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Research report

The relationship between visual word and face processing lateralization in the fusiform gyri: A cross-sectional study

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ABSTRACT

Visual words and faces activate similar networks but with complementary hemispheric asymmetries, faces being lateralized to the right and words to the left. A recent theory proposes that this reflects developmental competition between visual word and face processing. We investigated whether this results in an inverse correlation between the degree of lateralization of visual word and face activation in the fusiform gyri. 26 literate right-handed healthy adults underwent functional MRI with face and word localizers. We derived lateralization indices for cluster size and peak responses for word and face activity in left and right fusiform gyri, and correlated these across subjects. A secondary analysis examined all face- and word-selective voxels in the inferior occipitotemporal cortex. No negative correlations were found. There were positive correlations for the peak MR response between word and face activity within the left hemisphere, and between word activity in the left visual word form area and face activity in the right fusiform face area. The face lateralization index was positively rather than negatively correlated with the word index. In summary, we do not find a complementary relationship between visual word and face lateralization across subjects. The significance of the positive correlations is unclear: some may reflect the influences of general factors such as attention, but others may point to other factors that influence lateralization of function.

1. Introduction

Face and visual word recognition are both examples of expert visual processing, requiring fine discriminations between highly similar stimuli. Neuroimaging studies show that the processing of visual words and faces involves networks that include regions in inferior temporal cortex that respond more to faces or visual words than to any other categories of objects. The 'fusiform face area' (FFA) in the mid portion of the fusiform gyrus (Kanwisher et al., 1997a, 1997b), is thought to be involved in the processing of unique facial identity (Haxby et al., 2000a, 2000b), while the 'visual word form area' (VWFA) is another mid-fusiform region that shows a selectivity for visually presented words (Cohen et al., 2000).

A consistent observation about these networks and regions is that they show a lateralized asymmetry. The FFA is more often identified and larger in both size and magnitude of response in the right than in the left hemisphere (Davies-Thompson and Andrews, 2012; Rossion et al., 2012), while the VWFA (Cohen et al., 2000) is more often identified in the left than the right hemisphere (Cohen et al., 2000, 2002a, 2002b; Dehaene and Cohen, 2011; Szwed et al., 2011). These anatomic asymmetries have functional parallels. Tachistoscopic studies show a right visual field bias for words and a left field bias for faces (Leehey and Cahn, 1979; Levine and Banich, 1982; Levine and Koch-Weser, 1982), and the latter has been correlated with the degree of face activation in the right hemisphere on functional MRI (Yovel et al., 2008). Studies using evoked-potentials consistently show greater N170 potentials for words in the left occipital cortex (Maurer et al., 2008; Mercure et al., 2011) and for faces in the right occipital cortex (Scott, 2006). Neuropsychologically, the impaired face recognition of prosopagnosia typically follows damage to bilateral or right occipito-temporal cortex (de Renzi, 1986; Haxby et al., 2000a, 2000b; Sergent and Villemure, 1989), while the impaired reading of alexia is associated with left occipito-temporal damage (Kawahata et al., 1988; Sakurai et al., 1994).

Besides their complementary lateralization, there are additional relevant observations about the neural bases of face and

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word processing. For one, both faces and words activate similar bilateral networks, involving fusiform, lateral temporal and inferior frontal regions, among others (Barton et al., 2010a, 2010b; Haxby et al., 2000a, 2000b). For another, given that the lateralization of face and word regions is only partial, there remains significant overlap in each hemisphere between the regions activated by faces and those activated by words (Nestor et al., 2013). These points have led to recent speculations that the lateralized hemispheric specialization for words and faces evolves through competition between face and word processing for the neural resources in these object-recognition networks (Behrmann and Plaut, 2013; Dundas et al., 2013). Thus, while the recycling hypothesis initially proposed that the acquisition of literacy is accompanied by co-opting of object-recognition resources by word processing (Dehaene et al., 2010), recent accounts suggest that this specifically targets neural substrates that might otherwise be devoted to face processing (Plaut and Behrmann, 2011). Efficiency constraints to maximize local over long-range connections may exert pressure to lateralize visual word processing to the left hemisphere, where non-visual language processing is situated. In this view, the right lateralization of face processing may follow as a consequence of the left lateralization of word processing.

Other work has disputed the competition hypothesis. First, there are observations that a right hemisphere preference to faces is already present in newborns (de Heering and Rossion, 2015) and in monkeys (Zangenehpour and Chaudhuri, 2005), and that visual input to the right hemisphere during infancy is necessary for face expertise to develop (Le Grand et al., 2003). These suggest that a right hemisphere bias for faces may be innate.

