I WAS IN GREAT PERPLEXITY:
AN ELECTROENCEPHALOGRAPHIC INVESTIGATION OF MEANING THREAT

by

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ABSTRACT

Meaning Maintenance Model (MMM) predicts that violations in meaning can result in the affirmation of alternative or novel meaning frameworks. These violations, known as meaning threats, often occur unconsciously yet have been shown to significantly influence cognition. An increased ability to learn an artificial grammar when exposed to meaning threat has been reported as well as a polarization of beliefs in social justice and pacifism. Several different stimuli have been found to cause meaning threat behavior: anomalous playing cards, absurdist literature by Kafka, films by David Lynch, and the unconscious switching of experimenters half-way through a study. However, no studies have attempted to measure the neurological effects of meaning threats. Using the N400 event-related potential as a "window into the neurobiology of meaning," this study examined the change in mean N400 amplitude of related and unrelated word pairs due to meaning threat. Additionally, source localization techniques were used to examine if there was increased activation in the anterior cingulate cortex (ACC), a hypothesized prediction in the MMM literature. There were no significant differences found in mean N400 amplitude due to meaning threat nor were there any significant differences in ACC activation levels.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Drawing from work in psychology and existential philosophy, Heine, Proulx, and Vohs (2006) have proposed a model for how meaning (i.e., expected relationships) is maintained (Proulx & Inzlicht, 2012a). These expected relationships permeate all aspects of cognition: markings on a page are interpreted as words, a flame is expected to be hot, world events are supposed to happen according to our political beliefs. Meaning can be between one particular and another (e.g., a flame is hot) or it can be the collection of several abstract and complicated relationships forming an overarching meaning framework (e.g., political beliefs). The meaning maintenance model (MMM) has three simple claims (Heine et al., 2006): meaning is relation, humans are innate meaning makers, and violations of meaning or meaning frameworks result in the affirmation of alternative frameworks. This act of affirmation in the wake of a violation in meaning is known as fluid compensation (Heine et al., 2006). These violations, or meaning threats, can have several different causes such as unusual/absurd events, reminders of one's own death, and conflicting information of the self (Proulx & Heine, 2010). Additionally, being confronted with stimuli interpreted as meaningless can result in fluid compensation behaviors (Proulx & Heine, 2006).

Affirmed alternative frameworks can be completely unrelated to the meaning threat and can be disproportional in importance (i.e., a violation in a trivial framework can trigger the affirmation of a more 'important' framework). Using a set of anomalous playing cards (where the face cards and 10s were reverse colored), Proulx and Major (2013) were able to influence college students who held strong negative views of social inequality to be more in favor of affirmative action than students with similar views who

were exposed to a regular deck. Worldview affirmations from participants were found when same gendered experimenters were switched (without the participants' conscious awareness) halfway through the session (Proulx & Heine 2008). Under the hypothesis that people want to punish lawbreakers, participants were asked to set the bond of a hypothetical prostitute. Those who had their experimenter switched set a higher dollar bond than those who had the same experimenter throughout the session. Using the concept of national identity, Rovenpor, Leidner, Kardos, & O'Brein (2015) found that reading 'A Message from the Emperor' by Franz Kafka (an absurdist parable) resulted in lower levels of pacifism (measured by agreeableness toward diplomacy) for participants who more strongly agreed with the statements "I love the United States" and "America is better than other nations in all respects" than similar participants who read a more familiar control ('The Tortoise and the Hare' by Aesop). This suggests that meaning threats can result in the distrust of the 'other' if one already has a heightened opinion of the self or group membership.

In addition to fluid compensation, MMM also posits that when confronted with a meaning threat and if no alternative framework is available, people will create a novel framework (Heine et al., 2006). When presented with subliminal word-pairs, participants were better able to learn an artificial grammar if the pairs were meaningless (i.e., unrelated) than meaningful (i.e., related) (Randles, Proulx, & Heine, 2011). In a two-part study, Proulx and Heine (2009) found that participants could more easily identify letter strings in an artificial grammar after exposure to 'The Country Dentist' (another absurdist Kafka story) or if they were asked to argue that they had two separate selves existing in

one body. These findings show that meaning threats allow us to assign meaning more quickly to a novel stimulus or circumstance than we normally would.

While MMM has been shown to produce some novel effects, there has been research to suggest that it can explain other well-known psychological phenomena. In his 1919 work 'The Uncanny,' Freud stated that it is the unfamiliar familiar (an unsettling eeriness from a novel yet somehow familiar situation) which produces a state of arousal. This feeling of the uncanny can be seen in research by Proulx, Heine, & Vohs (2010) in which participants read an absurd comedic story entitled "Biggles: Pioneer Air Fighter" (modified from a Monty Python sketch) and were asked to set a bond for a hypothetical prostitute. If the participants were informed that "Biggles" was intended as a joke (or read a non-absurd joke), they were more likely to set the bond lower than those who were told that "Biggles" was an adventure story that was intended for children. While two groups read the same absurdist literature, only the participants who were uninformed of the story's comedic intent engaged in fluid compensation behaviors. When an absurd comedic story is passed off to be a child's adventure tale (unfamiliar familiar), people respond by affirming alternative frameworks (prostitutes are law-breakers and should be punished as such).

In a similar vein, researchers reduced the eeriness of a robot (Telenoid, a legless, armless, pale nightmare) that is associated with producing feelings of the uncanny (Mara & Appel, 2015). Masahiro Mori (2012) described a human-likeness and familiarity function for describing robots. Mori proposed that at a certain level of human-likeness, the level of familiarity drops rapidly causing great unease before the curve of the function

rises again. He termed this interval of greatest uneasiness the Uncanny Valley. Working off the hypothesis that the uncanny valley is a meaning threat and that the modification of what Telenoid was would reduce this threat, the researchers reported that after being exposed to a science fiction story that portrayed the robot as a hero that helped others, participants found it less eerie and more humanlike. The conclusion was that when confronted with a meaning threat (scary robot), people reaffirmed their belief that robots are not humanlike, but that by modifying how Telenoid was viewed this meaning threat was reduced.

Another classic psychology phenomenon, cognitive dissonance theory, has been shown to overlap with MMM. In his much-cited work, Festinger (1957) proposed that cognitive dissonance is the result of inconsistencies in peoples' mental representations of the world and that they will work to minimize those inconsistencies. As previously discussed, MMM predicts that when there are violations of meaning frameworks, people will affirm alternative or novel frameworks in an attempt to resolve the meaning threat. However, cognitive dissonance theory makes no prediction that inconsistencies in mental representations will result in fluid compensation behaviors. To test if cognitive dissonance could result in belief affirmations, a study measured the response to an induced-compliance dissonance task where participants read a boring passage and then asked to write why the passage was interesting (Randles, Inzlicht, Proulx, Tullett, & Heine, 2015). As predicted, the participants were found to have engaged in fluid compensation behaviors such as an increased belief in god, improved ability to learn an artificial grammar, and increased punishment toward law-breakers.

While there is extensive literature on the behavioral effects predicted by MMM, there is little biological research in this relatively new field. To date, the only reported study of testing MMM predictions with a biological component used a single dose of acetaminophen (Randles, Heine, & Santos 2013), which was under the assumption that meaning threat causes a state of discomfort similar to pain. Participants were exposed to the David Lynch short film 'Rabbits', which has all the performers in rabbit costumes and was assumed to cause meaning threat by the researchers. If given a dose of acetaminophen, participants were found to have reduced meaning threat effects after watching the film. Although this finding touches on how to biologically modulate the effects of meaning threats, it does not answer the fundamental question of what (and where) is the neurological basis for fluid compensation in the MMM? One area of brain interest is the anterior cingulate cortex (ACC). A review of ACC activity concluded that the function of this area is heavily associated with psychological states faced with a meaning violation: surprise, detection of errors and conflict, and feelings of dissonance (Tullett, Rimma, Teper, & Inzlicht, 2011; Proulx & Inzlicht, 2012b; Holroyd & Umemoto, 2016). However, to date no studies have been reported that examined ACC activity when exposed to a meaning threat. While this type of information would no doubt enhance our understanding of meaning violations as well as attest to the efficacy of MMM, we would only know where this phenomenon might occur or at least an area related to fluid compensation.

