Faces and Words: Flip Sides of the Brain?

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Abstract

The specialization of the right and left hemispheres of the human brain and their differential processing strengths has long been studied in the field of neuropsychology. One notable division between the hemispheres, which has been the focus of research for many years, is the right hemisphere specialization for face processing and the left hemisphere specialization for word processing. However, given that the hemispheres are densely interconnected, one might also expect to observe some collaborative efforts between the hemispheres but the interhemispheric function has not been studied in much detail. One possible form of hemispheric division is as follows: individuals who have a greater hemispheric asymmetry for one class (faces or words) should show an equivalent asymmetry for the second class and those who show a more graded asymmetry should show it equally for both classes of stimuli. This division of labor may be individualized throughout a population, and we see that the hemispheric organization within individuals reflects the outcome of the face/word representational competition. The study of the balance of hemispheres is critical for understanding visual-perceptual processes both typical individuals as well as atypical neurological patients with deficits in face or word recognition.
1. Introduction

The relative specialization of the right and left hemispheres in the human brain for differential processing of information has been demonstrated in a variety of cognitive and perceptual tasks, many of which involve either faces or words as primary stimuli. Based on these investigations, many researchers have concluded that separate domain-specific subsystems exist for faces and words; the face processing subsystem is located in the right hemisphere and word processing subsystem is in the left hemisphere of the brain. By examining the individual contribution of the two hemispheres and their respective subsystems we have gained much knowledge about their individual capabilities. However, this separate attention to each hemispheric individually has also limited our ability to understand what the hemispheres can accomplish together.

Due to the nature of communication between the two hemispheres during perceptual tasks, differing degrees of competition or collaboration may occur between them. Furthermore, the extent of specificity for the right hemisphere, left hemisphere, or for a collaborative effort between them may differ for each individual and for each perceptual task. Despite the many obvious differences between faces and words as stimuli, the neural mechanisms may not be as independent as we have been led to believe. Understanding the degree and nature of both the specialization of each hemisphere for faces and words and also the interaction of the two hemispheres on face and word perception tasks will provide a deeper understanding of the relationship between the brain and behavior.
**Separation between the hemispheres**

Face and word processing mechanisms have been studied extensively using different methodological approaches and perspectives. The fusiform face area, (FFA), located on the inferior surface of the ventral cortex of the right hemisphere, has been localized and claimed to be the region where faces are largely or exclusively mediated. On the other hand, word form processing (analysis of the perceptual properties of the words) has been localized to the visual word form area, (VWFA), which is a homologous region to the FFA only it is located in the left hemisphere (Cohen, Martinaud, Lemer, Lehéricy, Samson, Obadia, and Slachevsky, 2003). These regions have been identified as the specific biological structures that respond selectively to the domain-specific categories of faces and words, respectively.

Consistent with this, classical accounts of hemispheric specialization state that faces and words engage in separate and independent neuropsychological mechanisms. In the case of faces, the functionality of the FFA can be examined through neuropsychological studies of ‘face blindness’, or prosopagnosia. Prosopagnosia is an impairment of facial processing with the result that individuals are left to discriminate between even their closest family and friends by clothing, hair or other perceptual clues. Lesions in this disorder are found in an overlapping region of the FFA (Bouvier & Engel, 2006). Patients with this disorder have difficulties discriminating between novel faces, do not show an advantage for upright over inverted faces, and do not benefit from holistic processing of faces as normal individuals typically do. Similarly, more can be learned about the VWFA from studying individuals with ‘pure alexia’ (Montant & Behrmann, 2000) which is characterized by ‘pure word blindness’ in premorbidly literate individuals.
The lesion in this disorder is typically found in the left occipital temporal area along the fusiform and adjacent lingual gyri (Cohen et al., 2003) which is overlapping with the designated VWFA area described earlier. With this disorder, individuals show a linear increase in RT as a function of the number letters in a given string which reflects the breakdown of parallel processing in the VWFA leading to laborious letter-by-letter reading. Individuals with prosopagnosia, like those with pure alexia, exhibit a loss of configural abilities, leading to part processing rather than typical holistical processing methods in perceptual analyses. Whether part processing is in the form of letters to form a word or in features to form a face, the parts are processed in parallel to create the whole. Based on these separate deficits, we see an independence of word and face systems. The study of these neurological deficits can help us to unveil new ideas regarding typical and atypical perception and also help us to model processing of faces and words in normal individuals.

