

THE SHARED PSYCHOLOGICAL PROCESS UNDERLYING DIFFERENT FORMS
OF UNCERTAINTY

by

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ABSTRACT

How do people react when their meaningful worldviews are violated? What does it even mean to experience a lack of meaning? Drawing on work from both social and cognitive psychology, I advance two main hypotheses. First, humans employ a single domain-general process for recognizing and interpreting all violations of meaning and unexpected experiences. Second, as a result of this generality, all violations of meaning can trigger responses that have more to do with this broad process than with the specific problem at hand. Eight studies support these predictions from a number of methodological approaches. Experiences as superficially different as cognitive dissonance, mortality salience, and viewing surreal art all motivate people to affirm important beliefs that are not directly relevant to the experience. Acetaminophen, a drug known to inhibit physical pain and feelings of rejection, also prevents this motivation to affirm following meaning violations. In an ERP paradigm, acetaminophen inhibits activation associated with consciously recognizing that a mistake was made. Finally, these effects appear to occur spontaneously during everyday moments and are not restricted solely to artificial laboratory experiments. These findings speak to a broad process for identifying mismatches between one's mental model and reality. Discussion focuses on the implications of this process for studying a range of experiences, including uncertainty, meaning, goal frustration, dissonance, and existential anxiety.

PREFACE

The projects I report here are collaborative works that have benefited greatly by the contribution of my coauthors. Within that context, I am the primary contributor in each case with regards to originating the ideas, as well as much of the study design, analysis, and authorship.

Chapters 1 and 3 are theoretical reviews of my research area, and I am the sole author. Chapter 6 is a discussion of the results presented here, again for which I am the only author. The remaining chapters are manuscripts currently in print or being prepared for publication. In each case I have adapted the manuscript so that it fits the context of this dissertation, and in each case I am the first author.

Chapter 2 is a manuscript currently under review for publication. Author order is Randles, D., Inzlicht, M., Proulx, T., Tullett, A., & Heine, S. J. The research in this chapter was approved by the Behavioural Research Ethics Board of UBC (BREB certificate # H07-02089 and H11-00902).

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Chapters 5 presents collaborative work that will be prepared for publication. I am the originator of the research hypothesis and sole author of the chapter, which will be

converted to manuscripts at a later date. The coauthors of the project in Chapter 5 include Julia Kam, Steven Heine, Michael Inzlicht, and Todd Handy. This research was approved by the Clinical Research Ethics Board of UBC (CREB certificate #H04-70161).

TABLE OF CONTENTS

| | |
|---|-----------|
| ABSTRACT..... | ii |
| PREFACE..... | iii |
| TABLE OF CONTENTS..... | v |
| LIST OF TABLES..... | vii |
| LIST OF FIGURES..... | viii |
| ACKNOWLEDGEMENTS..... | ix |
| DEDICATION..... | x |
| 1 INTRODUCTION..... | 1 |
| Meaning..... | 2 |
| The history of fluid compensation..... | 6 |
| The Meaning Maintenance Mode..... | 12 |
| The present research: Integrating and advancing theories of uncertainty..... | 17 |
| 2 IS DISSONANCE REDUCTION A SPECIAL CASE OF FLUID COMPENSATION?..... | 19 |
| Dissonance and the Meaning Maintenance Model..... | 20 |
| Study 1..... | 23 |
| Study 2..... | 28 |
| Study 3..... | 31 |
| Study 4..... | 35 |
| Additional analyses..... | 40 |
| Discussion..... | 43 |

| | |
|--|------------|
| 3 THE ROLE OF THE ANTERIOR CINGULATE CORTEX IN PROCESSING UNCERTAINTY | 54 |
| Defining risk and uncertainty..... | 55 |
| The anterior cingulate cortex..... | 56 |
| Bridging social and cognitive psychological perspectives..... | 63 |
| 4 THE EFFECT OF ACETAMINOPHEN ON MEANING VIOLATIONS | 66 |
| Study 5..... | 69 |
| Study 6..... | 72 |
| Discussion..... | 75 |
| 5 THE EFFECT OF ACETAMINOPHEN ON EEG ERROR-RELATED NEGATIVITY AND POSITIVITY POTENTIALS | 81 |
| Study 7..... | 83 |
| Discussion..... | 91 |
| 6 GENERAL DISCUSSION | 100 |
| Limitations and future directions..... | 102 |
| REFERENCES | 107 |

LIST OF TABLES

| | |
|---|----|
| Table 2.1 Dissonance reduction and compensatory affirmation across studies..... | 47 |
| Table 2.2 Full ANCOVA model for Study 4 at mean, low, and high pre-existing attitudes towards positive discrimination..... | 48 |
| Table 5.1 Reaction time and number of errors for different trial types..... | 95 |

LIST OF FIGURES

| | |
|--|----|
| Figure 2.1 Dissonance causes higher affirmation of the social judgment survey..... | 49 |
| Figure 2.2 Dissonance leads to direct efforts to reduce dissonant cognitions..... | 50 |
| Figure 2.3 Polarizing effects of dissonance on prior attitudes..... | 51 |
| Figure 2.4 Polarizing effects of a meaning violation on prior attitudes..... | 52 |
| Figure 2.5 Effects of induced-choice dissonance on affirmation of entirely unrelated attitudes and beliefs..... | 53 |
| Figure 4.1 Bond values for prostitute described in social judgment survey..... | 79 |
| Figure 4.2 Increased penalty percentage (fine or jail time) for someone convicted of vandalism or theft during the Vancouver hockey riot..... | 80 |
| Figure 5.1 ERPs following an error of commission for the placebo group..... | 96 |
| Figure 5.2 ERPs following an error of commission for the acetaminophen group..... | 97 |
| Figure 5.3 Difference waves by condition at FCz..... | 98 |
| Figure 5.4 Differences waves by condition at CPz and Pz..... | 99 |

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I am thankful for the generous funding I have received from the Social Sciences and Humanities Research Council of Canada (SSHRC) and The University of British Columbia. Combined, they have funded my entire graduate career, making life as a graduate student not only possible, but downright livable.

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Finally I would like to thank all my friends in the department for their support and wisdom. Of particular note, Aiyana Willard, for tolerating my presence over these last six years with quiet amusement, Maciek Chudek, for teaching by example the hazards of using Linux, Michael Muthukrishna, for pilot-testing risky but potentially awesome life decisions, and Wanying Zhao, who's capacity for amused tolerance is so high that she agreed to marry me.

DEDICATION

To Wanying

Life is like a dissertation.

Though I could probably pull it off without you, I wouldn't enjoy it very much.

CHAPTER 1 – INTRODUCTION

“The following tale...is true. And by true, I mean false. It’s all lies, but they’re entertaining lies. And in the end, isn’t that the real truth? The answer is: No.”

-Leonard Nimoy (Groening et al., 1997)

Introductions are a delicate event, and epigraphs doubly so. In one pithy sentence you welcome someone into your world, but at the cost of over-simplifying your message. You let the reader begin to form their own ideas, make their own assumptions; you run the risk of being misconstrued.

This risk, however, highlights the need. People do not like to venture aimlessly into the unknown; we crave signposts and guiding stars. This dissertation is about the “entertaining lies”, or more accurately the functional but incorrect beliefs that individuals hold in order to give their world structure and meaning. The world is vastly more complicated than our minds can manage, and we carve a path through this complexity, relying on “good enough” mental models to get us through the day, or even through a door. Most of the time the world makes sense enough, but how do we realize when our model is critically flawed, and how do we react to this discovery?

The broad focus of this dissertation is to better understand the disruption of one’s mental model, what I will call violations of meaning, and the downstream consequences of that experience. In particular, I focus on three questions. The first is whether or not different violated expectations are experienced in a similar manner. Second, what the potential reactions to experiencing such violations are. Finally, I ask how this process could be described using models from cognitive neuroscience. I present the theoretical review in two chapters. Chapter 1 focuses on these questions from a social psychological

perspective, particularly through the lens of the meaning maintenance model. Chapter 3 extends this review from a cognitive neuroscience perspective.

Meaning

Defining meaning

Before considering violations of meaning, it is necessary to have a clear definition of “meaning”. Throughout this dissertation, meaning is defined as relationships between different concepts in the mind (Heine, Proulx, & Vohs, 2006; Proulx & Heine, 2006). This definition is deliberately broad, encompassing basic associations between all physical, social and symbolic concepts. Meaningful relationships may begin as simple observations about the world (e.g. “objects fall down” is a meaningful relationship we hold between objects and the environment), but build into the complex network of beliefs that allow for goals, social interaction and a persistent sense of self. Although theorists within and outside psychology may think about meaning in slightly different terms, the definition I use is either aligned with (e.g. Baumeister, 1991; Bruner, 1990), or can encompass these other definitions. Proulx & Inzlicht (2012), for instance, noted that psychologists and philosophers use a range of different terms to describe how individuals organize beliefs into a structured gestalt, such as schema, paradigms, prototypes, narrative and assumptive-worlds. While many of these terms are focused on specific types of relationships (e.g. prototypes represent and help define categories) all of them could be encompassed as specific examples of meaningful relationships.

Meaning is not solely experienced by humans; to the extent that a non-human animal can learn patterns, it is capable of experiencing both meaning and violations of

meaning. Every dog knows the difference between the meaning of a leash and a rolled-up newspaper, though neither of these evokes an innate response. Capacity for meaning, by this definition, is a matter of degrees between species rather than qualitative difference, even if the human capacity for meaning far exceeds that of our nearest evolutionary ancestor or any other animal (Proulx & Heine, 2006; Tomasello, 1999; Tomasello, Gruger & Ratner, 1993).

Creating meaning

Meaning may be formed via numerous avenues. Some meanings may be genetically predisposed and emerge with very little experience, or are learned through rudimentary associative learning. Whether it is intentional or not, parents take an active role in helping to build their children's meaning, providing a steady flow of narratives whenever they're with their children (Miller & Sperry, 1988). For humans at least, meaning is not just about passive learning, but also includes effortful motivation to understand our world and integrate our selves with the culture around us (Baumeister, 1991; Bruner, 1990). Just as parents are eager to help their children construct a worldview, children themselves are highly motivated to create meaning, their love of the question "why" being intuitive evidence of this (Hanfling, 1987). Bruner (1990) argues that the need to understand, and to effectively manipulate, one's environment may be an important catalyst for the explosion of vocabulary in the first few years of life. Rather than simply learning language for its own sake, children are compelled to find words that give meaning to their experiences, narratives, and changes to their life circumstances (Nelson, 1989; 2006). This need to understand can also be seen in the belief in illusions; explanations that can be neither proven true nor false. Religious belief is one example, in

that it typically cannot be confirmed or falsified, yet clearly benefits physical health and subjective well-being (Oishi & Diener, 2014; Taylor, 1989; Taylor & Brown, 1988). One possible explanation of this beneficial effect is that any explanation is sufficient to reduce stress, even if it doesn't require a change in behavior or lessen risk in the environment (Bulman & Wortman, 1976; Silver, Boon & Stones, 1983).

Meaning in life

Although the central topic of this dissertation is violations of meaning broadly construed, meaning in life is so wed to the broader definition that it's necessary to understand how the two fit together. At its core, meaning is the network of expected relationships that we use to organize our world. Meaning in life, then, is the network of relationships that link our individual actions and goals to a broader connected purpose, defining the totality of our life. Although meaning in life may be of greater interest to people, it is no different than thinking about the meaning of a sentence. In both cases meaning implies that the individual units (words or actions) cohere and define a relationship between each other and the greater context (sentence or life; cf. Baumeister, 1991). From an empirical perspective, researchers have also tended to frame meaning in life as the connection between one's actions and a larger purpose. For instance, after removing the somewhat tautological items from the Meaning in Life Questionnaire (e.g. I understand my life's meaning) the remaining items all reference a firm connection between one's daily actions and a larger purpose for those actions (e.g. My life has a clear sense of purpose, I have discovered a satisfying life purpose, etc.; Steger, Frazier, Oishi, & Kaler, 2006). Recognizing this is important, because it allows one to easily bridge the literatures covering meaning in life, and meaning more broadly defined.

Speaking to this overlap, when people discuss their “meaning in life”, it is possible they’re mostly summarizing the health of their current relationships and goals, in other words the meaningfulness of their world as it currently stands. There is an assumption that all people require that their smaller, fragmented meanings cohere to a larger purpose, but humans are driven by plenty of motivations other than for their achievements to echo through eternity (cf. Hanfling, 1987). Although low scores on the Meaning in Life Questionnaire or similar measures do predict important health outcomes (Boyle, Barnes, Buchman, & Bennett, 2009; Diener, Suh, Lucas, & Smith, 1999; Zika & Chamberlain, 1992), people may be focused more on short-term standards and goals rather than a lifelong narrative when completing these scales (Steger, 2012). Evidence from temporal discounting experiments may inform this debate. Temporal discounting refers to an individual’s tendency to value commodities less if they must wait for a period of time to receive them. Typically discounting rates are assessed by giving people the option of one sum of money now, or a larger amount some number of days into the future. One of the uncanny feats humans possess is to value rewards that will take months or years to acquire, but this ability is not infinite. Even educated adults trained to look to the future have discounting rates around 7%, a rate that quickly climbs with less education, less access to a market and higher mortality (Frederick, Loewenstein, & O’Donoghue, 2002; Kirby et al., 2002). In one famous example, Warner & Pleeter (2001) report that the majority of 60 000 US servicemen laid off from the military chose a lump sum severance of \$22 283 over an annual payment option of \$3 714 for 18 years, representing a discounting rate of 17.5%. In a world where even the most patient, educated, and existentially secure humans devalue rewards by 50% within a decade, it’s

unclear whether humans are emotionally equipped to care about a purpose that spans their entire life. To be sure, this is not to say that money is directly related to meaning or purpose. However, to the degree that money and meaning are made emotionally important by similar affective systems, temporal discounting rates suggest that meaning is mostly in the here and now, or at most the few years from now. Nagel comes close to expressing this issue, identifying that whether or not one's actions have permanent effect is irrelevant unless their effect is meaningful now

“Moreover even if what we did now *were* going to matter in a million years, how could that keep our present concerns from being absurd? If their mattering now is not enough to accomplish that, how would it help if they mattered a million years from now?” (Nagel, 1971, pg. 176; original italics).

