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Semantic Memory and Decision-Making: An fMRI Study Regarding COVID-19 Vaccine Misinformation

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Honors Thesis

SEMANTIC MEMORY AND DECISION-MAKING: AN FMRI STUDY REGARDING COVID-19 VACCINE MISINFORMATION

by
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ABSTRACT

SEMANTIC MEMORY AND DECISION-MAKING: AN FMRI STUDY REGARDING COVID-19 VACCINE MISINFORMATION

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Bachelor of Science

With the continued use and prevalence of social media, misinformation is likewise becoming more prevalent. Information about the COVID-19 pandemic was an example of the way misinformation spreads and presents challenges to society through polarization and discord. As people made decisions regarding whether to receive the COVID-19 vaccine, misinformation may have impacted their decision making. The goal of this study was to understand how misinformation and corrections to misinformation differentially activate the brain, in contrast to how correct information activates the brain, and how misinformation impacts decision making.

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Introduction

In March 2020, much of the world began facing a pandemic crisis (Ghebreyesus, 2020). The SARS-CoV-2 virus (COVID-19) spread quickly through countries and across continents, forcing many governments to initiate health policies and regulations to protect their citizens. During this time, many news reports focused on the spread of the virus, the governmental policies being put in place, and precautions individuals could take to protect themselves and their loved ones. As COVID-19 vaccines were being created and produced, social media attention added related information to the ongoing reports about the COVID-19 pandemic. As scientifically correct information was being spread across the globe, many locations also saw the rise of misinformation, especially from social media platforms. Allcott and Gentzkow (2017), reported that social media is the primary source of news for 62% of Americans above the age of 18. With the continued presence and rapidly growing popularity of social media, it can be assumed that this number has increased since the publication of Allcott and Gentzkow's (2017) study. This presents a concern as information and news stories can be passed very quickly by social media without fact checking. The continued increase in misinformation being passed around in societies has helped lead to a decreased trust in mass media across the country (Allcott & Gentzkow, 2017). If these trends continue, the power misinformation has to influence the decisions people make will increase and has the potential to cause significant problems in many areas of society, including increased tension in the home, in the political arena, and in widespread medical practice, as demonstrated during the COVID-19 pandemic.

The American Psychological Association defines misinformation as incorrect information that is not necessarily meant to be deceptive (*Misinformation and*

Disinformation, n.d.). Misinformation is spread quickly through social media (Allcott & Gentzkow, 2017) and other internet sources and can be written in a way that makes it difficult to distinguish from correct information. Additionally, misinformation continues to be believed, despite the printing of retractions (Ecker et al., 2010; Gordon et al., 2017), in a phenomenon known as the continued influence effect of misinformation (CIEM) and is often used to make decisions. Misinformation, rather than the corrected information, also influences reasoning, beliefs, and judgements (Gordon et al., 2019; Gordon et al., 2017; Gordon et al., 2019). Some studies have presented theories attempting to explain why misinformation is so damaging and persuasive. One such theory is that misinformation and correct information are stored together and when the neural correlate for misinformation is activated, it is not adequately suppressed (Gordon et al., 2017). A second theory is that when people are presented with correct information, they struggle to successfully update their mental model, resulting in the correction being forgotten instead of integrated (Gordon et al., 2019). Many studies have also shown that only printing retractions is not enough to prevent CIEM (Ecker et al., 2010; Gordon et al., 2017). While the effect of misinformation has not been shown to be completely eliminated by any efforts at correction, providing alternative information and an explanation for why the misinformation was presented can help (Ecker et al., 2010). These different elements of misinformation make it difficult to counteract and correct.

One particular area of interest for misinformation regards COVID-19 vaccines. With much debate about the efficacy and safety of the vaccines, misinformation was often used during the pandemic to support arguments and influence the decisions individuals made about whether or not to receive the vaccine. This tension resulted in

political and health debates, with effects spreading into many areas of people's lives. Due to the CIEM, corrections and retractions were not believed (Ecker et al., 2010; Gordon et al., 2017), adding to the tension societies experienced in places such as the workplace and within families. Often, these tensions resulted in emotionally based responses.

The purpose of this study was to look at neural correlates between individuals' reactions to correct or misinformation regarding COVID-19 vaccines and their agreement with the information presented through the use of functional magnetic resonance imaging (fMRI). Previous research indicated activation in many areas of the brain in different paradigms related to misinformation. While there is limited research, some of these areas include the right precuneus, the cuneus, the right posterior cingulate cortex, and the postcentral gyrus (Gordon et al., 2017; Moore et al., 2021). Emotion and attention are also thought to play a role in how this information is received (Moore et al., 2021). Based on this prior research, this study investigated how misinformation and correct information differentially activate the brain and the possible relations to individuals' decision-making based on the individual's held beliefs. We hypothesized that there would be differential activation in the cuneus region and the amygdala when individuals were presented with information that was contrary to their beliefs, with potentially greater activation for misinformation. If differential activation is seen in these regions, then a better understanding of the impact of misinformation might be reached and help determine ways to counter the effect misinformation has on decision making.

Methods

Behavioral Pilot Participants

Forty-five participants were recruited for this pilot (31 females). One participant was excluded for not completing the survey (final n = 44). Participants were between the ages of 18 and 45 (ages given on a range, *M* between 18-20). All participants volunteered for this pilot through the Brigham Young University (BYU) Psychology Research Participation System (SONA) website and were compensated with five SONA credits for participating. The participants were asked for their opinion regarding receiving the COVID-19 vaccine on a Likert scale of "Strongly Disagree," "Moderately Disagree," "Moderately Agree," and "Strongly Agree." No participants reported that they strongly disagreed with receiving the COVID-19 vaccine, five participants reported that they moderately disagreed with receiving the COVID-19 vaccine, 11 reported that they moderately agreed with receiving the COVID-19 vaccine, and 28 reported that they strongly agreed with receiving the COVID-19 vaccine. Participants were separated into two groups, pro- and anti-COVID-19 vaccine based on these self-reports, regardless of whether the opinion was "Moderately" or "Strongly".

Behavioral Pilot Methods

Stimuli were collected from various news and medical sites, including the Centers for Disease Control (CDC) website, the Mayo Clinic website, NewsGuard Tech, Facebook, etc. Some misinformation statements were created that were the opposite of correct statements. A total of 310 statements were gathered (155 categorized as misinformation, 155 categorized as correct information). A behavioral pilot study was used to determine how well the stimuli examined the parameters of this study. The pilot

subjects completed a Qualtrics survey where they were asked their opinion on receiving COVID-19 vaccines, then to read and respond to each stimulus. The participants' level of agreement was established by self-reporting on a Likert scale of "Strongly Disagree", "Moderately Disagree", "Moderately Agree", "Strongly Agree". For the purposes of this paper, CA will refer to correct information the participant responded either "Strongly Agree" or "Moderately Agree" to. CD will refer to correct information the participant responded "Strongly Disagree" or "Moderately Disagree" to. MA will refer to misinformation the participant responded "Strongly Agree" or "Moderately Agree" to. MD will refer to misinformation the participant responded "Strongly Disagree" or "Moderately Disagree" to. The responses were analyzed based on the percent of agreement within each group.

