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Examining Lateralized Semantic Access Using Pictures

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Abstract

A divided visual field (DVF) experiment examined the semantic processing strategies employed by the cerebral hemispheres to determine if strategies observed with written word stimuli generalize to other media for communicating semantic information. We employed picture stimuli and vary the degree of semantic relatedness between the picture pairs. Participants made an on-line semantic relatedness judgment in response to sequentially presented pictures. We found that when pictures are presented to the right hemisphere responses are generally more accurate than the left hemisphere for semantic relatedness judgments for picture pairs. Furthermore, consistent with earlier DVF studies employing words, we conclude that the RH is better at accessing or maintaining access to information that has a weak or more remote semantic relationship. We also found evidence of faster access for pictures presented to the LH in the strongly-related condition. Overall, these results are consistent with earlier DVF word studies that argue that the cerebral hemispheres each play an important and separable role during semantic retrieval.

The present research looks at hemispheric differences in patterns of semantic access with picture stimuli. There is an extensive body of literature concerning the role the cerebral hemispheres play in the processing of semantics using visually presented words as stimuli (Arambel & Chiarello, 2006; Atchley, Burgess, & Keeney, 1999; Beeman, 1998; Beeman & Chiarello, 1998; Chiarello, 2003; Chiarello, Liu, & Shears, 2001; Chiarello, Shears, Liu, & Kacinik, 2005; Coney, 2002; Coney & Evans, 2000; Faust, Ben-Artzi, & Harel, 2008; Koivisto, 1997; Titone, 1998). This literature has produced an emerging understanding of the strategies that the two hemispheres employ when semantic access and integration occurs during reading. Specifically, the two hemispheres each have access to somewhat comparable information about the features and literal meanings of words, but each hemisphere makes use of a different time course and scope of retrieval when it accesses this meaning information. Our primary theoretical goal in the current research was to determine if these semantic processing strategies employed by the cerebral hemispheres are specific to the reading of linguistic stimuli, or if they generalize to other modalities or methods for communicating semantic knowledge. Furthermore, the current research allows us to go beyond more sensory or encoding level hemispheric difference (specifically the left hemisphere advantage for early word processing and right hemisphere advantages in early picture processing) and instead look at within hemisphere semantic processing and integration strategies.

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As a point of comparison, we will briefly review the divided visual field (DVF) reading literature, in order to characterize how the cerebral hemispheres differ in the manner in which they access the semantic information that is associated with written words. In one of the first DVF priming experiments using lexically ambiguous words, Burgess and Simpson (1988) studied the time course of semantic access for ambiguous words by varying the time between the prime (BANK) and the target; either the dominant meaning (MONEY) or the subordinate meaning (RIVER). They found that in order to find priming in words presented to the right visual field (RVF/LH), at least 35 ms must elapse between the presentation of the prime and the target. Hence, in this short amount of time, words presented to the RVF/LH already elicit a quicker response to targets related to both the dominant and subordinate meanings of the word. Words presented to the left visual field (LVF/RH) take about 300 ms longer to show facilitation for both meanings (Atchley, Burgess, Audet, & Arambel, 1996; Chiarello, Maxfield, & Kahan, 1995; Koivisto, 1997). If 750 ms is allowed to elapse, words presented to the RVF/LH show reduced activation for the subordinate meaning, causing them to be responded to with the same speed or even more slowly than completely unrelated targets (Atchley, et al., 1999; Burgess & Simpson, 1988). It is at this longer duration that the unique contribution of the RH becomes apparent. Despite the fact that evidence suggests that the LH has deactivated the subordinate meaning of the word, it is argued that the RH continues to maintain activation for both meanings for at least 800 ms. It has also been suggested that while the LH actively selects the most likely meaning early in comprehension, the RH spreads and more passively maintains activation to a wider range of remotely related semantic information (Atchley, et al., 1999; Atchley et al., 1996; Beeman, 1998; Beeman, Friedman, Grafman, & Perez, 1994). Thus, these researchers argue that the RH may play a crucial role in discourse level comprehension by maintaining a diverse array of contextual information while the LH focuses on immediately comprehending the incoming speech or language stream.

Though there is also an established literature regarding using pictorial stimuli when examining the hemispheric processing of semantics, there appears to be less convergence in this domain regarding laterality effects. Within this literature, there is a good deal of research examining affective picture processing (for example see Klauer & Musch, 2003) and hemispheric differences in processing of emotion related picture stimuli (for example see Calvo & Avero, 2008; Hermans, DeHouwer, & Eelen, 1994). There has been less work done examining how the cerebral hemispheres utilize semantics when judging pictures. As a simplistic review, there are some studies that suggest that there are few hemispheric differences in how semantic information is accessed when we think about pictures (Coney & Abernethy, 1994; Koivisto & Revonsuo, 2000-Experiment 2; Nieto, Hernandez, Gonzalez-Feria, & Barroso, 1990). Other studies suggest that the RVF/LH is better at extracting semantic knowledge from pictures (Hines, et al., 1984; Koivisto & Revonsuo, 2000-Experiment 1) or utilizing semantics with pictorial cues (Federmeier & Kutas, 2002). Further, there is evidence that DVF research involving pictures might provide evidence for differences in semantic representation and access between the hemispheres in much the same way that DVF word research has (Koivisto & Revonsuo, 2003; Lag, Hveem, Ruud, & Laeng, 2006). In an attempt to clarify these conflicting findings, we used a task that utilized the use of strong and weak semantically related stimulus pairs in a DVF presentation paradigm so that we might determine if there is greater semantic accessibility caused by RVF/LH or LVF/RH target presentation.

