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An Extension Study: fMRI use to Distinguish Between Deception and General Memory

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Abstract

The purpose of this study is to expand upon the findings published by Junhong Yu, Qian Tao, Ruibin Zhang, Chetwyn C.H. Chan, and Tatia M.C. Lee in their paper, "Can fMRI discriminate between deception and false memory? A meta-analytic comparison between deception and false memory studies" by conducting a meta-analysis to compare brain activation between deception and general memory[1] recollection (Yu et al., 2019). Meta-analyses compile fMRI results from many individual studies with regard to a specific cognitive task into one, cumulative dataset. The meta-analyses for this extension were compiled by Neurosynth using FMRIB Software Library (FSL) to measure the amount of brain activation corresponding to areas involved in both deception and memory in general ("Nipype: Neuroimaging in Python," 2020). The purpose of this extension is to understand how general memory recollection might compare to deception. The prediction of this study is that by broadening the memory dataset to include data from false and true memory, activation will be reported in more areas than those reported in Yu and his colleagues separate analysis of each kind of memory. This, in turn, should make it more difficult to differentiate deception from memory recollection when it is not known to be true or false. While Yu et al. 2019 concluded that areas associated with truthful memory and false memory were both separately distinguishable from deception, the results found in this study indicate that activation involved with general memory was distinguishable from deception only in the precuneus and cingulate gyrus.

Keywords: general memory, deception, fMRI, brain activation, extension

[1]We call our dataset "general memory" because it is a meta-analysis containing articles on both false memory and true memory.

Introduction

Functional magnetic resonance imaging (fMRI) is a method of neuroimaging used to isolate where and when activation occurs in the brain when performing a given task, such as deception or memory recollection (Yu et al., 2019). Differences between fMRI data collected from separate tasks reflects differences in the areas of the brain responsible for carrying out those tasks (Yu et al., 2019). Lying involves more regions of the brain responsible for the manipulation of memory (Ganis et al., 2003) and theory of mind (Lisofsky et al., 2014) than it is expected to be involved in false memory or true memory alone. However, it is rarely the case that these cognitive processes can be isolated from one another when recalling a complex memory. Consider a hypothetical person recounting a memory he believes to be accurate in good faith: regardless of his truthfulness, he may still be unknowingly supplementing gaps in his memory with false memories (Lee et al., 2009). Therefore, in the evaluation of more complicated instances of memory recollection, it is of interest to investigate whether or not the two cognitive processes together are distinguishable from deception. Since true memory and false memory correspond to activation in different areas (Yu et al., 2019), this study hypothesizes that a meta-analysis of areas involved with general recognition will be too similar to deception for both datasets to be distinguishable from one another. To test this claim, the null hypothesis assumes that there is no difference in brain activity between deception and memory recollection.

First, an evaluation of the meta-analytic studies compiled by Neurosynth on deception[2] (Yarkoni, "Neurosynth: Topic 111") and memory[3] (Yarkoni, "Neurosynth: Topic 172") is conducted. Meta-analyses take the results reported from multiple independent fMRI studies that all correspond to a specific cognitive process and funnel them into one large dataset. The FMRIB Software Library (FSL) is used to isolate the areas involved in deception and general memory. The data is then used to determine whether or not the difference in brain activation patterns corresponding to each task is statistically significant. Since a different method is being employed from the one followed by the original publication which prompted the investigation in this study, the objective of this extension is limited to:

1. Verify Yu, Tao, Zhang, Chan, and Lee's claim regarding what areas are involved in deception using a different method (see appendix)
2. Compare these areas to those involved in memory recollection.