For each statement, three percentages were found: the total agreement out of the entire population, the percentage of responses categorized as MD or CA, and the percentage of responses categorized MA or CD. Thirty correct and thirty incorrect statements were selected for the fMRI portion of this study after participants' responses were analyzed. The selected correct statements were those that were categorized the most as CA from pro-vaccine participants while being categorized as CD from anti-vaccine participants. Similarly, the misinformation statements selected were those that were categorized the most as MA from anti-vaccine participants while being categorized as MD from pro-vaccine participants. The selected stimuli and their corresponding analyzed percentages are included in Appendix A.

fMRI Participants

Thirty-eight participants were recruited for the fMRI portion of this study. Participants were recruited through a survey on the BYU SONA website or by filling out a Qualtrics Survey on the Kirwan Memory and Decision-Making Lab website. Participants were screened for MRI compatibility and meeting study qualifications prior to having the option to sign up for the study. Two participants were excluded for MRI data collection errors. Two participants were excluded for failing to respond in all conditions (one lacked responses in the CD condition and one lacked responses in the MA condition). Two participants were excluded due to experimenter error. All participants were right-handed, healthy young adults with no history of psychological or neurological conditions, and no traumatic brain injuries. The final n for this study was 32 volunteers (16 females) between the ages of 18 and 25 (M = 21.4 ± 2.1). Eight were grouped as anti-COVID-19 vaccine (six females; all participants between the ages of 18 and 25; average 20.9 ± 2.7). Because of the low n in this group, we were unable to perform fMRI analyses on the data, but the behavioral data are included when appropriate and are labeled as such. Twenty-four participants were grouped as pro-COVID-19 vaccine (10 females; all participants between the ages of 18 and 25; average 21.6 ± 1.9). For the purposes of this study, those grouped as anti-COVID-19 vaccine will be referred to as anti-vaccine and those grouped as pro-COVID-19 vaccine will be referred to as pro-vaccine. These designations do not necessarily reflect the participants views of all vaccines, as this is outside the scope of this study. All participants gave written consent and were not informed that they would be seeing correct information and misinformation relating to COVID-19 vaccines. Following the scan, all participants were debriefed and

received a packet containing all the stimuli they read during the study, including the citations and whether it was categorized as correct information or misinformation. A script was read during the debriefing process and the contact information for the lab was given in the packet for participants to contact the lab if they had any questions. Participants were compensated for their participation with their choice of $20, a ¼ scale 3D model of their brain, or six BYU SONA credits.

fMRI Methods

In the MRI scanner, participants were asked to respond to the 60 stimuli collected from the behavioral pilot data (for a full list of the stimuli used here, see Appendix A). Each participant contributed a T1-weighted Magnetization Prepared Rapid Gradient Echo (MP-RAGE) anatomical scan, a GRE-field mapping scan, a Proton Density – Turbo Spin Echo (PD-TSE) hippocampal scan, and echo-planar imaging (EPI) scans over three runs. During the T2*-weighted EPI scans, participants read the presented stimuli and responded with their agreement on a Likert scale on one MRI compatible button box (1-Strongly Agree, 2-Moderately Agree, 3-Moderately Disagree, 4-Strongly Disagree) that recorded the responses and the reaction times. Stimuli were presented for a maximum of 2000 ms, progressing after the participant responded or when 2000 ms had concluded. Between stimuli presentation, the participant was shown a fixation cross ("+") that was jittered between 500 and 1500 ms. Three blocks of 20 trials were presented for each participant with the order of the stimuli randomized within and across runs. Stimuli were presented using the PsychoPy software system and viewed via an LCD screen placed at the head end of the bore and a series of mirrors.

All MRI imaging was performed on a Siemens 3 Tesla Vida scanner (Erlangen, Germany), using a 64-channel head coil. Participants were placed in the scanner in a head-first supine position. Foam head cushions and a foam knee bolster were provided to help prevent motion artifacts and make the time spent in the scanner more comfortable. The T1-weighted MP-RAGE used the following parameters: repetition time (TR) = 400 ms; echo time (TE) = 4.92 ms; flip angle = 60 degrees; field of view = 192 mm; voxel resolution = 1.0 x 1.0 x 1.0 mm; number of volumes = 1. The EPI scans used the following parameters: TR = 2000 ms; TE = 30 ms; flip angle = 66 degrees; field of view = 192 mm; voxel resolution = 2.043 x 2.043 x 2.043 mm, number of volumes = 160. The GRE scan used the following parameters: TR = 6490 ms; TE = 16 ms; flip angle = 120 degrees; field of view = 206 mm; number of volumes = 1.

Data Analysis

Data analysis occurred in multiple steps. First, data were converted from DICOM format to NIfTI using *dcm2niix*. Data were then deidentified using *3dAllineate* to comply with HIPPA regulations and ensure the anonymity of the participants. Second, data were uploaded to the BYU supercomputer to perform a preprocessing script. The script corrected for signal fallout using a field map method, detected outliers using volume registration, stripped the skull, calculated the rotated brain to template space transformation, calculated volume registration, and scaled the data. Third, data were transferred from the supercomputer to the local computer to perform single subject regressions. Timing files were created by accessing the PsychoPy data output and calculating the onset time for each stimulus in each of the three runs and the duration the stimulus was presented. Four timing files were generated per subject, one for each

possible response combination: agree with misinformation (MA), disagree with misinformation (MD), agree with correct information (CA), and disagree with correct information (CD). Fourth, group analysis was performed on the data.

Group Analysis

For group analysis, 3dmask was used to remove the voxels that did not include grey matter from the analysis. Using 3dmerge, the residual noise from the single subject regression analysis (the errts) was blurred. 3dClustSim was used to run Monte Carlo Simulations to determine the size of activation clusters to pay attention to, which was determined to be 55 (nearest neighbor [NN] 2, $p = .001$, $\alpha = .005$).

An analysis of variance (ANOVA) was used for comparing two variables. The first variable was information, with correct and misinformation as the categories. The second variable was bias, with agree and disagree as the categories. A 3dMVM group analysis was performed, with two comparisons. The first compared CA with CD. The second compared MA with MD. Based on the data from the ANOVA, some significant relationships were found. Three t-tests were performed to determine which relationships were significant. These tests looked at the comparisons between CA and CD, between CA and MD, and between MA and MD.

Results

Behavioral Results from fMRI

Behavioral data was collected from 37 participants, 29 participants in the pro-vaccine group, eight participants in the anti-vaccine group. Due to the small number of participants in the anti-vaccine group, fMRI data analysis was not able to be run on these participants. Only their behavioral data are included in this analysis. Each participant read

30 correct information statements and 30 misinformation statements that were randomly presented in three runs of 20 statements each. The pro-vaccine group responded with CA on average 25.8 ± 2.3 times out of 30 (proportions: $M = 0.9 \pm 0.1$). CD was recorded on average 3.8 ± 2.3 times (proportions: $M = 0.1 \pm 0.1$). No responses to correct information were given on average 0.4 ± 0.6 times (proportions: $M = 0.01 \pm 0.02$). MA was reported on average 3.3 ± 2 times (proportions: $M = 0.1 \pm 0.1$). MD was reported on average 26.3 ± 2.1 times (proportions: $M = 0.9 \pm 0.1$). No responses to misinformation were given on average 0.4 ± 0.6 times (proportions: $M = 0.01 \pm 0.02$). The results for the pro-vaccine group are summarized in Table 1.