Of the studies that have examined the role each cerebral hemisphere plays in the semantic processing of pictorial stimuli, some utilize pictures as primes and words as targets. These studies are generally aimed at determining the nature of the systems that are operating when representing common objects and their names. Coney and Abernethy (1994) conducted a study in which pictures were presented randomly to either the LVF/RH or RVF/LH. These pictures were followed by the random presentation of a target letter string to the LVF/RH or RVF/LH. Participants performed a lexical decision in response to the target letter string. When the target was a word, the words were either related or unrelated to the prime pictures by meaning. The results provide at least three important general findings, first there was an overall quicker reaction time when target letter strings were presented to the RVF/LH, with most reaction times coming before 500 ms. This should come as no surprise considering several other studies have found an initial advantage of the RVF/LH for processing verbal stimuli (Atchley et al., 1996; Burgess & Simpson, 1988). Therefore, to most effectively test how semantic knowledge is conveyed or accessed based on picture stimuli it might be best to avoid using word stimuli all together. Secondly, the results clearly indicate that lexical decisions to a target letter string is facilitated by the prime picture that depicts the target, as compared with unrelated pictures, irrespective of the visual field of stimulus presentation and even following relatively long SOAs (1000 ms).

A third observation that one can draw from this work is the finding in the Coney and Abernethy (1994) study that response latencies were significantly faster when primes and targets were presented to opposite hemispheres as opposed to the same hemisphere. They offer the explanation that modality-specific priming occurs at a hemispheric level. According to this theory, the processing of pictorial stimuli in one hemisphere would require the use of the pictorial modality-specific system. In effect, this would compromise the use of the verbal modality-specific system in that same hemisphere until the pictorial system is finished processing (Hellige, Cox, & Litvac, 1979). Two basic assumptions can be derived from this theory. First, the processing of pictures and their meanings involves a separate system than the one required to process words and their meanings. Second, each hemisphere is capable of performing these processes, as evidenced by equal semantic access across hemispheres. Koivisto and Revonsuo (2000) also did a lexical decision cross-modal task and found that the two hemispheres show comparable priming from picture to related word.

Other studies examining the semantic processing of pictorial stimuli in the cerebral hemispheres involve presenting pictures as target stimuli (Beeri, Vakil, Adonsky, & Levenkron, 2004; Koivisto & Revonsuo, 2003; Reinitz, Wright, & Loftus, 1989). In one of the few semantic facilitation tasks that utilize pictures as both prime and target stimuli, Hines et al. (1984) presented subjects with picture pairs that were either semantically related or unrelated and asked subjects to name the target picture. When examining reaction times, semantic facilitation was found when pictures were presented to the RVF/LH and semantic inhibition was observed in the LVF/RH. More specifically, target pictures of related picture pairs were named quicker than target pictures of unrelated picture pairs when presented to the RVF/LH. An opposite pattern was observed when pictures were presented to the LVF/RH. Hines et al. arrived at two conclusions based on the results of their study. First, because semantic facilitation was observed in RVF/LH trials, they concluded that the LH is necessarily involved when processing the semantic relationship of pictorial stimuli. Second, one could argue that the RH might not consider the semantic relationship between the prime and target pictures when naming the target picture. It was suggested that this may be a result of information regarding the semantic relationship of the two pictures not being available in LVF/RH trials. Instead it is argued that the RH may consider other characteristics of the pictures (i.e. visual characteristics) when determining the relationship between the prime and the target.

In addition to Hines and colleagues, Zaidel (1987) conducted a study in which subjects were presented bilaterally with target pictures belonging to superordinate categories and varying in levels typicality. Subjects were asked to judge whether both pictures belonged to a predetermined superordinate category. Zaidel found that for RVF/LH trials subjects were able to correctly judge pictures of both high and low typicality equally well, while for LVF/RH trials subjects were much more efficient at judging high typicality pictures as compared to pictures of low typicality. Zaidel interpreted these findings as indicating that each hemisphere uses a different strategy to classify objects. Zaidel argues that the RH adopts a strategy of looking for prototypes initially when classifying objects, while thedata suggests that the LH waits until sufficient criteria has been met before classifying an object. Although Zaidel used pictures as both prime and target, the task in the study was designed to examine semantic categorization, not judgments of whether two stimuli are related. Therefore, it is difficult to arrive at any definitive conclusions about the nature in which the two hemispheres judge the relationship between separate objects based on Zaidel's data. Nonetheless, the results offer insight on the nature in which each hemisphere accesses semantic information in relation to visual stimuli.

Finally, relevant to the current research design, there is evidence that the semantic processing of pictures occurs in a similar manner to that of words, in that each of the two hemispheres may have access to particular kinds of semantic information and may work in a more collaborative manner when processing the semantic information available in pictorial stimuli. Providing one example of this more complex pattern of DVF picture processing is evidence that the cerebral hemispheres process stimuli differently when the degree of their semantic relationship is varied. Laeng, Zarrinpar, and Kosslyn (2003) presented participants with pictures in lateralized manner and then read them a label that was either related or unrelated to the picture. The degree to which the names described the pictures varied. More specifically, some names were category names (i.e. bird) and some were exemplar (i.e., robin). The results showed better RVF/LH processing for category relationships, and better LVF/RH processing for exemplar relationships. This supports the idea that the RH encodes specific exemplars better than the LH. Another finding from this study is that basic-level or category relationships were always processed faster than exemplar relationships. Laeng, and colleagues (2003; Laeng, Overall, & Steinsvik, 2007) suggest that participants had to process more perceptual properties of a picture to confirm an exemplar relationship as compared to a category relationship. Thus, presentation of stimuli to the LVF/RH results in an advantage for utilizing this kind of perceptual property relationship when making relatedness judgments.