**Interhemispheric Cooperation**

Although much research, as reviewed above, suggests that the hemispheres operate independently and have their own specialization, some have argued that the hemispheres do interact. Of course, it is the case that the hemispheres are connected to each other via the densely interconnected corpus callosum and so transfer of information between the two sides is natural and automatic. One theory which has received much attention, the ‘inter-hemispheric cooperation’ theory, argues that it is often advantageous for task performance for the hemispheres to work together since the hemispheres both commit their processing resources to the task (Banich, 1998). Additionally, on this
account, the advantage of inter-hemispheric collaboration is further increased as the complexity of a task is increased. Thus, when the task is simple, only one of the hemispheres is needed to satisfy the demands of the task, but as complexity increases, there are benefits to collaboration between the right and left hemispheres. These ideas were first explored with simple stimuli such as letters, or shapes, and indeed, interhemispheric cooperation was observed, but even more robust results can be obtained with the introduction of complicated stimuli such as faces or words, as these stimuli presumably require even more inter-hemispheric interaction than simple stimuli. This increase in interhemispheric cooperation with increasingly complex stimuli was examined by Compton (2002) in the arena of face processing. By using only these simple stimuli in perceptual tasks there is also a lack of naturalistic validity in the results. In both Compton’s experimental process as well as ours, we use more complex stimuli and take advantage of a more natural perceptual task, hopefully increasing the validity of the findings and leading to more socially relevant neuropsychological advances by using stimuli such as faces.

Compton’s (2002) study specifically examined whether participants could match the identity and emotional expression of two novel faces when the faces were presented in the same visual field (within hemisphere) or across the two visual fields (across hemispheres). In that study, a ‘physical’ match referred to matching two identical emotion-containing faces whereas a category (emotional) match required matching the facial expressions of two different faces, despite identity. In each trial, a target face was presented along with 2 choices, one in each field (so the display had a triangular configuration with a face at each vertex). For example, in an emotional (category) match
there would be an ‘angry’ and ‘happy’ face on the top section of the triangular design, and another ‘happy’ face with a different identity on the bottom of the design; participants would then respond, using two buttons, that this ‘happy’ match stimuli corresponds with the above ‘happy’ target face. The same procedure was used for the physical match, faces still evoked emotions, but on these trials, participants matched on identity. Importantly, and consistent with the inter-hemispheric cooperation account, on both category and physical match experiments, participants performed significantly better in across-field scenarios than within-field. Compton (2002) identified the physical match as more difficult and in turn found the across-field advantage to be greater for this task, leading to the belief that inter-hemispheric interaction is increasingly advantageous as complexity is increased.

**The Current Investigation**

To explore the relative and joint contribution of the two hemispheres, we too adopt a triangular visual array paradigm given its success in the Compton (2002) study. In this paradigm, the participant sees three stimuli in a triangular pattern flashed briefly (two target choices at the top and the match at the bottom of the display). After this brief presentation, participants indicate whether the bottom ‘target’ stimulus is identical to the ‘match’ stimulus in the top left or top right visual field (see Figure 1 for example of display). The target and match can appear in the same visual field or in opposite fields. When matches occur in the same visual field, it is considered a within-field trial and when they occur across fields, it is a between- or across-field trial. For simple tasks, performance is similar for both trial types but as the task complexity increases,
performance is expected to be faster and more accurate for across field trials (Banich & Belger, 1990). Better performance on across-field trials during more complex tasks has been replicated across several studies, and with the use of faces and words as stimuli that are typically considered more perceptually complex, we hope to extend these findings.