Table 1: Pro-Vaccine Behavioral Data

	CA	**CD**	**Correct No Resp**	**MA**	**MD**	**Misinformation No Resp**
Average	25.83	3.76	0.41	3.31	26.31	0.38
Standard Deviation	2.28	2.25	0.63	1.98	2.07	0.56
Proportion Avg.	0.86	0.13	0.01	0.11	0.88	0.01
Proportion *SD*	0.08	0.07	0.02	0.07	0.07	0.02

Note: Thirty stimuli presented in each category (correct and misinformation). Statistics here presented out of 30 and are given as averages for both total quantities and proportions. CA refers to correct information participants agreed with. CD refers to correct information participants disagreed with. MA refers to misinformation participants agreed with. MD refers to misinformation participants disagreed with.

The anti-vaccine group reported CA on average 8.6 ± 8.3 times (proportions: $M = 0.3 \pm 0.3$). CD was reported on average 20.5 ± 7.7 times (proportions: $M = 0.7 \pm 0.3$). No response was given to correct information statements an average of 0.9 ± 1 times (proportions: $M = 0.03 \pm 0.03$). MA was reported on average 22.1 ± 7.4 times (proportions: $M = 0.7 \pm 0.3$). MD was reported on average 7.5 ± 7.3 times (proportions:

$M = 0.3 \pm 0.2$). No response was given to misinformation statements an average of 0.4 ± 0.5 times (proportions: $M = 0.01 \pm 0.02$). The results from the anti-vaccine group are summarized in Table 2.

Table 2. Anti-Vaccine Behavioral Data

	CA	CD	Correct No Resp	MA	MD	Misinformation No Resp
Average	8.63	20.50	0.88	22.13	7.50	0.38
Standard Deviation	8.26	7.73	0.99	7.36	7.27	0.52
Proportion Avg.	0.29	0.68	0.03	0.74	0.25	0.01
Proportion *SD*	0.28	0.26	0.03	0.25	0.24	0.02

Note: As in Table 1, these results are out of 30 presented stimuli and are presented with both the total quantity as an average and the proportion.

fMRI Results

A 2x2 ANOVA analyzed the comparison between information and bias. An interaction was found between information and bias in the left intraparietal sulcus, the left inferior frontal gyrus, and the left dorsolateral prefrontal cortex (for statistical data, see Appendix B). Table 3 outlines the location and size of the significant activation found in the ANOVA.

Table 3. Information-Bias ANOVA Structures

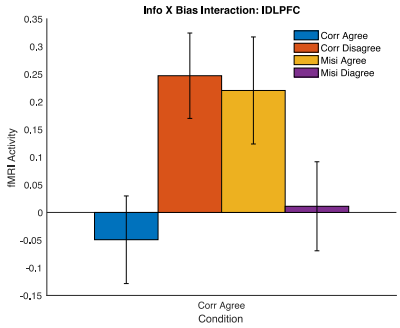
Region of Activation	Voxels	Peak X	Peak Y	Peak Z
Left Intraparietal Sulcus (lIPS)	96	-36	-56	+50
Left Dorsolateral Prefrontal Cortex (lDLPFC)	68	-54	+22	+33
Left Middle Frontal Gyrus (lMFG)	64	-26	+6	+60

Notes: $p = 0.001$, peak coordinates given in MNI (Montreal Neurological Institute) space. Clusters were included if they contained 55 voxels or more. Fifty-five voxels determined by the Monte Carlo Simulation performed during the group analysis.

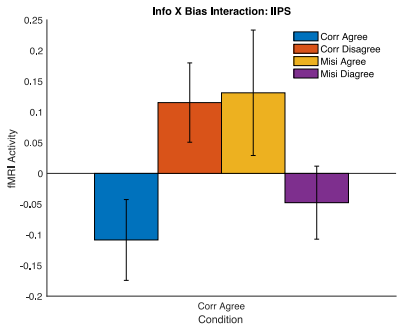
Based on the repeated measures ANOVA, charts were generated to analyze the condition interactions within each structure (Figure 1). Following the repeated measures ANOVA, a series of paired samples t-tests were performed. This allowed for the analysis of which bias conditions were significantly different from the others within each brain structure. The data from this analysis are included in Table 4, with significance indicated by an asterisk beside the corresponding two-sided *p* value. These analyses showed a significant increase in activation in the left dorsolateral prefrontal cortex (lDLPFC) and the left intraparietal sulcus (lIPS) for CD responses compared with CA and MD responses and for responses of MD compared to CA and MD responses. No significant change in activation was seen for responses of CD or CA compared with MD. In the left middle frontal gyrus (lMFG) a significant increase in activation was also seen for CD responses compared to CA and MD and for MA responses compared to CA. No significant change was seen for CA responses compared to MD, for CD compared with MD, or for MA compared with MD. ROIs with significant activation are shown in Figure 2.

Figure 1: Information-Bias ANOVA Charts

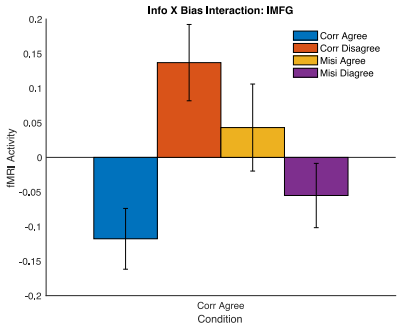
A.



B.



C.



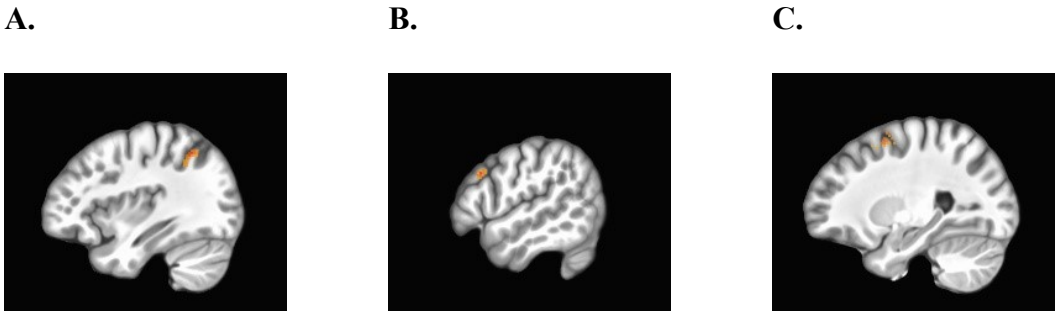
Note: These charts show the four response options and the correlated activation in each brain region where significant activation was seen in the Information-Bias ANOVA. A) Results for the left dorsolateral prefrontal cortex. B) Results for the left intraparietal sulcus. C) Results for the left middle frontal gyrus. The abbreviations “Corr” and “Misi” correspond to correct information and Misinformation, respectively. Significance was determined by a series of paired samples t-test, the results of which are shown in Table 4.