Literature Review

Deception and Cognitive Effort

In one study, it is found that incorrect responses are associated in the left medial frontal gyrus and the right supramarginal frontal gyrus (Lee et al., 2009). The findings of Lee and his colleagues show a significant correlation between frontal-parietal response and unintentionally lying. The cognitive effort comes not only from the engagement in the areas of the brain

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[2] Terms: deception, lying, truth, telling, deceptive, dishonest, answering, claims, truthful, impression, bad, correctly, honest, correlates, incorrectly, lies, cortices, faking, cit, feigned, concealed pretending, deceive, questions, crime, management, informed, instructed, guilty, producing detect, determine, countermeasures, details, giving, detecting, honesty, scientifically, fake, diagnosing. Date Accessed: April 6, 2020

[3] Terms: memory, recognition, recollection, retrieval, items, source, familiarity, item, test, false, studied, words, confidence, information, correct, strength, true, judgments, monitoring, pictures, episodic, remember, event, responses, elicited, correlates, details, word, accuracy, previously, lateral, accurate, subsequent, memories, material, hits, recollected, contextual, encoded, familiar. Date Accessed: April 6, 2020

involved in deception, but also in the active inhibition of areas of the brain involved in generating a truthful response (Priori et al., 2017). The deceiver must differentiate between reality and falsehood as well as assess whether or not the lie is believable. This requires further reasoning processes, therefore, leading to increased levels of brain activity (Ganis et al., 2003).

General Memory Recollection

However, memory cannot always be relied on to recall or recognize information truthfully. For instance, an individual trying to truthfully recount a complex memory may unconsciously fill in the gaps with false memories. True memory is considered to be a memory created right when an event occurs. That instant, the individual, without forming new memories, has true memories for a very brief time. Then, increasingly false memories are added to the core true memories. Such a notion is explored through experimentation involving "affective interferences (Kaplan et al., 2015), misleading suggestions (Bruck and Ceci, 1999), the misinformation effect (Ayers and Reder, 1998), and schemas (Webb et al., 2016)," as laid out in Yu et al., 2019. A meta-analysis of data collected during false recognition (Kurkela and Dennis, 2016) suggests that false memory is likely a product of schematic processes that function to fill in uncertainty from the top-down. Top-down processing is a form of cognition that works its way from abstract, higher level thought down to finer, more detailed thought. In this way, the addition of false memory datasets to true memory datasets reflects a more realistic representation of the activation that occurs in the brain during complex memory recollection. A past study suggests that false memory is produced excessively after damage to the frontal lobe, suggesting that the frontal lobe can be in control of preventing the creation of false memory(Alan J.Parkin, 2002).

The process of creating truthful memory and false memory seems to be different as the damage to one area creates new false memory and disrupts truthful memory.

Materials and Methods

Data Sources and Study Selection

The meta analysis and subsequent data synthesis is carried out using studies from Neurosynth, a database containing fMRI datasets from 14,371 published peer reviewed articles (Yarkoni, n.d.). The process by which Neurosynth generates their meta analysis images is as follows:

1. An automated parser extracts activation coordinates from published fMRI studies
2. An algorithm tags each article with terms it uses with high frequency
3. Another operation generates a list of datasets of coordinates associated with each term for every term found in twenty or more studies
4. The entire database of coordinates is divided into two sets for each term: one containing articles associated with the term and the other with articles that do not
5. Two-way ANOVA tests generate z-scores from the comparison of each data point within these two lists that determine whether there is a statistically significant non-zero association between term use and voxel activation ($p<0.01$)
6. An association test map assigns the z-scores from each voxel to their corresponding location in the brain (Yarkoni, n.d.).

For this article, a meta-analysis for deception, general memory, and each area of the brain[4] relevant to the extension from Neurosynth is used.

[4] Terms: insula, frontal gyrus, cingulate gyrus, middle frontal, inferior parietal, cingulate, inferior frontal, supramarginal gyrus, superior temporal, precuneus, caudate, inferior parietal, medial frontal, inferior frontal. Date accessed: April 6, 2020