Using electroencephalography methods (EEG) and the event-related potentials (ERPs), we would be able to examine the spatio-temporal changes in brain activity that result from a meaning threat. ERPs are time-locked changes in electric fields resulting

from summed postsynaptic potentials in response to stimuli or other cognitive processes (Kutas & Federmeier 2000). Several distinct ERPs have been identified and linked to various cognitive domains (i.e., language, attention, expectancy). By averaging the EEG across trials, researchers can observe the mean change in the amplitude of these waves as a function of the experimental treatment (i.e., ERPs). An obvious ERP component of interest to MMM is the much studied N400 since it has been said to "provide a window into the neurobiology of meaning" (Kutas & Federmeier, 2000, p. 469). N400 is a negative ERP component peaking approximately 400ms after the onset of the stimulus. It has been studied across several domains, most notably language (see Kutas & Federmeier, 2011 for a review). The amplitude of this ERP has been found to vary when observing word pairs, with higher amplitudes for unrelated pairs compared to related ones (once again, see Kutas & Federmeier, 2011 for a review). This effect could be the result of some word pairs having relationships with each other (related) and other pairs having no meaning framework to bind them together (unrelated). However, one of the aforementioned claims of MMM is the creation of novel meaning frameworks in the face of a meaning threat. After being exposed to a meaning threat, participants should be looking for novel frameworks in order to resolve their violation in meaning. When evaluating word pairs after a meaning threat, new connections in the word pairs may appear that would not have previously (i.e., word pairs that would normally be processed as 'unrelated' are processed as 'related'). As previously mentioned, mean N400 amplitude is lower when word pairs are processed as 'related' compared to 'unrelated.' Therefore, we expect a statistically significant decrease in mean N400 amplitude for unrelated word pairs after exposure to a meaning threat due to affirmation of a novel

framework. This would be a significant contribution to MMM research since it would give physiological markers of fluid compensation. Another advantage to using the EEG method is that it allowed the measurement of ACC activation levels using a source localization approach. Per the previously mentioned literature, ACC activation should increase following a meaning threat compared to control conditions (no meaning threat). Since increased ACC activation in the wake of a meaning threat is one of the only neurophysiological hypotheses in the MMM literature, it would no doubt be an invaluable contribution to the field.

METHODS

Participants

Participants were recruited from the research pool at Middle Tennessee State University. A total of 31 students participated in this study, however 7 were excluded due to technical errors and 1 was excluded due to having an excessively short reaction time to the sematic relatedness task (greater than two standard deviations). This resulted in a total of 11 participants in the control group and 12 participants in the treatment group (n = 23). All participants were right-handed and native English speakers. The control condition contained 6 females and 5 males (M_{age} = 19.64 , SD_{age} = 2.01) and the treatment condition contained 4 females and 8 males (M_{age} = 23.00 , SD_{age} = 5.67).The study was approved by the Middle Tennessee State University Institutional Review Board and informed consent was obtained from all participants prior to any testing. See Appendix A for Informed Consent form and Appendix D for IRB approval. The participants received class credit as compensation.

Materials

Four questionnaires were used in this study: the Personal Need for Structure Scale (PNS), the Schizotypal Personality Questionnaire – Brief (SPQ-B), Beck Anxiety Inventory (BAI), and the Big Five Inventory (BFI). All questionnaires were part of a study running parallel to this one and were not included in any analyses or to answer any research questions in this study.

The short story ‘The Country Dentist’ was used to induce meaning threat in the treatment condition. The story is a modified version of ‘The Country Doctor’ by Franz Kafka and was obtained from the materials provided by Proulx and Heine (2009). As an example of the differences between the two texts, ‘The Country Dentist’ begins with “I was in great perplexity,” and the modified text begins with “I was becoming extremely worried.” Kafka’s absurdist writings have been used in several meaning threat studies (Proulx & Heine 2009; Proulx et al., 2010; Rovenpor et al., 2015; Webber et al., 2016) and was chosen precisely for this reason.

Word pairs were created for the semantic relatedness task in accordance with Francis and Kucera (1982). To ensure the words in the related and unrelated conditions did not differ by frequency of use, the log HAL WF procedure was used. The analysis showed that the related pairs (M = 9.237, SD = 1.427) did not differ significantly in word frequency than the unrelated pairs (M = 9.009, SD = 1.374), $t(278) = 1.357$, $p = .176$. A latent semantic analysis was used to validate the pairings of words as being either related or unrelated. The results indicated that our pairings were in fact correctly identified as ‘related’ (M = 0.467, SD = 0.180) and ‘unrelated’ (M = 0.072, SD = 0.061), $t(134) = 16.880$, $p < .001$. The pairs were all monosyllabic and singular.

Procedure

The participants were first given the BFI, SPQ-B, BAI and the PNS with the order of presentation randomized for all participants. After the completion of these surveys, the EEG net was applied and participants were taken to a soundproof testing room. Participants were given a training session of 10 unique word pairs not used in the pre-test

and post-test in order to familiarize them with the procedure. They were prompted to determine if the word pairs were related or unrelated and given visual feedback if they answered too slowly or incorrectly. Participants were then instructed to evaluate pairs of words presented on a computer screen as being either related or unrelated. This was achieved by the pressing of a button on a device placed under the hand, with the order of the buttons (e.g. 1 = 'related', 2 = 'unrelated') counter-balanced between all participants. At the start of every trial, black Xs were displayed on the screen for the participants to have time to blink and prepare for the next trial. A black eye fixation cross was presented for 1000 ms before each word pair. The pairs consisted of the first word presented for 300 ms followed by the second for an additional 300 ms. A blank screen was displayed for 400 ms between each trial. After completing the semantic pairs task (34 word pairs), participants were given either 'The Country Dentist' (Treatment Group) or a control story (Control Group) and instructed to verbally notify the experimenter after reading it. Story completion times were also recorded for each group: Control ($M_{seconds}$ = 337.27, $SD_{seconds}$ = 109.75), Treatment ($M_{seconds}$ = 517.33, $SD_{seconds}$ = 160.66).The participants then completed a second sematic pairs task (a separate set of 34 word pairs) with the same instructions as previously mentioned. Word pair lists were counterbalanced for the participants. Immediately afterwards, the participants were once again given the PNS. After completing the PNS for the second time, participants were taken to an adjacent room and were photographed using the Geodesic Photogrammerty System. This photo was of the participants head with the EEG net on to be used for the source localization analysis. E-Prime software was used to program the presentation of the word pairs.

EEG was recorded continuously from 128 Ag/AgCl electrodes embedded in sponges in a Hydrocel Geodesic Sensor Net (EGI, Eugene, OR, USA) placed on the scalp with Cz at the vertex, connected to a NetAmps 300 high-impedance amplifier, using a MacBook Pro computer. (See Appendix C for the electrode layout on the scalp.) The sampling rate of the EEG acquisition was 500Hz, and impedances were kept below 50 kΩ. Data were referenced online to Cz, but later re-referenced offline to the average of the left and right mastoid electrodes. The vertical and horizontal electrooculograms (EOG) were also recorded in order to detect the blinks and eye movements. EEG preprocessing was carried out with NetStation Viewer and Waveform tools (EGI, Eugene, OR, USA). The EEG was filtered offline with a bandpass of 0.1 to 20 Hz. Epochs lasting 100 ms before and up to 1000 ms after the onset of the target word was extracted from the continuous EEG data. Trials contaminated by artifacts (e.g., eye movements, blinks, amplifier saturation, electrode drifting or muscle activity) or incorrect answers were excluded from further analysis. The ERPs were computed by averaging the remaining epochs for each participant, condition, and electrode site, relative to a 100 ms pre-stimulus baseline.

All statistical analyses performed on the ERPs utilized Matlab (The Mathworks, Natick, MA) and the Fieldtrip toolbox which uses a cluster-based permutation method (Oostenveld, Fries, Maris, & Schoffelen, 2011). This data analysis method provides temporal and spatial localization without the need of latency ranges or regions of interest (ROIs) *a priori* (Maris & Oostenveld, 2007), while controlling for the family-wise error rate. The average pre-test N400 amplitude was compared between the two groups (treatment and control). This comparison was conducted to ensure that there were no

initial significant differences between the groups. Comparisons were also made within groups between pre- and post-test N400 amplitude. This was done for two primary reasons: to examine whether the treatment had an effect on N400 amplitude and to ensure that the control story did not have a similar effect. For the primary hypothesis of this study, post-test N400 amplitude was compared between groups.

ACC activation levels were estimated using the sLORETA method outlined in Pascual-Marqui, Michel, and Lehmann (1994). Both left and right estimated ACC activation levels were used to test the hypothesis that participants in the treatment condition should have higher ACC activation levels compared to the control condition. After the activation levels were estimated, Excel was used to conduct a simple Welch t-test between the treatment and control groups.

RESULTS

ERP Data

A familywise alpha of .05 was used for all ERP analyses.

Pre-test

The cluster-based permutation analysis found that participants in the control condition had marginally significant differences in mean N400 amplitude between semantically related and unrelated word pairs, $p = .059$. Semantically unrelated words were found to have an increased negativity between 390 and 518 ms after the onset of the stimulus, see Figure 1 for spatial and temporal differences in mean N400 amplitude. Significant differences in mean N400 amplitude were found between semantically related and unrelated words for participants in the treatment condition, $p = .002$. Semantically unrelated words were found to have an increased negativity between 340 and 646 ms after the onset of the stimulus, see Figure 2 for spatial and temporal differences in mean N400 amplitude. There were no significant differences between the mean N400 amplitude between the control and treatment groups, $p = .174$.

Post-test

Control participants were found to have significant mean N400 amplitude differences between semantically related and unrelated word pairs ($p < .001$) with increased negativity for semantically unrelated words between 258 and 614 ms after the onset of the stimulus. See Figure 3 for spatial and temporal differences in N400 amplitude. Participants in the treatment condition were also found to have significant

differences in mean N400 amplitude between semantically related and unrelated word pairs ($p < .001$) with an increased negativity for semantically unrelated words between 364 and 700 ms after the onset of the stimulus. See Figure 4 for spatial and temporal differences in N400 amplitude. There were no significant differences in mean N400 amplitude between the control and treatment groups, $p = .167$.