Table 4: Information-Bias Paired Samples T-test

		Paired Differences								
					95% Confidence Interval of the Differences				Significance	
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided *p*	Two-Sided *p*
lIPS										
Pair 1	CA-CD	-0.22382	0.31755	0.06228	-0.35208	-0.09555	-3.594	25	<.001	0.001*
Pair 2	CA-MA	-0.23975	0.31652	0.06207	-0.36759	-0.11191	-3.862	25	<.001	<.001*
Pair 3	CA-MD	-0.06074	0.29418	0.05769	-0.17956	0.05808	-1.053	25	0.151	0.302
Pair 4	CD-MA	-0.01593	0.50458	0.09896	-0.21974	0.18787	-0.161	25	0.437	0.873
Pair 5	CD-MD	0.16307	0.37977	0.07448	0.00968	0.316478	2.189	25	0.019	0.038*
Pair 6	MA-MD	0.17901	0.37761	0.07406	0.02649	0.33153	2.417	25	0.012	0.023*
lDLPFC										
Pair 7	CA-CD	-0.2965	0.32329	0.06340	-0.42708	-0.16593	-4.677	25	<.001	<.001*
Pair 8	CA-MA	-0.26982	0.30504	0.05982	-0.39303	-0.14661	-4.51	25	<.001	<.001*
Pair 9	CA-MD	-0.06047	0.48606	0.09532	-0.25680	0.13585	-0.634	25	0.266	0.532
Pair 10	CD-MA	0.02668	0.47655	0.09346	-0.16580	0.21917	0.285	25	0.389	0.778
Pair 11	CD-MD	0.23603	0.50448	0.09894	0.03227	0.43979	2.386	25	0.012	0.025*
Pair 12	MA-MD	0.20935	0.50889	0.0998	0.00380	0.41489	2.098	25	0.023	0.046*
lMFG										
Pair 13	CA-CD	-0.25477	0.29553	0.05796	-0.37414	-0.1354	-4.396	25	<.001	<.001*
Pair 14	CA-MA	-0.16091	0.21807	0.04277	-0.24899	-0.07282	-3.762	25	<.001	<.001*
Pair 15	CA-MD	-0.06262	0.27932	0.05478	-0.17543	0.05020	-1.143	25	0.132	0.264
Pair 16	CD-MA	0.09387	0.40998	0.08040	-0.07173	0.25946	1.167	25	0.127	0.254
Pair 17	CD-MD	0.19216	0.37247	0.07305	0.04171	0.34260	2.631	25	0.007	0.014*
Pair 18	MA-MD	0.09829	0.30697	0.06020	-0.02570	0.22280	1.633	25	0.058	0.115

Notes: A comparison was determined to be significant if the two-sided $p < .05$. Significance is indicated by an asterisk beside the two-sided *p* value.

Figure 2: Information-Bias ROIs



Note: The ROIs with significant activation in the information versus bias ANOVA. Clusters shown have 55 or more voxels. A) Significant activation seen in the left intraparietal sulcus. B) Significant activation seen in the left dorsolateral prefrontal cortex. C) Significant activation seen in the left middle frontal gyrus.

Three subsequent t-tests were performed on the comparisons CA versus CD, CA versus MD, and MA versus MD. There was no main effect of information and bias. In these t-tests, some overlap was seen in the structures that showed significant activation in the ANOVA, however, additional unique structures were also seen. No significant results were seen in the MA vs MD t-test.

In the CA versus CD t-test, activation was seen in the left middle orbital gyrus and the left superior medial gyrus as shown in Table 5 and Figure 3. In both conditions, greater activation was seen for the CD condition than for the CA condition.

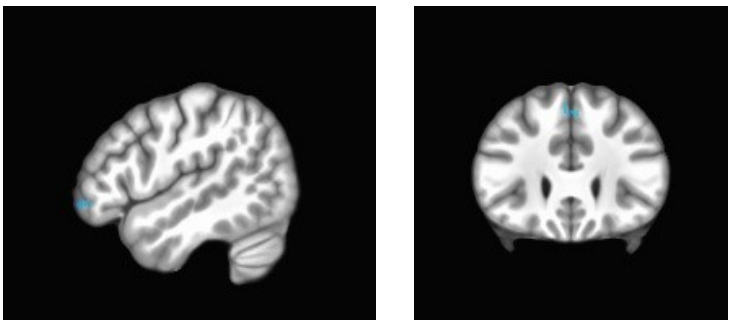
Table 5: CA-CD Structures

Structure	Voxels	Peak X	Peak Y	Peak Z
Left Middle Orbital Gyrus	86	-50	+50	-8
Left Superior Medial Gyrus	64	-1	+28	+48

Notes: $p = .001$, peak coordinates given in MNI space. Clusters included if they contained 55 voxels or more.

Figure 3: CA-CD ROIs

A. **B.**



Notes: ROIs with significant activation in the CA versus CD comparison with clusters having 55 or more voxels. A) Activation in the left middle orbital gyrus. B) Activation in the left superior medial gyrus.

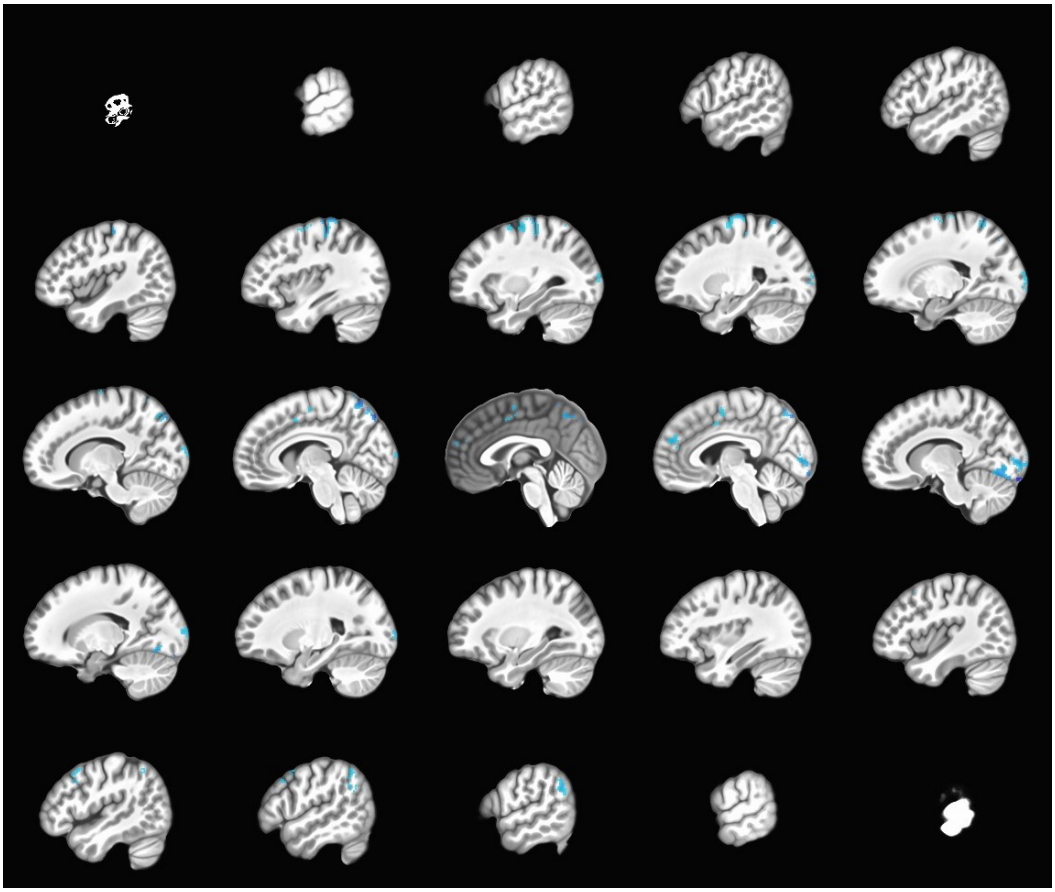
For the CA versus MD t-test, 10 regions of interest (ROIs) showed significant activation, as detailed in Table 6 and in Figure 4. In each of these regions there was greater activation for the MD condition than in the CA condition.

