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An Extension of "Can fMRI discriminate between deception and false memory? A meta-analytic comparison between deception and false memory studies"

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Abstract

fMRI has the potential of being able to differentiate between false memory and deception, but to apply this ability to real life situations, such as court cases or in neurodegenerative studies involving the brain's ability to recognize memory, it is vital that fMRI can detect the differences between general memory[1] and deception, as false memory is often mixed in with true memory during recollection. To determine whether fMRI can do this, the prior study, "Can fMRI discriminate between deception and false memory? A meta-analytic comparison between deception and false memory studies" (Yu et al., 2019) [18] was extended. Yu et al., 2019 found that true memory and false memory, independently, could be distinguished from deception. This extension aims to determine if brain activity resulting from deception can be distinguished from activity caused by general memory as opposed to false memory. Given the broader scope of general memory compared to false memory, the prediction is put forth that general memory recollection will not be distinguishable from deception due to broader regions of activation in the brain. Appropriate meta-analyses for deception and general memory recollection were selected and used to determine z-scores and voxel coordinates of activity in different regions of the brain. The brain structures with the highest z-scores during general memory analysis were the caudate, the medial frontal gyrus, and the insula. The brain structures with the highest z-scores during deception analysis were the inferior frontal gyrus, the supramarginal gyrus, and the insula. After further analysis, it was determined that activation for general memory vs deception can be distinguished by looking at the activation of the cingulate gyrus and the precuneus.

Keywords: fMRI, deception, false memory, meta-analysis

[1]The term "general memory" refers to both true and false memory recognition

Introduction

A recent focus of much psychological research has been conducted on discriminating between false memory and deception. Both result in misinformation; however, deception is defined as an intentional, conscious effort to mislead, whereas false memory is an unintentional recollection of misinformation. The inability to distinguish between intentional versus unintentional deceit carries many legal and moral implications. For example, misinformation due to false memory in the courtroom still has the potential for detrimental consequences, but takes its origins from the limitations of the human brain. On the other hand, intentional deception and lying under oath is a serious obstruction to justice and a punishable offense.

With this research aggregating in two major meta-analyses (Christ et al., 2009; Lisofsky et al., 2014), the potential for using fMRI to discriminate between the deception and false memory has been introduced. These two analyses found that deception increased brain activity in the frontal gyrus, insula, parietal lobule, and the caudate. However, another meta- analysis (Kurkela and Dennis, 2016) indicated that some of these same regions show increased activity levels due to false memory recollection, not deception. Therefore, these results have not warranted fMRI use in legal contexts due to the inability to distinguish brain activity due to false memory and deception. fMRI has the potential to discriminate between the two, but there may be cases where false memory is mixed in with true memory. In situations like these, it is important for an fMRI to distinguish between general memory recollection and deception.

In order to establish if fMRI can effectively and consistently differentiate between the two, studies have been performed to attempt to pinpoint the areas of the brain correlated with deception. Two studies were performed, and one found that deception was associated with increased activity levels in the left middle frontal gyrus (MFG) and left supramarginal frontal gyrus (Abe et al., 2008). The other study found deception correlated with higher activation in the left inferior frontal gyrus (IFG), right cingulate cortex, and left precuneus (Lee et al., 2009).

Yu et al. found distinctions between false memory and deception as well as between true memory and deception, but we assert that a meta-analysis of brain regions involved in memory and deception will be unable to tell each apart due to the broader scope of activation caused by general memory. We assume the null hypothesis that the brain activity caused by deception and general memory will be indistinguishable from each other.

Literature Review

Much research has been conducted on both false memory and deception individually; however, there are still gaps to be filled regarding research that focuses on comparing false memory and deception simultaneously. In this paper, some of those gaps will be filled, as mentioned above. There were no applicable tests to determine if general memory could also be distinguished separately. Therefore, this extension focuses only on false memory and deception, and does not account for a combination of false and true memories. It is important to carefully consider the prior research and analysis done on these topics and use this research to guide the extension.

