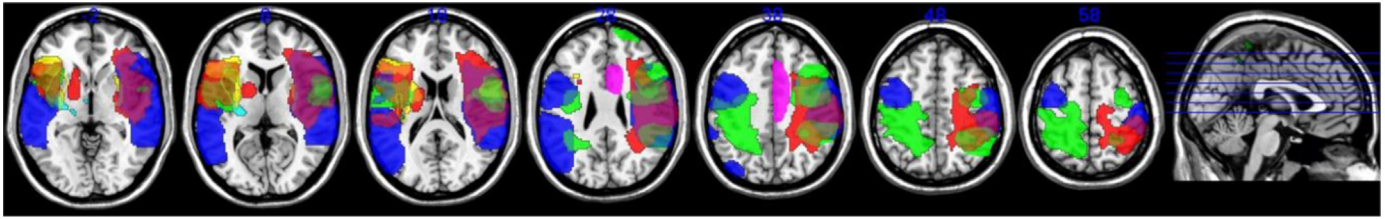
Fig. 1. Lesion reconstructions of RHD and LHD individuals; the right hemisphere is shown on the right, and the left hemisphere on the left. Brain imaging was not available for 1 RHD individual. Each color represents a different individual's lesion.

stroke. Lesion volumes for the RHD individuals (M =58.3 cc, SD=88.1) and LHD individuals (M=34.2 cc, SD=33.3) were not significantly different, $t(19) = -.84$, $p = .41$.

For comparison, we also tested 10 age- and education-matched healthy controls, 8 men and 2 women (mean age=60.0 years, SD=11.6, range 40–75; mean education=17.7 years, SD=2.3, range 14–20). All participants were right-handed and spoke English as their first language.

All testing took place at VA Northern California Health Care System as part of a larger study that was approved by the VA Institutional Review Board. Procedures were in keeping with the principles of the Helsinki Declaration for the treatment of human participants.

3. Materials and procedures

The materials consisted of 12 large, black-and-white, hand-drawn cartoons that depicted a single scene on an 8.5” × 11” page. The cartoons were specifically created for this test and rendered by a professional artist. Each cartoon showed a speech or thought bubble coming from one of the characters in the cartoon. The items were designed by the study authors to include two types of cartoons: six scenes of more constrained social situations that would elicit a formulaic response (e.g., a priest with a bride and groom) and six scenes of less constrained social situations that would elicit less formulaic responses (e.g., a woman staring at a boy who is looking down; see Table 1 for examples). In order to evaluate whether we succeeded in creating these two types of social situations, 14 raters (VA clinicians and researchers) blind to the purpose of the study were asked to score each cartoon as to *how formulaic (i.e., rigid, fixed)* the character's utterance would be, on a scale from 1-5. The average rating of the cartoons designed to be more formulaic was significantly higher (M=3.9, SD=0.7) than that of the less formulaic cartoons (M=2.2, SD=0.2), $t(13)=7.94$, $p < .001$, consistent with the authors' intentions.

The participants were tested individually by a licensed neuropsychologist or speech-language pathologist as part of a larger research battery of neuropsychological tests that were administered in several 1–2 h sessions. Participants were asked to look at each cartoon and to say what they thought the character with the speech/thought bubble in each drawing was saying/thinking. If examinees said they were not sure, they were prompted by the examiner to give their best guess. Participants' responses were recorded on paper by the examiner.

The appropriateness of participants' responses was scored by five independent raters who were undergraduate students at a neighboring university and received psychology course credit for their participation. The raters were blind as to the purpose of the study, including the source of the responses. They were provided with a booklet that contained all participants' responses for each item, alongside each cartoon. The raters were asked to rate the *appropriateness* of each participant's response on a scale from 1–5, from *very inappropriate* to *very appropriate* with respect to how

well the response captured the gist of what the character would be saying/thinking. Raters were given lengthy, written instructions which were reinforced with oral instructions by the proctor (one of the co-authors). The raters were instructed to focus on the content, rather than the grammar, of the responses with respect to how well they conveyed an appropriate interpretation of the character's words/thoughts. There was good inter-rater reliability with an intraclass correlation coefficient of .86 (95% confidence interval .84–.89, $p < .0001$), which suggested that the raters used reasonably consistent criteria for evaluating the responses with relatively few idiosyncratic interpretations.