Table 6: CA-MD Structures

Structure	**Voxels**	**Peak X**	**Peak Y**	**Peak Z**
Left Postcentral Gyrus	381	-38	-29	+72
Right Primary Visual Cortex	264	+3	-99	+10
Left Intraparietal Sulcus	261	-3	-62	+64
Right Lingual Gyrus	178	+11	-97	-18
Right Cingulate Gyrus	151	+1	+3	+42
Right Temporoparietal Junction	145	+62	-56	+35
Left Middle Occipital Gyrus	133	-30	-99	+11
Left Medial Prefrontal Cortex	74	-1	+61	+21
Left Superior Parietal Gyrus	73	-19	-58	+74
Right Middle Frontal Gyrus	55	+50	+20	+46

Notes: $p = .001$, peak coordinates given in MNI space. Clusters included if they contained 55 or more voxels.

Figure 4: CA-MD ROIs



Note: ROIs shown in a montage for the CA versus MD comparison, $p = .001$ with clusters having 55 or more voxels.

To gain a better understanding of the activation seen in the occipital lobe, additional t-tests were performed on the participant response times to correct and misinformation. Table 7 shows the results for the response time t-test for anti-vaccine participants. Participants took significantly longer to respond in CA and MD conditions than in CD conditions. Significance determined by a two-sided $p < .05$. Significant response time differences are marked with an asterisk.

Table 7: Paired Samples t-test for the Anti-Vaccine Conditions

			Paired Differences						Significance	
					95% Confidence Interval of the Differences					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided *p*	Two-Sided *p*
Pair 1	ACA-ACD	1.51	4.54	0.546	0.418	2.597	2.760	68	0.004	0.007*
Pair 2	ACA-AMA	1.01	5.00	0.603	-0.188	2.217	1.683	68	0.048	0.097
Pair 3	ACA-AMD	-0.12	4.90	0.633	-1.383	1.150	-0.184	59	0.427	0.854
Pair 4	ACD-AMA	0.20	4.87	0.381	-0.556	0.947	0.513	163	0.304	0.609
Pair 5	ACD-AMD	-1.58	4.86	0.628	-2.839	-0.327	-2.523	59	0.007	0.014*
Pair 6	AMA-AMD	-1.10	5.49	0.708	-2.517	0.317	-1.553	59	0.063	0.126

Notes: Paired samples t-test results for the anti-vaccine conditions. Significance determined by a two-sided *p* value of < .05 (marked with an asterisk).

Table 8 shows the response times t-test for pro-vaccine participants. Response times were significantly longer for the CD and MA conditions than for CA conditions.

Table 8: Paired Samples t-test for the Pro-Vaccine Conditions

			Paired Differences						Significance	
					95% Confidence Interval of the Differences					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided *p*	Two-Sided *p*
Pair 1	PCA-PCD	-1.05	5.32	0.510	-2.06	-0.035	-2.050	108	0.021	0.043*
Pair 2	PCA-PMA	-1.11	4.70	0.482	-2.07	-1.59	-2.315	94	0.011	0.023*
Pair 3	PCA-PMD	-0.03	5.76	0.210	-0.45	0.378	-0.165	748	0.434	0.869
Pair 4	PCD-PMA	-0.32	5.35	0.549	-1.41	0.774	-0.575	94	0.283	0.566
Pair 5	PCD-PMD	0.77	5.15	0.493	-0.21	1.748	1.563	108	0.060	0.121
Pair 6	PMA-PMD	0.88	4.44	0.455	-0.02	1.788	1.943	94	0.028	0.055

Notes: Paired samples t-test results for the pro-vaccine conditions. Significance determined by a two-sided *p* value of < .05 (marked with an asterisk).

Table 9 shows the response times t-test comparing pro-vaccine participant response times to anti-vaccine participant response times. Response times were significantly longer for anti-vaccine participants responding agree to correct information than their pro-vaccine counterparts and for anti-vaccine participants responding disagree to misinformation than their pro-vaccine counterparts.

Table 9: Paired Samples t-test for the Pro-Vaccine versus Anti-Vaccine Conditions

			Paired Differences							
					95% Confidence Interval of the Differences				Significance	
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided *p*	Two-Sided *p*
Pair 1	PCA-ACA	-2.043	5.169	0.622	-3.285	-0.802	-3.284	68	<.001	0.002*
Pair 2	PCD-ACD	-0.055	5.082	0.487	-1.020	0.910	-0.113	108	0.455	0.910
Pair 3	PMA-AMA	0.042	4.918	0.505	-0.960	1.044	0.083	94	0.467	0.934
Pair 4	PMD-AMD	-2.517	4.440	0.573	-3.664	-1.370	-4.391	59	<.001	<.001*

Notes: Paired samples t-test results for the pro-vaccine and anti-vaccine comparison. Significance determined by a two-sided *p* value of < .05 (marked with an asterisk).

Discussion

In this study, we saw an interaction between information and bias in regions of the brain that are related to memory and recognition when participants are presented with the stimuli. Further, increased activation was seen in the left middle orbital gyrus and left superior medial gyrus when participants responded disagree with correct information compared to agree with correct information. When responding to correct stimuli compared with responding to misinformation, activation of a network was seen related to novelty, rejection, and vision.

To better understand the information-bias interaction, additional t-tests were performed. These t-tests showed a significant increase in activity in the left DLPFC and the lIPS for the CD condition and the MA condition compared to CA and MD. A significant increase in activity was also seen in the lMFG for CD compared to CA and MD and for responses of MA compared to CA. These significant increases in activation could indicate that these regions respond when the participant is wrong, implying that participants are ignoring something that is correct by holding tightly to beliefs that are not cohesive with correct information. However, it could also be related to the quantity of time spent looking at the stimuli and deciding how to respond. Many of these regions are involved in aspects of memory, such as working memory (Cowan et al., 2011; Crottaz-Herbette et al., 2004; Silk et al., 2010; Staresina & Davachi, 2006) or recognition memory (Blumenfeld & Ranganath, 2006; Henson et al., 1999), which could also indicate that the participant is working more to remember if they have seen statements similar to the stimuli they are responding to.