Imagination can often lead to false memory. In “The formation of false memories” (Loftus and Pickrell, 1995)[10], Elizabeth Loftus and her research team discover that by suggesting events or imagining events, individuals can have clear, distinct memories of events that never actually occurred. She furthers this research and shows that by being told eyewitness information by an actual witness, one can presume to recall eyewitness information. This raises the question of whether someone may have incorrectly been told the information. These crucial findings can be detrimental in terms of legal cases. If individuals are able to readily recall inaccurate information that they believe to be true, they can falsely incriminate individuals or skew the outcome in other harmful ways. Because of this possibility, it is necessary to be able to identify false memory with fMRI technology.

Another study titled "Neural correlates of true memory, false memory, and deception." (Abe N. et al., 2008)[1], focuses on using fMRI data to attempt to distinguish false memory, deception, and true memory. This study is unique given it included true memory in its analysis, which resulted in three findings: deception recruits prefrontal activity, the difference between true and false memory is found in the left temporoparietal regions, and the left prefrontal cortex is activated during deception, while the right anterior hippocampus is activated during false memory. These findings provide a guideline and additional general areas to inspect while conducting our extension.

A more recent study titled "Neural global pattern similarity underlies true and false memories" (Ye et al., 2016)[19] attempts to use the encoding-retrieval neural global pattern similarity (ER-nGPS) to find the brain areas where true or false memories arise the strongest. According to their findings, while the ER-nGPS in the parietal regions recognizes both true and false memory, ER-nGPS in the visual cortex contributes to true memory only. This finding can be further corroborated through the use of fMRI; the visual cortex should not show much activation during the extension. Instead, parietal regions may potentially be the focus of the research.

The findings from the literature will be referenced throughout our research, and some of the remaining gaps after the current research will be attempted to be filled; the primary objective is to be able to differentiate false memory and deception using fMRI technology.

Materials and Methods

A search was conducted for a meta analysis of deception and general memory. To acquire the datasets for each, a search was done on Neurosynth with the keywords [deception OR lying OR lie OR dishonest OR memory OR fake memory OR true memory OR recollection OR recall]. The most appropriate meta-analysis was then picked for each term. Next, nifti image files were downloaded for each region of the brain that was deemed a region of interest in the original paper by Yu et al. Specifically, files for the supramarginal gyrus, superior temporal, precuneus, middle frontal, medial frontal, insula, inferior parietal, inferior frontal, frontal gyrus, cingulate, and caudate brain areas were downloaded.. These files were then processed in an Anaconda[2] Jupyter Notebook using NiPype to create binary masks of each region. Once the binary masks were created, each one was applied to the deception and memory datasets, respectively. This allowed for the classification of the activity displayed in each dataset into specific regions of the brain.

Once the masks were applied, an activation threshold of six was applied to each one. This served to remove activity from any regions that did have a demonstrated z-score of six or above. A value of six was chosen as it is standard in fMRI studies. The z-score of each applied mask was then taken using the FSL[5] interface in NiPype to determine the statistical significance of activity in each region of the brain. Additionally, the coordinates of the voxel with highest intensity were calculated using NiPype as well.

Results

A few key metrics were used to determine the similarity between the results of both papers. These metrics are the z-scores of each brain region, the coordinates of the most activated voxel in each region, the number of activated voxels in each region (cluster size), and p-values in each region. These factors were used to, first, determine if an fMRI can distinguish between deception and memory, and, second, determine if the results of the analysis conducted with NiPype agrees with the results of the analysis conducted with GingerALE.

In coordination with Table 1.1 (see appendix) and with the comparison to the original paper, the analysis is based on the observation that higher z-score values are related to areas of statistically significant activation in the brain in comparison to normal level of activity. There are certain areas of the brain that did not have statistically significant data for deception. The z-scores for cingulate gyrus, middle frontal, and precuneus indicated that the activity found in these regions of the brain during deception were not statistically significant. For general memory, the activity in the cingulate gyrus, middle frontal, and supramarginal gyrus was found to be statistically insignificant. The coordinate locations for the voxel activations and their norm values shown in Table 1.2, are comparable between the original paper and this extension for the corresponding brain regions.