Meaningful relationships then, define all aspects of our worldview. Whether humans need a solid life-defining narrative is not clear, but what is clear is that one must have meaning in the here and now in order for small goals to build to a larger purpose.

The History of Fluid Compensation

The central topic of the following sections, and my dissertation, is how people react when they experience a violation of meaning. Although a number of responses are possible, my research focuses on compensatory affirmation; the motivation to affirm importantly held beliefs in the face of a violation of meaning, even though the violation and affirmation share no overlap in content. Much in the same way that affirming a person's sense of self appears to buffer them from *any* self-threat (Steele, 1988; Sherman

& Cohen, 2006) compensatory affirmation appears to be a catch-all reaction to potentially any violation of meaning. While my research is framed within the Meaning Maintenance Model, the origins of the compensatory affirmation hypothesis emerged from Terror Management Theory, one of the MMM's theoretical predecessors.

Terror Management Theory

Terror Management Theory (TMT) argues that amongst all living organisms, self-awareness is a quality unique to humans. Although beneficial, self-awareness makes us uniquely vulnerable from a psychological perspective, in that we can understand death as it will eventually apply to ourselves. This theory explicitly attempted to incorporate perspectives from philosophy, sociology and anthropology in building its argument for a universal human need to manage death anxiety (Greenberg, Pyszczynski, & Solomon, 1986). TMT argues that the motivation to create and maintain culture is to create “world views that imbued the universe with order, predictability, meaning, and permanence.” (Greenberg et al., 1986, pg. 196). These worldviews provide a buffer against constant anxiety over eventual death, allowing the individual to continue functioning in an adaptive manner.

TMT built a foundation from the self-esteem literature, in particular evidence that self-esteem is an intrinsically motivating drive and, under certain circumstances, leads to maladaptive beliefs and behaviors. The theory argues that biases such as the self-serving bias and better-than average effect occur because people are intrinsically motivated to maintain high self-esteem, even when it yields problematic outcomes. This happens because self-esteem subjectively represents our standing in the eyes of our culture, and our cultural worldview defines the conditions under which we should feel safe, both in

this life and a perceived after-life. The rich theoretical background that TMT drew on generated a number of unique predictions (Greenberg et al., 1990; Rosenblatt, Greenberg, Solomon, Pyszczynski, & Lyon, 1989) that could not have been generated by, nor easily incorporated into, related theories at the time. Chief among these predictions was that reminders of death should lead people to bolster their self-esteem *or* affirm their cultural worldview, even if the affirmed beliefs had no direct or intuitive connection to survival. These predictions motivated an enormous amount of research (for reviews see Burke et al., 2010; Solomon, Greenberg & Pyszczynski, 2004) and generated the sub-area of existential psychology, primarily focused on the psychological process underlying compensatory affirmation. This increased interest eventually generated a number of theoretical criticisms of TMT and new empirical data that, as with previous theories, TMT neither predicted nor could incorporate into its own framework.

Criticisms of terror management theory

A number of the theoretical criticisms mounted against TMT have emerged from evolutionary and cognitive psychology, two disciplines that the theory had not initially drawn from. The strongest criticism is that there is no need to propose a latent psychological variable for motivations that can be justified by their own behavioral output (Hart, 2014; Kirkpatrick & Navarrete, 2006; Tritt, Inzlicht, & Harmon-Jones, 2012). That is, motivations to maintain self-esteem, efficacy, healthy relationships and a strong sense of one's cultural worldview generate, on balance, enough benefit to be self-justified drives, much like hunger¹. Interestingly, while the first articulation of TMT (Greenberg et al. 1986) makes the case for this latent fear by pointing to the sometimes-

¹ Or as some psychologists might prefer, the need for fullness.

maladaptive results of self-esteem striving, the remainder of the paper uses death anxiety to justify a host of behaviors that are themselves adaptive and healthy. Preference for social contact with in-group members, for example, is a behavior that exists amongst many social animals (Kirkpatrick & Navarrete, 2006; Tritt et al., 2012) whom presumably do not need to satisfy a broad existential angst. As Kirkpatrick and Navarrete (2006) have argued, neither humans, nor any animals possess a "survival instinct", any more than they possess a "spread your genes instinct" (p. 290) that would lead to an automatic fear of death. Animals often possess packages of instincts that lead to predictable responses to certain stimuli, giving the impression of a broad instinct to survive. However, in many scenarios these instincts will adaptively lead them on a suicide run in the service of mating, or protecting genetically related conspecifics (Sober & Wilson, 1998). Salmon provide an intuitive example, where they will leap away from brown and black bears while running up-stream to mate, but are vulnerable to mutant "spirit bears", whose white fur fails to trigger the salmon's evasion impulse (Klinka & Reimchen, 2009). There is no instinct to "fear all bears", nor is it clear what that instinct would respond to. All this, of course, occurs in the context of a suicide-run that will leave their eggs fertilized, but their own bodies dead on the rocks.

Finally, there is no evidence that I am aware of that humans will spontaneously and uncontrollably ruminate on death in the abstract, and as a result be paralyzed from other goal-related behavior. Even if a fear-of death instinct existed, evolution likely moderated its activation long before self-awareness emerged, as it did with hunger or any other adaptive process. Although we inherited hunger from our evolutionary ancestors, our capacity for self-awareness does not cause hunger cognitions to be ever-present and

debilitating in the absence of caloric needs. This notion of stimulus-free anxiety is reminiscent of Tolstoy's "My Confession", one of the most widely read arguments for the necessity of immortality for there to be any real meaning in life (Tolstoy, 1905). In the midst of a successful career and family life, Tolstoy became increasingly distracted over the ultimate meaning of his life and his inevitable death. The essay continues from this point to argue for religion as the sole redeemer of a purposed life, but overlooks two important points embedded in its own argument. First, Tolstoy thrived for years before this question bothered him. Tolstoy himself notes that he was not always pre-occupied thusly, though he preferred to view his functioning life as "drunken" and his current state of inability as "sober" (page 13). Second, he laments the lack of concern amongst his social circle over this problem, but in doing so highlights that life without religion is perfectly plausible, as only "one in a thousand" of his class had true faith (page 19; surely an exaggeration). Given these two points, one might more quickly argue that Tolstoy was suffering from depression or had become chronically bored with the challenges in his life (as some have argued: Edwards, 1967; Flew, 1963; Schopenhauer, 1970), rather than experiencing a universal human concern.

In line with an emphasis on anxiety requiring a provoking stimulus, some have argued that religion is most valuable to those who lack everyday meaning, rather than primarily allaying chronic concerns about meaning in life (Baier, 1957). Earlier I noted that religious belief possibly reduces chronic stress by providing an explanation for one's state, but it's not always clear whether that explanation is needed to justify one's whole existence, or merely the parts of it that are immediate and terrible. This perspective lead to the hypothesis that religion is most valued by those who are suffering (Baier, 1957;

Schopenhauer, 1970) and that an increase in daily meaning will decrease the need for religious meaning (Stark & Bainbridge, 1985). The general relationships between higher education, income, health and economic equality of a nation with lower levels of religiosity (The United States perhaps being one exception) appears to support this perspective (Norris & Inglehart, 2004; Paull & Maryland, 2005; Solt, Habel, & Grant, 2011).

These theoretical concerns have led to a number of empirical results that also pose a challenge for TMT. Since TMT first proposed that thoughts of death could lead to compensatory affirmation, other researchers have shown that troubling experiences which are not directly related to death, such as threats to certainty, control, meaning or important relationships, all can lead to the same affirmation (Kay, Gaucher, McGregor, & Nash, 2010a; McGregor, 2006; Proulx & Heine, 2006; Van den Bos, 2001). A counter-argument framed as the death-thought accessibility hypothesis, is that these experiences cause affirmation indirectly, by first making thoughts of death more accessible (Schimel, Hayes, Williams, & Jahrig, 2007). Later work, however, showed that compensatory affirmation occurs even when the troubling experience is neither consciously perceived nor shares any direct relationship with concerns of death or thoughts of survival (Proulx & Heine, 2008; Randles, Proulx, & Heine, 2011). Further, the death-thought accessibility hypothesis is proving to be less robust than the mortality salience effect (Hart, 2014; Trafimow & Hughes, 2012).

Whatever criticisms may exist however, the mortality salience hypothesis was clearly validated. As a result, an alternative explanation was required that could explain mortality salience as a phenomenon, but address the larger theoretical issues. A number

of theories emerged around the same time to address this issue, all of which offer largely similar predictions. In slightly different terms, these theories suggest that a wide range of unsettling experiences lead to compensatory affirmation because they all trigger a warning that the world is not as expected. This experience has alternatively been called meaninglessness, lack of control, uncertainty, and anxious uncertainty (Heine, Proulx, & Vohs, 2006; Kay et al., 2010a; McGregor, 2006; Van den Bos, 2001). The similarity of these theories, and a need for synthesis has been a topic of interest in recent years (Hart, 2014; Proulx & Inzlicht, 2012; Proulx, Inzlicht, & Harmon-Jones 2012; Tritt et al., 2012) and motivated two authors to suggest everyone put their own toothbrush down, and carry the banner of *disanxiousuncertlibrium* (Proulx & Inzlicht, 2012, pg. 322). This dissertation is written from the perspective of the meaning maintenance model, but I am largely in agreement with the sentiment that these theories are describing similar processes, and that the few predictive differences will be sorted over time.

The Meaning Maintenance Model

The meaning maintenance model (MMM; Heine et al., 2006; Proulx & Heine, 2006; Proulx & Inzlicht, 2012) argues that all violated expectations first trigger an awareness of anomaly, before additional responses can be generated. As such, inconsistent cognitions, experiences that do not match expected outcomes, interruptions to salient goals, or information that defies one's understanding of the world may all create the same arousal, signaling to the individual that something is not as expected, and motivating them to address the anomaly. Although the initial theory did not clearly define this arousal, it differentiated it from sympathetic activation, which is more strongly associated with fear or anger. Later papers and my own work have

discussed this arousal in terms of activity in neurological systems associated with perception of and response to expectancy mismatch (discussed in Chapter 3).

Rather than represent a latent underlying fear then, as suggested by TMT, meaning violations arguably trigger a process that serves as the catalyst for an adaptive response. From this perspective, reminders of death are bothersome precisely because people tend not to think about their death, and how it will destroy all their other goals, relationships and preferences that they are focusing on. For people who haven't incorporated the idea of death (particularly an untimely one) into their worldview, reminders of death should be most bothersome. Supporting this argument, young westerners, particularly city-dwelling students, seem to be most bothered by reminders of their death (Burke, Martens, & Faucher, 2010).

When a meaning violation occurs, individuals may be able to react by updating their mental model to incorporate the anomaly. The individual can assimilate the unexpected event into their understanding of the world, or they can change how they see the world to accommodate to this new information. This is reflective of the Piagetian modes of learning; a process that itself is described as being motivated by negative affect upon discovering that one's knowledge framework is incomplete (Muller, Carpendale & Smith, 2009). However, when the above process fails to yield a reasonable target for the source of distress, or the problem at hand is too difficult to respond to, individuals may seek to dispel the arousal in another indirect way, which is termed fluid compensation (Allport, 1943; 1954). There are at least two distinct ways that it can occur (Proulx, & Heine, 2010). The first takes the form of compensatory affirmation: Espousing greater support in

personal beliefs, greater adherence to personal opinions and more aggressive actions towards out-group members (Burke et al., 2010; McGregor, Nash, & Prentice, 2011; Randles, Proulx, & Heine, 2011). While a number of explicit violations have been shown to cause compensatory affirmation, including disjointed narratives, surreal art or challenges to one's relationships and goals (McGregor, Zanna, Holmes, & Spencer, 2001; Proulx, Heine, & Vohs, 2010) implicit violations that have no relationship to the self or concerns for mortality also produce this effect, such as subliminally viewing incoherent word pairs (e.g., "quickly-blueberry"; Randles et al., 2011), experiencing a change-blindness paradigm (Proulx & Heine, 2008) or playing card-games with doctored cards (Proulx & Major, 2013).

Although the initial MMM papers did not give much detail on why fluid compensation occurs, later papers articulated that because meaning threats create domain-general distress, individuals may be able to engage in any other palliative activity that eliminates this distress (Proulx & Heine, 2008), and focusing on intact meaning frameworks may incidentally trigger the pleasant emotional message that the world again makes sense. A similar theory describes this process as Reactive Approach Motivation (RAM; McGregor, 2006), arguing that the unpleasant arousal created by violated expectations can be quelled by palliative behaviors that are not in themselves adaptive. Although animals typically do not engage in purely palliative behavior (which would be maladaptive in the wild) animals in capture are known to commonly develop "displacement" behaviors in response to anxiety-provoking environments, such as rats running compulsively on a wheel (McGregor et al., 2010). The authors argue that affirmation is a human parallel of this, seen when individuals

experience anxious uncertainty that cannot be addressed in the moment, such as the anxiety of an upcoming surgery causing hypomania and fantasies of power in the weeks prior (Fenichel, 1945, from McGregor et al., 2010).