In summary, there is no agreed upon general theory describing how the cerebral hemispheres process semantics in pictorial stimuli, much less, how varying degrees of semantic relationship might uniquely influence patterns of semantic access that result from picture stimuli presented laterally. One seemingly obvious reason for the disparity of results in previous research using pictures as stimuli is the inconsistency in methodology. Most studies have employed a cross-modal presentation paradigm. As indicated earlier, this seems to diminish our ability to explicitly examine the influence of pictures as a method for communicating semantic information. Thus, in our current research we will employ only picture stimuli.

Additionally, in an attempt to parallel common methodologies used in the DVF word literature we will employ picture pairs that have been shown to have varying degrees of semantic relatedness. In previous word DVF studies, the word pairs are primarily selected via word generation norming studies (see Atchley, Burgess, & Keeney, 1999 as an example). For example the word *LAMB* may be provided and participants are asked to generate a list of 5 or 10 features or associates of this target word. With pictures, we cannot perfectly reproduce this norming procedure. However, instead picture pairs were provided to a large number of subjects and they were asked to judge the degree of relationship between the picture pairs. Based on this alternative norming approach, we selected picture pairs that varied in the degree of observed semantic relationship for the specific picture pairs employed.

Finally, in an attempt to examine the semantic meaning accessed in response to our lateralized picture stimuli, we asked participants to make an on-line semantic judgment in response to the picture pairs. This task is less common in the DVF word literature, but it was used to discourage the use of other possible strategies (i.e. a comparison of picture valance) for picture comparison and to encourage semantic retrieval during the processing of both the first picture (acting much like a prime) and the second picture in the sequentially presented pair. This task was also employed in an attempt to diminish the impact of well-recognized laterality differences in general picture processing (see Laeng, Overvoll, & Steinsvik, 2007; Metcalfe, Funnell, & Gazzaniga, 1995), because it would require that participants, again, focus on semantic content.

One concern that must be raised with regards to the semantic relatedness judgment task used in the current study is that it is clearly not directly comparable to the more traditionally used "priming" paradigms (employing naming or lexical decision) that are used in the DVF domain because we can not say that there is a the same kind of direct, item specific facilitation with individual pictures that it thought to occur with specific lexical items or words. However, we are hoping to learn about the kind of mediated activation that might result from retrieving the semantic content of one picture and then considering its possible relationship to a subsequent picture. In other words, we are not hoping to replicate the kind automatic kind of spread of activation that likely influences early word priming studies (see Simpson, 1991 for a review). Instead, we hope to tap into the more controlled kinds of context driven semantic facilitation and semantic integration that likely occurs with any stimulus that conveys meaning.

Previous research provides the basis for making some empirical predictions about the current research. Given that the research design used is meant to allow for the examination of semantic retrieval mechanisms, the critical, theoretically motivated predictions relate to expected patterns of lateralized semantic facilitation for strongly and weakly related picture pairs. If retrieval of semantics via picture stimuli relies upon some of the same hemispheric mechanisms that support semantic facilitation between related words, then we would expect a very different pattern of lateralized access when judging the semantic relationship between strongly associated picture pairs as compared to more weakly associated pairs (see Atchley et al., 1999 or Beeman & Chiarello, 1998 for a review). For the strongly associated pairs, we would expect that both RVF/LH and LVF/RH trials would result in rapid and accurate semantic relatedness judgments. If the RH continues to serve the role of showing sustained activation for a wide range of semantic associates, we would expect to see subjects accurately identifying weakly related picture pairs as semantically related when these trials are presented to the LVF/RH. In contrast, the LH seems to actually shut down or even inhibit accessibility for more distant semantic associates, and this would lead to the prediction of slower and less accurate semantic judgments for weakly associated picture pairs in our study. Again, these predictions represent a direct extension of findings from the DVF word literature. However, as reviewed above, inconsistencies in previous DVF picture processing research could lead to predictions distinct from those formulated by DVF word literature.

Therefore, we expect to see one of three possible outcomes. First, there could be few hemispheric differences in how semantic information is accessed when we process pictures. Alternatively, the results might suggest that the presentation of stimuli to the RVF/LH results in the more effective extraction of semantic knowledge from pictures, or finally, pictures might provide evidence for differences in semantic representation and access between the hemispheres similar to that seen in the DVF word literature. If this final prediction were to be supported we would specifically expect to see a LVF/RH advantage for accessing more remote semantic relationships, as reflected by faster and more accurate identification of the semantic relationship depicted in the weakly related picture pairs. The predictions above focus on our expectations for the strong and weakly related picture pairs, we do not feel comfortable offering a-priori predictions regarding DVF differences in how the unrelated picture pairs might be processed.

Methods

Participants

Seventy-three undergraduate students (35 females, 38 males) were selected using the University of Kansas Psychology Research Participation System. Each subject was awarded class credit for participation in the study. Only individuals who were right-handed, native English speakers, and had normal or normal-to-corrected vision were allowed to participate. Handedness was determined via a short (5–item version) of the Edinburgh handedness questionnaire.

Design

The experiment was a 3 (strength of semantic relationship: strongly related, weakly related, or unrelated) × 2 (visual field of target presentation: left or right) within-subjects design.