Norm values based on both deception data and memory data for brain structures were computed, as shown in Table 1.2. Taken into account with z-scores, these values were analyzed. The brain structures with the three highest z-scores for deception were the inferior frontal gyrus, the insula, and the supramarginal gyrus, as depicted in Figure 1.1. The insula had a very small norm, with a value of 6.00, but the inferior frontal gyrus and the supramarginal gyrus had larger values, with norms of 98.10 and 92.28, respectively. The brain structures with the three highest z-scores for memory, which are depicted in Figure 1.2, were the caudate, inferior frontal gyrus, and the insula. These structures also had relatively small norm data, with values being 35.38, 14.28, and 32.12, respectively.

Discussion

The results of this analysis demonstrate that there is a statistically significant difference between brain activity caused by deception and brain activity caused by general memory recognition. There were two statistically significant regions of the brain that were activated in either deception only or general memory recollection only: the precuneus and the supramarginal gyrus. As seen in Table 1.3, the precuneus had a z-score of 7.201914 during general memory recollection and a z-score of 0.000000 during deception, which was a result of thresholding. The supramarginal gyrus had a z-score of 0.000000 during general memory recollection as a result of thresholding and a z-score of 6.993481 during deception. Observing statistically significant activity in these two regions of the brain can therefore help distinguish between general memory recollection and deception, as the precuneus is noticeably active during recollection only, and the supramarginal gyrus during deception only. Aside from this binary display of brain activity, the relative strength of the z-scores can be used to help guide interpretation of brian activity. For instance, the insula had a z-score of 9.497595 for memory and a z-score 7.46275 for deception. This correlates to an observation of less statistical significance in the insula when deceiving versus when recalling memory. The only other instance where a significant difference in z-score can be seen is in the medial frontal gyrus, which had a z-score of 8.037641 for memory and 6.645480 for deception.

To test for similarity with the results of Yu et al., 2019, the coordinates of the most activated voxel in each brain region were compared. The norm for each set of coordinates was under one hundred voxels with the exception of the inferior parietal lobule and the superior temporal gyrus during deception, which had norms of 101.034656 and 135.380944, respectively. The insula during deception and inferior parietal lobule during memory recollection had the smallest norms at 6.000000 and 11.489125, respectively. The fact that the majority of the norms are under one hundred voxels indicates that the areas of the brain that were active during deception and general memory recollection align with those areas found by Yu et al., 2019 during deception, false memory recollection, and true memory recollection.

In the overall comparison of the extension to the original study, the data found generally agrees with the results found by Yu et al. The observation data was distinguished through z-score values for each brain region used in the study. The probability of observing activation for deception in each of the relevant regions (see appendix), excluding the middle frontal gyrus and the precuneus, corresponds to p-values that are all under 0.01, and are therefore statistically significant. This strongly indicates that the regions found to be involved with deception in this analysis (Table 1.1) correspond to those regions that are active during deception. Additionally, the regions proposed to be involved in false memory by Yu et al. are all also involved in general memory. This corresponds to p-values of less than 0.01 as well.

Conclusion

Overall, there was some correlation found between the data from the meta-analyses used in this paper and the meta-analyses used in the original paper -- "Can fMRI discriminate between deception and false memory? A meta-analytic comparison between deception and false memory studies" (Yu et al., 2019). This extension found that fMRI data can, in fact, be used to distinguish between deception and general memory recollection. Some regions of the brain display a different z-score, and thus statistical significance, during recollection of memory versus deception. This dichotomy in statistical significance can provide hints as to whether the data being analyzed is from a moment of memory or deception. One can, therefore, conclude that the precuneus is activated for memory and the supramarginal gyrus is activated for deception through interpretation of z-scores. To improve on this study, it would make sense to test a few other datasets in retrieving z-score values, voxel coordinates, and the number of voxels to determine if there is a pattern of generally stronger levels of activation for false memory and weaker levels of activation for deception or vice versa. More studies with alterations need to be done to find more patterns and consistency, such as testing of general memory versus deception using ALE.