There is still no consensus regarding when someone is likely to affirm instead of reacting directly to the violation. Violated expectations that do not require a concrete response, or that attack a more abstract belief may be more prone to affirmation relative to a direct response (Tullett, Teper, & Inzlicht, 2011). Another possibility is that what appears to be fully fluid compensation is an artifact, caused by giving participants only one option to affirm. With multiple options they may prefer affirmations that somehow directly relate to the violation (Kay, Moscovitch, & Laurin, 2010b; Shepherd, Kay, Landau, & Keefer, 2011). From this perspective, the surge in church attendance and patriotism following the 9/11 terrorist attacks (Landau, 2004; Uecker, 2008) may be better characterised as an attempt to directly cope with the event, rather than merely affirm any belief. In a similar vein, some beliefs may lend themselves to affirmation more readily than others. One argument is that any behavior that puts an individual into a goal-oriented mode can be palliative, whether it is a biological reinforcer (such as eating chocolate), a concrete goal (achieving a high test score), or an abstract goal, such as living up to the ideal's of one's community or religion. While any of these could work, abstract goals may have a distinct advantage, in that they are never satisfied but always perceived as progressing, and can be largely maintained within the confines of one's own mind (McGregor et al., 2011). Abstract goals also tend to involve illusions (unverifiable beliefs; Baumeister, 1991; Stace, 1948), which may be

particularly appealing because they cannot be violated themselves. Finally, it is possible that compensatory affirmation merely represents a misattribution of arousal. That is, under normal circumstances the anomaly is typically the most active cognition, so the arousal system is adapted to merely target whatever cognitions are salient. As a result of experimenter trickery, participants find themselves focusing on a topic that is not what caused the arousal, but mistakenly assume they are deeply concerned about this unrelated material. From this perspective, compensatory affirmation would be less about motivated cognition, and more accurately described as a misfire of the process.

Instead of affirming unrelated beliefs after a violation, people may instead seek out and learn novel meaning frameworks. This process, termed abstraction (Proulx & Heine, 2009) involves perceiving new relationships between objects or ideas that were previously unidentified. For example, upon encountering violations to meaning as diverse as considering the contradictory nature of one's self-concept, reading a surreal Kafka story, or seeing incoherent word pairs, participants have been found to perform better on an implicit pattern-learning task (Proulx & Heine, 2009; Randles et al., 2011). In a similar line of work, being made to feel uncertain can increase perceptions of patterns amongst noisy images or stock market information, and a preference for scientific explanations that emphasize clear order or patterns when describing reality (Rutjens, van der Pligt, & van Harreveld, 2010; Rutjens, van Harreveld, van der Pligt, Kreemers, & Noordewier, 2013; Whitson & Galinsky, 2008). As some of these studies used implicit measures of pattern learning, it is clear that this process can occur automatically and without conscious effort (e.g. Randles et al., 2011). However, studies have not directly

addressed whether there may also be a motivational component, such that people are explicitly trying to identify new information when they are aware that something unexpected occurred. It remains unclear whether this process serves to reduce arousal and could be considered a component of fluid compensation, or whether it is a component of the searching process that is relevant to learning (assimilation or accommodation).

The present research: Integrating and advancing theories of uncertainty

The guiding aim of this dissertation is to further integrate the meaning maintenance model with broad theories of human behavior and cognition. Chapter 2 begins by drawing parallels between the meaning maintenance model and cognitive dissonance theory, one of the predecessors to TMT. Dissonance theory is considerably older than other theories of threat compensation discussed here, but recently some theorists have noticed that it shares striking similarities to newer theories attempting to explain fluid compensation (Proulx & Inzlicht, 2012). The goal of Chapter 2 is to assess whether cognitive dissonance can lead to fully fluid compensation as the more contemporary theories would predict, thus allowing us to draw on the insight developed through this theory over the last 70 years.

Chapter 3 is a theoretical review that continues to pursue integration, bridging the social psychological and cognitive neuroscience perspectives on uncertainty. I've elected to present this component of the review as a stand-alone chapter as it was informed by the results of Chapter 2.

A number of novel hypotheses emerge from considering the overlap in social and cognitive theories of uncertainty. Chapters 4 and 5 test some of these predictions. Chapter 4 assesses whether a drug that inhibits brain regions associated with pain and social

rejection (acetaminophen) will also inhibit compensatory affirmation. Chapter 5 extends this work by directly observing the effect of acetaminophen on EEG evoked response potentials following errors.

CHAPTER 2 – IS DISSONANCE REDUCTION A SPECIAL CASE OF FLUID COMPENSATION?²

Arguably one of the most prominent theory in social psychology, the conceptualization of cognitive dissonance has traversed a long and meandering path since it was first proposed by Leon Festinger (1957). Despite an unusually large number of revisions and re-revisions of the theory (Aronson, 1969; Cooper & Fazio, 1984; Greenwald & Ronis, 1978; Harmon-Jones, Amodio, & Harmon-Jones, 2009; Harmon-Jones, Brehm, Greenberg, Simon, & Nelson, 1996; Steele & Liu, 1983; Tedeschi, Schlenker, & Bonoma, 1971; Zanna & Cooper, 1974), the core of dissonance theory remains relatively unchanged: people are bothered by inconsistencies between their mental representations, and will work towards reducing those inconsistencies (Festinger, 1957; Harmon-Jones et al., 1996; Harmon-Jones, Amodio & Harmon-Jones, 2010). Recently, it has been argued that dissonance theory and other theories concerned with uncertainty share a number of similarities (Heine, Proulx, & Vohs, 2006; Proulx & Inzlicht, 2012). In particular, inconsistent cognitions or unexpected events are described by both dissonance and uncertainty reduction theories as leading to an aversive arousal state, which leads to predictable behavioral change in the service of addressing the anomaly.

Although a number of theorists have argued that dissonance reduction is primarily related to self-consistency, in that the inconsistency represents a threat to one's self-esteem (Aronson, 1999; Steele & Liu, 1983), the original articulation of dissonance theory (Festinger, 1957), as well as some current ones (e.g. Harmon-Jones et al., 2009;

² This chapter is adapted from a manuscript under submission for publication. See Preface.

Harmon-Jones et al., 2010) represent the perspective that any psychologically or logically inconsistent cognitions that occur simultaneously can create aversive arousal. For example, Festinger (1957, p. 14) writes that “If a person were standing in the rain and yet could see no evidence that he was getting wet, these two cognitions would be dissonant with each other.” In elaborating on his core definition of dissonance, Festinger argues that feeling fear when there is no stimulus would also create dissonance (p. 13), framing dissonance theory as applying even more broadly than logical contradiction, but rather any mismatch amongst active experiential states.

Although there are many similarities between cognitive dissonance theory and uncertainty reduction theories, there are also a number of key predictive differences. This chapter focuses on one such difference: Dissonance theory does not predict that inconsistencies will lead to compensatory affirmation in domains unrelated to the dissonance-inducing event (Festinger, 1957; Harmon-Jones et al., 2009), while the MMM argues that affirming any committed belief may provide a palliative to the arousal elicited by inconsistencies. Thus, I am proposing an extension to classical dissonance theory by arguing that dissonance may not only change attitudes and behavior regarding the perceived inconsistency, but also attitudes in other unrelated domains, as people aspire to engage in any behavior that reduces the unpleasant arousal.

Dissonance and the Meaning Maintenance Model

The MMM argues that meaning violations lead to an arousal that is context general. That is, the same arousal is triggered for any perceived mismatch between one’s expectations and experience; contextual cues are required to identify the proximal cause of the aversive feeling (See pg. 12-16 for a full discussion). Dissonance may prompt

unpleasant arousal for the same reason as other violations of expectations: the relevant cognitions are inconsistent with available meaning frameworks. Although some versions of dissonance theory and the MMM agree on the conditions that cause this disrupted state, they differ in explaining how people respond to the corresponding arousal. In the case of the typical dissonance experiment, participants seek to directly reduce the offending inconsistency by accommodating their attitudes (e.g., “I just agreed to write an essay in favor of a tuition increase, it must be because I have discovered that I actually am in favor of such an increase”). Direct accommodation is possible only when participants are consciously aware of the anomaly that lies at the source of their arousal. In contrast, many MMM studies have involved inconsistent cognitions that are either not consciously accessible (e.g., a change blindness manipulation; Proulx & Heine, 2008), or have included a number of distractor tasks following the manipulation and prior to the measure of fluid compensation (Burke et al., 2010; Proulx & Inzlicht, 2012; Randles, Heine, & Santos, 2013). All else being equal, people may prefer to directly deal with the inconsistency rather than indirectly reduce their arousal (Stone & Cooper, 2001; Stone, Wiegand, Cooper & Aronson, 1997; Tullett, Teper, & Inzlicht, 2011). However, given that in these situations there is no direct way to accommodate the inconsistencies or affirm related beliefs, and it is easy to misattribute the cause of one’s state, people may use alternative indirect tactics to dispel the arousal, such as affirmation or abstraction of unrelated meaning frameworks (see pg. 13-16 for definitions of affirmation and abstraction).

Experimental evidence from the existing literature provides indirect support for this process. First, some of the meaning violations that have been found to prompt fluid

compensation represent discrepancies that are similar to those implied by cognitive dissonance manipulations. For example, participants showed enhanced implicit pattern learning if they were reminded of situations where they had acted inconsistently (i.e., they were shy in one situation and outgoing in another) and were asked to argue against their own unified self-concept (Proulx & Heine, 2009). To the extent that dwelling on behavioral inconsistencies could be seen as a dissonance manipulation, this would be evidence that dissonance leads not only to dissonance reduction, but also to abstraction.

Second, the role of general arousal is apparently key in mediating the compensation process for both types of manipulations. When participants are given a placebo that they believe will cause them to feel tense or anxious, they show less motivation to reduce dissonance (Zanna & Cooper, 1974), affirm beliefs following a meaning violation (Proulx & Heine, 2008) or affirm alternative controlling agents following a control violation (Kay, Moscovitch, & Laurin, 2010b), presumably because they have a benign explanation for their arousal that reduced the necessity for further action. The implication is that arousal is a necessary component for both dissonance and meaning violations.

Finally, a number of studies have shown that self-affirmation can provide what could be called a compensatory buffer against the experience of dissonant arousal (Steele & Liu, 1983; Sherman & Cohen, 2006). These studies suggest that any bolster to global self-integrity can provide an emotional buffer, such that when a person discovers their behavior is dissonant, they are not as bothered. The authors discuss these effects in terms of dissonance impacting self-integrity or consistency, and as such argue that any affirmation of the self can buffer one's concern for dissonant events in unrelated

domains. This finding is consistent with the MMM, but may hint at a much broader process of compensatory affirmation, where the self is neither a critical component of either dissonant arousal or repair, and that participants will be motivated to reduce arousal via any avenue when feeling dissonant.

Thus far, dissonance studies have not investigated whether dissonant cognitions will lead people to affirm unrelated beliefs or to abstract new patterns, as participants have never been provided with opportunities to do so. I hypothesized that participants will use any means at their disposal to alleviate their aversive arousal, and although in traditional dissonance studies this has been largely limited to attitude change or affirmation of important personal attributes, I propose that affirmation of unrelated beliefs and abstraction could also occur, if those options are made available. Four studies were conducted to test this hypothesis, using two versions of the induced-compliance dissonance paradigm. The first two studies employ an induced-choice dissonance paradigm and give participants the opportunity to affirm their moral position on prostitution (Study 1) and their belief in God (Study 2). In the third study, I employ a different version of the induced-choice paradigm and additionally test whether abstraction as well as affirmation can occur following dissonance. Study 4 directly compares the effects of induced-choice dissonance relative to a meaning violation on the motivation to affirm unrelated beliefs.

Study 1

Participants and procedure

Four-hundred and forty-six participants (35% women) with a mean age of 30 (SD=10.6) were recruited online through MTURK (www.mturk.com). MTURK is an

online recruitment system, where participants agree to complete studies for an advertised fee. The study was restricted to site members whose IP address identified them as North American. Participants were largely White (76%), followed by Black (7%), South Asian (4.5%), East Asian (4%), or other (8.5%). Participants were given fifty cents to complete the study, and up to an additional dollar based on their success in a memory task.

After giving informed consent and completing some demographic questions, participants were then given a boring passage to read, which they were told had been randomly selected from a set of articles. The participants were asked to read the article thoroughly and that there would be a memory test based on the content.

After this task, participants were told that the researchers were interested in studying whether the act of describing an event as interesting or not interesting affects recall memory for the event. The participant was therefore asked to write a paragraph describing this article, which would be read by a future participant before receiving the same article. In the control condition, participants were told that they had been randomly assigned to write that the passage they read was very interesting. In the dissonance condition, participants were told they could freely choose to write a paragraph describing the passage as very interesting or not at all interesting. However, before they began, a prompt informed them that it would be helpful to the researchers if they could choose to write that the passage was interesting, as follows:

“A large number of people have chosen to write about why they thought the article was not very interesting. Thus, in order to finish the study with a good number of people on both sides, we need people to now write that they thought the passage they read was very

interesting. Although it is your choice, we would really appreciate it if you would write one short paragraph that firmly says that the passage you read was very interesting.”

The expectation is that even though the induced choice group was given some external motivation for writing that the paragraph was interesting (it would help the researcher finish the study) they should perceive themselves as having more choice on the issue, and thus needing to justify to a greater degree why they wrote what they did.