Data Synthesis and Analysis

Data synthesis on the gathered Neurosynth meta analyses are conducted through FSL, a comprehensive library of analysis tools for fMRI, MRI, and DTI brain imaging data. The process begins with creating a binary mask of each brain region of interest using the BET function in FSL with Nipype (Gorgolewski). The BET function uses the specified activation value threshold to assign all coordinates within each desired region a value of one and all other regions of the brain a value of zero. The purpose of this is to filter out voxels with too small of values to be relevant and to create a model of the region that could be superimposed over the deception and general memory meta-analyses ("Nipype: Neuroimaging in Python," 2020). These models allow the program to individually calculate the mean activation and retrieve the coordinates of the most activated voxel corresponding to each region. Each region's mean activation value is then compared to the value expected of that region. Z-score lower than six are removed with a threshold[5] to restrict results corresponding to p-values of greater than 10^{-6} from being considered statistically significant. The difference in z-scores from each region of both meta-analyses are then evaluated for statistical significance using a Two Sample Z Test.

Data synthesized through the above process provide the information necessary to carry out this extension. The following data is collected from each region:

1. The coordinates of the maximum value voxel
2. The statistical significance of sampling the mean activation value reported assuming the null hypothesis to be true[6]
3. The amount of active voxels

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[5] A threshold of six is used here, as is the standard used for fMRI studies

[6] This null hypothesis corresponds to the goal of this study to establish what regions are involved in each task

4. The statistical significance of the comparison between both datasets' z-score.

Results

Table 1

Brain Activation Results of Deception and General Memory

	Deception Dataset					General Memory Dataset				
Region	Coordinates			P<	Vox. Sum	Coordinates			P<	Vox. Sum
	x	y	z			x	y	z		
Inferior Frontal	50	24	0	3.138×10^{-12}	377	-34	22	-4	3.649×10^{-16}	649
Insula	50	24	0	3.235×10^{-13}	577	14	22	-4	1.037×10^{-20}	425
Frontal[7]	-42	28	-4	7.270×10^{-10}	68	-44	66	50	8.119×10^{-14}	180
Cingulate	-40	-18	-8	8.262×10^{-11}	177	0	-26	32	4.905×10^{-13}	152
Medial Frontal	0	14	48	1.029×10^{-10}	17	2	18	48	3.755×10^{-15}	12
Inferior Parietal	54	-46	36	2.618×10^{-10}	52	-38	-62	46	5.365×10^{-14}	85
Supramarginal	-50	-50	32	9.593×10^{-9}	6	—	—	—	0.5	0
Middle Frontal	—	—	—	0.5	0	—	—	—	0.5	0
Superior Temp.	52	28	-2	3.680×10^{-9}	1	-50	26	-8	4.273×10^{-11}	9
Caudate	-12	2	4	3.680×10^{-9}	1	-12	10	0	4.605×10^{-16}	275
Precuneus	—	—	—	0.5	0	-6	-50	32	7.201×10^{-12}	122

Note. The incredibly low p-values reported in Table 1 indicate that all areas but the middle frontal gyrus and the precuneus are likely involved in deception, while all areas but the middle frontal gyrus and supramarginal gyrus are likely involved in general memory. Table 1 also reports the maximum value voxel and number of voxels activated with regard to each region.[8]

[7] Since there was no available meta-analysis for the superior frontal gyrus, a meta-analysis of the frontal gyrus was used in this extension.
[8] For results reported by Yu et al. 2019, refer to the appendix