Appendix

Table 1.1: False Memory and Deception Z-Scores

	z-scores	
Region	Deception	Memory
Caudate	6.083325	8.294122
Cingulate	6.678427	7.406781
Cingulate gyrus	~~0.000000~~	~~0.000000~~
Frontal gyrus	6.344326	7.645588
Inferior frontal gyrus	7.151611	8.322352
Inferior parietal lobule	6.503397	7.699644
Insula	7.462755	9.497595
Medial frontal gyrus	6.645480	8.037641
Middle frontal gyrus	~~0.000000~~	~~0.000000~~
Precuneus	~~0.000000~~	7.201914
Superior temporal gyrus	6.083325	6.776579
Supramarginal gyrus	6.993481	~~0.000000~~

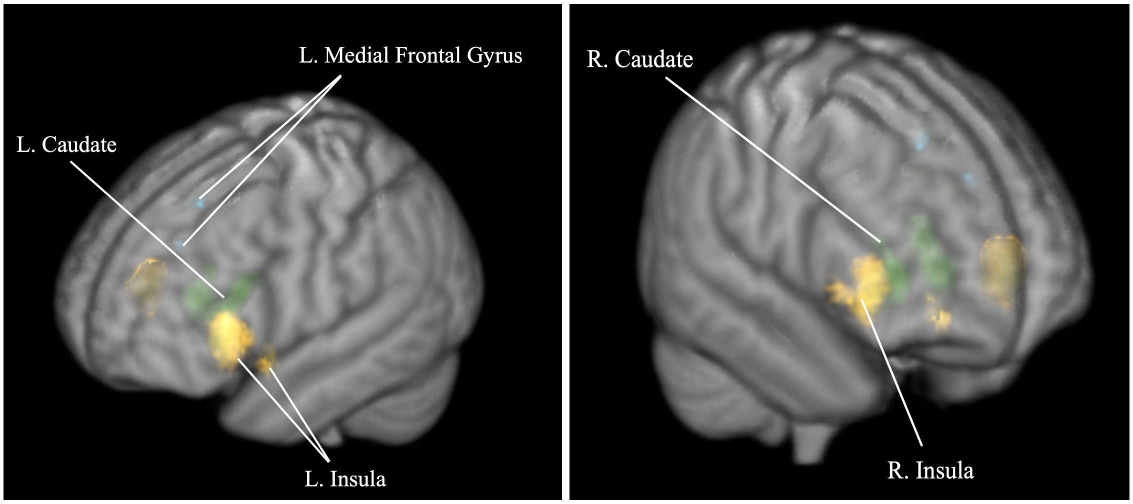
Table 1.2: False Memory and Deception Voxel Coordinates and L_2 Norm Values

	Deception		**General Memory**	
Region	**Coordinates**	**L2 Norm with Original Paper**	**Coordinates**	**L2 Norm with Original Paper**
Caudate	(-12, 2, 4)	31.559468	(-12, 10, 0)	35.383612
Cingulate	(-40, -18, -8)	71.414284	(0, -26. 32)	47.455242
Cingulate gyrus	~~(0, 0, 0)~~	--	~~(0, 0, 0)~~	--
Frontal gyrus	(-42, 28, -4)	66.060578	(-44, 66, 50)	0.000000
Inferior frontal gyrus	(50, 24, 0)	98.101988	(-34, 22, -4)	14.282857
Inferior parietal lobule	(54, -46, 36)	101.034656	(-38, -62, 46)	11.489125
Insula	(50, 24, 0)	6.000000	(14, 22, -4)	32.124767
Medial frontal gyrus	(0, 14, 48)	22.715633	(2, 18, 44)	19.798990
Middle frontal gyrus	~~(0, 0, 0)~~	--	~~(0, 0, 0)~~	--
Precuneus	~~(0, 0, 0)~~	--	(-6, -50, 32)	34.456376
Superior temporal gyrus	(52, 28, -2)	135.380944	(-50, 26, -8)	82.969874
Supramarginal gyrus	(-50, -50, 32)	92.282176	~~(0, 0, 0)~~	--