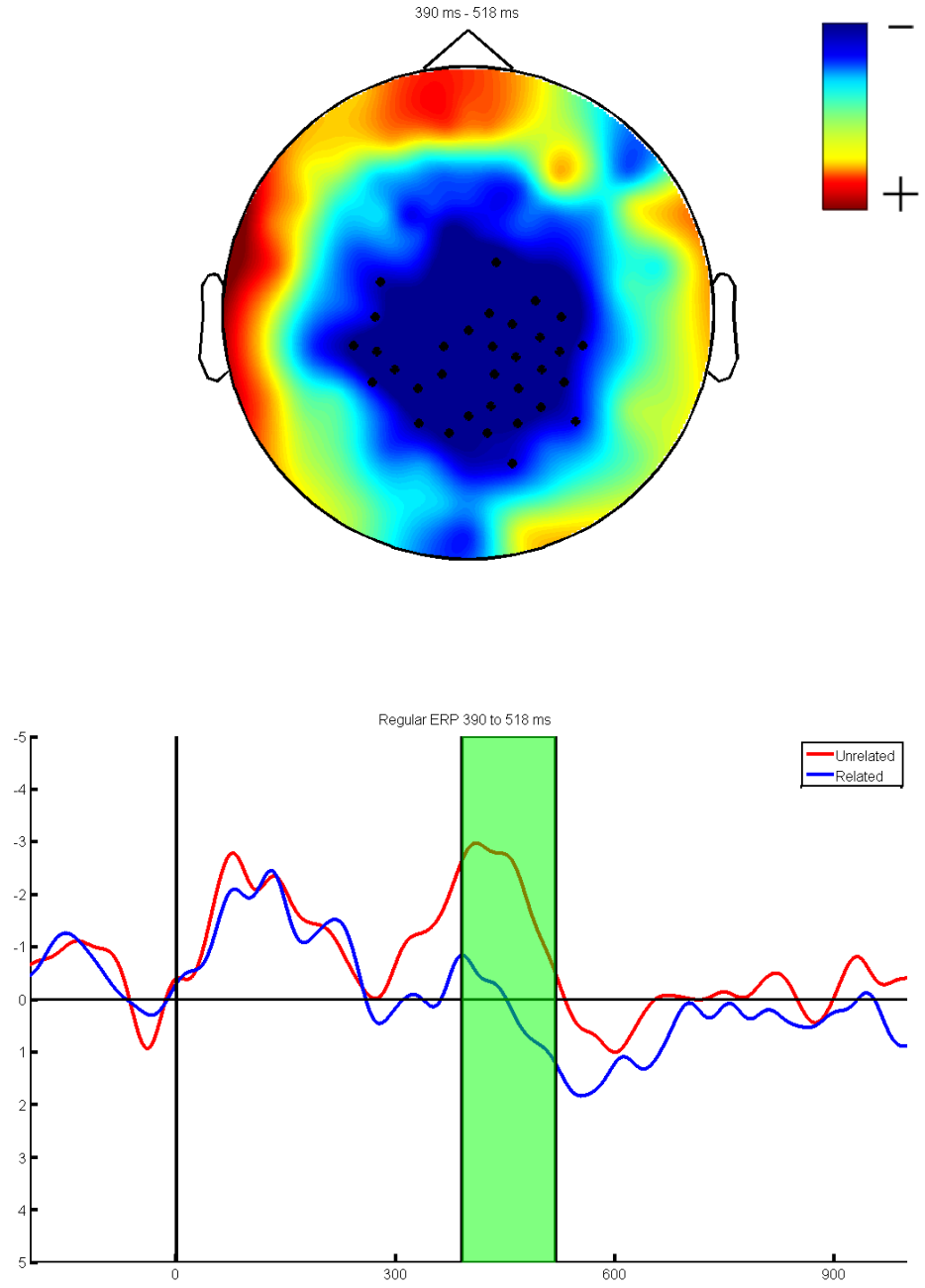


Figure 1. Pre-Test control ERP results. The topographic map in the top panel shows the mean difference in scalp amplitudes in the latency range of the marginally significant negative cluster of the control pre-test group. The electrodes in the EEG net that were included in the negative cluster are indicated by a black dot. The lower panel shows the mean waveforms for the semantically related and unrelated word pairs. The green rectangle indicates the latency range in which the negative cluster was marginally significant.

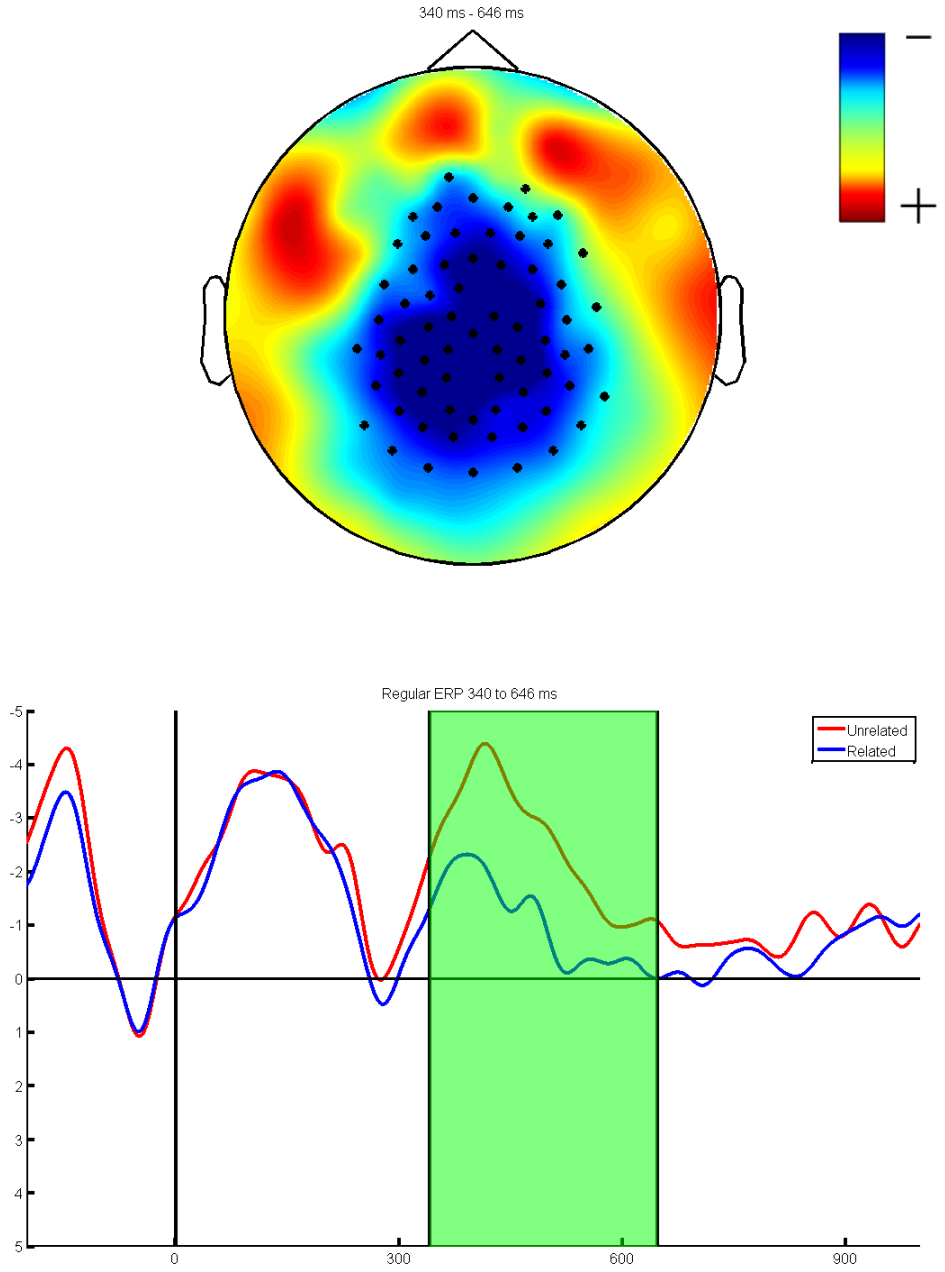


Figure 2. Pre-Test treatment ERP results. The topographic map in the top panel shows the mean difference in scalp amplitudes in the latency range of the significant negative cluster of the treatment pre-test group. The electrodes in the EEG net that were included in the negative cluster are indicated by a black dot. The lower panel shows the mean waveforms for the semantically related and unrelated word pairs. The green rectangle indicates the latency range in which the negative cluster was significant.