To measure the typicality of participants' responses, a score was calculated based on the average frequency with which an individual's responses matched other participants' responses in the sample (across both stroke and control groups). Responses needed to be identical in order to be considered the same response, except that contracted and uncontracted forms were considered equivalent (e.g. *I'm sorry* and *I am sorry*). For example, in response to the graduation scene shown in Table 1, seven participants said 'Congratulations, son," three participants said 'Congratulations,' two participants said 'Congratulations graduate,' and two participants said 'We're so proud of you son.' Those seven participants who said 'Congratulations son," all received a score of 7 for that item; the three participants who said 'Congratulations ' received a score of 3; the two participants who said 'Congratulations graduate' received a score of 2; and the two participants who said 'We're so proud of you son' received a score of 2 as well. The same scoring procedure was used for the less constrained context scenes. For example, for the first scene shown in Table 1, two participants said 'I'm sorry,' two participants said 'I'm sorry, dear,' and two participants said 'I'm sorry. I won't do it again.' All of these participants received a score of 2 for this item. Participants who generated idiosyncratic responses that did not match a single other individual's response in the sample received a score of 0 for that item. To clarify, this typicality score was based purely on how frequently an individual's exact response was also generated by others in the sample and was not based on any type of qualitative/subjective interpretation of how typical their responses were.

Last, participants' responses were analyzed based on the proportion of words in their overall output that were formulaic expressions. The definition of what constitutes a formulaic expression was based on previous work by Sidtis and colleagues (Sidtis et al., 2009; Van Lancker-Sidtis and Rallon, 2004; Sidtis and Postman, 2006). Formulaic expressions were defined as: formulaic speech (e.g. "How goes it?"), idiomatic expressions (e.g., "He's hopping mad"), proverbs ("Too many chefs spoil the soup"), pause fillers (e.g., "um"), expletives (e.g., "damn"), exclamations (e.g., "Oh!"), and slang expressions (e.g., "that's cool"). Based on previous methods by Sidtis and colleagues, two independent raters who were blind to participants' status (i.e., LHD, RHD or control) identified the words in each response that met this definition and a subsequent discussion among the raters was used to reach consensus on a small number of discrepant items. The number of words in formulaic expressions was then divided by the
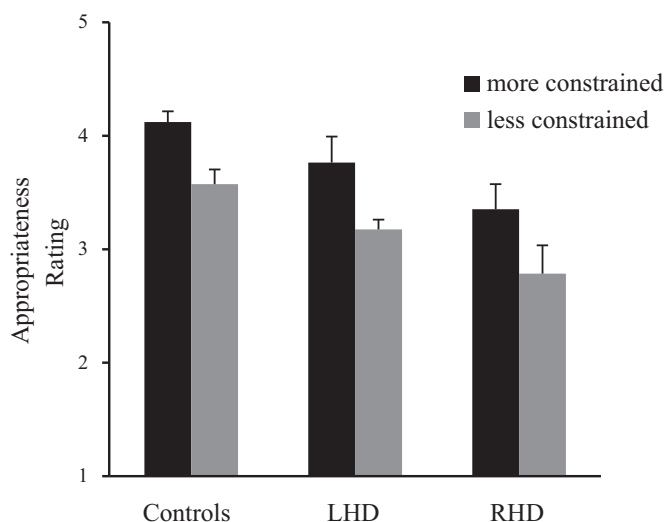
Fig. 2. Average appropriateness ratings for LHD, RHD, and control groups on cartoons with more and less constrained social contexts. Higher scores represent responses judged to be more appropriate.

participant's total word count to calculate the proportion of words in formulaic expressions for each participant.

Appropriateness and typicality scores along with the proportion of words in formulaic expressions were analyzed using a series of two-tailed Mann–Whitney U Tests, comparing responses in RHD and LHD individuals and controls. In addition, 3×2 analyses of variance with Group (RHD, LHD, control) and Condition (more constrained vs. less constrained context) as independent variables were run to evaluate the pattern of performance across conditions by the different groups.