Apparatus

A Dell, Pentium-class processor with a 15″ × 12″ Dell monitor along with the E-prime (E-studio) program was used for stimulus presentation. An adjustable chinrest placed 18″ from the center of the monitor was used to minimize overall head movement and maintain fixation on the center point of the monitor. Responses were made via the keypad that is built into the computer's keyboard.

Procedure

Upon arrival for the experiment, each participant was asked to read over, sign, and date a consent form. The experiment consisted of a brief practice block and an experimental block. The same set of instructions were presented visually on the computer screen and read aloud by the experimenter before both the practice and experimental blocks. Participants were instructed that a fixation cross would appear in the center of the screen, followed shortly by the presentation of a picture in the center of the screen. The first picture (Picture-1) would then be followed by the presentation of a second picture (Picture-2), which would appear either to the left or to the right of the fixation cross. After the two pictures were presented, the participants were then instructed to press the "1" key on the keyboard's number pad using their right hand if they considered the two pictures to be either related to each other by meaning or in the same category. If they did not consider the two pictures to be related by meaning or in the same category, participants were instructed to press the "2" key using their right hand. Mapping of key press responses were held constant throughout the experiment.

For each block the initial fixation cross was presented for 500 ms. Picture-1 was presented for 750 ms. Picture-2 was presented for 185 ms. Following Picture-2, a solid brown square functioning as an object mask appeared in each visual field. The subjects were given 2000 ms to make a response. If they made a correct response, the message "Correct!" was presented in the center of the screen. If they made an incorrect response, the message "Incorrect!" was presented in the center of the screen (see Figure 1). The experiment lasted approximately 15 minutes. Participants were fully debriefed after the experiment.

Stimuli

All pictures used in this experiment were adopted from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2001). The IAPS is made up of full color photographs that represent, primarily real world scenes or objects (see Figure 2 for examples). The IAPS was selected as a picture database because of its normative scores for affective valence and general arousal, and only pictures of neutral valence and arousal were used in this study to avoid potential confounds. For all picture pairs, Picture-1 was presented in the center of the display, while Picture-2 was presented laterally. The inside of edge of the pictures was approximately 2-degrees visual angle from the center of the screen and subtended approximately 7-degrees visual angle. Before final picture pairs were selected, a normative study was conducted to confirm the strength of semantic relationship (SSR) for each picture pair. In this normative study, 89 participants were asked to judge the SSR between 140 pairs of pictures on a scale ranging from 1 to 7. The scores from all participants were then averaged for each picture pair. The scores for picture pairs in the strong-SSR condition ranged from 4.96 to 6.71, with an average score of 5.86. The scores for picture pairs in the weak–SSR condition ranged from 3.02 to 4.89, with an average score of 4.05 (see Figure 2). Unrelated pairs were not judged in the normative study. Unrelated pairs were generated by the experimenters by repairing pictures that appeared in the related conditions.

The practice block consisted of 10 picture pairs. None of the pictures that were used in the practice blocks were used in the experimental block. Five picture pairs were selected from each of the related SSR conditions (strong and weak) and ten were selected from the unrelated condition, resulting in a total of 20 trials in the practice block. As in the experimental block, half of the Picture-2 stimuli were presented to the LVF and half to the RVF.

The experimental block consisted of 48 core picture pairs. 24 picture pairs were selected from each of the related SSR conditions. These same Picture-2 stimuli from the related SSR conditions were also paired with an unrelated Picture-1 in order to control for general processing differences across our picture stimuli. In other words, if a Picture-2 stimulus appeared in the LVF and it was related to the Picture-1, it would also appear in the RVF and be paired with a different, unrelated Picture-1 stimulus in a second trail in the block. This made for a total of 96 trials and six distinct conditions consisting of 12 picture pairs in each of the related conditions (strong-LVF, strong-RVF, weak-LVF, and weak-RVF) and 24 trials in each of the unrelated SSR conditions (unrelated-LVF and unrelated-RVF). Once the final list of pictures was made, its order was randomized, making sure that no more than four trials from the same condition appeared in a row.

Results

An analysis of variance (ANOVA) was conducted for the primary dependent variables, response accuracy (ACC) and reaction time (RT). For all LSD planned analyses to be discussed, a $\underline{p} < .05$ was used as the critical value of significance.

Accuracy

A significant main effect was observed for both independent variables; SSR ($\underline{F}$ (1, 72) = 250.69, $\underline{p} < .001$) and VF ($\underline{F}$ (1, 72) = 56.26, $\underline{p} < .001$). Picture pairs with a strong-SSR (96%) were judged more accurately than unrelated pictures (92%; $\underline{t}$(72)= 5.089, $\underline{p} < .001$ (two-tailed)), which were in turn judged more accurately than picture pairs with a weak-SSR (75%; $\underline{t}$(72)= 14.849, $\underline{p} < .001$ (two-tailed)). Also, picture pairs presented to the LVF/RH (91%) were judged more accurately than picture pairs presented to RVF/LH (85%).

A significant 2-way SSR × VF ($\underline{F}$ (1, 72) = 14.78, $\underline{p} < .001$) interaction was also observed (see Table 1 and Figure 3). Within the SSR × VF interaction, picture pairs with a strong-SSR presented to the LVF/RH (97%) were judged with the same degree of accuracy as picture pairs with a strong-SSR presented to the RVF/LH (95%; $\underline{F}$ (1,72)= 2.76, $\underline{p}$ = NS). However, for both weakly related picture pairs and unrelated picture pairs there was a LVF/RH advantage. The difference between the visual fields for picture pairs with a weak-SSR was a difference of about 11% (weak-LVF/RH = 80%; weak-RVF/LH = 69%; $\underline{F}$ (1,72)= 34.87, $\underline{p} < .001$) and for unrelated picture pairs the numeric difference in accuracy between the two visual field conditions was about 4% (unrelated-LVF/RH=95%; unrelated-RVF/LH= 89%; F (1,72) = 37.79, p < .001).