In order to see what is causing this, additional t-tests were performed on the reaction times to see if there were significant differences between the time it took to respond to CA conditions and the time it took to respond to CD conditions (Tables 7, 8, and 9). The results from the anti-vaccine t-test show that participants took significantly longer in their response to CA and MD conditions than to CD conditions. The results from the pro-vaccine t-test show that participants took significantly longer in their respond to CD conditions than to CA conditions. Participants also took significantly longer to respond to MA conditions than CA conditions. This increased reaction time correlates well with the activation trends that were observed in the ROI data and in the

graphs. Additional research needs to be done that focuses on this interaction and includes a group with participants who identify as anti-vaccine to see if these trends stay consistent. In the pro-vaccine versus anti-vaccine t-test, anti-vaccine participants took significantly longer to respond to CA and MD conditions than their pro-vaccine counterparts.

In the CA versus MD t-test, an increased activation was seen in a network of regions for the MD condition. Many of these regions are involved in novelty and rejection, which are important in recognition memory tasks (for review see: Kim, 2013). However, regions such as the right primary visual cortex and the left middle occipital gyrus are heavily involved in vision and visual processing (Pernet et al., 2004; Tootell et al., 1998). These results indicate a possible confounding variable in the length of time spent reading the presented stimulus. To help determine if this confounding variable is present, the response times paired samples t-tests (in Tables 7, 8, and 9) were looked at. Response times were determined based on the length of time a stimulus was presented, since the PsychoPy presentation software was programmed to automatically advance once an answer had been selected. For additional results gained as part of these t-tests, see Appendix C.

Each of these t-tests showed conditions where the reaction time was significantly longer. This could indicate that there is a confounding variable in the length of the stimuli participants are asked to respond to. The longest stimulus was 51 words, while the shortest was six words. The increased length would cause increased activation in the occipital lobe, accounting for the increased activation that was seen. However, the increased length of time spent on certain stimuli could also reflect additional decision

making and evaluation taking place. The anterior cingulate cortex has been implicated in decision-making and contributes part of the activation seen in this study (Fishbein et al., 2005; Grossman et al., 2010; Paulus & Frank, 2006). This explanation would help to explain the activation of the network seen in the CA versus MD task. Additional research needs to be performed to determine this.

In the CA versus CD t-test, additional activation was seen in the left middle orbital gyrus and the left superior medial gyrus during a CD condition than during a CA condition. The superior medial gyrus has been implicated in decision making and task conflict responses, (Aarts et al., 2009; Nakao et al., 2012). These structures imply that novelty and recognition may be taking place in addition to decision-making and evaluation. It is possible that the correct stimuli the participant disagrees with is due to a lack of recognition of the presented material, leading to the participant evaluating the information and choosing to say agree or disagree. Again, additional research needs to be done in order to determine the reason for this increased activation.

Conclusion

Misinformation is a prevalent issue in society today and has the power to impact many aspects of life. By understanding the neural correlates tied to misinformation and why individuals hold tightly to misinformation, researchers can take additional steps to help prepare society to ignore the misinformation that they encounter. Additional research will need to be conducted to understand the functions of the structures involved and to discover what more can be done to aid people in disbelieving the misinformation they encounter.

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APPENDIX A

Correct information stimuli used in the fMRI task

Stimuli	Category	Total % Disagree	% of Anti Vaccine Disagree	% of Pro Vaccine Disagree
Roughly 12 months of data show that the vaccines are safe.	C	20%	60%	15%
Unvaccinated people who already had COVID-19 are more than twice as likely as fully vaccinated people to get reinfected with COVID-19.	C	30%	60%	27%
It's recommended that you get a COVID-19 vaccine if you are pregnant or breastfeeding.	C	37%	80%	32%
A COVID-19 vaccine can prevent your child from getting COVID-19 and spreading it at home and in school.	C	15%	60%	10%
COVID-19 vaccination might offer better protection than getting sick with COVID-19.	C	15%	60%	10%
There is also some evidence that being vaccinated will make it less likely that you will pass the virus on to others, which means your decision to get the vaccine also protects those around you.	C	11%	60%	5%
COVID-19 vaccines are safe for people who have existing health conditions.	C	33%	60%	44%
COVID-19 vaccines are safe and effective.	C	13%	60%	7%
Vaccination - new shots, second doses, and boosters - is particularly urgent now.	C	46%	100%	39%
If your child gets COVID-19, having a COVID-19 vaccine could prevent severe illness. Getting a COVID-19 vaccine can also help keep your child in school and more safely have playdates and participate in sports and other group activities.	C	20%	80%	12%
The vaccines, offered to the U.S. population, have proved to be 90 percent effective against infection. Ready within a	C	17%	60%	12%

year of the outbreak, they have proved to be safe.				
People who are pregnant should also be prioritized for vaccination.	C	28%	80%	22%
COVID-19 vaccines were developed using science that has been around for decades.	C	22%	100%	12%
The COVID vaccine will give you or your child much safer, better and longer-lasting protection against serious illness than an infection.	C	13%	60%	7%
COVID-19 vaccines are safe for most people of 18 years and older, including those with pre-existing conditions of any kind such as auto-immune disorders. These conditions include hypertension, diabetes, asthma, pulmonary, liver, and kidney disease as well as chronic infections that are stable and controlled.	C	30%	60%	27%
COVID-19 vaccines don't cause infection with the COVID-19 virus, including in pregnant women and their babies. None of the COVID-19 vaccines contain the live virus that causes COVID-19.	C	26%	60%	22%
The current vaccines cause a powerful immune response that makes them highly protective, even if there is a drop in antibody strength.	C	15%	60%	10%
Data is showing that boosters increase vaccine effectiveness.	C	11%	60%	5%
Getting a booster dose can decrease your risk of infection and severe illness with COVID-19.	C	28%	80%	22%
The benefits of vaccination outweigh the risks.	C	15%	80%	7%
The vaccine does not contain the virus.	C	52%	80%	49%
Delaying vaccination can be harmful to your health and the health of your community.	C	17%	100%	7%
Unvaccinated people were 14 times more likely than the vaccinated to die of COVID.	C	37%	80%	32%
Getting a COVID-19 vaccination is a safer and more dependable way to build immunity to COVID-19 than getting sick with COVID-19.	C	20%	60%	15%

With a booster, vaccine effectiveness against symptomatic infection is 60-70% when compared to no vaccine. The effectiveness of a primary series is less with Omicron and effectiveness does wane over time, so boosters are really important for protection against the Omicron variant.	C	13%	60%	7%
Getting any COVID-19 vaccine is better than not getting a COVID-19 vaccine.	C	22%	100%	12%
All COVID-19 vaccines are manufactured with as few ingredients as possible.	C	50%	80%	46%
1 or 2 days of side effects after the COVID-19 vaccine mean it's working.	C	28%	60%	24%
The greatest risk of transmission is among unvaccinated people.	C	13%	60%	7%
Evidence from the hundreds of millions of COVID-19 vaccines already administered in the United States, and the billions of vaccines administered globally, demonstrates that they are safe and effective.	C	17%	80%	10%