Figure 1a: Face Within-Field Trial – Match Right & Target Right

Figure 1b: Face Across-Field Trial – Match Left & Target Right
Because we are interested in whether there are differences in the within- and between-field processing for faces and for words, in this experiment, participants make target/match judgments both within- and between-fields for words and for faces. In
addition to understanding whether, as a group, individuals show inter-hemispheric cooperation for faces and for words, we are also interested in understanding on an individual-by-individual basis whether those particular individuals who do show inter-hemispheric cooperation, do so for faces as well as for words and if so, whether the magnitude of the cooperation is equivalent across the stimulus type. Given that we expect interhemispheric cooperation in both cases of words and faces, and indeed this has already been shown for faces by Compton (2002), with relative specialization for the right hemisphere for faces and the left hemisphere for words, the question is whether the two hemispheres are relatively specialized but still able to cooperate. If so, one prediction is that the degree of hemispheric asymmetry for the right hemisphere seen during the experiment with face stimuli will correlate with the degree of asymmetry for the left hemisphere during word recognition trials. Since we believe the regions responsible for word and face recognition to be similar structures of different representations, we should see a correlation individualized to each subject which can also be calculated across the population. Only by performing this with words and faces as stimuli, can we see the relationship between the FFA and VWFA in this type of perceptual task.

In summary, due to the hemispheric specialization of words in the left and faces in the right hemisphere, researchers interested in cerebral asymmetry have focused on the study of these separate domain-specific subsystems for each class. With this bias, researchers have overlooked the fact that the same computational principles may apply in both cases, only played out over different representations. Based on this, individuals who have a greater hemispheric asymmetry for one class should show an equivalent asymmetry for the second class. This division of labor is individualized throughout a
population but over a large group, the correlation aspects of this asymmetry can be
determined and will support the view that the hemispheric organization within
individuals reflects the outcome of the face/word representational competition. This
information is critical for understanding perceptual processes in typical individuals and
can also benefit the study of many neural deficits in face or word recognition.

2. Experimental Methods

2.1. Participants

Twenty-three undergraduates from Carnegie Mellon University (9 male, 14
female) participated in the study, either for course credit or a small payment. The
participants were aged 18-22 (mean age 20 years). All participants were right handed,
with a mean score of 69 on the Edinburgh handedness inventory (Oldfield, 1971) and the
range included scores from 40 to 100. Subjects varied in race but all were native English
speakers. Participants each completed both the Face and Word Experiments in
counterbalanced order with a short break in between the two experiments.

2.2. Stimuli and Design

Nine grayscale faces and 356 4-letter English words were used as stimuli for the
two experiments. The faces and the words were constructed for this experiment. The
words and faces were randomly chosen by E-prime software so that each word set was
presented only once to each participant during each condition. The four letter non-match
words differed by one letter for each trial (e.g. mast versus mask). The letter change
location was distributed evenly across the different positions of the word. Stimuli were
presented on a Dell laptop computer running E-prime software (Psychology Software
Tools) and the subject was centered in front of the monitor at a viewing distance of approximately 50 cm.

2.3 Procedure

For both experiments, the display was presented for 150 ms exposure durations in a triangular formation design. Two ‘target’ stimuli, one in the left and one in the right visual field, were presented above the fixation and one ‘match’ stimulus was presented below the fixation point, half the time on the left and half on the right. The bottom stimulus matched either the top right or the top left stimuli in the design. Stimulus presentation was randomized and controlled by the E-prime experiment package. Each trial consisted of a central fixation cross presented for 150 ms, followed immediately by three stimuli: one positioned 2.5 degrees to the left of center, another positioned 2.5 degrees to the right of center, and the last 2.5 degrees below center and 1.5 degrees to the right or left of center. The innermost point of each stimulus was 1.3 degrees from central fixation. After stimuli presentation, a blank screen was shown for 150ms and participants were asked to make a response indicating the side of the match. Participants were asked to press the ‘z’ key if the bottom ‘match’ stimulus was identical to the top left ‘target’ stimuli in the display or to press the ‘m’ key if the bottom ‘match’ stimulus matched the top right ‘target’ in the display. If no answer was recorded after 150ms, the experiment moved onto the next trial. Responses were recorded by the E-prime software and were analyzed based on accuracy and reaction time. Individual correlations between within-versus across-field performance on word and face tasks were also analyzed.