Table 2

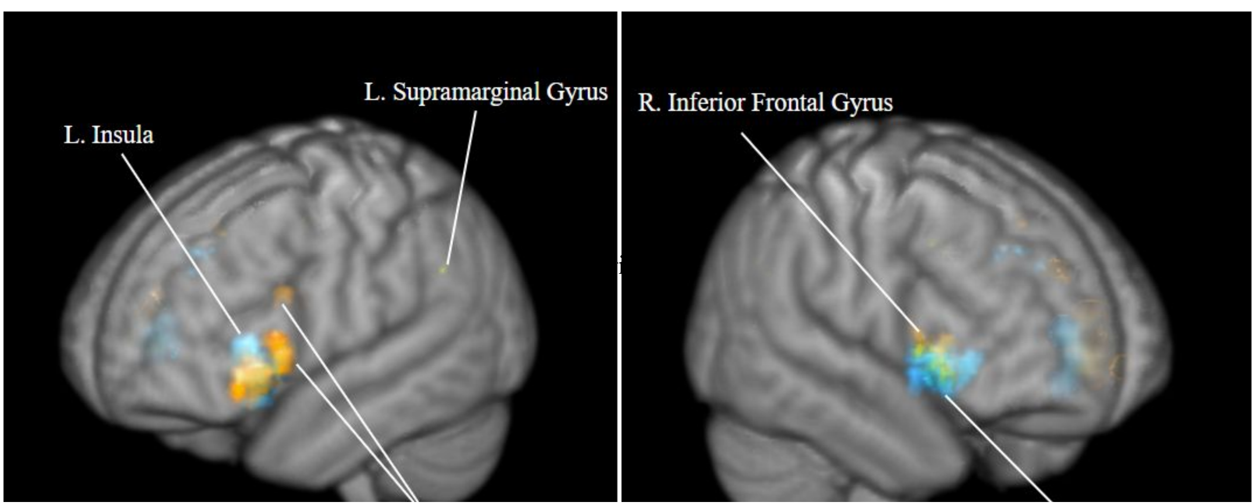
Two Sample Z Test Results Comparing Deception to General Memory

Region	P-value
Inferior Frontal	$2.688x10^{-6}$
Insula	$2.439x10^{-12}$
Frontal[9]	$4.023x10^{-24}$
Cingulate	$1.810x10^{-5}$
Medial Frontal	$1.702x10^{-15}$
Inferior Parietal	$9.085x10^{-14}$
Supramarginal	≈0
Superior Temporal	$1.455x10^{-21}$
Caudate	≈0
Precuneus	≈0

Note. P-values close to 0 represent statistical significance that was not calculable. The p-values in Table 2 contradict the initial hypothesis that deception would not be able to be distinguished from general memory. Statistically significant p-values are observed in all but the inferior frontal gyrus and the cingulate, indicating that deception and general memory are very distinguishable from one another.

Figure 1

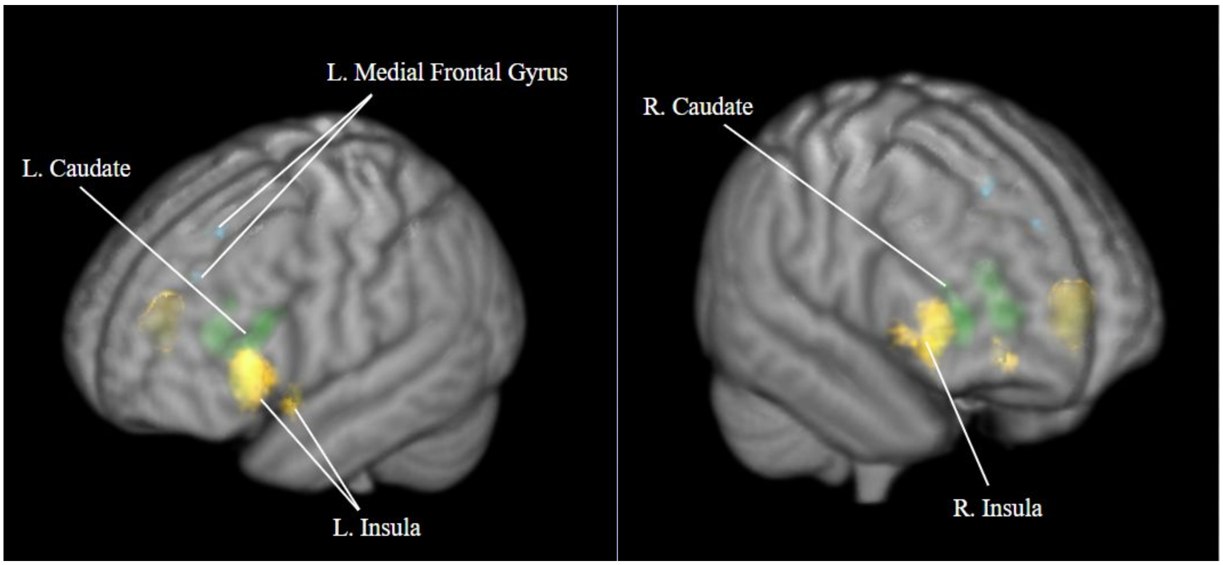
Activation Model of Left and Right Hemisphere in Deception



Note. Figure 1 illustrates the insula, supramarginal gyrus, and inferior frontal gyrus within the left hemisphere (left) and of the inferior frontal gyrus and insula within the right hemisphere (right) activated during deception.