Nevertheless, the presence of an innate right hemisphere bias and the competition hypothesis are not necessarily mutually exclusive phenomena. A competition for resources between words and faces would predict that the left dominance of word processing and the right dominance of face processing have a non-arbitrary relationship in human subjects. If the neural resources of the left and right hemispheres for which faces and words compete are finite, then one possible outcome would be that the degree of lateralization of one would be inversely correlated with that of the other across a sample of the population. That is, given that the degree of lateralization for words and faces varies across subjects, one might expect that a competition that resulted in more left and fewer right hemispheric resources being devoted to visual words would also create a strongly lateralized face processing system, with more right and less left hemispheric activation by faces. On the other hand, a subject with more balanced visual word activation across left and right fusiform regions would also be expected to have a less asymmetric face processing system.

Some suggestive evidence for this predicted relationship between word and face activation has been produced. A study reported that the magnitude of the N170 potential for faces in the right hemisphere were positively correlated with those for words in the left hemisphere (Dundas et al., 2014). However, another study using functional MRI did not find a correlation between the lateralization of the FFA and VWFA (Pinel et al., 2015). Hence the issue is not yet settled. To test this prediction further, we examined a cohort of right-handed literate subjects with functional neuroimaging. We used standard localizers of face and word activation to determine if there was an inverse correlation across the cohort between the left/right balance of visual word activity and that for face activity.

2. Results

2.1. Same-ROI analysis

There was a positive correlation between the MR responses of the peak voxels activated for faces and those for words in both the left FFA ($r=0.68$, $p<0.001$) and left VWFA ($r=0.55$, $p<0.005$). Thus subjects with a greater response to faces had a greater response to words in these regions (Fig. 1A). Face and word MR responses were not correlated in the right FFA ($r=0.17$, $p=0.42$) but there was a trend to a positive correlation in the right VWFA ($r=0.36$, $p=0.09$).

When we examined the lateralization index (Fig. 1B), there was a positive correlation between the degree of lateralization of face activity and that for words within FFA regions ($r=0.49$, $p<0.05$), but not within VWFA regions ($r=0.02$, $p=0.93$). Including subjects' handedness scores, cortical thickness, and cortical volume as additional regressors did not significantly change the model (P's > 0.24) and showed again a positive correlation for the lateralization indices within the FFA ($r=0.45$, $p<0.05$) but not in the VWFA ($r=0.02$, $p=0.93$).

2.2. Different-ROIs analysis

This analysis examined the relationship between regions in their response to their preferred stimulus (i.e. the response to faces in FFA regions versus the response to words in VWFA regions). For the numbers of voxels activated by the localizers, there was no correlation between the activation by words in VWFA regions and the activation by faces in the FFA regions, in either the left ($r=-0.14$, $p=0.49$) or right hemisphere ($r=0.09$, $p=0.65$). For the peak MR response, there was a positive correlation in the left hemisphere between the scores for faces in FFA regions and those for words in VWFA regions ($r=0.55$, $p<0.005$), but not in the right hemisphere ($r=0.32$, $p=0.11$) (Fig. 2A).

The lateralization indices for the numbers of voxels did not show any correlation between face activation in FFA regions and word activation in VWFA regions. Including handedness and cortical volume thickness did not change the model (P's > 0.52), but including cortical thickness did, though the correlation was still not significant ($r=0.20$, $p=0.37$). For the peak MR responses, however, there was a positive correlation between the lateralization index for word activation in the VWFA regions and face activation in the FFA regions ($r=0.41$, $p<0.05$) (Fig. 2B). Including subjects' handedness scores, cortical thickness, and cortical volume as additional regressors did not significantly change the model (P's > 0.27) and a similar positive correlation was still found ($r=0.47$, $p<0.05$). However, this was driven by a single data-point (in the lower-left corner of Fig. 2B); repeating the correlation without this data-point resulted in a non-significant correlation ($r=0.27$, $p=0.21$).

Finally, we performed an additional correlational analysis, to investigate parallels with a prior report that the magnitude of the N170 potential for faces in the right hemisphere were positively correlated with those for words in the left hemisphere (Dundas et al., 2014). Thus we studied the relationship between the response to words in the left VWFA and the responses to faces in the right FFA. This showed no correlation for the number of voxels ($r=0.01$, $p=0.93$), but a positive correlation for the peak MR response ($r=0.44$, $p<0.022$). The positive correlation was even stronger when fusiform cortical thickness ($r=0.57$, $p<0.003$) and cortical volume ($r=0.54$, $p<0.006$) were taken into account.

At first glance, these last results might be taken as supporting the hypothesis that stronger lateralization for words is associated with stronger lateralization for faces. However, greater activation for faces in one hemisphere cannot be taken as indicating a more