Words were presented in a white fixed font (Courier) and had a physical size on the screen of approximately 7 × 25 mm against a black background. Faces were seen in
grayscale against the black background and had a physical size of approximately $7 \times 25$ mm. The four conditions create a 2 by 2 design with the target appearing in the left or right field and the match appearing in the left or right field. Thus there were four trial types of 108 trials each, with the first two being within-field and the latter two-across field (target left match left, target right match right, target left match right, and target right match left). Trials from the four conditions appeared equally often but with randomized order in each block of trials. Participants completed 6 blocks of 72 trials each, totaling 432 trials, with a break between blocks if desired.

3. Results

**Interhemispheric interaction versus unilateral hemispheric advantage**

A repeated measures ANOVA was performed to examine accuracy (proportion correct) with the within-subject factors of match (left, right visual field), target (left, right visual field), and trial type (word or face). Main effects and interactions emerged as significant from the omnibus ANOVA.

The ANOVA revealed that accuracy was overall higher for face trials than for word trials ($F(1, 22) = 9.935, P < 0.05$). Accuracy was also higher overall when the target is on the right compared with the left ($F(1, 22) = 5.146, P < 0.05$) and when the match is on the right compared with the left ($F(1, 22) = 5.146, P < 0.05$). An interaction between match $\times$ target exists ($F(1, 22) = 13.651, P < 0.05$) as well as a marginally significant match $\times$ word/face interaction ($F(1, 22) = 1.824, P = 0.191$). Both of these interactions are explored further using a Tukey’s Honest Significant Difference (HSD) analysis, which determines where the significant differences occur in the interactions.
The interaction between match \times target elicited a Tukey’s HSD value of 12.2%, therefore, the means of the trial types that differ more than that amount are significantly different from one another. As can be seen from Figure 3, across-field trials where the match is on the left and the target is on the right have the highest accuracy of 67.9% which is 14.5% more and hence significantly different from the within-field trials where the match is on the left and the target is on the left which had an accuracy of 53.4%. No other condition means were significantly different from one another.

![Accuracy- Match*Target Interaction](image)

**Figure 3:** Mean percent correct for visual field of match stimuli as a function of visual field of target

The marginal interaction between target \times word/face had a Tukey HSD value of 11.38%. Here, we see significant differences between target right for faces at 65.4% accuracy over target left for words with only 58.3.7% accuracy. This difference does not exceed the Tukey value of 11.38% and therefore is not enough to push this interaction to significance. When a face target is located on the right accuracy is highest whereas when a word target is located on the left accuracy is lowest; this coincides with the idea of an advantage, in the left hemisphere for words and in the right hemisphere for faces.
In terms of reaction time, we found a main effect of target with overall faster reaction times for right than left matches ($F(1, 22) = 5.478, P < 0.05$) as well as a main effect of word/face trials indicating that face trials are faster than words ($F(1, 22) = 7.017, P < 0.05$). These two factors interacted, as in the accuracy analysis, indicating the relevance of the target location when looking across the two trial types, faces and words ($F(1, 22) = 6.048, P < 0.05$). A marginal interaction between match and target existed as well ($F(1, 22) = 6.048, P = 0.167$). To examine these interactions more closely, Tukey’s tests were performed – allowing us to see where the differences between condition means lie. For the interaction between target and word/face we found a Tukey value of 33.72 ms. When target words were on the left, they were significantly slower than target words on the right, and also slower than target faces in both fields. The largest difference in mean reaction time medians was found between words in the target left position which were 47.728 ms slower than faces in the target right position.
Figure 5: Mean Reaction Time in ms for visual field of target stimuli as a function of stimuli type, faces or words.

For the marginal interaction between match and target we found a Tukey HSD value of 55.4355ms, yet no two means differed by that great of a value; match left target right was only faster than match left target left by approximately 31 ms which may explain the marginally significant result.

Correlations of hemispheric cooperation for words and faces within individuals

To address the question of whether a relative balance between the two hemispheres existed across the sample we included individual analyses of faces and words. The number of people with visual field advantages for either face or word stimuli can be seen in Figure3 (a –c). These analyses were done by creating difference scores separately for match, target, and match × target interaction. When examining match or target individually, this was done by subtracting match left - match right trials for words (with the expectation that RT for match left for words will be longer than match right for words; hence, a larger positive score means a greater right field advantage) and match
right- match left trials for faces (with the expectation that RT for match right for faces will be longer than match left for faces; hence, a larger positive score means a greater left field advantage). For the match × target interaction, subtractions were match right/target right – match left/target left for words and visa versa for faces. As alluded to, the subtractions were different for faces and words because we expected participants to perform better when the stimuli were in the left visual field for faces and better when stimuli were in the right visual field for words. This would allow us to examine within an individual subject, whether she/he has a hemispheric advantage for faces and for words and whether these are of equal magnitude (hence balanced) or not.