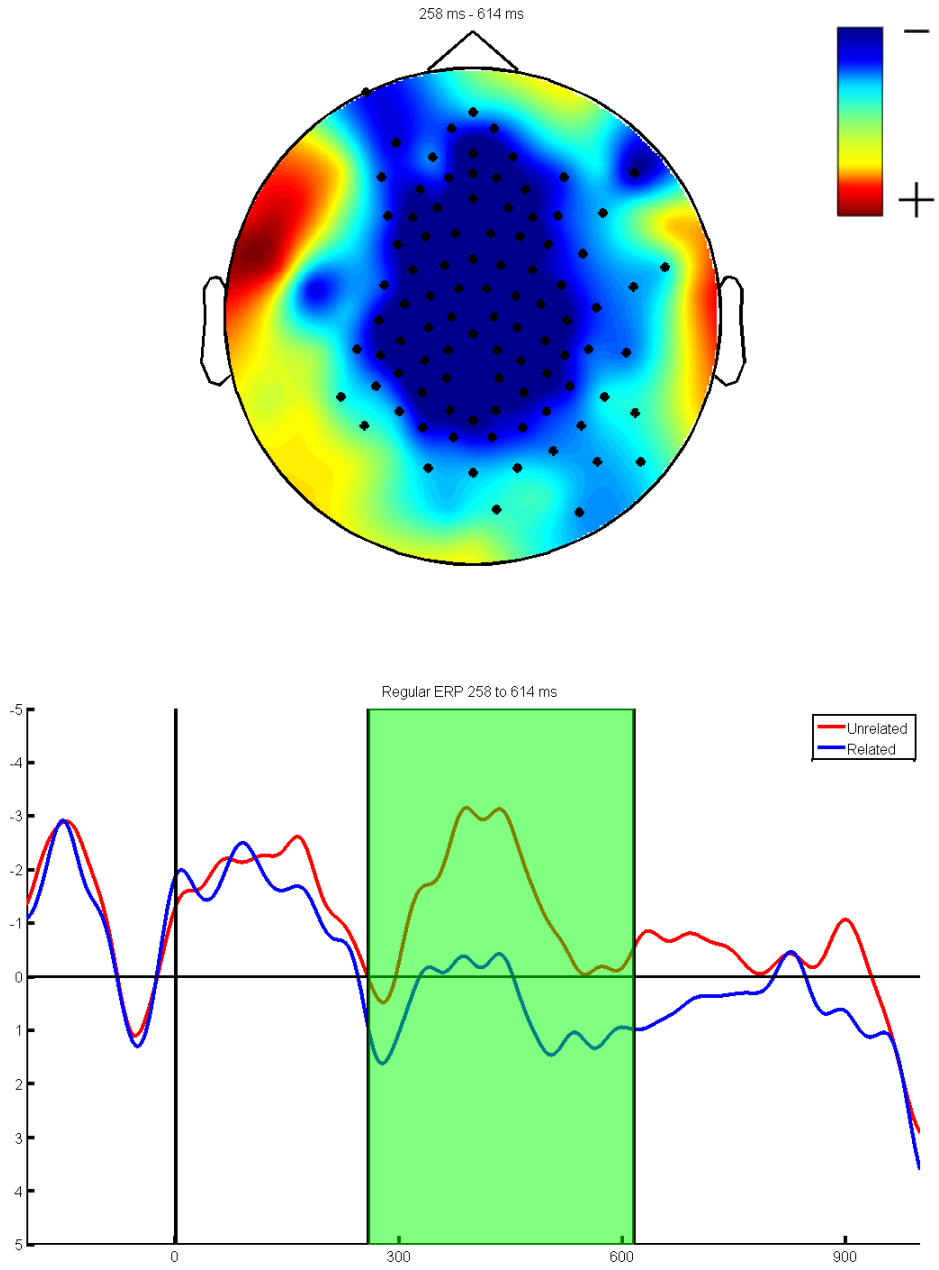


Figure 3. Post-Test control ERP results. The topographic map in the top panel shows the mean difference in scalp amplitudes in the latency range of the significant negative cluster of the control post-test group. The electrodes in the EEG net that were included in the negative cluster are indicated by a black dot. The lower panel shows the mean waveforms for the semantically related and unrelated word pairs. The green rectangle indicates the latency range in which the negative cluster was significant.

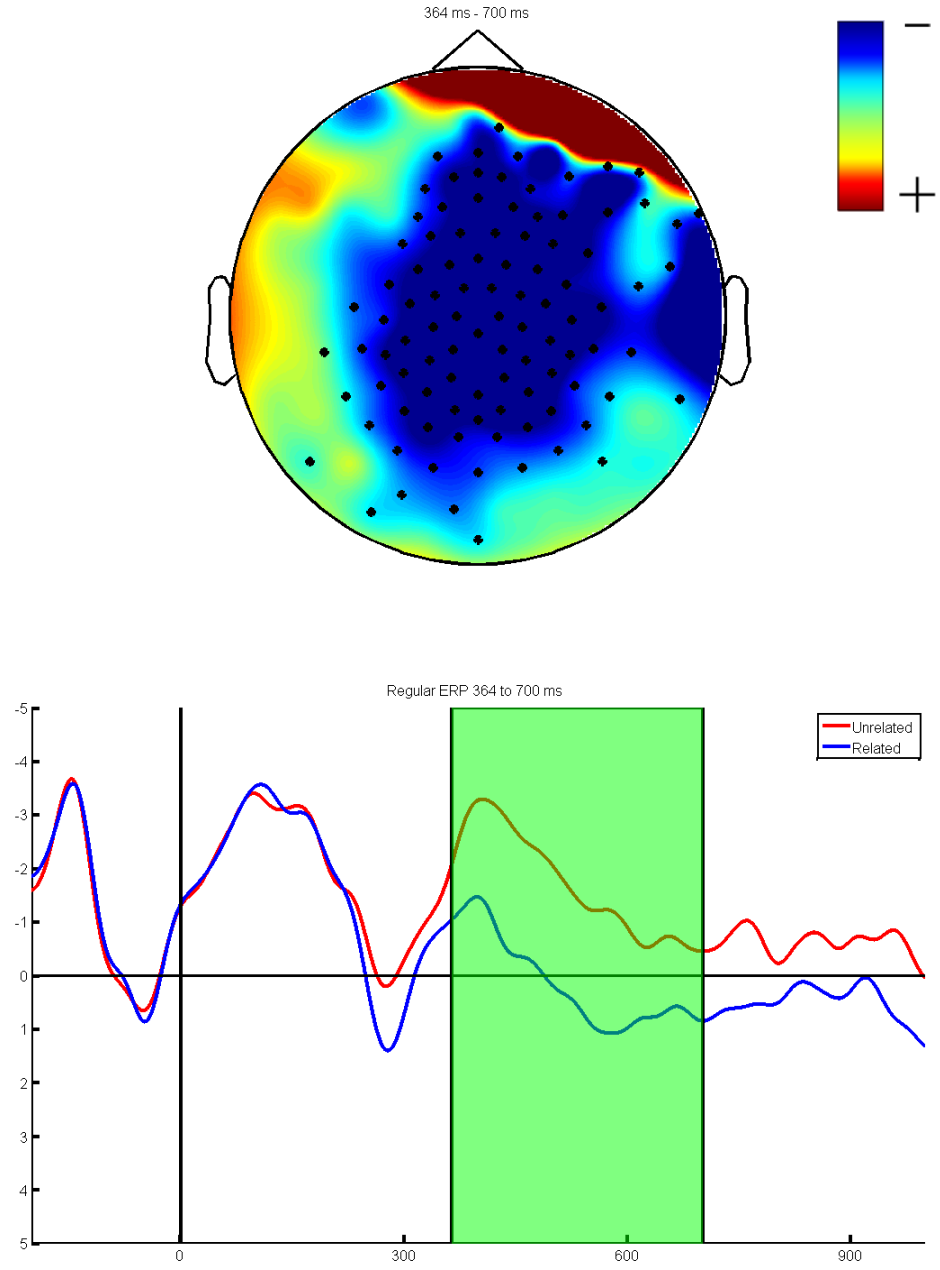


Figure 4. Post-Test treatment ERP results. The topographic map in the top panel shows the mean difference in scalp amplitudes in the latency range of the significant negative cluster of the treatment post-test group. The electrodes in the EEG net that were included in the negative cluster are indicated by a black dot. The lower panel shows the mean waveforms for the semantically related and unrelated word pairs. The green rectangle indicates the latency range in which the negative cluster was significant.

Source Localization

Due to uneven and low sample sizes, Welch t-tests ($\alpha = .05$) were conducted on the right and left ACC activation levels between the control and treatment groups for the pre-test and post-test conditions. See Figure 5 for pre-test estimated ACC activation levels and Figure 6 for post-test estimated ACC activation levels. There were no significant differences in left ACC activation between the pre-test control ($M = 0.425$, $SD = 0.155$) and treatment ($M = 0.422$, $SD = 0.113$) groups, $t(16.0) = 0.066$, $p = .474$, and the post-test control ($M = 0.439$, $SD = 0.140$) and treatment ($M = 0.434$, $SD = 0.240$) groups, $t(19.9) = 0.074$, $p = .471$. There were also no significant differences in the right ACC activation levels between the pre-test control ($M = 0.697$, $SD = 0.153$) and treatment ($M = 0.679$, $SD = 0.115$) groups, $t(16.6) = 0.225$, $p = .412$, and the post-test control ($M = 0.663$, $SD = 0.213$) and treatment ($M = 0.718$, $SD = 0.253$) groups, $t(20.8) = -0.590$, $p = .27$.