4. Results

The average appropriateness ratings for the RHD, LHD, and control groups' responses are shown in Fig. 2. As evident from the Figure, there was a main effect of Condition: Responses to the more constrained cartoons designed to elicit formulaic responses were rated as more appropriate overall across all participants,
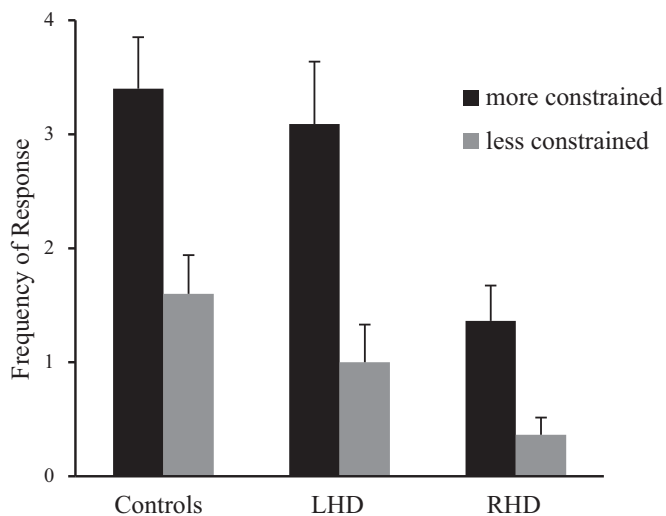

Fig. 3. Average typicality scores based on the number of instances a participant's response matched another individual in the sample, shown separately for cartoons with more and less constrained social contexts. Higher scores represent more typical/less novel responses.
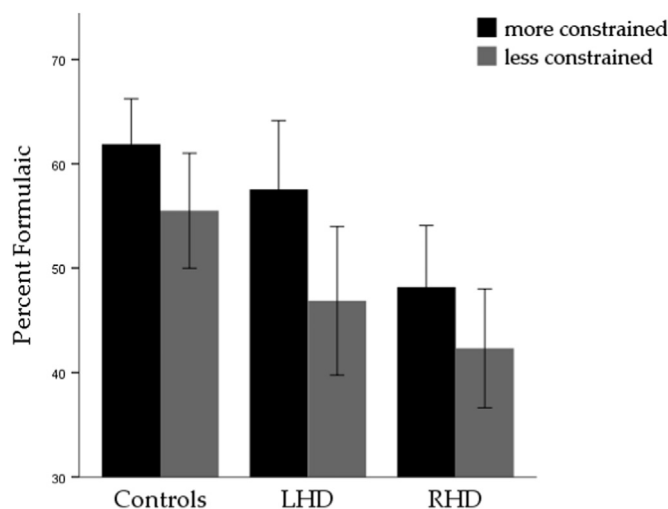

Fig. 4. Percent of words in participants' responses that were formulaic expressions, shown separately for cartoon stimuli with more or less constrained social contexts.

$F(1, 29)=20.85$, $p < .001$. In accordance with our prediction, RHD individuals' responses were rated as significantly less appropriate overall than controls', $z=$-2.82, $p=.005$. The LHD individuals' ratings fell between those of the RHD and control groups, but these differences did not reach significance, $ps > .05$. The interaction of Group X Condition was not significant, $F(1, 29)=.009$, $p > .05$. This finding indicates that the pattern of performance in RHD and LHD individuals did not differ, since the relative proportion of their impairment was similar across more and less constrained social contexts.

In the second set of analyses, the typicality of participants' responses was analyzed, based on the frequency with which an individual's response matched that of another participant in the sample (see Fig. 3). As expected, the main effect of Condition was significant again, $F(1, 29)=55.3$, $p < .001$, as all participants generated more typical responses for the constrained cartoons designed to elicit more formulaic utterances. Consistent with our prediction, the responses of RHD individuals were found to be significantly less typical relative to controls', $z= -3.24$, $p < .001$, and LHD individuals', $z= -2.23$, $p < .05$. LHD individuals did not differ from controls, $p > .05$. As in the previous analysis, the Group X Condition interaction was not significant, indicating that the pattern of performance on cartoons designed to elicit more or less formulaic responses did not differ among participant groups, $F(2, 29)=2.28$, $p > .05$.

Last, we analyzed the proportion of words in participants' responses that were formulaic expressions. As can be seen in Fig. 4, there was a main effect of Condition, $F(1, 29)=5.20$, $p < .05$, as all participants generated more formulaic speech in response to cartoons with more constrained contexts as expected. As predicted, there was a numeric pattern of diminution in the use of formulaic expressions between LHD and RHD individuals; however, the main effect of Group was not significant, $p > .05$. Individual Mann–Whitney U tests revealed no significant differences between groups except for a trend with RHD individuals generating less formulaic expressions overall than controls, $p=.097$. The Group X Condition interaction was also not significant, $p > .05$, as the proportion of formulaic expressions was similar across groups for the more and less constrained contexts.