Figure 2

Activation Model of Left and Right Hemisphere in General Memory



Note. Figure 2 illustrates the insula, caudate, and medial frontal gyrus within the left hemisphere (left) and of the insula and caudate within the right hemisphere (right) activated by general memory.

Discussion

The data from this study indicate that there is a statistically significant difference between activation values associated with general memory and deception. Therefore, the null hypothesis must be rejected. Activity in all but the cingulate gyrus and inferior frontal gyrus meets the standard set for statistical significance. Thus, little quantitative data supports the claim that general memory is not distinguishable from deception. However, qualitative analysis indicates that each cognitive process involves all but two of the same areas with very large degrees of statistical significance. This shows that both tasks do in fact activate many of the same regions. Analysis of Figure 1 and Figure 2 reveals that the three most involved regions in each task show some overlap in the insula and frontal lobe. Additionally, further inspection of the two areas not involved in both tasks reveals that both tasks involve a unique region not shared with the other. The results indicate that deception is characterized by activity within the supramarginal gyrus, while general memory is characterized by activity within the precuneus. Overall, the data do not show that general memory is any less distinguishable to deception than false memory or true memory independently.

The results of the novel method of data synthesis and analysis employed in this extension mirror the conclusions reached by Yu, Tao, Zhang, Chan, and Lee with surprising similarity (Yu et al., 2019). The likelihood of obtaining mean activation values reported in each selected region aside from the precuneus and the middle frontal gyrus correspond to significant p-values which are all less than 10^{-8}. The implications of this degree of statistical significance strongly suggests that each region Yu et al. conclude in their meta-analysis to be involved in deception (see appendix), except for the middle frontal gyrus, reflects the areas that facilitate deceptive behavior. Similarly, each region concluded by Yu et al. 2019 to be involved with false memory is also involved in general memory, also corresponding to p-values of less than 10^{-8}. Additionally, the hypothesis that similar statistically significant values would also be found in regions[10] not concluded by the original study to be involved in false memory is supported.

Another product of the analysis conducted is the maximum value voxel coordinate for each region. These data allow for qualitative[11] evaluation of the similarities and differences

[10] I.e. the supramarginal gyrus, middle frontal gyrus, superior temporal gyrus, caudate, and inferior frontal gyrus
[11] Further analysis would be necessary to determine the quantitative statistical significance of a comparison between the coordinates of the maximum value voxel reported by Yu, Tao, Zhang, Chan, and Lee

between the dataset from this study and those reported in Yu et al. 2019. In deception, the inferior frontal gyrus, insula, inferior parietal lobule, and the supramarginal gyrus are all within ten voxels of the original dataset on a given plane. The medial frontal gyrus is within twenty voxels, but all other regions of interest show no similarity. In general memory, the medial frontal gyrus is again within twenty voxels. The precuneus and inferior parietal lobule are similar in two planes, but varies too much in the third to be eligible for consideration. Other than this, no other regions show similarity in maximum value voxel coordinates. The differences in both sets of results can again be attributed to differences in method from those which were used by the original study. It is also likely that data from the general memory meta-analysis include more candidates for maximum value voxels than do data from just the false memory meta-analysis. This would also contribute to the disparity of results observed.