After the manipulation, participants then completed a measure of compensatory affirmation (the social judgment survey), and a question measuring dissonance reduction: “despite what you wrote earlier, how interesting was the passage you read?” The order of these two items was counter-balanced. Finally, participants completed a manipulation check question: “How much choice do you feel you had over which type of sentence you wrote?”

Materials

Boring passage: A 3-page advertisement for Gerbrands Tachistoscopes was selected as a boring passage, where the tachistoscope is described in highly specific and technical terms. This passage was picked because it is very difficult to read, has no narrative and contains no information that an individual would find meaningful or worthwhile unless they were purchasing a tachistoscope. This passage has been used in previous induced-compliance dissonance paradigms (Harmon-Jones et al., 1996; Harmon-Jones, Harmon-Jones, Serra, & Gable, 2011).

Social judgment survey: Participants read a hypothetical arrest report about a prostitute and were asked to set the amount of the bail, between \$0 and \$999. This

identical measure has been used in several meaning violation studies (e.g., Proulx & Heine, 2008; Rosenblatt, Greenberg, Solomon, Pyszczynski, & Lyon, 1989). The rationale for expecting participants to increase the bond value following a meaning violation, is that sex for money is at odds with commonly held views of relationships in North American culture, and is against the law throughout most of the continent. Thus, increasing the penalty provides an opportunity to affirm what most of our participants already believe: that prostitution is morally wrong.

Oppenheimer Instructional Manipulation Check: This measure contains a short, dense paragraph, explaining to the participant that researchers are concerned about people not reading instructions, and that to show that they are paying attention, some of the questions will be left blank. This measure has been shown to effectively remove people who complete the study, but who are not paying attention to the materials. There is evidence showing that people who fail the check are not different in demographics or psychological characteristics, other than that they are not attending to the study (Oppenheimer, Meyvis, & Davidenko, 2009).

Results

A total of 87 participants refused to write that the passage was interesting (80.6% compliance), 28 were additionally removed for failing the Oppenheimer Instructional Manipulation Check, and 6 were removed for taking more than 3 standard deviations longer than average to complete the study. This left a final sample of 325 in the study.

Analysis of covariance (ANCOVA), controlling for sex and age, was used for all analyses across studies. I control for these variables, as they are both related to most of our dependent variables across the studies, independent of condition. The manipulation

check indicated that participants who were coaxed into writing the paragraph did believe they had more choice. On a scale from 1 ("I had no choice at all") to 7 ("It was very much my choice"), participants in the dissonance condition claimed they had more choice in writing about the paragraph ($M = 3.76$, $SD = 2.01$) compared to the control group ($M = 2.16$, $SD = 1.78$; $F_{(1,321)} = 59.3$, $p < .001$, $d = .86$ $CI_{.975} [.64, 1.09]$)³. Although the free-choice group did not have a mean on the positive side of the scale, it is not uncommon for dissonance manipulations to lead to a significant but incomplete change in perception of choice (e.g. Balcetis & Dunning, 2007; Cooper et al., 1978; Gosling, Denizeau, & Oberlé, 1006).

There was no significant interaction between dissonance manipulation and order of the dependent variables for the prostitution bond ($F_{(1,321)} = .04$, $p > .50$), so analyses were collapsed across order. As hypothesized, dissonance caused compensatory affirmation, where participants experiencing dissonance re-affirmed their cultural worldview by increasing the value of the bond ($M = 447.68$, $SD = 304.62$) compared to the control group ($M = 367.19$, $SD = 265.12$; $F_{(1,321)} = 6.90$, $p < .01$, $d = .30$ $CI_{.975} [.08, .52]$; Figure 2.1).

I also observed a classic dissonance effect, such that participants in the dissonance condition claimed that the passage was more interesting ($M=3.14$, $SD = 1.84$) than the control condition ($M = 2.31$, $SD = 1.57$; $F_{(1,321)} = 20.6$, $p < .001$, $d = .51$ $CI_{.975} [.29, .73]$; collapsed across condition; See Table 2.1, Figure 2.2). In this case there was an interaction between condition and the order of the dependent variables ($F_{(1,321)} = 3.48$, $p < .10$), such that motivation to reduce dissonance appeared to be stronger when addressed

³ Point and interval estimates of Cohen's d for main effects within an ANCOVA are based on recommendations in Nakagawa, Innes & Cuthill (2007).

before the compensatory affirmation measure ($F_{(1,321)} = 23.07, p < .001, d = .50$ CI_{.975}[.28, .73]) as apposed to after ($p < .05, d = .25$ CI_{.975}[.03, .47]). However, while the pattern of effects is theoretically sensible, this should be interpreted cautiously. Rather than see a low interest score for participants who experienced dissonance but were given the bond first, a high score for bond-first participants in the control condition emerged (See Figure 2.2). Given that the main effect remains significant for both orders and that there is no significant effect of order when the bond is the dependent variable, the only conclusions one can draw with confidence are that dissonance increased both compensatory affirmation and dissonance reduction motivation, but it is unclear whether engaging in one type of response reduces subsequent motivation to continue affirming or accommodating.

In Study 1, I found both a classic dissonance effect and compensatory affirmation. However, it is possible that dissonance only increases one's sense of frustration or negative affect (Harmon-Jones et al., 2009), which led to a more punitive action. In Study 2, I attempt to replicate these findings with a different form of cultural affirmation that should be less sensitive to negative mood: belief in God. This not only provides an opportunity to affirm a strongly-held view, but some have argued is an especially effective form of affirmation, because it serves as a reminder that the world is orderly and intentional, and that one's identity is part of a larger purposed world (Kay, Gaucher, McGregor, & Nash, 2010a; Norenzayan & Gervais, 2012). To this end, past research has shown that people will affirm their belief when made to feel that they lack control (Kay et al., 2010b) or mortality salience (Norenzayan & Hansen, 2006).

Study 2

Participants and procedure

Students completed the same dissonance paradigm online as in Study 1, in exchange for partial credit in a psychology class. Instead of a scenario about norm or law violations, participants were asked about their belief in God and the role of God in creating and maintaining the world. Specifically, they were asked how strongly they would endorse the following items: “I believe in God”, “I think that God is in control of the events in our universe,” “I think that the actions of God explain what happens in our world,” and “I think that God created all life on the planet” ($\alpha = .93$ in this sample). As most students in this sample hold at least moderately strong belief about God, increased belief was taken to be evidence of affirmation of an unrelated schema.

Eighty-eight students were recruited from a university in Central Canada (72% women, mean age = 19.6, SD=2.8). The ethnicity of the sample was primarily of South Asian (38%), East Asian (33%), European (15%) and other ethnicities (14%).

Results

A total of 28 participants refused to write that the paragraph was interesting and were dropped, leaving $N = 59$ (71% compliance). As in Study 1, ANCOVA was used for all analyses, controlling for age and sex. The manipulation check indicated that the dissonance paradigm had been successful, although again the dissonant group was not on the positive side of the 7-point scale. Participants in the dissonant condition claimed they had more choice to write that the article was interesting ($M = 3.53$, $SD = 2.27$) compared to the control ($M = 2.03$, $SD = 1.43$; $F_{(1,55)} = 7.98$, $p < .01$, $d = .76$ CI_{.975}[.22, 1.30]).

As predicted, a manipulation of free-choice dissonance again led to affirming an entirely unrelated schema; in this case, belief in God. Participants in the dissonance

condition marginally supported an increased belief in God ($M = 4.17$, $SD = 1.09$) relative to the control condition ($M = 3.62$, $SD = 1.08$; $F_{(1, 58)} = 3.5$, $p < .10$, $d = .51$ CI_{.975}[-.03, 1.05]).

In Study 3, I attempted to replicate the cultural affirmation effect using a different dissonance paradigm: arguing in favor of increased tuition. I also attempted to extend the fluid compensation findings by showing that dissonance leads to increased abstraction, as well as affirmation. Recent work in areas of uncertainty, meaninglessness and lack of control show that violations increase a person's propensity for identifying patterns in the environment (Proulx & Heine, 2009; Whitson & Galinsky, 2008). This includes detecting basic visual patterns amongst noise, but can also lead to beliefs that behaviors amongst people are connected, such as with conspiracy theories (Whitson & Galinsky, 2008). The notion that dissonance might lead to enhanced abstraction is not entirely without precedent. In one field study, participants who had just purchased a car in the last 6 weeks were more likely to notice and read ads for their selected car, rather than others they had been considering or not considering (Ehrlich, Guttman, Schönbach & Mills, 1957). This was an example of seeking out consonant information, but the new owners were also more likely to read *any* car ad, suggesting they were still sensitive to information in this domain. Likewise, Festinger (1956/2012) reports that after a failed prophecy of an alien landing, members of the prophetic cult became increasingly sensitive to any and all potential cues of alien contact, going so far as attempting to decode messages in comedy shows and encouraging guests to admit that they were, in fact, alien emissaries. Although again this suggests directed attempts to resolve

dissonance, it is possible that the motivation to gather information increases regardless of conscious direction.

Study 3

Participants and Procedure

A total of 67 students at a Western Canadian university (72% women) participated in exchange for partial credit in a psychology class. I used the classic dissonance paradigm (Pittman, 1975; Steele et al., 1981), where students were either instructed, or politely asked, to write in favor of a tuition increase at their university. Participants were 49% East Asian, 31% European, 3% South Asian and 17% other ethnicities.

The study was advertised as soliciting student opinions on university policy. After completing basic demographic materials, participants were told that the university Board of Governors was soliciting student opinions on whether tuition should be raised by 20% for the following academic year. When participants opened their essay package, there was a note on university letterhead urging the participants to write in favor of a tuition increase. In the dissonance condition, the note explained to the participant that many people had written against the idea, and the researcher would appreciate if they could write a paragraph in favor of an increase:

Dear Participant,

The following UBC Board of Governors questionnaire will ask you to state your opinion regarding a proposed tuition increase. Not surprisingly, we have received a large number of arguments opposed to a tuition increase. To complete our study, it would be helpful if

we could generate a sample of participant arguments in favor of a tuition increase. You are free, of course, to argue either for or against a tuition increase, depending on how you actually feel about the topic. It would really help us out, however, if you argued in favor of a tuition increase, regardless of your actual opinion.

In the forced choice condition, the last three sentences were changed to indicate that the participant had no choice: "To complete our study, we now require a sample of participant arguments in favor of a tuition increase. For the purpose of this study, we require that you present an argument in favor of a tuition increase regardless of your actual opinion on the matter."

After participants submitted their paragraph, they completed the Positive and Negative Affect Schedule (Watson, Clark, & Tellegen, 1988) as a delay distractor between the manipulation and dependent variable. This questionnaire asks participants to report how they are feeling right now, regarding a list of positive (e.g. Interested, Excited) and negative (e.g. Distressed, Guilty) affective descriptors (In this sample $\alpha = .XX$ for positive affect items and $\alpha = .XX$ for negative affect items). It has become common practice to use the PANAS as a filler task for manipulations of uncertainty or meaning, and doing so appears to increase the effect size of the manipulation (Burke et al., 2010). As this measure almost never shows a change following manipulations (e.g. Landau et al., 2006; Proulx & Heine, 2008; Randles et al., 2011), I did not expect to see significant differences between conditions in either self-reported positive or negative affect.

Participants were then given an implicit grammar task previously used in other meaning violation studies (Proulx & Heine, 2009; Randles et al., 2011). These past studies have shown that after a meaning violation, participants are more likely to perceive and remember patterns in their environment, even when they aren't consciously aware of having experienced a violation of meaning, nor are they explicitly trying to learn anything new. The implication is that increased attention to patterns automatically follows from experiencing a violation of meaning. Participants were asked to copy a series of letter strings (e.g. XXRVTM), with no additional instructions. Every string adheres to the same strict syntactical grammar (e.g. M can follow X, M, or V, but not T, unless T is preceded by V.; see Dienes & Scott, 2005 for full description). Once completed, new strings were presented one at a time on a computer, half of which were based on the same grammar, and half that were not. Participants were told that all the previous strings were generated using a strict grammar, and they were to identify the new strings that adhered to the same grammar, without being told how many strings were correct. Past work has shown that even without attempting to do so, participants learn enough about the grammar during the copying phase to correctly select new strings of letters at better than chance rates (Dienes & Scott, 2005). Participants were scored for how many strings they selected (a measure of their motivation to detect patterns) and their actual success on the task (hits and correct rejections are scored correct, false alarms and misses are incorrect).

After the artificial grammar task, participants then completed the social judgment survey dependent variable, as in Study 1. To confirm that our manipulation had produced dissonance, we asked participants to tell us how they really felt about tuition increases,

regardless of what they had written previously. The mean of the items “I support an increase in tuition,” “I think there are many valid reasons why tuition should be increased,” and “students can handle an increase in tuition” were used as a score to measure dissonance reduction. Afterwards, participants were fully debriefed.

Results

Twelve participants refused to write in favor of a tuition increase (82% compliance) and two participants had been in a similar dissonance study, leaving 53 participants. The manipulation check again showed the dissonance group perceived they had more choice to write the essay ($M = 4.12$ $SD = 2.55$) than the control group ($M = 1.96$ $SD = 1.77$; $F_{(1,49)} = 14.61$, $p < .001$, $d = 1.17$ $CI_{.975} [.55 - 1.79]$), though again the dissonant group did not cross to the positive side of the scale (9-point response). The study revealed a classic dissonance reduction effect, where participants supported tuition increases more if they had been asked ($M = 3.04$, $SD = 1.20$) rather than told to write in favor of them ($M = 2.04$, $SD = .96$; $F_{(1,49)} = 11.99$, $p < .01$, $d = .99$ $CI_{.975} [.42, 1.57]$; See Table 1).