Misinformation stimuli used in the fMRI task

Stimulus	Category	Total % Agree	% Anti Vaccine Agree	% Pro Vaccine Agree
Researchers rushed the development of the COVID-19 vaccine, so its effectiveness and safety cannot be trusted.	M	24%	80%	17%
The Pfizer/BioNTech and Moderna vaccines both contain preservatives.	M	33%	80%	27%
Many people have died even after being vaccinated against COVID-19.	M	48%	80%	44%
Most people don't need a COVID-19 booster shot.	M	30%	100%	22%
The vaccine does not have any impact on how likely you are to pass the virus on to others. Your decision to receive the vaccine does not impact any of those around you.	M	15%	60%	10%
The COVID-19 vaccines are not effective against the different variants that are emerging, such as the delta variant and the omicron variant. These vaccines do	M	22%	60%	17%

not provide protection against severe COVID-19.				
The COVID-19 vaccines are unsafe because drug companies created them quickly.	M	17%	60%	12%
Getting a booster will not decrease your risk of infection and severe illness with COVID-19.	M	15%	80%	7%
China was unwilling to share genetic information about the COVID-19 virus, so scientists could not start working on vaccines.	M	35%	80%	29%
Vaccines are not crucial and we can wait for herd immunity to be effective.	M	17%	80%	10%
Vaccines do not reduce the risk of COVID-19 and do not reduce the risk of severe illness and death from getting COVID-19.	M	17%	60%	12%
People who receive a second booster shot can still get infected, proving that vaccines and booster shots are ineffective against the COVID-19 virus.	M	26%	80%	20%
COVID-19 vaccines are not safe for children and will not protect them or keep them from spreading it at school.	M	11%	60%	5%
The COVID-19 vaccine is not safe because it was rapidly developed and tested.	M	13%	60%	7%
COVID-19 vaccines are not safe for people, especially those with pre-existing conditions of any kind, such as auto-immune disorders. Many of these conditions cause negative reactions with the COVID-19 virus that jeopardize the life of the patient more than the possibility of contracting COVID-19.	M	22%	80%	15%
Getting sick with COVID-19 is the safest and most dependable way to build an immunity to COVID-19, better than getting a vaccine.	M	17%	60%	12%
Booster shots should be unnecessary because we have the vaccines. We have to have booster shots to be considered fully vaccinated, which shows that the vaccines don't work. COVID vaccines and booster shots are just a way for the government to	M	20%	60%	15%

maintain its control over the people and limit their rights.				
The governments and world organization that are responsible for administering the vaccine are supplying false information about the safety and efficacy of the vaccines in an attempt to vaccinate everyone.	M	24%	80%	17%
Spike proteins from coronavirus vaccines are dangerous toxins that cause damage in the body.	M	24%	60%	20%
COVID vaccines are not effective and only cause harm to people who receive them. People who get vaccinated are continuing to get COVID and are going to the hospital to get treated because they are experiencing severe illness and complications.	M	11%	60%	5%
COVID-19 vaccine protection decreases over time, which shows that they are ineffective at providing protection against the virus or its variants.	M			
The COVID vaccines were not rigorously tested, which is why they have only emergency authorization approval and not full Food and Drug Administration approval.	M	28%	80%	22%
Natural immunity is safer than immunity from a COVID-19 vaccine.	M	28%	100%	20%
Not getting a COVID-19 vaccine is better than getting a COVID-19 vaccine.	M	13%	60%	7%
Vaccination does not help your body's protection, as only natural immunity will increase your protection against the virus that causes COVID-19. Natural immunity is the safest way to protect yourself from COVID-19 illness.	M	13%	60%	7%
If I've already had COVID-19, I don't need a vaccine.	M	22%	60%	17%
There are severe side effects of the COVID-19 vaccines.	M	28%	80%	22%
I already had COVID-19 and I have recovered, so I don't need to get a COVID-19 vaccine when it's available.	M	15%	60%	10%
The technology used to create the COVID vaccines is too new to be safe.	M	17%	60%	12%

COVID-19 vaccines are very dangerous and scientists are not monitoring the adverse events that many people are experiencing. The CDC is covering up just how dangerous these vaccines are by not reporting all of the serious side effects that people are experiencing.	M	13%	60%	7%

APPENDIX B

lIPS – Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig	Partial Eta Squared
Info	Pillai's Trace	0.018	0.447	1.000	25.000	0.510	0.018
	Wilks' Lambda	0.982	0.447	1.000	25.000	0.510	0.018
	Hotelling's Trace	0.018	0.447	1.000	25.000	0.510	0.018
	Roy's Largest Root	0.018	0.447	1.000	25.000	0.510	0.018
Bias	Pillai's Trace	0.006	0.153	1.000	25.000	0.699	0.006
	Wilks' Lambda	0.994	0.153	1.000	25.000	0.699	0.006
	Hotelling's Trace	0.006	0.153	1.000	25.000	0.699	0.006
	Roy's Largest Root	0.006	0.153	1.000	25.000	0.699	0.006
Info*Bias	Pillai's Trace	0.535	28.760	1.000	25.000	<.001	0.535
	Wilks' Lambda	0.465	28.760	1.000	25.000	<.001	0.535
	Hotelling's Trace	1.150	28.760	1.000	25.000	<.001	0.535
	Roy's Largest Root	1.150	28.760	1.000	25.000	<.001	0.535

lDLPFC – Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig	Partial Eta Squared
Info	Pillai's Trace	0.003	0.066	1.000	25.000	0.799	0.003
	Wilks' Lambda	0.997	0.066	1.000	25.000	0.799	0.003
	Hotelling's Trace	0.003	0.066	1.000	25.000	0.799	0.003
	Roy's Largest Root	0.003	0.066	1.000	25.000	0.799	0.003
Bias	Pillai's Trace	0.016	0.412	1.000	25.000	0.527	0.016
	Wilks' Lambda	0.984	0.412	1.000	25.000	0.527	0.016
	Hotelling's Trace	0.016	0.412	1.000	25.000	0.527	0.016
	Roy's Largest Root	0.016	0.412	1.000	25.000	0.527	0.016
Info*Bias	Pillai's Trace	0.518	26.862	1.000	25.000	<.001	0.518
	Wilks' Lambda	0.482	26.862	1.000	25.000	<.001	0.518
	Hotelling's Trace	1.074	26.862	1.000	25.000	<.001	0.518
	Roy's Largest Root	1.074	26.862	1.000	25.000	<.001	0.518

lMFG – Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig	Partial Eta Squared
Info	Pillai's Trace	0.004	0.101	1.000	25.000	0.753	0.004
	Wilks' Lambda	0.996	0.101	1.000	25.000	0.753	0.004
	Hotelling's Trace	0.004	0.101	1.000	25.000	0.753	0.004
	Roy's Largest Root	0.004	0.101	1.000	25.000	0.753	0.004
Bias	Pillai's Trace	0.095	2.638	1.000	25.000	0.117	0.095
	Wilks' Lambda	0.905	2.638	1.000	25.000	0.117	0.095
	Hotelling's Trace	0.106	2.638	1.000	25.000	0.117	0.095
	Roy's Largest Root	0.106	2.638	1.000	25.000	0.117	0.095
Info*Bias	Pillai's Trace	0.516	26.617	1.000	25.000	<.001	0.516
	Wilks' Lambda	0.484	26.617	1.000	25.000	<.001	0.516
	Hotelling's Trace	1.065	26.617	1.000	25.000	<.001	0.516
	Roy's Largest Root	1.065	26.617	1.000	25.000	<.001	0.516