Conclusion

The objective of this extension is to verify which areas Yu, Tao, Zhang, Chan, and Lee claim are involved in deception using a different method and to compare these areas to those involved in general memory recollection. In this study, Neurosynth and FSL are used to distinguish activation levels of different brain regions associated with deception versus general memory. In order to determine whether there is a difference in activation of the two tasks, the null hypothesis is determined to be that both deception and general memory show comparable activation levels in the same brain regions. Through a meta-analysis of 297 studies for general memory and 39 studies for deception, the results show distinguishable levels of activation between areas involved in each task. However, it is worth noting that deception alone showed activation in the supramarginal gyrus and general memory alone showed activation in the precuneus.

There are a few limitations to the results of this study worth mentioning. One such limitation is that no map of the superior frontal gyrus is available on Neurosynth, so a map of the entire frontal gyrus is used in this study instead. This, although a broader region of study, resembles the activation in superior frontal gyrus that can be seen in the original paper. Next, Neurosynth is used in this analysis. Though it is a great utility in the analysis of more general subjects of study, it tends to be inaccurate when analyzing more sensitive data. The reason behind this is due to the processing of large amounts of sample data. Since a given meta-analysis may contain dozens of studies that each provide an even greater magnitude of individual data points, conducting rigorous permutation tests is next to impossible. Moreover, Neurosynth sorts data with an algorithm that detects words with high frequency. This method, though efficient in gathering large sums of data, does not grant accuracy in how relevant each article might be to the hypothesis made in this study. Overall, Neurosynth meta-analyses value quantity of data over quality of data, causing possible inaccuracy in the measurements. Despite the possible errors that may accompany the use of Neurosynth, the similarity of the results found in this study and the original study by Yu et al. 2019 supports the credibility of the results. To further confirm this conclusion, future studies should be conducted.

Future studies have the potential for capitalizing on the differences between false memory and deception. One example of doing such is exploring how deception versus false memory invokes different nonverbal physical cues such as fidgeting, which can add insights on additional ways of differentiating between general memory and deception. Future research should also focus on diving deeper into the connections among the different parts of the brain that showed activations in this study. More knowledge on what each region controls specifically and why activation of these regions are seen together might spark new findings on how the control of one's cognitive processes are divided in the brain. Other future studies could be to explore whether socioeconomic or ethnic backgrounds can be a confounding factor using fMRI to show a trend in the brain activation in participants while doing difficult tasks. Another direction of future research, could be to explore whether how conventionally “good” a liar is influences the differences in brain activity observed.

In a judicial context, the research can provide insight to a threshold of what differentiates deception from general memory quantitatively using fMRI. The research and discoveries found in this extension can support growing evidence for legal use such as in courts and criminal interrogations. fMRI analysis of brain activation can be used on eye-witnesses and testimonies as well as during police interrogations (Langleben et al., 2013). The ability of differentiating deception from general memory would be vital in eliminating false accusation and judgement in court. If it is possible to successfully establish the ability to detect deception from general memory with accuracy, it can serve an important role in court in testifying and greatly improves the credibility of testimonial evidence.

Appendix

Brain Activation for Deception and False Recognition Tasks from Yu. et al. 2019

	Deception Dataset					False Recognition Dataset				
Region	MNI Coordinates			ALE (10^{-2})	Sum of Voxel Clusters	MNI Coordinates			ALE (10^{-2})	Sum of Voxel Clusters
	x	y	z			x	y	z		
Inferior Frontal	46	24	-8	4.1	1496	—	—	—	—	—
Insula	46	20	-2	4	—	—	—	—	—	—
Superior Frontal	-8	14	58	3.8	951	-6	22	48	1.9	388
Cingulate	-6	20	42	1.9	—	-8	36	36	1.5	—
Medial Frontal	-12	20	42	1.7	—	-6	38	32	1.8	108
Inferior Parietal	54	-44	42	2.6	712	-32	-36	46	2	121
Supramarginal	58	-48	30	2.4	—	—	—	—	—	—
Middle Frontal	-40	14	46	2.9	660	—	—	—	—	—
Superior Temp.	-54	-56	34	2.5	297	—	—	—	—	—
Caudate	16	-2	18	2.6	105	—	—	—	—	—
Precuneus	—	—	—	—	1496	-32	-66	48	1.6	122

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