Reaction Times

For the Reaction Time dependent variable a significant main effect was observed only for SSR (F (1, 72) = 142.07, p < .001). Picture pairs with a strong-SSR (641 ms) were judged most quickly followed by the unrelated SSR condition (682 ms; t(72)= 4.326, p < .001 (two-tailed)). The picture pairs that were judged as related in the weak-SSR condition (796 ms) were far slower than these other two conditions (strong vs. weak: t(72)= 4.337, p < .001 (two-tailed); weak vs. unrelated: t(72)= 11.066, p < .001 (two tailed)). No main effect was observed for VF (F (1, 72) < 1).

A significant 2-way SSR × VF (F (1, 72) = 12.72, p < .001) interaction was again observed (see Table 1 and Figure 4). For both the weakly related picture pairs and for the unrelated picture pairs the pattern of RT results mimics the results seen with accuracy. For both the weak-SSR condition (F (1, 72) = 5.00, p < .05) and for the unrelated condition (F (1,72) = 7.66, p < .01) there is a RT advantage for trials presented to the LVF/RH over the RVF/LH trials. However, we did see one result that is different from the accuracy data. Specifically, we found that there is reliable RVF/LH reaction time advantage for strong SSR trials (RVF/LH= 623 ms; LVF/RH= 659 ms; F (1,72) = 14.58, p < .001). This finding was not consistent with our a-priori predictions.

Discussion

The results provided by the two dependent variables utilized in this study (response accuracy and reaction time), are most consistent with the a-priori predictions that come from the DVF word literature. In other words, the retrieval of semantics via picture stimuli seem to rely upon some of the same hemispheric mechanisms that support semantic facilitation between related words (see Atchley et al., 1999 or Beeman & Chiarello, 1998 for a review), and the two hemisphere access semantic information using dissociable strategies. The accuracy results suggest that the RH likely serves the role of showing sustained activation for a wide range of semantic associates. We suggest this because we see subjects identifying weakly related picture pairs as semantically related more quickly and more accurately when these trials are presented to the LVF/RH, while when the same targets are presented to the RVF/LH there are many more errors and the participants are slower in making their decisions. Unlike the word literature, the strongly related and weakly related trials in the LVF are not of equal accuracy (the weakly related trials are less accurate in both hemispheres), which is likely a reflection of differences between the types of stimuli utilized as discussed in the introduction. Nonetheless, the DVF results suggest that the RH is far more effective at detecting this more remote association than is the LH.

Interestingly, there is also a difference in both accuracy and reaction time between targets presented to the two visual fields for the unrelated trials. In traditional priming research, it is generally not common for researchers to make specific predictions regarding hemispheric differences in processing for the unrelated trials, but in our own research (for example Atchley, et al. 1999, 1996) we do not see hemispheric differences in responses to the unrelated trials when we use a lexical decision task. However, with the relatedness judgment task utilized here, which is not designed to study initial lexical activation- but instead later stages of semantic activation and integration, we see what might be interpreted as additional evidence for a LVF/RH advantage in accurately identifying more remote semantic relationships. Specifically, stimuli presented to the LVF/RH result in the more effective detection of existing weak semantic relationship, additionally LVF/RH trials are also better at correctly identifying trials as unrelated.

For the strongly associated pairs, we expected that both RVF/LH and LVF/RH trials would result in rapid and accurate semantic relatedness judgments. We did see that both hemispheres are able to very accurately judge the strongly associated pictures as being semantically related, but we found that the RVF/LH was also reliably faster when subjects are making this judgment. This RVF/LH advantage for accessing more directly related semantic associates is not completely unheard of. Specifically in the visual word DVF priming literature, it has been argued that the LH is more effective at accessing directly related or finely coded semantic representations of words. Greater RVF/LH priming for strongly associated word pairs has been demonstrated in previous studies, and our observation in the current study is completely consistent with these earlier results (Beeman, 1998). This effect is also commonly seen when the primes are summation primes (containing multiple related words; Faust & Lavidor, 2003; Beeman, Friedman, Grafman, Perez, Friedman, et al., 1994). In fact, one might argue that picture stimuli might behave more like summation primes than single word primes given that pictures might allow access to multiple interrelated characteristics of a concept much like convergent compound primes are thought to do.

Prior research suggests that trials presented to the LVF/RH result in an advantage in processing for various perceptual features of non-verbal stimuli such as size, exposure duration, and spatial frequency (Christman, 1989 Christman, 1993). However, it is not clear that this general hemispheric advantage in picture processing should translate into an overall LVF/RH advantage when processing a semantic relationship that can be illustrated by two pictures. Indeed, several previous attempts to find hemispheric differences in semantic processing of pictures failed to provide any reliable hemispheric differences (Biederman & Cooper, 1991; Levine & Banich, 1982). In addition the prediction that the LVF/RH should enjoy an overall advantage in the processing of pictures would be particularly inconsistent with the findings of Hines et al. (1984) and others who have suggested that the LVF/RH is less able to utilize the semantic relationship between prime and target pictures. Nonetheless, despite this finding in the literature, our results can be taken to indicate that the RH is better than the LH at making semantic relatedness judgments for picture pairs. For the current experiment there is one condition (the strong SSR condition) in which there is a reaction time advantage for the RVF/LH trials, but for all other comparisons in which a visual field difference there is a LVF/RH advantage. It is possible that this LVF/RH advantage in judging semantic relationships reflected in picture stimuli might be due to differences in tasks between the current experiments and previous research. More specifically, participants in previous studies were not usually required to explicitly think about the semantic relationship between the prime and target pictures, they were required only to name the target picture. Whereas in the current study, participants were forced to consider both the prime and target pictures before making their judgment; they would be unable to consistently answer correctly without considering both stimuli in the current experiment. Regardless of whether the difference in task is responsible for the differences in results between the current study and previous studies, our findings suggest that the RH is fully capable of processing the semantic relationship between the picture pairs.