Consistent with main hypothesis, the dissonant group showed increased motivation to identify patterns amongst noise ($F_{(1,49)} = 4.70$, $p < .05$, $d = .62$ $CI_{.975} [.05, 1.20]$), with the dissonant group selecting a mean of 31.44 strings ($SD = 7.04$) compared to the control ($M = 26.36$, $SD = 10.32$). However, they did not show increased success at correctly identifying patterns ($M_{CONT} = 7.21$, $SD_{CONT} = 7.06$, $M_{DISS} = 5.44$, $SD_{DISS} = 6.46$; $F_{(1,49)} = 1.02$, $p < .50$, $d = .29$ $CI_{.975} [-.29, .86]$). This suggests that the participants were more motivated to identify patterns regardless of whether a signal was present or absent (Whitson and Galinsky, 2008), but were not actually more effective at identifying

patterns, as was seen with past meaning violation studies (Proulx & Heine, 2009; Randles et al., 2011).

Nine participants were familiar with the social judgment survey, and so were removed only from this analysis. As in Study 1 and 2, the dissonant group affirmed an unrelated schema that could not directly reduce the dissonant cognition. Higher fines were assigned for the prostitution scenario in the dissonance condition ($M = 497$, $SD = 228$) compared to the control condition ($M = 377$, $SD = 212$; $F_{(1,40)} = 4.5$, $p < .05$, $d = .67$ $CI_{.975} [.03, 1.31]$).

Although I anticipated no difference between conditions on the PANAS, the dissonant group reported both marginally more positive affect ($M_{DISS} = 2.65$, $SD_{DISS} = .53$; $M_{CONT} = 2.41$, $SD_{CONT} = .59$; $F_{(1,49)} = 3.80$, $p < .10$ $d = .56$ $CI_{.975} [-.02, 1.14]$) and more negative affect ($M_{DISS} = 1.92$, $SD_{DISS} = .54$; $M_{CONT} = 1.81$, $SD_{CONT} = .50$; $F_{(1,49)} = 5.70$, $p < .05$, $d = .68$ $CI_{.975} [.11, 1.26]$) relative to the control group.

In studies 1-3, classic dissonance manipulations lead to compensatory affirmation as well as attempts to reduce dissonant cognitions. In study 4, I attempt to show parallel effects of a dissonance manipulation and a meaning violation.

Study 4

Participants and procedure

One hundred and twenty-four participants were recruited from a university in the Netherlands, (80% women; mean age = 20.48 years, $SD = 2.22$ years) in exchange for partial credit in a psychology class. All participants were Western European nationals who spoke English as a first or second language.

Participants entered the lab room and were seated in front of a computer. The experiment began with participants filling out a demographics questionnaire. Participants then had their attitudes towards positive discrimination assessed prior to the experimental manipulation (scale $\alpha = .61$ in this sample). Positive discrimination or affirmative action refers to efforts towards elevating the status of minority groups to increase their representation in society. We anticipated that experiencing either dissonance or a meaning violation would motivate participants to affirm their recently assessed positive discrimination attitudes, as has been previously demonstrated by Proulx & Major (2013).

Following this, participants engaged in one of 3 experimental conditions. Participants either completed neutral (control) tasks, experienced induced-compliance dissonance using the boring paragraph paradigm from studies 1 and 2, or were exposed to a surreal video previously used as a meaning violation (Randles et al., 2013). In the control condition, participants were firmly told to write that the boring paragraph was interesting, and viewed the control version of the video clip (described below). Participants in the dissonance condition completed the induced compliance dissonance manipulation and viewed the control version of the video clip. Participants in the meaning violation condition were also firmly told to write that the article was interesting, identical to the control condition instructions, but viewed the surreal version of the video clip. After these videos, participants completed the PANAS ($\alpha = .89$ for positive affect items and $\alpha = .86$ for negative affect items) and then our dependent variable, an affirmation measure of positive discrimination. Participants were then debriefed and excused from the experiment.

I expected that after experiencing either dissonance or a meaning violation, participants would feel motivated to more strongly affirm the position they already held regarding positive discrimination. That is, those who were in favor of positive discrimination should endorse the post-manipulation measure more strongly than the control condition, and those who were generally opposed to positive discrimination and experienced either manipulation should endorse the final measure *less* than their like-minded participants in the control condition.

Materials

Positive Discrimination Scale. Participants completed a 4-item measure of their relevant attitudes “I think it is positive that the Dutch government tries to increase the number of women and minority policemen.”, “Women must be given more opportunities, compared to men, to occupy chief executive or general management positions.”, “It is a good thing that the European parliament compensates small countries for their potential lack of influence by giving them more parliament seats per citizen. (E.g., Luxembourg receives 1 seat per 80.000 citizens were Germany receives 1 seat per 800.000 citizens).”, “I think it is a good idea from the Dutch Organisation for Scientific Research (NWO) to encourage the promotion of female academics to senior lecturer (or professorial) level.”

Meaning threat and control videos. All participants watched three video clips, under the pretense that they would be asked questions regarding various details later on. This manipulation was previously used in Randles et al. (2013), and has been shown to lead to compensatory affirmation. The first and last clips were the same for both conditions, including a segment from a Disney cartoon starring Donald Duck, and a Peanuts cartoon starring Snoopy. The first clip was intended to help participants get

comfortable with the task, while the latter clip added a delay between the manipulation and dependent variable, a practice that has been shown to increase the robustness of meaning violations (e.g., Burke et al., 2010). In the meaning violation condition, participants watched a 4-min clip from the short film, *Rabbits*, created by David Lynch (2002). The film at first appears to resemble a sitcom, but includes non-sequiturs and a complete lack of narrative, random laugh and applause tracks, and all characters dressed in rabbit costumes with no explanation or reference. The control group watched a clip from *The Wizard of Oz*. This clip replaced the original control video (Randles et al., 2013) featuring a clip from *The Simpsons* cartoon show, to reduce potential positive affect as a confounding explanation for the effect.

Positive discrimination affirmation. The dependent variable was a 1-item measure of support for affirmative action, “How do you generally feel about acts, policies, and measures that are driven by the idea of positive discrimination?”

Results

A total of 25 participants refused to write that the paragraph was interesting (80% compliance) and were removed before analysis. As with the previous studies, ANCOVA was used for analysis, controlling for sex and age. Initial positive discrimination (PD) pre-scores were entered as a continuous variable. I treated the control condition as the reference group, observing the effect between it and either the dissonance or meaning violation conditions. Interaction terms between PD and the manipulations were entered, to test whether those high in PD responded to the manipulations differently than those low in PD. As expected, results show a significant interaction between high and low PD

and either the dissonance ($F_{(1,91)} = 3.70, p = .057$) or meaning violation condition ($F_{(1,91)} = 4.36, p = .04$; See Table 2.2).

I anticipated that those relatively low in PD would lower their support further after either type of manipulation, while those relatively high would raise it. To assess this, I re-ran the model after centering PD at one standard deviation below the mean and one standard deviation above. This approach allows evaluation of the main effect at different levels of the critical variable (in our case, pre-existing views on positive discrimination) without inflating Type I error by running separate models (Aiken & West, 1996).

For those low in PD, experiencing either dissonance ($F_{(1,91)} = 6.12, p < .05, d = .55$ CI_{.975}[.11, .99]) or the meaning violation ($F_{(1,91)} = 4.40, p < .05, d = .44$ CI_{.975}[.02, .86]) caused decreased support for affirmative action relative to the control condition (See Figure 2.3, 2.4). Those high in PD did not show this effect for either manipulation, although in both cases the non-significant trend was in the anticipated direction (For dissonance, $F_{(1,91)} = .19, p > .50, d = .1$ CI_{.975}[-.34, .54]; for meaning $F_{(1,91)} = .98, p > .30, d = .21$ CI_{.975}[-.21, .62]). Although no significant effect was seen for those high in PD, this was true for both manipulations, just as both manipulations did have a significant impact on those low in PD, suggesting that both the dissonance and meaning violation were affecting our sample in similar ways.

As is typical for meaning violation studies, participants showed no difference in either positive ($F_{(1,91)} = 1.17, p < .50$) or negative affect ($F_{(1,91)} = 1.02, p < .50$). Given that I did not anticipate significant PANAS results in Study 3 or 4, I am hesitant to interpret the significant effects in Study 3.

Additional Analyses

As all four studies investigated measures of compensatory affirmation following manipulations of dissonance, additional analyses were conducted with the combined sample.

Estimate of effect size for affirmation following dissonance

A meta-analytic average of the dissonance manipulations on compensatory affirmation effect is presented below, including the non-significant results from participants high in positive discrimination attitudes in Study 4. Because participants in high and low positive discrimination in study 4 are drawing on the same analysis (and in fact represent two arbitrarily chosen effects along a continuous dimension of positive discrimination) the sample size was divided between them, to prevent the study from being over-represented in the meta-analysis (Borenstein, Hedges, Higgins & Rothstein, 2009). Across the four studies and five effects, the meta-analytic effect size is $d = .35$, $CI_{.975} [.19, .51]$ (See Table 2.2, Figure 2.5).

Secondary analysis of cultural moderation

Given that the samples in Studies 2 and 3 contained a diverse range of ethnicities, I tested whether cultural differences in responding to dissonance might be present. To boost power, the samples were merged after participants' dependent variable scores were Z-transformed within their own sample. Using Hofstede's (2001) regional scores of individualism/collectivism as a guide, I assigned participants into either group in a binary manner. I then re-ran the analysis including collectivism status as both a covariate and moderating term. The result was a non-significant interaction term between condition and collectivist/individualist grouping ($F_{(1,97)} = .47, p = .50$) while the main effect for

condition reflected the significant effects in studies 2 and 3 ($F_{(1,97)} = 5.53, p < .05$). This suggests that our effects are invariant to cultural background, at least in terms of ethnicities associated with collectivism, living within North America (cf., Heine & Lehman, 1997; Kitayama, Snibbe, Markus, & Suzuki, 2004).

Addressing the confound of prior preference and selective attrition

Recently, Chen & Risen (2010) identified a confound in dissonance manipulation paradigms. Although their core argument was concerned with imperfect measurement in the free-choice paradigm, a similar problem regarding the induced-choice paradigm (which I have used here) was revealed. More participants in the induced compliance condition tend to refuse to write the essay compared to those in the forced compliance condition. If we can assume that those who most disliked the boring article (studies 1,2 and 4) or those most against tuition increases (study 3) are the most likely to refuse, and that it is easier for such a person to refuse in the context of induced compliance, than the induced-choice condition is more likely to lose participants with the most negative opinion of the task. In brief, one cannot identify whether a low measure of dissonance reduction for a non-compliant participant is because they failed to experience dissonance (which is why they are removed), or because they had the strongest counter-attitude in the group on this issue.

I agree that this issue presents a confound. However, my primary concern with measuring dissonance reduction here was to a) verify the paradigm replicated past effects and b) assess order effects of dissonance reduction and compensatory affirmation. Regarding compensatory affirmation, it's not necessarily true that this confound is a concern. Someone who refuses to lie about a paragraph being interesting should be no

more or less likely to have negative views towards prostitution. As long as a person's views regarding the affirmation measure are orthogonal to their willing to write, then the selective removal of participants should not artificially inflate affirmation scores. To assess whether this was the case, I correlated measures of dissonance reduction and affirmation in the control groups (forced choice conditions) from Study 1 and 3. If there was a general relationship between low opinions of the task and low affirmation measures, a positive correlation between the two measures should be present. Such a correlation is not present in either Study 1 ($r = -.07, p < .50$) or Study 3 ($r = -.17, p < .50$), in fact numerically the correlation is negative in both cases, though non-significant. Thus it is unlikely that even if selective attrition inflated the measure of dissonance reduction, that this attrition also inflated the measure of compensatory affirmation.

A different approach to this concern is to directly assess whether the non-compliant group actually do show the strongest distaste for the tasks. Comparing the non-compliant participants in the dissonance condition with the compliant participants in the control condition can assess this. Presumably neither of these groups experienced dissonance; the only difference between them is whether they agreed to write the essay. What I find is that the non-compliant participants do, in fact, report a lower opinion of the article (Study 1; $M_{\text{compl}} = 2.39, M_{\text{non-compl}} = 1.78, F_{(1,243)} = 8.20, p < .01$) and show the least support for a tuition increase (Study 3; $M_{\text{compl}} = 2.02, M_{\text{non-compl}} = 1.29, F_{(1,31)} = 3.20, p < .10$), supporting the concern that selective attrition is inflating these measures in the dissonance condition. Again, however, I do not find these differences for the affirmation measure in either Study 1 ($M_{\text{compl}} = 347.62, M_{\text{non-compl}} = 381.06, F_{(1,242)} = .81, p < .50$) or Study 3 ($M_{\text{compl}} = 372.70, M_{\text{non-compl}} = 357.51, F_{(1,29)} = .02, p > .50$), indicating

that the only difference between compliant and non-compliant participants when it comes to affirmation, is that the non-compliant participants did not experience dissonance.