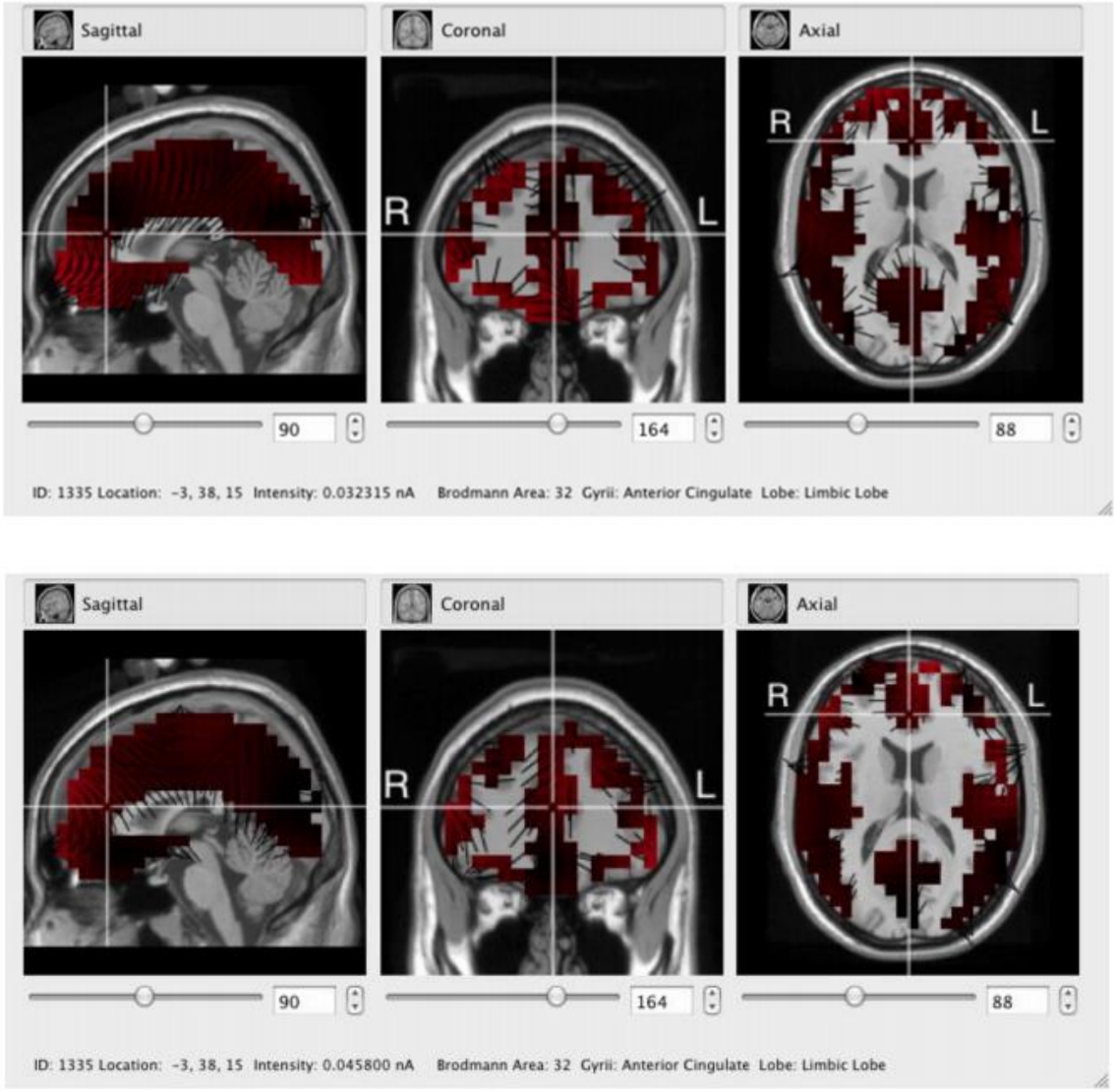


Figure 5. Pre-Test ACC activation levels. The top panel shows the estimated ACC activation levels for the pre-test control group. The black lines indicate the estimated direction and magnitude of the electrical vector field. Brighter areas indicate increased activation while dark areas indicate decreased activation. The bottom panel shows the estimated ACC activation levels for the pre-test treatment group.

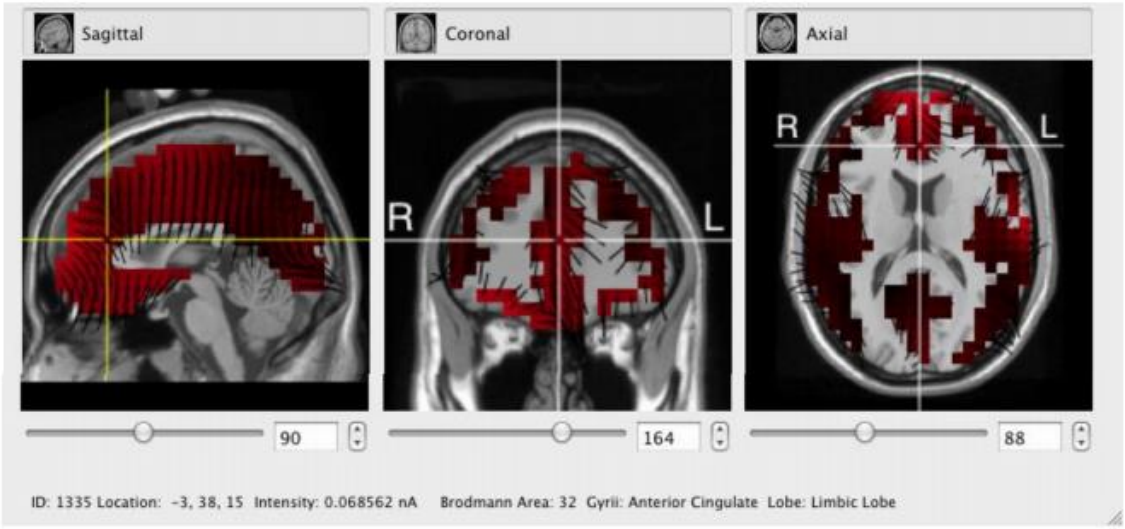


Figure 6. Post-Test ACC activation levels. The top panel shows the estimated ACC activation levels for the post-test control group. The black lines indicate the estimated direction and magnitude of the electrical vector field. Brighter areas indicate increased activation while dark areas indicate decreased activation. The bottom panel shows the estimated ACC activation levels for the post-test treatment group.

CONCLUSIONS

Effect of Meaning Threat on N400 Amplitude

The hypothesis that participants who read ‘The Country Dentist’ would have a lower mean N400 was not supported since there was no statistically significant difference in mean N400 between control and treatment participants in the post-test. While this finding is straightforward to report, the interpretation is a little more challenging. Two factors that contribute to the complexity of interpretation are an experimental limitation and a technical limitation of this study. Experimentally, the nature of the word list chosen for this study may have affected the participants’ processing of the ‘related’ and ‘unrelated’ word pairs. Care was taken to ensure that the ‘related’ word pairs were indeed related to one another and the ‘unrelated’ word pairs were not related to each other, but this may have resulted in an experimental confound. It is possible the ‘unrelated’ words were so unrelated that even the exposure to ‘The Country Dentist’ could not significantly influence the processing of these word pairs. Future research should use word pairs that are less extreme in their relatedness or unrelatedness.

The technical limitation in this study was the presence of a second training session before the presentation of the second word pair list. This training session was exactly identical to the original training session of the word pairs and was due to a scripting error in E-Prime. After reading either the control or treatment story, participants were given the same list of word pairs from the initial training session and prompted to decide if the word pairs were related or unrelated. Unlike the evaluation of the word pairs during EEG recording, participants were given visual feedback in the training session

after deciding ‘related’ or ‘unrelated’ (e.g., indicating ‘related’ on an unrelated word pair would result in ‘Incorrect’ appearing on the screen). While this training session was appropriate before the pre-test EEG recording, it may have resolved any meaning threat that the participants had by reaffirming their previous meaning frameworks (i.e., they were shown that words they previously thought were related are in fact related and vice versa).

However, several MMM studies have included filler tasks after the meaning threat exposure that would have the same possible effects that the second training session did. Randles, Heine, and Santos (2013, p. 968) reported that after giving participants in a meaning threat condition a dose of acetaminophen, the participants were asked to complete “a page of Sudoku puzzles, a memory task involving matching faces of individuals to their biographies, and a series of personality questionnaires…” Proulx, Heine, and Vohs (2010, p.821) reported that participants were given a filler task after reading ‘An Imperial Message’ that asked them to sort “…objects according to their relative usefulness on a camping trip.” Both of these studies reported positive results of the effects of the meaning threat used yet these filler tasks could be seen as possible resolvers of meaning threat. According to Heine et. al (2006) meaning threats can result in the affirmation of alternative meaning frameworks and as was previously reported, these affirmations have been found in cultural and national frameworks. Could not the personality questionnaires used in Randles et. al (2013) also be seen as an affirmation of one’s own personal identity? Additionally, the sorting task in Proulx et. al (2010) required the participants to make judgements on the functionality of objects for a

camping trip; a task that could be influenced by the novel connections expected from the meaning threat.