One concern that might be raised regarding the current methodology is that we asked participants to make all responses with their dominant (right) hand. It should be noted that this is the approach is not uncommon in the DVF word literature (for examples see Atchley, Burgess, & Keeney, 1999; Burgess & Simpson, 1988; Faust, Ben-Artzi, & Harel, 2008), however it is also common to ask participants to use a bimanual response or to switch hands of response during the course of the experiment. Hand of response could have some effect on our findings given that one hand is presumably responsible for all motoric responses and this could have some impact on the results, particularly on the pattern of reaction time results. Future research is this area should explore the potential impact of this methodological variable.

A second concern that also needs to be expressed regards stimuli selected for the current research. In order to find stimuli that were more strongly semantically related it was often necessary to utilize stimuli that also had some degree of perceptual similarity. In contrast, the perceptual similarity that exists between the weakly related picture pairs is likely somewhat less (please see Appendix 1 for a list of all related picture pairs). This distinction between the relatedness conditions represents a methodological concern because one might argue that the results obtained might be in part a reflection of hemispheric differences in processing of these perceptual characteristics. However, we would argue that this explanation does not satisfactorily explain all aspects of our results given that the unrelated trials, which were judged quickly and accurately, share the lowest degree of perceptual similarity and also show hemispheric differences. Additionally, from a theoretical perspective, we would argue that a shared degree of perceptual similarity in some ways might mimic the relationships that occur between words. This is not to say that highly related words are necessarily physically similar, but the semantic features that they evoked are likely referencing objects with a high degree of perceptual similarity (i.e. puppy-kitten) much like occurs with our highly related picture pairs. Nonetheless, future research employing related picture pairs could be designed in such a way as to more carefully control for perceptual similarity.

In conclusion, the current study found hemispheric differences in judging the semantic relatedness between two pictures. This is evidenced by significantly higher accuracies and in many situations (particularly in weakly related and unrelated conditions) faster reaction times to picture pairs presented to the LVF/RH as opposed to the RVF/LH. We suggest that our results are reasonably consistent with earlier DVF word priming studies that argue that the RH plays an important and separable role during semantic retrieval.

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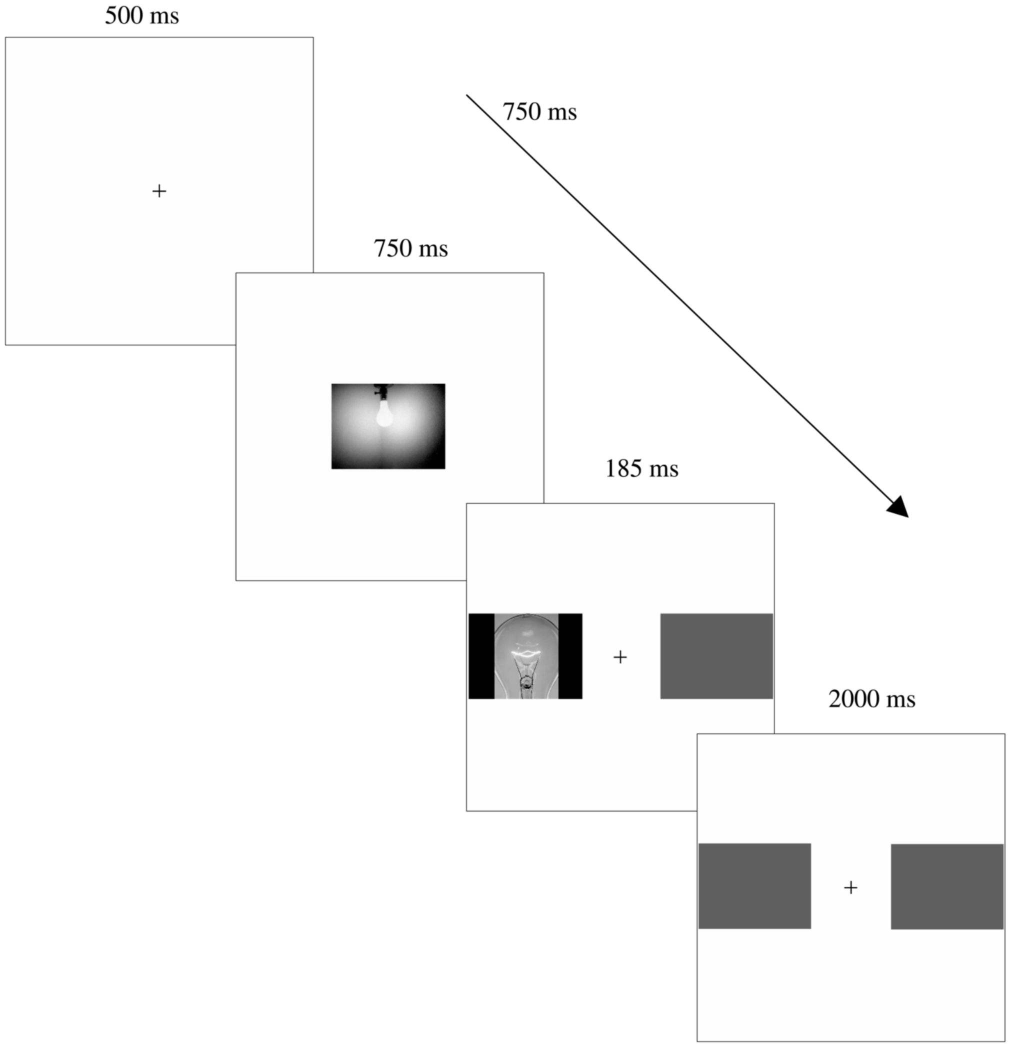