Discussion

Across four studies, induced-compliance dissonance manipulations led not only to classic dissonance reduction, but also to greater affirmation of committed, unrelated beliefs (See Table 2.1, Figure 2.5). Participants were more likely to punish a norm violator, espouse a stronger belief in God, and had increasingly polarized views of positive discrimination. Additionally, participants in Study 3 also showed an increased likelihood of perceiving patterns in an implicit grammar task, which is evidence for abstraction motivations. These results indicate that the process involved in dissonance reduction and meaning maintenance may overlap, if they are not actually the same process. There may not be a unique “dissonance-reduction” psychological mechanism, but rather, dissonant cognitions lead to general arousal, and participants address these cognitions when their attention is drawn to them.

There are a number of limitations in the findings across the studies. In Studies 2 and 4 participants were not given an opportunity to reduce dissonance. However, the same dissonance manipulation in Study 1 and an additional manipulation in Study 3 demonstrated that both dissonance reduction and compensatory affirmation can occur following a dissonance induction. An important limitation to the abstraction results in Study 3, is that dissonance only appeared to increase motivation to identify patterns, but not accuracy, as has been seen in other studies (Proulx & Heine, 2009; Randles et al., 2011). The two attempts at revealing order effects (study 1 and 3) revealed that participants engaged in both compensatory affirmation and dissonance reduction

regardless of which was presented first. I had anticipated that engaging in one would reduce motivation to follow-through with the 2nd dependent variable, similar to how self-affirmation manipulations prior to dissonance appear to buffer the need to reduce the dissonant cognitions (Sherman & Cohen, 2006). One possibility is that buffering someone against dissonance is more effective than attempting to reduce the arousal afterwards. If dissonance represents a change in motivational or drive-state, then it is possible that affirmations may help to increase the reduction rate of this felt drive, but that ultimately time is required to return to equilibrium, and any opportunities for affirmation during this period will be seized upon.

Finally, I did not see an increase in positive attitudes towards affirmative action in Study 4 amongst those who were initially high in positive discrimination attitudes. However, I did see the same pattern of effects for low positive discrimination, where either dissonance or a meaning violation caused further reduced support for affirmative action, supporting the core hypothesis that dissonance is experienced by participants in much the same way as other meaning violations. These results are not uncommon in the threat-compensation literature, where the particular population and measure may lead to one group displaying more affirmation tendency than the other (e.g. Jost et al., 2007; Proulx & Major, 2013).

Although varied in ethnic background, participants were largely from Western countries. This carries some limitations in terms of confidence that the effects will generalize outside this group, however these results at least generalize to a broader North American population, with one European sample. Additionally, an attempt to find a moderated effect by culture in studies 2 and 3 yielded no evidence of different effects

based on collectivistic or individualistic leanings, suggesting that the results may generalize even more broadly.

Although these results encourage the possibility that dissonance and other threat-compensation theories are discussing similar phenomena, there are still a number of questions that need to be addressed. Most manipulations of uncertainty or expectancy violation show little or no change in self-reported affect, while dissonance is consistently associated with negative affect (Elliot & Devine, 1994; Harmon-Jones, 2000; Harmon-Jones et al., 2009) and has a detectable arousal component (Croyle & Cooper, 1983; van Veen et al., 2009), something that has not yet been shown in other meaning violation paradigms. However, studies conducted under the MMM and similar theories have found that arousal is produced, insofar as participants are able to misattribute it (Kay et al., 2010b; Proulx & Heine, 2008). This lack of self-conscious affect has been discussed more broadly in the uncertainty literature (Proulx & Inzlicht, 2012; Tritt, Inzlicht, & Harmon-Jones, 2012), where it is noted that subjective experience, physiological arousal and behavioral expression often do not correlate as much as might be predicted following an affective trigger (Lang, 1968), and that the experience of anxiety may occur without conscious awareness (Winkielman & Berridge, 2004). As such, the differences in self-reported affect may have more to do with how consciously accessible a violation is, but further work is needed to state this with confidence.

While cognitive dissonance theory and the MMM may be referring to a similar psychological process, the fact that they come from different perspectives creates a rich and likely fertile ground for advancing a more unified theory. Further attention to the overlap in both theories may help build a more complete understanding of human

cognition and behavior in response to unexpected or dissonant cognitions. The following three chapters attempt to directly build on this work, and more broadly address the tautological nature of defining meaning maintenance based on its behavioral outcomes. I will attempt to build a framework for this process that incorporates not only literature on dissonance, but also the cognitive neuroscience perspective on violated expectations.

Table 2.1

Dissonance reduction and compensatory affirmation across studies

| Study | Dissonance Reduction | Compensatory Affirmation |
|----------|----------------------|--------------------------------------|
| Study 1 | .51*** | .30** |
| Study 2 | | .51† |
| Study 3 | .99** | .67* |
| Study 4a | | .1 ^c /.21 ^d |
| Study 4b | | .55* ^c /.44* ^d |

Both dissonance reduction and affirmation are presented as estimated Cohen's d effect sizes (Nakagawa & Cuthill, 2007) between the forced-compliance (control) condition and the induced-compliance (dissonance) condition. For Study 4, the first effect sizes (a) represent participants high in pre-existing positive discrimination attitudes, while b) are those low in this attitude. c) affirmation following dissonance, (d) affirmation following a meaning violation.

† = p < .10

* = p < .05

** = p < .01

*** = p < .001

Table 2.2

Full ANCOVA model for Study 4 at mean, low and high pre-existing attitudes towards positive discrimination

| | Mean PD | Low PD | High PD |
|--------------------------------|---------|--------|---------|
| <i>F</i> model statistic | 4.03** | 4.03** | 4.03** |
| Predictors | | | |
| Positive discrimination | 1.01** | 1.01** | 1.01** |
| Dissonance | -.17 | -.41* | .07 |
| Meaning violation | -.08 | -.32* | .15 |
| Dissonance X Pos. Disc. | .20† | .32† | .31† |
| Meaning violation X Pos. Disc. | .26* | .32* | .38* |
| Covariates | | | |
| Age | .29** | .29** | .29** |
| Gender | -.01 | -.01 | -.01 |

ANCOVA results for study 4. Standardized beta coefficients are reported.

Pre-existing positive discrimination (PD) values are set at the mean (column 1), one standard deviation below the mean (column 2) and one above (column 3). Dissonance and Meaning violation are referenced against the control condition. Dependent variable is a post-manipulation measure of positive discrimination affirmation.

† = $p < .10$

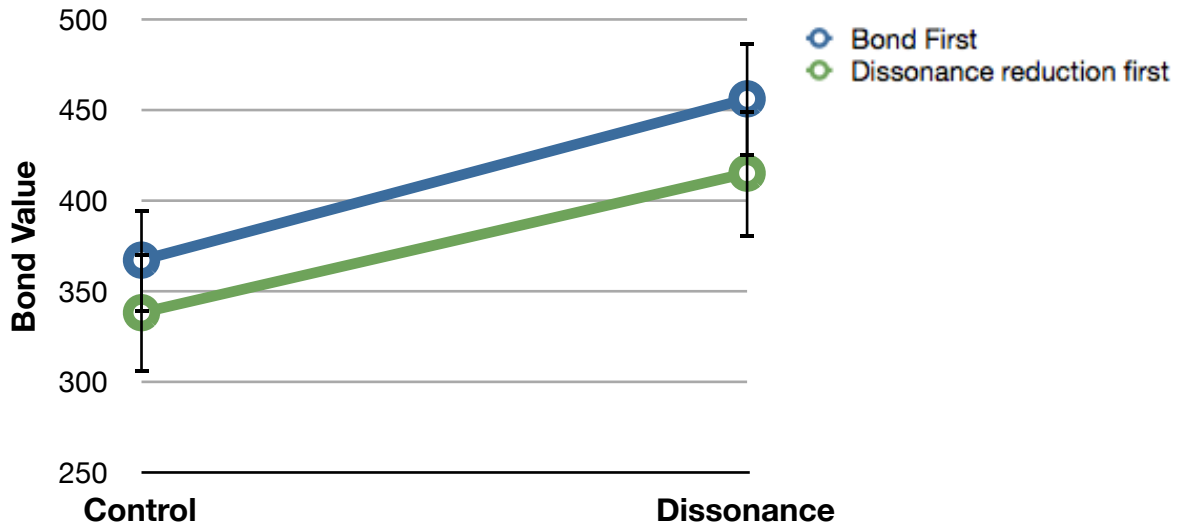
* = $p < .05$

** = $p < .01$

*** = $p < .001$

Figure 2.1

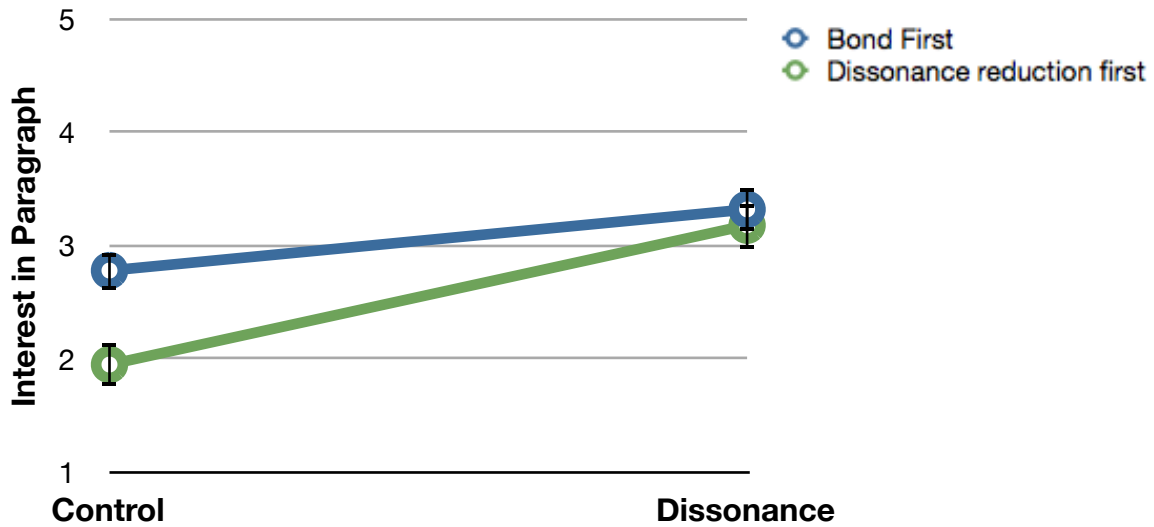
Dissonance causes higher affirmation of the social judgment survey



Dissonance predicts greater compensatory affirmation, as measured by an increased fine set in the prostitution scenario. Interaction is not significant, $p > .50$, main effect is significant $p < .01$, $d = .30$ when order is collapsed.

Figure 2.2

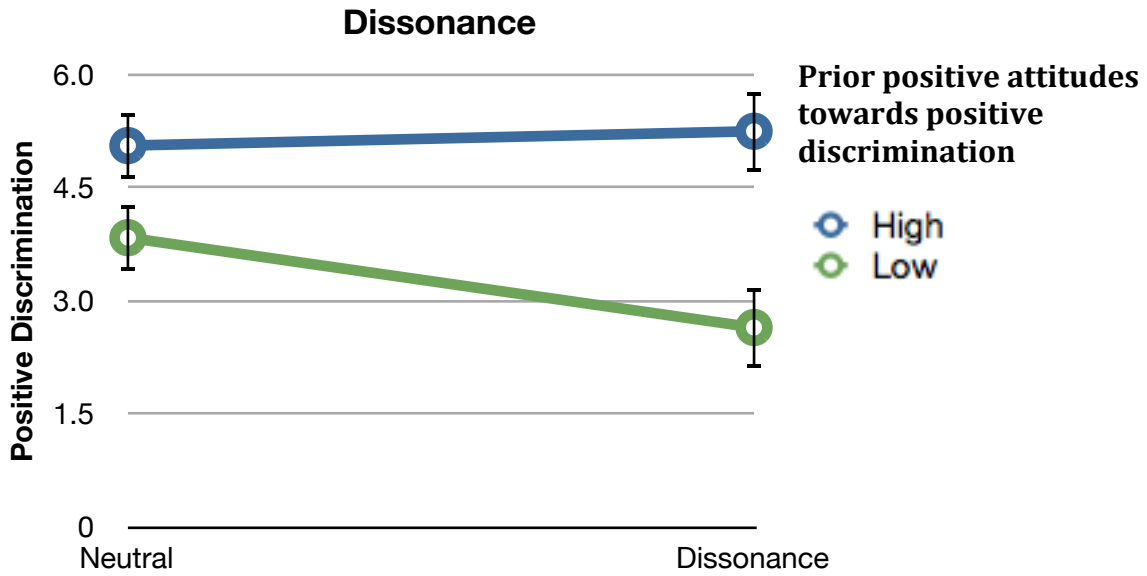
Dissonance leads to direct efforts to reduce dissonant cognitions



When politely asked to tell a future participant that paragraph was interesting, participants later on report that they did find it personally more interesting than if they had been explicitly instructed to convince someone else. Although participants who first complete a measure of compensatory affirmation show less motivation to directly reduce dissonance main effect of condition is present for both groups with the interaction term $p > .001$ $d = .50$, or collapsed across order $p < .001$, $d = .51$.