An examination of participants' actual responses to the cartoon stimuli is particularly revealing with respect to the pragmatic impairments exhibited by RHD individuals, compared to LHD and control participants. Examples of individual patient and control responses to less and more constrained social contexts are

provided in Table 1. These examples illustrate that the RHD individuals often failed to capture the implied gist of the cartoon but instead provided more literal interpretations. For example, multiple RHD individuals referred to the boy noticing the woman's shoes in the cartoon at the top of Table 1, but did not appreciate that the boy was looking down out of shame rather than to comment on her shoes. There were also many cases where the RHD responses were socially inappropriate and/or vulgar, in contrast to a single, mildly inappropriate response given by one LHD individual and one control participant. It is important to note that although RHD individuals tended to give inappropriate or unusual responses, these responses still reflected multiple elements across the scene of the cartoons, indicating that their poor performance was not the result of neglecting portions of the visual scene. Moreover, a post-hoc analysis revealed no relationship between RHD individuals' line bisection scores and performance on any of the task measures (all $ps > .05$).

The other very noticeable aspect of the qualitative responses in Table 1 is the fact that RHD individuals produced verbose responses, relative to LHD individuals and controls. This was confirmed by a post-hoc analysis: RHD individuals' responses were longer overall (contained more words) than controls' responses, $z = -2.78$, $p = .005$. The length of LHD individuals' responses was not statistically different from either that of RHD individuals, $z = -1.81$, $p > .05$, or controls, $z = -1.27$, $p > .05$. It is notable that RHD individuals provided more verbal output and yet still produced less appropriate responses.

5. Discussion

The current study showed that individuals with right hemisphere damage (RHD) produced less appropriate, less typical, and less formulaic responses on a task in which they were asked to interpret what a character in a cartoon would be saying or thinking, relative to individuals with left hemisphere damage (LHD) and healthy controls. This pattern of performance is broadly consistent with previous theoretical models suggesting that the RH is dominant for processing social/contextual information and for producing formulaic language, as evidenced by previous work in both patients and healthy individuals (Bambini et al., 2011; Canessa et al., 2005; Cardillo et al., 2012; Channon et al., 2007, 2010; Fournier et al., 2008; Krueger et al., 2009; Mashal et al., 2007; Mosch et al., 2005; Noordzij et al., 2009; Pachalska et al., 2010; Semrud-Clikeman et al., 2011; Shamay-Tsoory and Aharon-Peretz, 2007; Sidtis, 2012; Weed et al., 2010). These findings are also in keeping with previous studies linking RH abnormalities to social and communicative impairments in individuals with Asperger's syndrome (Ellis et al., 1994), semantic dementia (Eslinger et al., 2007; Irish et al., 2013), and schizophrenia (de Achával et al., 2012; Rapp et al., 2013).

The main goal of this study was to compare the abilities of RHD, LHD, and control groups to interpret and generate appropriate responses to more or less constrained social scenes. Overall, the current findings are in accordance with our predictions and prior research implicating the RH in formulaic language (Sidtis and Postman, 2006; Sidtis et al., 2009; Sidtis, 2012), because the utterances of participants with RHD were generally less appropriate and less typical (i.e., less formulaic) than those of LHD participants and controls. Also, an analysis of the proportion of formulaic expressions in participants' responses revealed a trend for RH individuals to generate less formulaic language overall.

Contrary to our expectations, RHD individuals did not exhibit disproportionate performance on the more specific situations designed to elicit formulaic responses. Rather, all groups performed better with stimuli depicting more constrained and formulaic

social situations. This finding appears to present a challenge to the claim that the RH is particularly important in processing formulaic language (Sidtis and Postman, 2006; Sidtis et al., 2009; Sidtis, 2012; but see Goldberg and Costa, 1981; Goldberg et al., 1994 for an opposing view). One possible explanation is that the interpretation of contexts and the exact formulaic expressions generated by participants varies across individuals. Even though our independent formulaicity ratings confirmed the validity of our stimuli, potential differences across participant samples may make it difficult to generate stimuli that are consistently perceived as more or less formulaic and/or reliably likely to generate the same formulaic utterances. Future research should include a larger number of stimuli of each type, with norms collected across a larger, demographically-matched sample.