Figure 1.
Example procedure for strongly-related SSR condition.

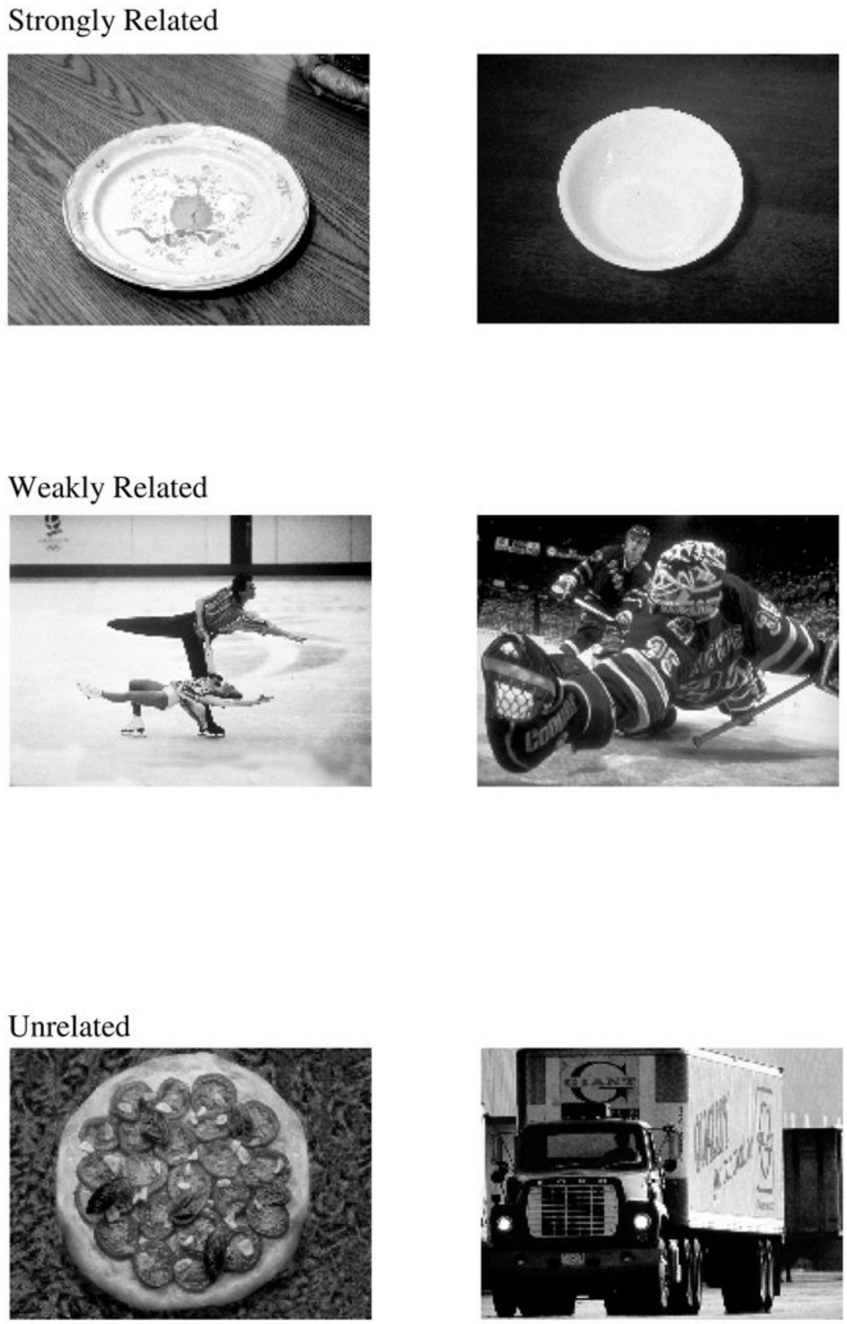

Figure 2.
Example picture pairs from strongly-related, weakly-related, and unrelated conditions.