Based on these analyses, we see that most participants appear to have performed best when the target was presented in the left visual field for both faces and words; this could possibly be explained by the fact that we read from left to right so our initial instinct draws us to the upper left stimuli. In the case of match and the interaction between match*target we see stronger advantages existing. For match, we see the majority of individuals perform best when the match stimuli are located in the left visual field for words and for faces we see equal performance across the visual fields and so no obvious advantage. In the case of match*target, the largest number of individuals performed best when both the target and match were presented in the left visual field for words and best for faces when the target and match were found in the right visual field. These results testify for a graded population, and though we see that across field trials exhibited high performance, there is high variability across individuals in terms of advantages for visual stimuli in varying visual fields.
### Table: Number of Individuals with advantage

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<thead>
<tr>
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<th>Word Visual Field Advantage</th>
<th>Face Visual Field Advantage</th>
<th>Target</th>
<th>Match</th>
<th>Target*Match</th>
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<td>Right</td>
<td>Left</td>
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<td>Right</td>
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<tr>
<td>Face Visual Field Advantage</td>
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<tr>
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<td>4</td>
<td>8</td>
<td>5</td>
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<tr>
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<td>10</td>
<td>9</td>
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<tr>
<td>Target*Match</td>
<td>4</td>
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Figure 6: Individual Advantages across Stimuli Type and Visual Field in terms of Median Reaction Time

To further understand these data, we may look at the graphs, showing the relative distribution of right and left hemisphere advantages for individual subjects, which have been plotted independently for match, target, and the match*target interaction. We see that individuals located in the double positive quadrant exhibit both a word RVF and face LVF advantage i.e. the expected pattern of asymmetry, and double negative individuals exhibit the reverse pattern i.e. a word LVF and face RVF advantage. We would expect the greatest number of participants to be located in the double positive upper right quadrant but that is not the case, therefore we are seeing more graded results rather than a high asymmetry for either hemisphere.
Figure 7: Reaction Time Individual Analyses for Match Trials – difference score for the right visual field.

Figure 8: Reaction Time Individual Analyses for Target Trials - difference score for the right visual field.
4. Discussion

The main finding from this study is that there was no significant interaction between hemispheres when subjects completed physical matches for either faces and words in across field trials. This is surprising given the previous results indicating that on complex trials, the hemispheres working in parallel can give rise to better performance than a single hemisphere can do. The lack of significant across-field interaction might arise from a number of possible reasons. One possibility is that even though complexity is desirable, our tasks were too complex. This is less convincing as the task did not differ from that of Compton (2002) who did find evidence for interhemispheric cooperation. It is possible then, that we tuned in on perceptual complexity rather than our intended conceptual complexity. Despite the absence of an interaction between match x target x wordface, there were significant interactions that can divulge some important
information. We see that subjects performed better with face trials over word trials, and were able to calculate performance biases for face and word trials. Though we failed to see significant inter-hemispheric cooperation, we did find a half-field advantage for words and faces that could be seen as a distribution among the individual subjects in our sample. The individual variability between subjects was seen in the difference scores between their performance on the face and word trials. This helped to explain the balance between hemispheres for each individual subject.

