A comparison of tabular-based meta-analysis and activation likelihood estimation in the Stroop task

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Introduction

Meta-analysis is an important tool for interpreting results of functional neuroimaging studies, and is highly influential in predicting or testing new outcomes. The most common meta-analysis method is tabular-based, in which reported coordinates from individual studies are tallied up and plotted as a bar graph. This method is widely used and well accepted. However, this form of meta-analysis is not optimal and can be difficult to interpret. In addition, tabular-based meta-analyses are much cruder than voxel-based comparisons since concordance is often assessed across large regions. A new method of meta-analysis, activation likelihood estimation (ALE), is a great improvement over traditional methods [1,2]. In this method, each reported focus is modeled as a Gaussian function that approximates intersubject variability (14 mm FWHM). In comparison with tabular-based meta-analyses, the output of ALE is a pseudo-SPI (statistical parametric image) that allows direct comparison with the SPIs obtained in the individual studies. Here we present a comparison of a tabular-based meta-analysis and an ALE meta-analysis of the Stroop color-word task. In this task, subjects are instructed to name the ink color in which a color name is presented. The Stroop task is known for its effect of producing conflict due to the subjects' tendency to read the word presented regardless of the instruction to name the ink color.

Methods

A list of studies investigating the Stroop effect was compiled via Medline search. This list was limited to include only the studies that published their activation results as 3-dimensional coordinates (x,y,z) in stereotactic space. The ALE meta-analysis consisted of 17 Stroop papers (11 fMRI and 6 PET). Contrasts were selected as those comparing the incongruent condition (conflict between name of color and color of ink) with a control condition to yield a total of 184 foci. Talairach coordinates were transformed to MNI305-space using a Brett transform [3]. A tabular-based meta-analysis was conducted by utilizing the Talairach Daemon [4] as this technique does not introduce bias by relying on author-based labels. An activation likelihood estimate (ALE) map was also created according to the method of Turkeltaub *et al.* [1]. Statistical significance was determined using a permutation test of randomly distributed foci. The resultant ALE map quantifies the degree of concordance across studies for the Stroop task.

Results

The tabular-based meta-analysis (Fig. 1) shows consistent frontal lobe activation reported in the left inferior frontal gyrus (10 of 17 papers) and the left middle frontal gyrus (13 of 17 papers). In the limbic lobe, 6 and 7 of 17 papers reported activation in the right and left cingulate gyrus, respectively. Similarly, the ALE meta-analysis (Fig. 2, Table 1) revealed a lateralized response in the left inferior frontal gyrus (z = -4, 16) and the left middle frontal gyrus (z = 12, 16). In addition, an extremely high degree of bilateral convergence was seen in the cingulate gyrus (z = 26).

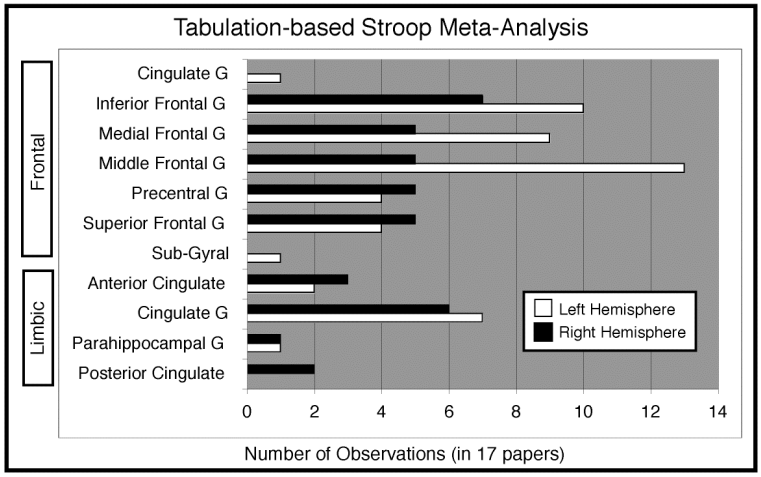

Figure 1. Results of the tabulation-based Stroop meta-analysis.

Conclusions

It is interesting to note that the cingulate gyrus response (z = 26) is much more prominent in the ALE meta-analysis, as compared to the tabulation-based meta-analysis. This is evidence of the effect of the higher spatial resolution allowed with the ALE method. The Stroop task is frequently used to elicit response inhibition and selective attention. Although no unified theory exists on the function of the anterior cingulated (ACC), it is understood to be involved in response selection, attention, and higher-order motor control. Additionally, some theories suggest that the ACC is associated with anxiety or anticipation. Based on the results of the ALE meta-analysis, it is clear to see that involvement of the ACC is crucial to performance of the Stroop task.

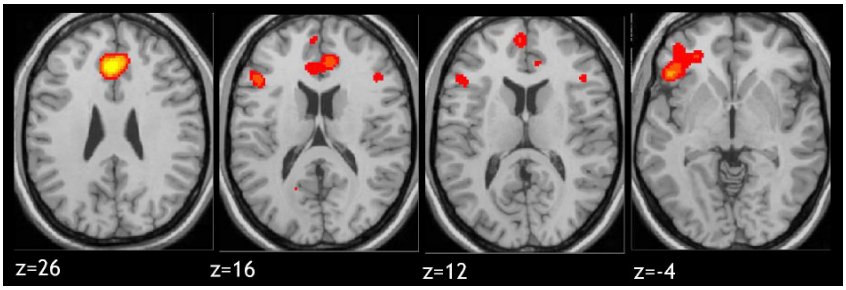

Figure 2. Activation likelihood estimation (ALE) meta-analysis of the Stroop color-word task ($p<0.0001$). The meta-analysis included 17 papers with 184 foci.

Label	BA	L/R	P/A	I/S	mm^3
ACC	32	0	33	25	6416
L IFG	47	-38	33	-6	5280
L IFG	45	-47	23	18	1048
L MFG	10	-3	55	12	552
R IFG	45	45	25	15	184

Table 1. Location and description of ALE results. ACC = anterior cingulate cortex; IFG = inferior frontal gyrus; MFG = middle frontal gyrus.

References

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