Both of these studies involved a filler task that could conceivably influence the resolution of the meaning threat used, but both studies reported positive effects. However, the training session actively suppressed the participants finding novel connections in the training word pairs, which was the exact task that was used to measure the effects of meaning threat. While the previously mentioned filler tasks found in the literature may or may not have also affected the levels of meaning threat that were measured, the training session in this task almost assuredly did. Any follow-up to this study must ensure that there is no unintentional extra training session after the subjects have been exposed to the meaning threat manipulation.

Effect of Meaning Threat on ACC Activation

The hypothesis that ACC activation would be higher in the treatment participants compared to the control participants was not supported. This finding appears to be a clear refutation of the MMM literature which has predicted, as previously mentioned, that ACC activation levels should be higher when in a meaning threat state. Since activation levels were recorded after reading the ‘Country Dentist’ however, future studies should record ACC activity during the exposure to the meaning threat to have more confidence in this finding. Sample size was another issue in this analysis and future research should have a larger number of participants to reduce the possibility of a Type II error.

General Discussion

The MMM literature has made broad claims in its explanatory power of how meaning is maintained and the effects of violations in meaning. It has its roots in existential philosophy and has had a decade of research in cognitive psychology to support it, yet it has been unable to test the specific hypothesis of increased ACC activation in a meaning threat state and explain the neurological basis of fluid compensation. While this study does not claim to definitively answer either of these questions, neither hypothesis based on MMM research was supported in this study. Diehard defenders of MMM may point to the few technical or design flaws of this study as the culprit behind these conclusions, but to criticize for those reasons would result in implicit criticism for previous MMM research. Did the second training session result in the effects of meaning threat to be resolved? If so, why did ten word pairs do what personality questionnaires and sorting objects by function supposedly did not? Did recording ACC activation levels after reading 'The Country Dentist' instead of during reading confound our results (i.e., ACC level went back to 'normal' between the reading the story and the start of the post-test)? The average reading time for 'The Country Dentist' was just under eight and a half minutes. In Proulx and Heine (2008) participants were given five minutes to write down brand names of cars after meaning threat exposure; the results of the study were in support of the participants being in a meaning threat state even after the 5-minute task. What happened in the three and a half minutes difference between this study and Proulx and Heine (2008) that caused the ACC activation levels to go down?

While this is the first study aware to the author to experimentally fail to find results in support of the effects of meaning threat, there is a body of literature that has expressed concern over the claims of the MMM. Gawronski (2012) points out that MMM fails to provide a distinction between meaning violations and meaninglessness; one would be the violation of a belief system while the later would be the absence of such a system. Is a meaning threat salient when it lacks any meaning whatsoever, or must it be directly threatening to the belief system of the individual? Once meaning is threatened, MMM predicts 'compensatory behaviors' will occur in response to the meaning threat. Galinsky, Whitson, Huang, and Rucker (2012, p. 343) ask if these compensatory behaviors are "…linked more to the defense of existing worldviews or the creation of new worldviews." As previously noted, MMM states that if there are no alternative frameworks to affirm in response to a meaning threat, novel frameworks are created. However, MMM does not provide a clear definition of when an alternative framework is no longer affirmable. Galinksky et. al (2012) also proposes that there is likely a hierarchy of strategies used by people when confronted with a meaning threat.

MMM aims to broadly explain how our meaning is maintained and what happens when our meaning frameworks are violated, but this broadness may be seen as a weakness. Routledge and Vess (2012) argue that even though many lab studies have shown the effects of meaning threat, the meaning threats used were so varied (e.g., playing cards, absurdist literature and films, unconsciously switched experimenters) that MMM is throwing several distinct phenomena under one cognitive model. Conversely, Moser and Schroder (2012) ask if the 'meaning' in MMM is actually just expectation and that meaning threats are in fact a type of expectation violation. They argue that if this is

the case, MMM should use the term ‘expectation’ instead of ‘meaning’ for the sake of parsimony. When assuming that meaning is actually expectation, a similar model has been proposed that aims to explain how we form expectations of the world and when do we know we should change our expectations. The predictive processing model (PPM) (Lupyan & Clark, 2015) proposes that higher-level cognitive constructs are formed to reduce the prediction error we encounter in the world and we can change the expectations of these constructs when they are shown to be significantly incorrect. Unlike MMM, the claims of PPM are more generalized to language and argues that language allows us to internally change our expectations of future events when our expectations are violated. Future research should experimentally compare the hypotheses put forward by adherents of the MMM and the PPM to examine if the two models are actually one in the same, or if one model is superior to the other in explanatory and experimental power.

REFERENCES

Festinger, L. (1957). *A theory of Cognitive Dissonance*. Stanford, CA: Stanford University Press.

Francis, W. N., Kucera, H. (1982). *Frequency analysis of English usage*. Boston, MA: Houghton Mifflin.

Freud, S., Strachey, J., Freud, A., Strachey, A., Tyson, A. (1955). *The standard edition of the complete psychological works of Sigmund Freud, volume XVII (1917-1919): An infantile neurosis and other works*. London, UK: The Hogarth Press.

Galinsky, A., D., Whitson, J., A., Huang, L., & Rucker, D., D. (2012). Not So Fluid and Not So Meaningful: Toward an Appreciation of Content-Specific Compensation. *Psychological Inquiry, 23*(4), 339-345. doi : 10.1080/1047840X.2012.730978

Gawronski, B. (2012). Meaning, violation of meaning, and meaningless in meaning maintenance. *Psychological Inquiry, 23*, 346-349. doi: 10.1080/1047840X.2012.706507

Heine, S., Proulx, T., & Vohs, K. (2006). The Meaning Maintenance Model: On the coherence of social motivations. *Personality and Social Psychology Review, 10*(2), 88-110.

Holroyd, C., & Umemoto, A. (2016). The research domain criteria framework: The case for anterior cingulate cortex. *Neuroscience and Biobehavioral Reviews, 71*, 418-443. doi: 10.1016/j.neubiorev.2016.09.021

Kutas, M., & Federmeier, K. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Cell, 4*(12), 463-470. doi: 10.1016/S1364-6613(00)01560-6

Kutas, M., & Federmeier, K. (2011). Thirty years and counting: Finding meaning in the N400 component of the event related brain potential (ERP). *Annual Review of Psychology, 62*, 621-647. doi: 10.1146/annurev.psych.093008.131123

Lupyan, G., & Clark, A. (2015). Words and the world: Predictive coding and the Language-Perception-Cognition Interface. *Current Directions in Psychological Science, 24*(4), 279-284. doi: 10.1177/0963721415570732

Mara, M., & Appel, M. (2015). Science fiction reduces the eeriness of android robots: A field experiment. *Computers in Human Behavior, 48*, 156-162. doi: 10.1016/j.chb.2015.01.007

Maris, E., Oostenveld, R. (2007). Nonparametric statistical testing of EEG- and MEG-data. *Journal of Neuroscience Methods, 164*(1), 177-190. doi: 10.1016/j.jneumeth.2007.03.024

Mori, M. (2012). The uncanny valley. *IEEE Robotics & Automation Magazine*. doi: 10.1109/MRA.2012.2192811

Moser, J., S., & Schroder, H., S. (2012). Making sense of it all? Cognitive and behavioral mechanisms needing clarification in the meaning maintenance model. *Psychological Inquiry, 23*, 367-373. doi: 10.1080/1047840X.2012.721338.

Oostenveld, R., Fries, P., Maris, E., & Schoffelen, J.,M. (2011). FieldTrip: Open source software for advanced analysis of MEG, EEG, and invasive electrophysiological data. *Computational Intelligence and Neuroscience*. *2011,* 1-9. doi: 10.1155/2011/156869

Proulx, T., & Heine, S. (2006). Death and black diamonds: Meaning, mortality, and the Meaning Maintenance Model. *Psychological Inquiry, 17*(4), 309-318. doi: 10.1080/10478400701366985

Proulx, T., & Heine, S. (2008). The case of the transmogrifying experimenter. *Psychological Science, 19*(12), 1294-1300. doi: 10.1111/j.1467-9280.2008.02238.x

Proulx, T., & Heine, S. (2009). Connections from Kafka: Exposure to meaning threats improves implicit learning of an artificial grammar. *Psychological Science, 20*(9), 1125-1131. doi: 10.1111/j.1467-9280.2009.02414.x

Proulx, T., & Heine, S. (2010). The frog in Kierkegaard's beer: Finding meaning in the Threat-Compensation literature. *Social and Personality Psychology Compass, 4*(10), 889-905. doi: 10.1111/j.1751-9004.2010.00304.x

Proulx, T., & Inzlicht, M. (2012)a. Moderated Disanxiousuncertlibrium: Specifying the moderating and neuroaffective determinants of violation-compensation effects. *Psychological Inquiry, 23*, 386-396. doi: 10.1080/1047840X.2012.734912