Figure 2.3

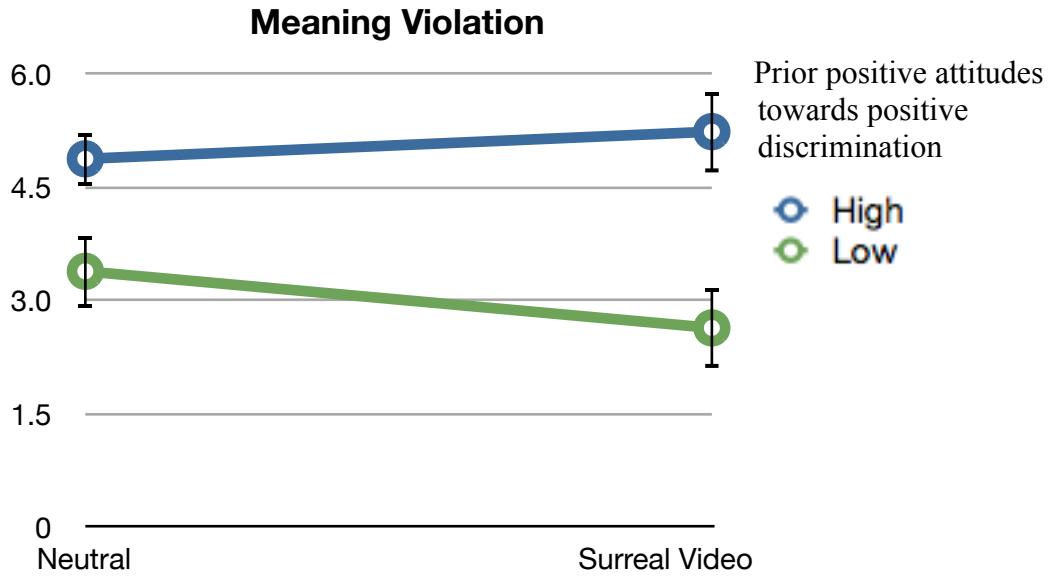
Polarizing effects of dissonance on prior attitudes



Participants who reported high prior positive attitudes towards positive discrimination did not affirm this value when feeling dissonant. However, participants low in prior positive attitudes did affirm their position following dissonance.

Figure 2.4

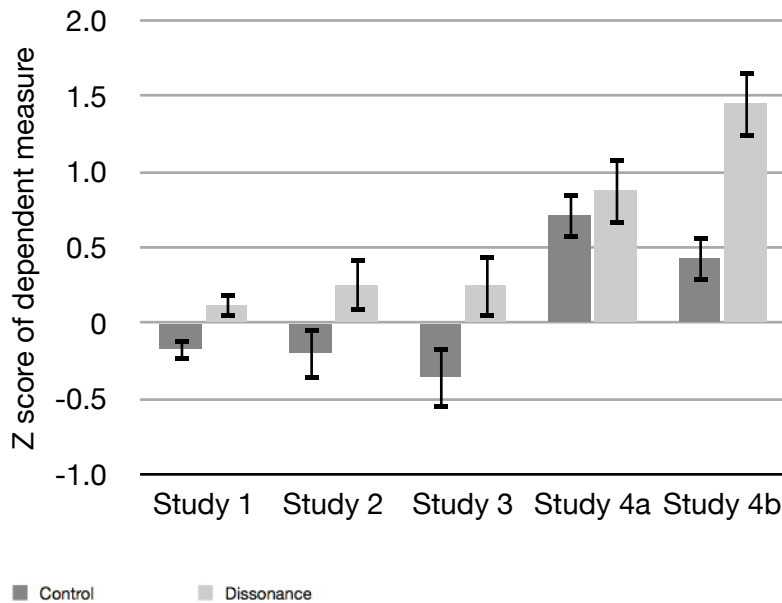
Polarizing effects of a meaning violation on prior attitudes



As with dissonance, participants who reported high prior positive attitudes towards positive discrimination did not affirm this value after the meaning violation, but, participants low in prior positive attitudes did affirm their position.

Figure 2.5

Effects of induced-choice dissonance on affirmation of entirely unrelated attitudes and beliefs



Marginal means controlling for age and gender are presented with standard error bars. All dependent variables are presented as Z scores for comparison purposes. Study 4a and b represent participants high and low in pre-study positive discrimination attitudes respectively. Values for 4b are reversed for visual consistency, but participants report *lower* post-manipulation support for positive discrimination.

CHAPTER 3 – THE ROLE OF THE ANTERIOR CINGULATE CORTEX IN PROCESSING UNCERTAINTY

Chapters 1 and 2 described a number of social psychological theories that have attempted to explain how humans process confusing, contradictory and uncertain events. Recently, neuroscience studies have shed considerable light on the process of uncertainty, emerging from an independent research line focused on brain anatomy. In a recent review, Proulx, Inzlicht & Harmon-Jones (2012) identified ten social psychology theories of uncertainty, of which three have begun to employ neuroscience research in describing the uncertainty process. Broadly speaking, incorporating neuroscientific research in a question of social behaviour helps to structure boundary conditions regarding how a psychological process plays out in the mind, and incorporates the perspectives from researchers studying the same topic but from a approach of different methodology and research goals. Ideally, this merging of view points should bring us closer to accurately understanding the objective process of psychological uncertainty.

All three have explicitly targeted a particular region of the brain known as the dorsal anterior cingulate cortex (dACC) as a region that is active when experiencing an anomaly or conflicting experience. This region has been targeted because of growing evidence over the last fifteen years that the dACC monitors for conflicts in both sensory perception and behavior (Carter, 1998). However, on-going neuroscience research has additionally identified the dACC as an important component involved in learning, negative emotional processing, pain, social frustration, cognitive control, and decision making. The goal of this chapter is to review the cognitive neuroscience research on the dACC and extend uncertainty theories, making new predictions based on this review.

Defining risk and uncertainty

While I have discussed uncertainty and violations of meaning at length in Chapter 1, uncertainty in the animal learning literature (from which much neurological work is based) has a particular definition (Rushworth & Behrens, 2008) that is helpful in interpreting research on the dACC. Risk is defined as the variance of an expected rate of return, whereas uncertainty is the confidence the organism holds in its estimate of the risk. Risk, then, is the possibility that a particular event will occur, or a resource will be available, more or less frequently than it tends to be on average. Risk exists even when the animal possesses perfect information, because there is always some deviation around the average rate of an event. However, if an animal understands the risk of an event, then it knows whether a particular instance is within the bounds of that risk, or highly unusual.

Uncertainty on the other hand, is captured by neither of these values, but is represented by a higher order term that tracks how volatile the variance is over time (Rushworth & Behrens, 2008). The most likely outcome of an action is the *average* expected value. The risk is the *variance* of that estimate; there is a chance that sometimes more (or less) of some resource will be available, despite the expected value. The *uncertainty* is the volatility an organism perceives to exist around its estimate of the risk interval, that is, the variance of the variance estimate. As with first order variance, this value typically becomes smaller with each additional data point, implying that uncertainty is reduced for any learned behavior over time, even when the variance (risk) surrounding that behavior is high.

Reacting to uncertainty

Rushworth (2008) argues that, given the advantages of knowing what opportunities and costs exist in the environment, animals should be prepared to pay a cost

in order to learn about their options. The value of the immediate expected reward is weighted against future values that could be increased if more information is gathered. There are two situations when this should occur (Cohen & Ranganath, 2007; Daw, O'Doherty, Dayan, Seymour, & Dolan, 2006). The first is when the animal begins a new behavior (e.g. foraging in a new patch). The second learning cue should be when a payoff is considerably outside the range of the expected variance. This implies that the environment has changed, and that effort should again be given to updating information.

In terms of how animals actually learn, many do not possess the cognitive capacity to manage these calculations, likely relying on different heuristics that make it look like they are optimizing their behavior. However, humans, primates and some other mammals have dedicated neurons located in the dorsal anterior cingulate cortex (dACC), designed exactly to track information of this nature (Matsumoto, 2003; Seo & Lee, 2007). In the following section I expand on the role that the dACC plays in this process, as well as its additional roles of tracking cognitive conflict, error, and pain. I then elaborate on why understanding this region can also help us to understand some of the more uniquely human causes of uncertainty that do not immediately seem related to the animal learning definition, such as being stood up on a date, trying to understand statistics, or experiencing absurd or surreal art.

The anterior cingulate cortex

This section describes research that unpacks how uncertainty is processed in the human brain. Ultimately, there are a number of brain structures that are involved in reacting to and processing uncertainty, from perception of initial sensory information to the final executed response. In this review I focus on the anterior cingulate cortex (ACC),

because activity in this region consistently emerges as one of the earliest responses to many types of uncertainty. Additionally, there has been considerable research attention on this topic for the ACC, allowing for a manageable comparison between its function and social psychological theories of uncertainty⁴.

The ACC tracks environmental uncertainty

The ACC appears to perform exactly the calculations needed to monitor known environmental risks for uncertainty, tracking the magnitude and probability of reward, and signaling prediction errors at the time of an outcome (Matsumoto, 2003; Matsumoto et al., 2007; Seo & Lee, 2007). That is, activity in this region is altered based on cumulative expectation of rewards and punishments (Amiez, Joseph, & Procyk, 2005; Matsumoto, Matsumoto, Abe, & Tanaka, 2007), increasing in response to a payout that falls outside the expected variance (Jessup, Busemeyer, & Brown, 2010) and producing weaker signals when payouts match the expected value (Matsumoto et al., 2007). Indeed, when this area is lesioned, monkeys lose the ability to track this information over time, and base behaviors solely on the payout from the previous trial (Amiez et al., 2005; Seo & Lee, 2007). Macaques and rhesus monkeys, show increased ACC activity during initial learning phases of a task, but reduced activity once reward associations have been learned (Procyk, Tanaka, & Joseph, 2000); unless payoffs change stochastically throughout the task, in which case ACC activity remains high throughout (Amiez, 2006). In one such

⁴ There are two sections of the ACC that appear to serve somewhat different functions. The rostral ACC attends primarily to affective cues and processing, while the dorsal ACC attends to both affective information, and cognitive conflict, a distinction that is based on a meta-analysis of hundreds of brain imaging studies (Shackman et al, 2011). In this review, I will only use ACC when referring to studies that were unable to distinguish between activity in the two regions (for instance, when using electroencephalographic data).

study, the authors argue that the ACC response is stimulus-general, in that the response activity following errors, task-interruptions and cues that the task was changing were not distinguishable between each other (Amiez et al., 2005). Signals emerge from this area after any cue that the previously expected outcome has changed, even when the change leads to rewards that are greater than expected (Jessup et al., 2010), or unexpected positive feedback is given (Oliveira, McDonald, & Goodman, 2007; Walton, Devlin, & Rushworth, 2004).

Human participants also show this pattern of activation. Relatively more ACC activity is seen in gambling tasks if the payout for each option changes frequently (Behrens et al., 2007). When the environment becomes volatile (success rates randomly change for the options within the block of trials), there is greater ACC activation following stimulus onset, and this corresponds to higher learning rates and selection strategies. Thus, the ACC is more active during any event when the possibility of environmental change is cued. This effect has been replicated in a multi-armed bandit game, where participants selected from multiple “slot machines” with payout rates that changed at random intervals. Even after finding a high payout machine, there was an increasing possibility over time that a different machine had become more lucrative. Participants often chose to resample previously low payout machines to test for changes, and activation throughout the ACC prior to choice predicted the decision to do so (Daw et al., 2006).

Interestingly the pattern of ACC activity and behavior implies that humans use a very similar strategy to the most successful algorithm in a recent social learning tournament (Rendell et al., 2010). In this tournament, contributors submitted 104

different algorithms that guided their simulated “species” to optimally select from individual learning, social learning and choosing to exploit the environment for resources. The simulated environment was a 100-armed bandit with payoffs drawn from an exponential distribution (thus leading to many poor payouts, a large selection of average payouts and a few jackpots). Although the main result of the tournament was that social learning has an enormous advantage, an additional finding that emerged was that spending moves to learn by either method was negatively correlated with the contributor’s rank score. Species did better if they spent fewer turns learning (and thus more turns exploiting), started exploiting sooner in the game, and timed their learning moves to coincide with changes in the payout structure. The message is that learning is a costly trade-off with behaviors that accrue resources, and should be avoided unless the current behavior is no longer beneficial. This parallels ACC function, which tracks information about payouts (the mean and variance estimates coupled with a confidence in those estimates) and is inhibited when payout structures are understood, potentially preventing motivation to deviate and learn new behaviors. In line with this perspective, inhibited activity in the ACC helps to maintain goal-pursuit and ignore pursuing new options (Daw et al., 2006; Newman & McGaughy, 2011). Thus, animals that sense they are getting a reasonable return for their effort appear to experience inhibited motivation to pursue other options.

The ACC tracks goal-related errors

In addition to learning payoff structures, humans also show dACC activation when they commit errors. Prior to this empirical discovery, Botvinick (2001) predicted that a conflict detection mechanism must exist, on the expectation that the brain, which

processes parallel information, will run into “crosstalk interference,” a conflict where simultaneous behaviors or thoughts attempt to use the same cognitive resources. He cites Mozer and Sitton (1998) who summarize the problem:

One can conceive of processing...as occurring along a certain neural pathway. If the processing pathways for two stimuli are non-overlapping, then processing can take place in parallel. But if the pathways cross—i.e., they share common resources or hardware—the stimuli will interact or interfere with one another. (p.342)

Botvinick’s assumption was that *all* behavior and thought is associated with a goal, and that any cue that behavior is not leading to a set goal, or that simultaneous behaviors are interfering with each other, should activate the conflict monitor. This definition of conflict goes beyond the definition of uncertainty in the previous section, but is related to it by assuming that any interference in the chain of thought, action, and feedback that yields unexpected results, can trigger a warning cue. This perspective does not suggest qualitative distinctions between errors and conflicting cognitions, but rather errors merely lead to an unusually strong activation of the monitoring system (Botvinick, Cohen, & Carter, 2004).