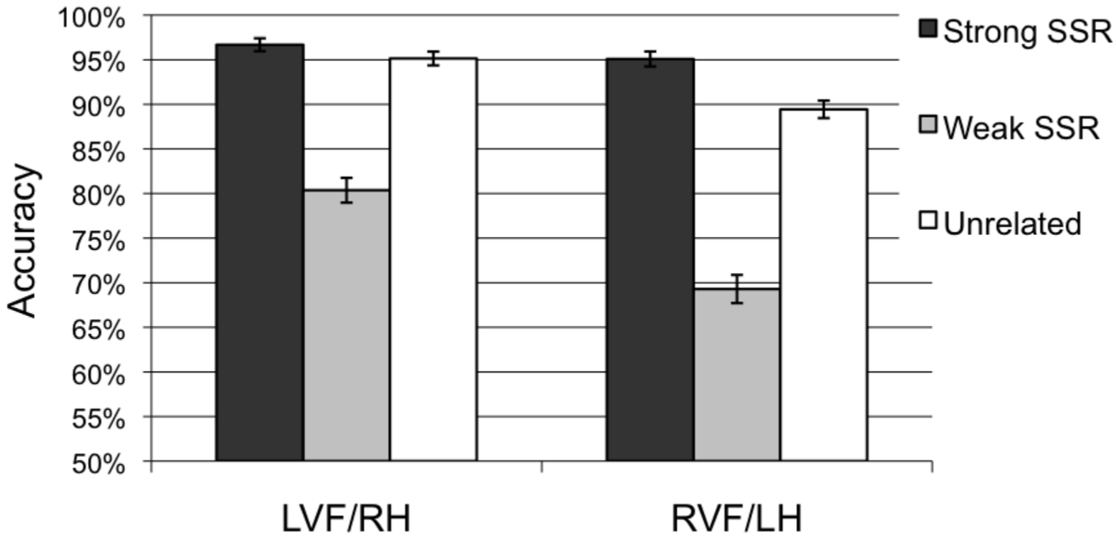

Figure 3.
Mean accuracy as a function of visual field of target presentation and strength of semantic relationship.

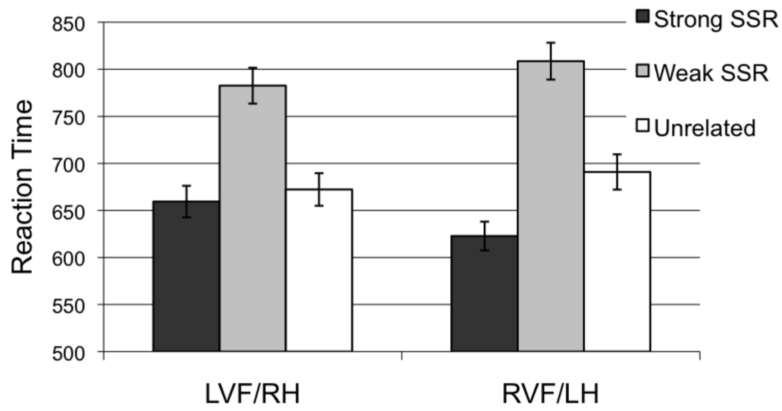

Figure 4.
Mean reaction time as a function of visual field of target presentation and strength of semantic relationship.

Table 1

Mean Accuracies and Reaction Times

	Visual Field			
	Acc		RT	
Condition	**LVF**	**RVF**	**LVF**	**RVF**
Strong SSR	.967 (.007)	.951 (.008)	659ms (16.8)	622ms (15.3)
Weak SSR	.804 (.014)	.693 (.016)	783ms (19.0)	807ms (19.6)
Unrelated	.951 (.008)	.894 (.010)	672ms (17.3)	690ms (18.8)

Appendix 1

List of stimuli from IAPS database

Strong-SSR		Weak-SSR	
1302 (Dog)	1640 (Coyote)	1931 (Shark)	1726 (Tiger)
1333 (Parrots)	1560 (Hawk)	2206 (Fingerprint)	2681 (Police)
2092 (Clowns)	2780 (Actor)	2357 (Man)	7710 (Bed)
2235 (Butcher)	2745.1 (Shopping)	2372 (Woman)	2410 (Boy)
2580 (Chess)	2840 (Chess)	2491 (Sick Man)	2394 (Medic Woman)
5395 (Boat)	7036 (Shipyard)	2515 (Harvest)	7472 (Grapes)
5740 (Plant)	5800 (Leaves)	2620 (Woman)	1850 (Camel)
5875 (Bicyclist)	8251 (Motorcycle)	2635 (Cowboy)	1670 (Cow)
5920 (Volcano)	5940 (Lava)	5661 (Cave)	8160 (Rock Climber)
6910 (Bomber)	6930 (Missiles)	5720 (Farmland)	5900 (Desert)
7004 (Spoon)	7080 (Fork)	6900 (Aircraft)	6800 (Gun)
7009 (Mug)	7035 (Mug)	7002 (Towel)	7050 (Hair Dryer)
7010 (Basket)	7041 (Basket)	7037 (Trains)	7590 (Traffic)
7025 (Stool)	7235 (Chair)	7040 (Dustpan)	7060 (Trash Can)
7030 (Iron)	7234 (Ironing Board)	7095 (Headlight)	7130 (Truck)
7031 (Shoes)	7038 (Shoes)	7100 (Fire Hydrant)	9635.2 (Fire)
7170 (Light Bulb)	7236 (Light Bulb)	7150 (Umbrella)	5950 (Lightning)
7182 (Checkerboard)	7183 (Checkerboard)	7160 (Fabric)	7179 (Rug)
7205 (Scarves)	7217 (Clothes Rack)	7289 (Food)	2560 (Picnic)
7211 (Clock)	7190 (Clock)	7351 (Pizza)	2702 (Binge Eating)
7224 (File Cabinet)	7705 (Cabinet)	7490 (Window)	7491 (Building)
7233 (Plate)	7006 (Plate)	7700 (Office)	2383 (Secretary)
7500 (Building)	7510 (Skyscraper)	8032 (Ice Skater)	8117 (Hockey)
7920 (Car Crash)	9913 (Truck)	9582 (Dental Exam)	7195 (Teeth)