Table 1.3: False Memory and Deception Voxel Count

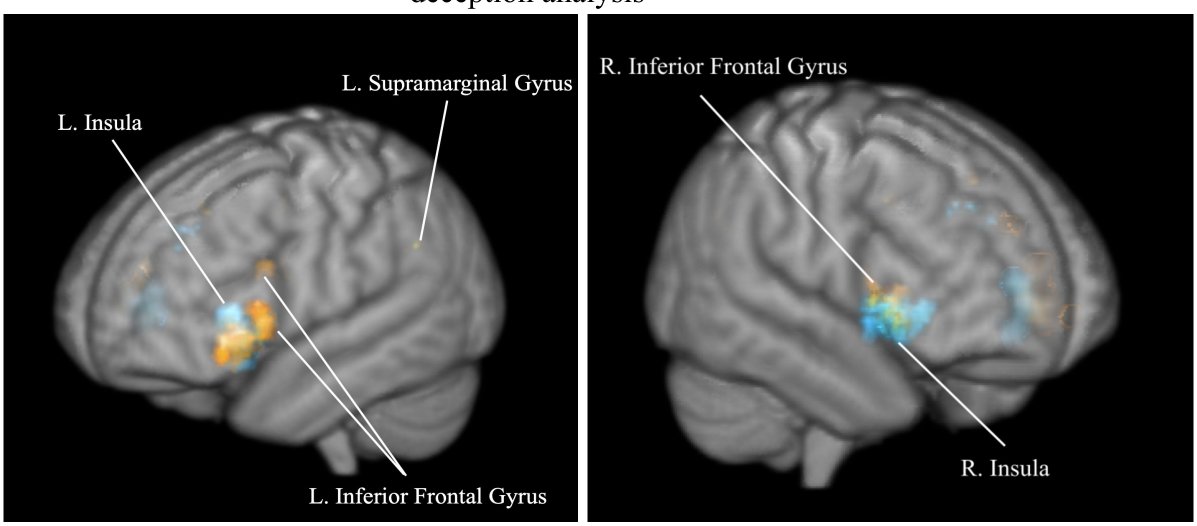
	Deception	Memory
Region	**Cluster Size (number of voxels)**	**Cluster Size (number of voxels)**
Caudate	1	275
Cingulate	117	152
Cingulate gyrus	0	0
Frontal gyrus	68	180
Inferior frontal gyrus	377	649
Inferior parietal lobule	52	85
Insula	577	425
Medial frontal gyrus	17	12
Middle frontal gyrus	0	0
Precuneus	0	122
Superior temporal gyrus	1	9
Supramarginal gyrus	6	0

Figure 1.1: False Memory and Brain Structures: Three areas with the highest z-scores during false memory analysis



Note: Activation in the medial frontal gyrus was not present in the right hemisphere of the brain and was therefore not displayed here. The two images differ only in orientation.

Figure 1.2: Deception and Brain Structures: Three areas with the highest z-scores during deception analysis



Note: Activation in the medial supramarginal gyrus was not present in the right hemisphere of the brain and was therefore not displayed here. The two images differ only in orientation.

Table 1.5: Z-scores and P-values of Deception & Memory Datasets

	Deception		**Memory**	
Region	**z-score**	**p-value**	**z-score**	**p-value**
Caudate	6.083325	$3.680x10^{-9}$	8.294122	$4.605x10^{-16}$
Cingulate	6.678427	$8.262x10^{-11}$	7.406781	$4.905x10^{-13}$
Cingulate gyrus	~~0.000000~~		~~0.000000~~	46.904158
Frontal gyrus	6.344326	$7.270x10^{-10}$	7.645588	$8.119x10^{-14}$
Inferior frontal gyrus	7.151611	$3.138x10^{-12}$	8.322352	$3.649x10^{-16}$
Inferior parietal lobule	6.503397	$2.618x10^{-10}$	7.699644	$5.365x10^{-1}$
Insula	7.462755	$3.235x10^{-13}$	9.497595	$1.037x10^{-20}$
Medial frontal gyrus	6.645480	$1.029x10^{-10}$	8.037641	$3.755x10^{-15}$
Middle frontal gyrus	~~0.000000~~	<0.5	~~0.000000~~	<0.5
Precuneus	~~0.000000~~	<0.5	7.201914	$7.201x10^{-12}$
Superior temporal gyrus	6.083325	$3.680x10^{-9}$	6.776579	$4.273x10^{-11}$
Supramarginal gyrus	6.993481	$9.593x10^{-9}$	~~0.000000~~	<0.5