The interactions we did find existed between target*wordface for reaction time, and match*target and match*wordface for accuracy. With these analyses, we see that subject’s had the quickest reaction times when face targets are located in the right visual field and when words were located in the left visual field, subject’s had the slowest reaction times. The decrease in reaction time when words were located in the left visual field is understandable due to the bilateral advantage for word processing in the left hemisphere and in turn a bias for words in the right visual field. The difficulty of the word task may also be a reason why words are slowest in this case. Another interaction between match and target showed that when the match was located in the left visual field and the target in the right participants had the highest accuracy. This was followed by match right, target left trials with the second highest accuracy indicating that across field trials had highest accuracy. An interaction between match and word/face showed that face matches in the right had the highest accuracy followed by face matches in the left visual field which signified that faces were the easier of the two stimuli. The lowest accuracy trials were word matches in the left visual field. In comparison with the previous interaction, we see that the slowest reaction times occurred when word targets
were on the left and the lowest accuracy occurred when the word match was found on the left; performance was decreased most when word stimuli, both match and target, were located in the left visual field which corresponds with the bilateral field advantage for words in the right visual field.

Understanding the lack of significant inter-hemispheric interaction found in this experiment may aid in the further development of the task-demands theory. This theory states that inter-hemispheric interaction becomes more advantageous as the task difficulty increases. Our study carries valuable information for this theory’s development in the sense that there may be a ceiling for the level of complexity that can benefit from inter-hemispheric interaction. As mentioned above, it is possible that our task was overly complex due to the very quick stimulus presentation or the similarity between the stimuli subjects were discriminating between. This may be especially true for the word stimuli which elicited low accuracy and high reaction times when compared to the face stimuli.

Another possibility is the presence of floor effects accounting for the failure to find the inter-hemispheric interaction. The task’s difficulty may have lead participants to perform at near chance levels and that this in turn, diminishes the effect we may have been able to find. This is especially true for word trials where subjects performed at near chance levels, around the 50th percentile range. On the other hand, a ceiling effect could also be the limiting factor, as it is possible that there is a limit to the extent to which inter-hemispheric advantages can increase as tasks continue to increase in complexity. Previous research complements this idea as it has showed that for complex letter-matching decision tasks, increasing the stimulus item amount didn’t produce a greater across-field advantage, but that same manipulation did increase the across-field
advantage on a simple letter-matching task (Banich & Belger, 1990). Important items to note while evaluating the reasoning behind the lack of effects are the nature of task demands and complexity. In order to maximize our results we altered the stimulus presentation time, finally deciding on a 150 ms stimulus presentation. Though this presentation time was optimal in some ways for our experiment, this extremely short presentation may have increased the perceptual complexity and in turn diminishing inter-hemispheric interaction. Our experimental design targeted perceptual complexity rather than conceptual complexity as we intended, and as a result we realized the definition of complexity must be altered to gain the results we intended.

In addition to the inter-hemispheric interaction analysis, we examined the individual variability and the balance between face and word processing per subject. By determining both RVF and LVF advantages we can see each individual’s hemispheric processing preferences. By looking at this for target, match, and the interaction between target*match we can examine the advantages of varying the locations for the target and the match stimuli. Following the hypothesis that facial and word form processing are not completely separate systems but instead have an important relationship and balance we expect to see maximum performance in the LVF for faces and in the RVF for words. We found that the location of the target had very little effect on performance as individuals had similar performance despite the location of the target stimuli. This could be due to the fact that two targets existed on the top region of the screen consistently throughout the experiment and therefore the location of the target was obsolete without the coinciding match identifier. The locations of match that were most advantageous were a word left visual field advantage and a face right visual field advantage. Though these
seem to be opposite of what we would expect, when we look at match we must keep in mind the target location. Looking back to the ANOVAs performed, we see that across field trials were most advantageous for both faces and words therefore the advantageous match visual fields may not necessarily be what we would ultimately expect.

Our idea that individuals who have a greater hemispheric asymmetry for one class should show an equivalent asymmetry for the second class, though possibly true, was not revealed by this experimental design. The belief that hemispheric organization within individuals reflects the outcome of the face/word representational competition still exists, yet is not fully reflected by our results.

5. Conclusion

In summary, the results demonstrate that there is a fine line in the arena of complexity and that this must be adhered to in the generation of inter-hemispheric interaction paradigms and principles. Though complexity is necessary to elicit the across hemisphere collaboration, too much complexity or complexity of the wrong kind may impede the results. Faces were matched more accurately and also more quickly than words, as words proved to be the more complex and difficult stimuli. Individual analyses to examine the balance between hemispheres showed a preference for the right visual field for faces and the left visual field for words.
References


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