It is also possible that greater RH involvement in generating formulaic expressions may have interacted with the processing advantages provided by the more context-specific social situations in these cartoons. Indeed, there is evidence that the RH is normally superior in processing more ambiguous and difficult contexts, due to its ability to activate broader aspects of meaning than the LH (Faust et al., 2006; Jung-Beeman, 2005; Kacinik and Chiarello, 2007; Peretz and Lavidor, 2013; Prat et al., 2012; but see Gouldthorp and Coney, 2011; Kandhadai and Federmeier, 2008; Peleg et al., 2012). However, if those RH processes were compromised by brain injury as in the current study, then the more constrained, less ambiguous situations could be advantageous and result in the pattern of data obtained in the current study.

Another finding in the current dataset was the increased verbosity in RHD individuals: Overall, they produced numerically longer utterances than LHD and control individuals and yet those responses were not necessarily on point. This finding is consistent with previous work linking the RH to discourse production that is generally more disorganized and verbose (Bloom, 1994; Sherratt and Penn, 1990; for a review, see McDonald, 1993) and even sometimes inferior to aphasic individuals (Rivers and Love, 1980). Indeed, it was our intention at the outset of this study to demonstrate that LHD individuals, despite residual aphasic symptoms, can actually generate language that is in many ways superior to RHD individuals who, on a superficial level, demonstrate seemingly preserved speech. This pattern of data supports the notion that both the RH and LH play an important role in language and communication, with the RH mediating higher level processing at the level of larger linguistic, supra-sentence units (Bloom, 1994).

Unlike many previous lesion studies (Blonder et al., 2012; Champagne-Lavau and Joanette, 2009; Martin and McDonald, 2006; Pachalska et al., 2010; Weed et al. 2010; Winner et al., 1998), an advantage of the current study is that it involved directly comparing RHD individuals to both LHD and healthy control groups. This direct comparison allowed us to observe both quantitative dissociations and striking qualitative dissociations, such as RHD individuals' tendency to focus on particular elements of the scene and their failure to appreciate the overall situation, as well as their tendency toward verbosity. With respect to the less appropriate nature of RHD individuals' responses, it is possible that some responses were inappropriate attempts to be humorous. Indeed, the formal testing situation itself is a pragmatic challenge for individuals with RHD (Siegal et al., 1996). We did not typically observe similarly humorous/inappropriate responses from LHD individuals or controls. One interesting example was a LHD individual who began responding to the matrimony cartoon with a humorous remark (*Do you really want to go through with this?*) and then quickly corrected himself (*Or he could be saying the usual stuff like, Do you take this woman…*). We did not observe such "editing" from RHD individuals. Nonetheless, this failure of RHD individuals to appreciate the social pragmatics of the testing situation does not explain all our findings; many of their low ratings were due to their fundamental failure to fully integrate and

understand the gestalt of the social scene and make the appropriate inferences, consistent with prior studies (Ferstl et al., 2005; Myers, 2005; Shamay-Tsoory and Aharon-Peretz, 2007; Weed, 2008; Weed et al., 2010).

Another issue with respect to the interpretation of the current results is the potential role that visuospatial deficits can play in the performance of RHD individuals, given that the stimuli consisted of visual images (Myers, 2005; Papagno et al., 2006; Rinaldi et al., 2004). Individuals tested in the current study did not have gross visual distortions, as measured by line bisection, nor did performance on the main task correlate with line bisection deviations. However, this issue has been raised with respect to numerous previous studies with RH individuals (see Myers, 2005; Myers and Brookshire, 1996; Rinaldi et al., 2004, for reviews). To address this concern, Papagno et al. (2006), Rinaldi et al. (2004), and Tompkins et al. (2008) all showed that the performance of RHD individuals across various figurative language and theory of mind tasks with pictorial or verbal stimuli was not related to their degree of neglect, similar to the current study. A comprehensive study by Myers and Brookshire (1996) showed that RHD individuals with high and low levels of neglect were equivalently accurate, and not significantly different from controls, in their ability to identify the elements in a scene, even when that scene was visually complex. They also showed that although neglect accounted for a modest amount of variance in the visual and inferential accuracy of their performance, RHD individuals were primarily impaired in their ability to integrate and process the entire scene to make appropriate inferences. The results from these and other studies (Champagne-Lavau and Joanette, 2009; Grindrod, 2012; Myers, 2005; Pachalska et al., 2010) generally converge on the consensus that the main communicative difficulty of RHD individuals is an impaired ability to globally process a situation visually or verbally to understand and/or produce a contextually appropriate meaning or response.