References

[1] Abe, N., Okuda, J., Suzuki, M., Sasaki, H., Matsuda, T., Mori, E., … Fujii, T. (2008, December). Neural correlates of true memory, false memory, and deception. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18372290

[2] Anaconda. (2018). Anaconda. https://www.anaconda.com/

[3] Cui, Q., Vanman, E. J., Wei, D., Yang, W., Jia, L., & Zhang, Q. (2014, October). Detection of

deception based on fMRI activation patterns underlying the production of a deceptive response and receiving feedback about the success of the deception after a mock murder crime. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23946002

[4] Farrow, T. F. D., Burgess, J., Wilkinson, I. D., & Hunter, M. D. (2015, January). Neural correlates of self-deception and impression-management. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/25527112

[5] *FSL - FslWiki*. (n.d.). Fsl.Fmrib.Ox.Ac.Uk. Retrieved April 11, 2020, from https://fsl.fmrib.ox.ac.uk/fsl/fslwiki/FSL

[6] FSL Stats Help - fslstats.help. (n.d.). Retrieved from https://johnmuschelli.com/fslr/reference/fslstats.help.html

[7] interfaces.fsl.maths¶. (n.d.). Retrieved from https://nipype.readthedocs.io/en/0.12.0/interfaces/generated/nipype.interfaces.fsl.maths.html

[8] Kim, H., & Cabeza, R. (2007, November 7). Trusting our memories: dissociating the neural

correlates of confidence in veridical versus illusory memories. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/17989285

[9] Liang, C.-Y., Xu, Z.-Y., Mei, W., Wang, L.-L., Xue, L., Lu, D. J., & Zhao, H. (2012, June). Neural correlates of feigned memory impairment are distinguishable from answering randomly and answering incorrectly: an fMRI and behavioral study. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/22361169

[10] Loftus, E. F., & Pickrell, J. E. (1995, December 1). The Formation of False Memories. Retrieved from https://www.healio.com/psychiatry/journals/psycann/1995-12-25-12/{2060e727-596-43bd-8580-55b09b96f074}/the-formation-of-false-memories

[11] *Neuroimaging in Python - Pipelines and Interfaces — nipy pipeline and interfaces package*. (n.d.). Nipype.Readthedocs.Io. Retrieved April 11, 2020, from https://nipype.readthedocs.io/en/latest/

[12] *Neurosynth*. (n.d.). Neurosynth.Org. Retrieved April 11, 2020, from https://neurosynth.org/

[13] (n.d.). Retrieved from http://www.smart-stats.org/wiki/some-useful-fsl-commands

[14] Vilberg, K. L., & Rugg, M. D. (2007, June 11). Dissociation of the neural correlates of recognition memory according to familiarity, recollection, and amount of recollected information. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/17449068

[15] Wais, P. E., Squire, L. R., & Wixted, J. T. (2010, January). In search of recollection and familiarity signals in the hippocampus. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19199424

[16] Wu, D., Loke, I. C., Xu, F., & Lee, K. (2011, May 10). Neural correlates of evaluations of lying and truth-telling in different social contexts. Retrieved from

https://www.ncbi.nlm.nih.gov/pubmed/21382353

[17] Yarkoni, Tal. "Neurosynth: Topic 111." Accessed April 15, 2020. https://www.neurosynth.org/analyses/topics/v4-topics-400/111

[18] Yarkoni, Tal. "Neurosynth: Topic 172." Accessed April 15, 2020. https://www.neurosynth.org/analyses/topics/v4-topics-200/172

[19] Ye, Z., Zhu, B., Zhuang, L., Lu, Z., Chen, C., & Xue, G. (2016, June 22). Neural Global Pattern Similarity Underlies True and False Memories. Retrieved from https://www.jneurosci.org/content/36/25/6792.short

[20] Yu, J., Tao, Q., Zhang, R., Chan, C. C. H., & Lee, T. M. C. (2019). Can fMRI discriminate between deception and false memory? A meta-analytic comparison between deception and false memory studies. *Neuroscience & Biobehavioral Reviews*, *104*, 43–55. https://doi.org/10.1016/j.neubiorev.2019.06.027