APPENDIX C

Additional Anti-Vaccine T-test Results

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	ACA	8.43	69	3.37	0.406
	ACD	6.93	69	3.03	0.365
Pair 2	ACA	8.43	69	3.37	0.406
	AMA	7.42	69	3.8	0.458
Pair 3	ACA	8.57	60	3.52	0.455
	AMD	8.68	60	3.75	0.484
Pair 4	ACD	7.68	164	3.35	0.261
	AMA	7.48	164	3.53	0.276
Pair 5	ACD	7.1	60	3.15	0.407
	AMD	8.68	60	3.75	0.484
Pair 6	AMA	7.58	60	3.92	0.501
	AMD	8.68	60	3.75	0.484

Paired Samples Correlations

				Significance	
		N	Correlation	One-Sided p	Two-Sided p
Pair 1	ACA & ACD	69	-0.001	0.496	0.992
Pair 2	ACA & AMA	69	0.029	0.406	0.812
Pair 3	ACA & AMD	60	0.092	0.242	0.484
Pair 4	ACD & AMA	164	-0.004	0.48	0.961
Pair 5	ACD & AMD	60	0.014	0.457	0.914
Pair 6	AMA & AMD	60	-0.022	0.434	0.869

Paired Samples Effect Sizes

					95% Confidence Interval	
			Standardizer	Point Estimate	Lower	Upper
Pair 1	ACA-ACD	Cohen's d	4.536204647	0.332	0.089	0.574
		Hedges' correction	4.561413576	0.330	0.088	0.570
Pair 2	ACA-AMA	Cohen's d	5.007326261	0.203	-0.037	0.440
		Hedges' correction	5.035153341	0.201	-0.036	0.438
Pair 3	ACA-AMD	Cohen's d	4.902754904	-0.024	-0.277	0.229
		Hedges' correction	4.934194035	-0.204	-0.275	0.228
Pair 4	ACD-AMA	Cohen's d	4.873715717	0.040	-0.113	0.193
		Hedges' correction	4.884964197	0.040	-0.113	0.193
Pair 5	ACD-AMD	Cohen's d	4.861790375	-0.326	-0.584	-0.065
		Hedges' correction	4.892966819	-0.324	-0.580	-0.064
Pair 6	AMA-AMD	Cohen's d	5.485574302	-0.201	-0.455	0.056
		Hedges' correction	5.520750788	-0.199	-0.452	0.056

Additional Pro-Vaccine T-test Results

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PCA	6.26	109	3.35	0.320
	PCD	7.30	109	3.76	0.360
Pair 2	PCA	6.40	95	3.47	0.356
	PMA	7.52	95	3.72	0.382
Pair 3	PCA	6.98	749	3.49	0.128
	PMD	7.02	749	4.68	0.171
Pair 4	PCD	7.20	95	3.73	0.382
	PMA	7.52	95	3.72	0.382
Pair 5	PCD	7.30	109	3.76	0.360
	PMD	6.53	109	2.96	0.283
Pair 6	PMA	7.52	95	3.72	0.382
	PMD	6.63	95	2.90	0.297

Paired Samples Correlations

				Significance	
		N	Correlation	One-Sided p	Two-Sided p
Pair 1	PCA & PCD	109	-0.122	0.103	0.206
Pair 2	PCA & PMA	95	0.148	0.076	0.153
Pair 3	PCA & PMD	749	0.029	0.214	0.428
Pair 4	PCD & PMA	95	-0.031	0.382	0.763
Pair 5	PCD & PMD	109	-0.164	0.044	0.089
Pair 6	PMA & PMD	95	0.119	0.125	0.249

Paired Samples Effect Sizes

					95% Confidence Interval	
			Standardizer	Point Estimate	Lower	Upper
Pair 1	ACA-ACD	Cohen's d	3.556304075	-0.294	-0.485	-0.102
		Hedges' correction	3.568712194	-0.293	-0.484	-0.101
Pair 2	ACA-AMA	Cohen's d	3.597077948	-0.310	-0.515	-0.103
		Hedges' correction	3.611507950	-0.309	-0.513	-0.103
Pair 3	ACA-AMD	Cohen's d	4.127767753	-0.008	-0.080	0.063
		Hedges' correction	4.129838597	-0.008	-0.080	0.063
Pair 4	ACD-AMA	Cohen's d	3.725220482	-0.085	-0.286	0.117
		Hedges' correction	3.740164539	-0.084	-0.285	0.116
Pair 5	ACD-AMD	Cohen's d	3.380326242	0.228	0.037	0.418
		Hedges' correction	3.392120366	0.227	0.037	0.416
Pair 6	AMA-AMD	Cohen's d	3.335680398	0.265	0.060	0.469
		Hedges' correction	3.349061780	0.264	0.060	0.467

Additional Pro-Vaccine versus Anti-Vaccine Conditions T-test Results
Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PCA	6.39	69	3.69	0.444
	ACA	8.43	69	3.37	0.406
Pair 2	PCD	7.30	109	3.76	0.360
	ACD	7.36	109	3.09	0.296
Pair 3	PMA	7.52	95	3.72	0.382
	AMA	7.47	95	3.64	0.373
Pair 4	PMD	6.17	60	2.71	0.350
	AMD	8.68	60	3.75	0.484

Paired Samples Correlations

				Significance	
		N	Correlation	One-Sided p	Two-Sided p
Pair 1	PCA & ACA	69	-0.069	0.285	0.571
Pair 2	PCD & ACD	109	-0.094	0.165	0.331
Pair 3	PMA & AMA	95	0.108	0.148	0.297
Pair 4	PMD & AMD	60	0.084	0.263	0.525

Paired Samples Effect Sizes

					95% Confidence Interval	
			Standardizer	Point Estimate	Lower	Upper
Pair 1	PCA-ACA	Cohen's d	5.169010551	-0.395	-0.639	-0.149
		Hedges' correction	5.197736155	-0.393	-0.636	-0.148
Pair 2	PCD-ACD	Cohen's d	5.082349381	-0.011	-0.199	0.177
		Hedges' correction	5.100081946	-0.011	-0.198	0.176
Pair 3	PMA-AMA	Cohen's d	4.918302314	0.009	-0.193	0.210
		Hedges' correction	4.938032526	0.009	-0.193	0.209
Pair 4	PMD-AMD	Cohen's d	4.439772733	-0.567	-0.838	-0.292
		Hedges' correction	4.46824297	-0.563	-0.832	-0.290