Recently, Achim et al. (2013) proposed an 8-factor framework by which to characterize social interpretation tasks in order to facilitate the comparison of findings across studies. As they highlight, it is possible for a given patient to perform well on one type of social task and not another if those tasks differ by one of the eight factors that is particularly affected in that individual. They give the example of a patient who misinterprets how a character with a downturned face feels about receiving flowers because the patient does not appreciate perceptual social cues, while the same patient might do well on a verbal task with the same scenario. Achim et al. stress the importance of identifying which of the specific factors that contribute to mentalizing are present in a given task/study. Based on their framework, the stimuli used in the current study provide both immediate agentive and contextual information, along with general, stored contextual information based on prior knowledge in the more constrained contexts. In the current study, we attempted to create two groups of stimuli for comparison that differed by the degree to which they involved constrained/predictable social contexts or, in Achim et al.'s terms, the degree to which they provided more context-general information based on prior knowledge. As the results showed, this manipulation did have an impact on patient performance overall, with better performance in the more constrained contexts, although not differentially so for RHD versus LHD individuals.

The purpose of the current study was focused on the ability of participants to understand the entire social scene and the ability to generate appropriate language in their responses. Given that participants had to infer and express what they thought a cartoon character was thinking or saying, the pragmatic nature of the task thus involved some theory of mind processing. Theory of mind refers to the ability to attribute mental states to other individuals. Previous work has linked theory of mind to RH functioning, and

individuals with RH injury generally perform poorly on such tasks (e.g., Champagne-Lavau and Joanette, 2009; Griffin et al., 2006; Happé et al., 1999; Shamay-Tsoory et al., 2005a; Siegal and Varley, 2002; Winner et al., 1998; but see Geraci et al., 2010; Saxe and Kanwisher, 2003). As RHD individuals were generally impaired on the current task, our findings are consistent with these previous reports. A similar process to theory of mind, empathy, involves the ability to infer the emotional experiences of others (Rueckert and Naybar, 2008; Völlm et al., 2006). As with theory of mind, previous findings have linked empathy to the RH (Perry et al., 2001; Rankin et al., 2006; Rueckert and Naybar, 2008; Shamay-Tsoory et al., 2003; Spinella, 2002). Again, the current study did not directly set out to test the role of the RH versus LH in processing empathy, and only a subset of our stimuli required empathic understanding. Unfortunately, this subset was too small to do any type of systematic analysis to compare performance across different stimulus types in the different participant groups, but future studies would be improved by systematically manipulating this factor.

In conclusion, the present study further demonstrates the importance of RH functioning in processing social aspects of communication, as participants with RHD were found to be significantly impaired in their ability to generate appropriate responses to a variety of social scenes. From a practical perspective, although the language and communication deficits arising from LHD often appear more critical than the seemingly subtle communication deficits arising from RHD, the impact of RHD social communication deficits on everyday life can be very detrimental (Blonder et al., 2012; Mosch et al., 2005; Pachalska et al., 2010). Indeed, the impaired abilities of RHD individuals to accurately process social situations and generate appropriate formulaic responses creates a vicious cycle, such that those unusual and inappropriate responses further degrade the quality of their social interactions and relationships (Sidtis et al., 2009; Sidtis, 2012).

Compared to the large cadre of tests and treatment options for treating individuals with LH language disorders, there is a lack of sufficiently sensitive assessments and particularly interventions designed to improve pragmatic impairments in individuals with RHD (Blake, 2007; Ferre et al., 2011; Klonoff et al., 1990; Weed, 2011). A small number of researchers have begun to develop and evaluate promising treatment approaches for improving the ability of RHD individuals to appreciate subtle aspects of communication (Lundgren et al., 2011; Tompkins et al., 2012). The current finding that task performance was considerably better with more specific contexts suggests that an effective strategy for improving the communicative deficits of such individuals could involve initially training them to successfully process and make appropriate comments in highly constrained social situations to bootstrap those abilities to less constrained contexts. In fact, some recent research has demonstrated the benefits of a contextual, constraint-based treatment using verbal materials with respect to improving the ability of RHD individuals to understand discourse (Blake et al., 2015; Tompkins et al., 2012). A similar approach using pictorial stimuli such as those in the current study could potentially be used to track recovery and train individuals to effectively process and communicate across a range of social situations.

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