Proulx, T., & Inzlicht, M. (2012)b. The five “A”s of meaning maintenance: Finding meaning in the theories of sense-making. *Psychological Inquiry, 23,* 317-335. doi: 10.1080/1047840X.2012.702372

Proulx, T., & Major, B. (2013). A raw deal: Heightened liberalism following exposure to anomalous playing cards. *Journal of Social Issues, 69*(3), 455-472. doi: 10.1111/josi.12024

Proulx, T., Heine, S., & Vohs, K. (2010). When is the unfamiliar the uncanny? Meaning affirmation after exposure to absurdist literature, humor, and art. *Personality and Social Psychology Bulletin, 36*(8), 817-829. doi: 10.1177/0146167210369896

Randles, D., Heine, S., & Santos, N. (2013). The common pain of surrealism and death: Acetaminophen reduces compensatory affirmation following meaning threats. *Psychological Science, 24*(6), 966-973. doi: 10.1177/0956797612464786

Randles, D., Proulx, T., & Heine, S. (2011). Turn-frogs and careful-sweaters: Non-conscious perception of incongruous word pairings provokes fluid compensation. *Journal of Experimental Social Psychology, 47,* 246-249. doi: 10.1016/j.jesp.2010.07.020

Randles, D., Inzlicht, M., Proulx, T., Tullett, A., & Heine, S. (2015). Is dissonance reduction a special case of fluid compensation? Evidence that dissonant cognitions cause compensatory affirmation and abstraction. *Journal of Personality and Social Psychology, 108*(5), 697-710. doi: 10.1037/a0038933

Routledge, C., & Vess, M. (2012). More than meets the eye: There's more to meaning maintenance than violated expectations. *Psychological Inquiry, 23,* 374-380. doi: 10.1080/1047840X.2012.721078

Rovenpor, D., Leidner, B., Kardos, P., & O'Brien, T. (2015). Meaning threat can promote peaceful, not only military-based approaches to intergroup conflict: The moderating role of ingroup glorification. *EJSP, 46*(5), 544-562. doi: 10.1002/ejsp.2183

Tullet, A., Teper, R., & Inzlicht, M. (2011). Confronting threats to meaning: A new framework for understanding responses to unsettling events. *Perspectives on Psychological Science, 6*(5), 447-453. doi: 10.1177/1745691611414588

Webber, D., Zhang, R., Schimel, J., & Blatter, J. (2016). Finding death in meaninglessness: Evidence that death-thought accessibility increases in response to meaning threats. *British Journal of Social Psychology, 55,* 144-161. doi: 10.1111/bjso.12118

APPENDICES

APPENDIX A: Consent Form

Principal Investigator: Micah D'Archangel
Study Title: A neurophysiological investigation of short stories and words
Institution: Middle Tennessee State University

Name of participant: _____ Age: _____

The following information is provided to inform you about the research project and your participation in it. Please read this form carefully and feel free to ask any questions you may have about this study and the information given below. You will be given an opportunity to ask questions, and your questions will be answered. Also, you will be given a copy of this consent form.

Your participation in this research study is voluntary. You are also free to withdraw from this study at any time. In the event new information becomes available that may affect the risks or benefits associated with this research study or your willingness to participate in it, you will be notified so that you can make an informed decision whether or not to continue your participation in this study.

For additional information about giving consent or your rights as a participant in this study, please feel free to contact the MTSU Office of Compliance at (615) 494-8918.

1. **Purpose of the study:**
   You are being asked to participate in a research study because we are interested in how the brain processes short stories and words.

2. **Description of procedures to be followed and approximate duration of the study:**
   You will be asked to complete three tasks. First, you will be asked to answer a short questionnaire (99 questions) and then you will read word pairs and judge whether they are related or unrelated. Next you will read a short story (8 pages). Next, you will read word pairs and judge whether they are related or unrelated again. Your brain's electrical activity will be measured during this study. A cap containing electrodes will be placed on your head while you read the stories and judge the words, so your total time commitment will be about two hours. The actual story, questionnaire, and word portion of the study should take about one hour.

3. **Expected costs:**
   There are no expected costs associated with this study.

4. **Description of the discomforts, inconveniences, and/or risks that can be reasonably expected as a result of participation in this study:**

You will have to sit still for 10 to 20 minutes at a time, which may be tiring or annoying. Your hair may be a little wet at the end of the session from the EEG cap. We will provide you a hair dryer and towel for your convenience.

5. **Anticipated benefits from this study:**
   a) The potential benefits to science and humankind that may result from this study are a better understanding of how the brain processes short stories and words.
   b) The potential benefits to you from this study are a better understanding of what psychological research entails. You will not receive a direct benefit from participating in this study.

6. **Alternative treatments available:**
   You may choose not to participate in this study.

7. **Compensation for participation:**
   You may be eligible to receive extra credit for participating in this study.

8. **Circumstances under which the Principal Investigator may withdraw you from study participation:**
   You may be withdrawn from the study if you do not wish to continue.

9. **What happens if you choose to withdraw from study participation:**
   You may choose to withdraw at anytime without penalty.

10. **Contact Information.** If you should have any questions about this research study or possible injury, please feel free to contact **Dr. William Langston** at **615-898-5489 or Micah D'Archangel at 931-209-3659.**

11. **Confidentiality.** All efforts, within reason, will be made to keep the personal information in your research record private but total privacy cannot be promised. Your information may be shared with MTSU or the government, such as the Middle Tennessee State University Institutional Review Board, Federal Government Office for Human Research Protections or if you or someone else is in danger or if we are required to do so by law.

12. **ACT Scores Request.** By agreeing to participate in this study, you are also agreeing to allow researchers access to your Reading ACT and English ACT scores. Your name will be used to access your scores, but your name will not be associated with them once they are acquired. If you agree to allow access to these scores, please initial here _____.

13. **STATEMENT BY PERSON AGREEING TO PARTICIPATE IN THIS STUDY**

I have read this informed consent document and the material contained in it has been explained to me verbally. I understand each part of the document, all my questions have been answered, and I freely and voluntarily choose to participate in this study.

_____ _____

Date Signature of patient/volunteer

_____ _____

Email MTSU ID (M#)

Consent obtained by:

_____ _____

Date Signature

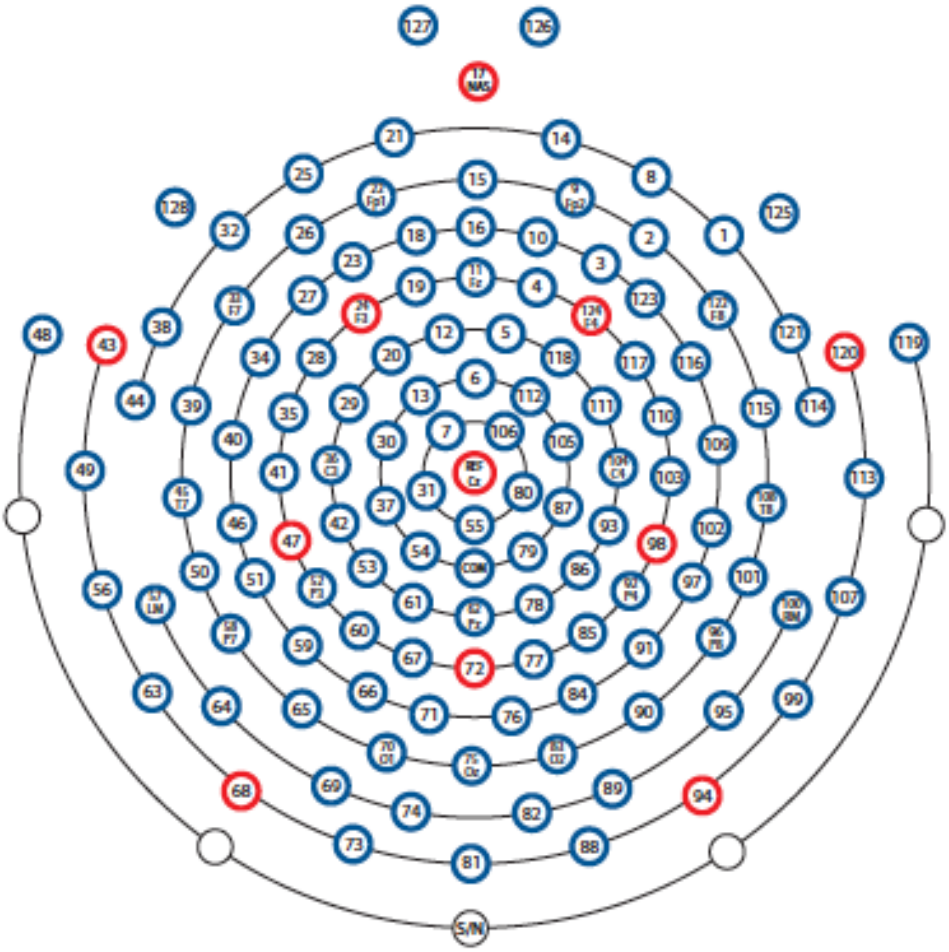
_____

Printed Name and Title

APPENDIX B: Word List

RELATED					UNRELATED							
WORD1	WORD2	LSA VALUE			WORD1	WORD2	LSA VALUE					
											Related	Unrelated
BULL	COW	0.21	31.68	SUM	WITCH	EGG	0.02	4.9	SUM		0.06	0
GOOSE	DUCK	0.49	0.46588235	AVG	ROSE	BRAIN	0.05	0.07205882	AVG		0.15	0
OWL	HAWK	0.35	0.18	SD	CROW	TRAY	0.02	0.0612	SD		0.18	0
MOUSE	RAT	0.54			WATER	JUDGE	0.03				0.19	0
LAMB	SHEEP	0.53			PRINCE	LIMB	0.03				0.19	0
CRAB	SHRIMP	0.4			HORN	CREAM	0.11				0.19	0
TOAD	FROG	0.87			HERB	JET	0.02				0.2	0
COD	TROUT	0.37			MOTH	LOCK	0.03				0.21	0.01
PEA	BEAN	0.36			GRASS	PRIEST	0.06				0.24	0.01
LEMON	LIME	0.33			PIG	BRASS	0.14				0.25	0.02
BARN	SHED	0.63			NUN	FLUTE	0.1				0.27	0.02
TIE	BELT	0.43			NEST	DRUM	0.04				0.28	0.02
PLATE	BOWL	0.39			WOOD	CALF	0.04				0.3	0.02
BROOM	BRUSH	0.3			STORM	GOAT	0.07				0.3	0.02
GOWN	DRESS	0.59			ANT	INN	0.03				0.31	0.03
DOOR	GATE	0.47			ELK	VEIL	0.06				0.32	0.03
CUP	MUG	0.48			ROOM	SNAIL	0.05				0.33	0.03
POT	PAN	0.61			OAK	DOLL	0.1				0.35	0.03
BOLT	SCREW	0.71			TAXI	SNAKE	0.01				0.36	0.03
YACHT	SHIP	0.31			WHEEL	BAND	0.16				0.36	0.03
BLOUSE	SKIRT	0.7			HARP	SHACK	0.1				0.37	0.03
BOOT	SHOE	0.3			SKIS	PEACH	0.04				0.37	0.03
SPEAR	SWORD	0.54			ANCHOR	FILM	0.03				0.38	0.03
FORK	SPOON	0.48			BASE	CAGE	0.06				0.39	0.03
SPRING	FALL	0.58			DIRT	SCARF	0.17				0.4	0.04
ROCK	STONE	0.15			SMOKE	TOY	0.08				0.42	0.04
PIN	TACK	0.19			JOKE	HAND	0.24				0.42	0.04
BUS	TRAIN	0.32			SKUNK	TAPE	0.04				0.42	0.04
TRUCK	VAN	0.25			CHISEL	EEL	0.02				0.43	0.04
DOLPHIN	WHALE	0.64			SOCK	STICK	0.27				0.43	0.05
WALRUS	SEAL	0.37			KEY	FAN	0.09				0.44	0.05
CHERRY	GRAPE	0.19			PINK	FLEA	0.17				0.45	0.05
SOFA	COUCH	0.71			FOX	RAKE	0.11				0.46	0.05
CANOE	RAFT	0.56			FENCE	TANK	0.07				0.47	0.05
WAGON	CART	0.46			DRAIN	BOARD	0.05				0.48	0.06
OVEN	STOVE	0.57			SWAN	WALL	0.01				0.48	0.06
SHOVEL	HOE	0.36			RADIO	SHELL	0.03				0.48	0.06
RED	BLUE	0.69			TABLE	GEL	0.03				0.48	0.06
GRAY	BLACK	0.48			JEANS	SKY	0.1				0.48	0.07
FOOD	DRINK	0.19			OLIVE	DOCK	0.1				0.49	0.07
CHAPEL	CHURCH	0.42			DESK	HOOK	0.16				0.5	0.08
JACKET	COAT	0.6			GLUE	ROBE	0.1				0.53	0.08
RUBY	GEM	0.2			EAGLE	GLASS	0				0.53	0.08
PENCIL	PEN	0.42			DOME	LEAF	0	* = -.01			0.53	0.09
COVER	QUILT	0.18			PEPPER	SIGN	0.09				0.54	0.09
METAL	STEEL	0.48			ZEBRA	HOUR	0.08				0.54	0.09
UNCLE	AUNT	0.82			MATH	RUG	0.11				0.54	0.1
HEEL	TOE	0.67			WASP	GYM	0.05				0.56	0.1
CORD	PLUG	0.06			DONKEY	PURSE	0.09				0.57	0.1
WHEAT	GRAIN	0.72			WIFE	FIELD	0.08				0.57	0.1
HOT	COLD	0.48			LUNCH	SAND	0.12				0.58	0.1
JELLY	JAM	0.44			RAM	COIN	0.05				0.59	0.1
BOY	GIRL	0.53			TIRE	STAGE	0	*= -.02			0.6	0.1
JUICE	MILK	0.42			FLAME	MOUTH	0.2				0.61	0.11
OCEAN	SHORE	0.43			DAWN	GAS	0.03				0.62	0.11
HINT	CLUE	0.24			BRIDGE	TOAST	0.02				0.63	0.11
DAY	NIGHT	0.54			ELBOW	CAMP	0.11				0.64	0.11
DARK	LIGHT	0.57			ATTIC	MAIL	0	* = -.01			0.64	0.12
MOON	SUN	0.28			NOTE	SAW	0.14				0.67	0.14
STAR	SPACE	0.27			HEAD	TEA	0.23				0.69	0.14
PIE	CAKE	0.62			NOON	PILL	0.04				0.7	0.16
HAMMER	NAIL	0.5			LAKE	JAIL	0.03				0.71	0.16
KITE	STRING	0.45			VASE	POND	0	* = -.01			0.71	0.17
WINE	BEER	0.85			ICE	CLOCK	0.06				0.72	0.17
BAT	BALL	0.84			LID	MAP	0	* = -.03			0.82	0.2
FROST	SNOW	0.64			EYE	SONG	0.1				0.84	0.23
CLOUD	RAIN	0.53			ENGINE	HAIR	0				0.85	0.24
RIVER	STREAM	0.38			SCIENCE	YARD	0.03				0.87	0.27

APPENDIX C: Electrode Layout on the Scalp



APPENDIX D: IRB Approval Letter

IRB
INSTITUTIONAL REVIEW BOARD
Office of Research Compliance,

010A Sam Ingram Building,

2269 Middle Tennessee Blvd

Murfreesboro, TN 37129

IRBN001 - EXPEDITED PROTOCOL APPROVAL NOTICE

Friday, January 13, 2017

Investigator(s): Micah D'Archangel (Student PI), William Langston (FA) and Christof Fehrman

Investigator(s') Email(s): mad5s@mtmail.mtsu.edu; william.langston@mtsu.edu

Department: Psychology

Study Title: A neurophysiological investigation of meaning threat

Protocol ID: **17-2109**

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU Institutional Review Board (IRB) through the **EXPEDITED** mechanism under 45 CFR 46.110 and 21 CFR 56.110 within the category *(7) Research on individual or group characteristics or behavior* A summary of the IRB action and other particulars in regard to this protocol application is tabulated as shown below:

IRB Action	APPROVED for one year from the date of this notification
Date of expiration	**1/31/2018**

Participant Size	70 (SEVENTY)	
Participant Pool	**Adult MTSU students**	
Exceptions	NONE	
Restrictions	**Mandatory informed consent**	
Comments	NONE	
Amendments	**Date** xx/xx/xxxx	**Post-approval** **Amendments** NONE

This protocol can be continued for up to THREE years (**1/31/2020**) by obtaining a continuation approval prior to **1/31/2018**. Refer to the following schedule to plan your annual project reports and be aware that you may not receive a separate reminder to complete your continuing reviews. Failure in obtaining an approval for continuation will automatically result in cancellation of this protocol. Moreover, the completion of this study MUST be notified to the Office of Compliance by filing a final report in order to close-out the protocol.

Continuing Review Schedule:

Reporting Period	Requisition Deadline	IRB Comments
First year report	12/31/2017	INCOMPLETE
Second year report	12/31/2018	INCOMPLETE
Final report	12/31/2019	INCOMPLETE

The investigator(s) indicated in this notification should read and abide by all of the post-approval conditions imposed with this approval. Refer to the post-approval guidelines posted in the MTSU IRB's website. Any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918 within 48 hours of the incident. Amendments to this protocol must be approved by the IRB. Inclusion of new researchers must also be approved by the Office of Compliance before they begin to work on the project.

All of the research-related records, which include signed consent forms, investigator information and other documents related to the study, must be retained by the PI or the faculty advisor (if the PI is a student) at the secure location mentioned in the protocol application. The data storage must be maintained for at least three (3) years after study completion. Subsequently, the researcher may destroy the data in a manner that maintains confidentiality and anonymity. IRB reserves the right to modify, change or cancel the terms of this letter without prior notice. Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board

Middle Tennessee State University

Quick Links:

Click here for a detailed list of the post-approval responsibilities. More information on expedited procedures can be found here.