Following this prediction, increased ACC activity is observed after commission of errors in a number of cognitive paradigms, including the Stroop task, Go/NoGo task and Flanker task (See Shackman et al., 2011 for a review). This signal does appear to enhance cognitive control, as strength of ACC activation in a preceding trial predicts reduced reaction time and errors on a subsequent trial, as well as reduced ACC activation and

increased activation of the prefrontal cortex (a region associated with cognitive control; Kerns, 2004). In other words, detecting an anomaly that leads to error, triggers greater control and greater expectation that anomalies will occur, which in turn reduces both ACC activation in response to anomalies and the likelihood of making an error. Although the issue of whether error-detection involves a unique system or partially overlapping system with cognitive conflict has not been fully addressed (Taylor, Stern, & Gehring, 2007), there appears to be considerable overlap in experiences that trigger this system, ranging from external conflict perceived in the environment to unexpected thoughts or actions originating from within the self, so long as they interfere with a goal or lead to an unexpected result.

Subjective experience of ACC activation

Thus far I have discussed the types of experiences that lead to activation, but not how that activation is experienced subjectively. ACC activation appears to trigger negative affect, which motivates the organism to attend to the environment and select new behaviors. In fact, there is considerable overlap in dACC activation when processing negative affect, pain or cognitive conflict (Eisenberger & Lieberman, 2004). The physical size of the dACC can predict individual differences in trait negative affect (DeYoung et al., 2010), ease of conditioning a fear response (Milad et al., 2007), and more effective cognitive control in interference tasks such as the Stroop task (Huster et al., 2009). Greater resting activity in the ACC is associated with obsessive-compulsive disorder (Graybiel & Rauch, 2000), a disorder marked by persistent worry about errors or environmental threats that have not been attended to. Additionally, engaging in a cognitive control task (which inhibits the dACC), leads to reduced experience of negative

affect and pain (Bantick, 2002; Buhle & Wager, 2010). Trait neuroticism, which is often found to correlate with trait negative affect, is associated with stronger ACC activation following both emotionally conflicting events (Haas, Omura, Constable, & Canli, 2007) and uncertain feedback (Hirsh & Inzlicht, 2008). As the timing and magnitude of unpleasant stimuli becomes less predictable, both negative affect and reports of pain increase (Alvarez, Chen, Bodurka, Kaplan, & Grillon, 2011; Oka et al., 2010).

This research implies that events as distally related as getting a paper cut, seeing movement while walking in an alley at night and being fired from a job all rely on the same or similar underlying affective component. Although each of these events involves unique sensory components and context, they each appear to trigger the same general warning system. Some theorists have argued that as some species became more socially complex, employing evolutionarily ancient pain and conflict detection mechanisms in service of more complex events was an adaptively expedient solution (Eisenberger, 2012; Eisenberger & Lieberman, 2004). Similarly, in reviewing the function of the dACC, Shackman et al. (2011) point out that negative affect, cognitive-conflict and pain have all been independently described as an "...early warning system that allows animals to proactively alter attention or behavior to avoid future errors." (pg. 159). These similar descriptions encouraged them to put forth the **adaptive control hypothesis**, a functional explanation of the role of the dACC that bears some striking similarities to uncertainty theories discussed in Chapter 1, including the Meaning Maintenance Model. It argues that the role of the dACC is to integrate information about punishment, response competition and uncertainty, and signal the necessity for greater control and attention to be exerted in selecting behaviors.

Bridging social and cognitive psychological perspectives

The social psychological theories discussed in Chapter 1 are largely consonant with neuroscience theories of the ACC, including agreement that there is a universal human response to experiencing and responding to inconsistencies or unexpected events.

Although cultures may foster different ways of interpreting and responding to uncertainty, these theories argue that there is a biological basis for this process and an evolutionary explanation that ties the function of felt uncertainty to similar dilemmas faced by other species. This is similar to describing anger or any emotion that leads to adaptive behavior; it is a genetically predetermined process with neural specificity, triggered by a wide range of content that may contain very different sensory and semantic components (cf. Tracy & Randles, 2011).

When an inconsistency is detected, this system generates a signal that is perceived as unpleasant arousal, motivating changes in behavior. Engaging in the appropriate type of behavior reduces the negative arousal and is thus proximally motivating, but likely is tied to adaptive problems that emerge when cues of uncertainty are present. Shackman et al. (2011) notes that the dACC did not evolve to handle cold cognition tasks like the Stroop and that we shouldn't backwards-infer from empirical studies that the mechanism is purely adapted towards mundane perceptual errors. Likewise, the dACC did not evolve to be disturbed by surreal art or discussing one's death. The fact that we can manufacture experiences that trigger this anxiety is interesting, but we should expect that the inconsistencies present in these cultural products are building on mechanisms sensitive to more adaptive concerns.

The dACC reacts to "high-level" conflict and uncertainty

Although the animal definition of uncertainty (See pg. 48) largely describes payout structures and cues of predation, and much neuroscience work focuses on “low-level” response conflicts and errors, there is evidence that this region also attends to the more complex high-level conflicts that interest uncertainty theorists. For instance, the dACC is activated not only by low-level response conflict (such as a Stroop task), but also during both induced-choice, post-choice dissonance (Izuma et al., 2010; van Veen, Krug, Schooler, & Carter, 2009), and behaviors that are inconsistent with one’s self-concept (Amodio, Devine, & Harmon-Jones, 2008; E. Harmon-Jones, 2004). Likewise, participants who take a placebo that they believe will cause mild anxiety, show less ACC reactivity when making errors in a Go/NoGo task (i.e. low-level response conflict; Inzlicht & Al-Khindi, 2012), reflecting the same misattribution of arousal that leads to inhibited compensation in meaning violations (Proulx & Heine, 2008), dissonance (Fried & Aronson, 1995; Zanna & Cooper, 1974), control threats (Kay, Moscovitch, & Laurin, 2010) and goal-frustration (Nash et al., 2011). Additionally, drugs that actually increase arousal appear to aggravate dissonance responses, and drugs that decrease arousal inhibit the motivation to reduce dissonance (Cooper, Zanna, & al, 1978b). Inzlicht et al. (2009) have also shown a relationship between trait religiosity and Stroop errors, such that more religious participants (i.e. those that chronically employ a high-level abstract goal) show less ACC activation when they make a Stroop error. In a similar vein, high trait neural activation (measured at baseline) in areas associated with approach motivation are related with both decreased ACC activation after Stroop errors (Nash, Inzlicht, & McGregor, 2012) and reports of wellbeing and meaning in life (Jackson et al., 2003; Urry et al., 2004). In other words, individual differences that predict how strongly a person reacts to

Stroop errors, also predict how likely that person is to lie awake at night, wondering what it's all for.

Emergent hypotheses

This chapter drew on two independent literatures to argue that all forms of violated expectations are processed in a similar way, both anatomically and subjectively, and that any conflicting experience requires context to help direct the organism towards a beneficial compensation effort. Three social psychological theories of conflict, namely dissonance, the reactive approach model and the meaning maintenance model, all appear to be describing this process, a process that also appears similar to the adaptive control hypothesis. The considerable overlap suggests that the same theoretical process is being described. The following two chapters test hypotheses that emerge from this comparison. Chapter 4 tests whether acetaminophen, a drug known to inhibit dACC activity, can also inhibit compensatory affirmation following meaning violations. Chapter 5 assesses whether this same drug can inhibit the ability to register errors and respond with greater control.

CHAPTER 4 – THE EFFECT OF ACETAMINOPHEN ON MEANING VIOLATIONS⁵

The meaning-maintenance model (MMM) proposes that domain-general arousal is triggered by any experience that is surprising, confusing, or in violation of expectations (Heine, Proulx, & Vohs, 2006). This chapter incorporates recent work on the common neural pathway for physical and social pain to put forward the argument that any unexpected event, not just events with a physical or social component, produces the same initial neural and subjective experience of distress. On this basis, I argue that acetaminophen, which has been shown to reduce both physical and social pain, will also prevent typical meaning-maintenance responses. Although the following review indicates that many pain relievers may have similar effects, acetaminophen is particularly appealing from a methodological perspective because it alleviates pain without typically without creating a noticeable change in mood or sense of euphoria for the user. As a result, it is quite amenable to a true double-blind experiment.

Physical pain and social rejection share a neural process and subjective component that are experienced as distress (Eisenberger & Lieberman, 2004; MacDonald & Leary, 2005). Although there are experiences unique to each type of event, such as the sensory awareness of specific pain, there are many subjective similarities and overlapping brain regions that lead to the same general felt unpleasantness (Price, 2000). For instance, there is evidence that experiencing more or less of one type of pain (physical or social) influences sensitivity to the other (Asmundson, Norton, & Jacobson, 1996; MacDonald, Kingsbury, & Shaw, 2005). Likewise, social support has been found to reduce physical

⁵ This chapter is adapted from a published manuscript. See preface.

pain (Hoogendoorn, van Poppel, Bongers, Koes, & Bouter, 2000), and a number of drugs (including opiate-based drugs, antidepressants, and acetaminophen) have been shown to reduce both physical and social pain (e.g., DeWall et al., 2010; Panksepp, 2004).

One brain region that responds to both physical and social pain is the dorsal anterior cingulate cortex (dACC; Eisenberger, Lieberman, & Williams, 2003). Its activation is correlated with subjective reports of felt unpleasantness after physical pain (Tölle et al., 1999) and social exclusion (Eisenberger et al., 2003). However, as discussed in Chapter 3, there is evidence that the dACC reacts to all conflicts and errors in general. The dACC has been described as a cortical alarm system, sensitive to any discrepancy in the environment, not just to discrepancies that relate directly to physical damage or social rejection (Eisenberger & Lieberman, 2004; Inzlicht, McGregor, Hirsh, & Nash, 2009; Shackman et al., 2011). Although it is true that an individual will not likely confuse a stubbed toe with being snubbed on a date, I suggest that the early-stage neural mechanisms for both of these events, or for any perceived anomalies, share much in common and that additional context is required to give them specificity.

The dACC has been theorized to be the source of the unpleasant arousal associated with uncertainty and violations of expectations (McGregor, Nash, Mann, & Phills, 2010), and strong adherence to belief systems that serve as affirmations, such as religion and political conservatism, inhibit activity throughout the ACC (Amodio, Jost, Master, & Yee, 2007; Inzlicht et al., 2009). The arousal caused by meaning violations is not always consciously accessible, which is a clear departure from the experience of physical pain or social distress. However, when participants are given an explanation for their unpleasant arousal (e.g., when they are told that it is due to a dietary supplement

they have taken), they fail to show compensatory responses (Kay, Moscovitch, & Laurin, 2010; Proulx & Heine, 2008; Zanna & Cooper, 1974), suggesting that they are in fact experiencing some form of distress or negative affect that they have attributed to this other source. The fact that dissonance both can be misattributed (Zanna & Cooper, 1974) and leads to compensatory affirmation (Chapter 2) is particularly telling, as recent studies have shown that the dACC is critical to the experience of dissonance. Induced-compliance dissonance leads to greater activation in the dACC, and individual differences in this activation predict greater motivation to reduce dissonance (van Veen, Krug, Schooler & Carter, 2009). This relationship extends to post-decision dissonance, where participants show more dACC activation when selecting between foods or music CDs that they have previously rated as very similar in subjective value (Izuma et al., 2010, Kitayama, Chua, Tompson & Han, 2013).

The present research is predicated on five key findings in the literature: (a) Both physical and social pain are associated with activation in the dACC (e.g., Eisenberger et al., 2003), (b) social rejection can produce the same compensatory affirmation as other meaning violations (e.g., Nash et al., 2011), (c) the dACC is activated in response to anomalies (e.g., Botvinick et al., 2004), particularly (d) dissonance, which has been shown to lead to compensatory affirmation, and (e) acetaminophen has been shown to reduce physical and social pain, as well as activation in the dACC (DeWall et al., 2010). These findings led me to predict that acetaminophen may also inhibit compensatory affirmation following violations of meaning. Participants who experience a meaning violation after having consumed acetaminophen should fail to detect any increase in arousal and thus will not show the kinds of compensatory affirmation identified in

previous research. Toward this end, I conducted two studies with different meaning violations and affirmations.

Study 5

Participants and Procedure

I recruited 121 participants (81 women, 40 men) from an Eastern Canadian university. The sample was predominantly of East Asian (45%), European (29%), and South Asian (12%) descent. Participants were offered \$15 through flyers posted on campus or received partial course credit in psychology classes. The study was advertised as a general assessment of the cognitive and emotional impacts of acetaminophen.

Participants received a single acute dose of acetaminophen, which was active in their system while they experienced the manipulation. Participants were randomly assigned to receive either 1,000 mg of Tylenol-brand acetaminophen (Rapid Release formula) or 1,000 mg of sugar (a placebo), packed in two opaque gel capsules. The experimenter was blind to both the type of capsules administered (coded bottles were used) and the version of the materials that participants completed. When taken orally, Tylenol's expected time to reach peak absorption is 45 to 60 min, and its ceiling effectiveness in adults occurs at 1,000 mg (Bertolini et al., 2006; Gibb & Anderson, 2008); this is also the maximum recommended single dose.

After receiving the capsules to ingest, participants were given 30 min of free time prior to working on filler tasks, which took approximately 25 min to complete. They then completed a writing task (mortality-salience manipulation), followed by measures of affect and social judgment (our index of compensatory affirmation). The expectation was that among participants in the mortality-salience condition, those who had taken the

placebo would show typical compensatory affirmation, whereas those who had taken Tylenol would not show this reaction.

Filler tasks. First, participants completed a number of materials not relevant to the task, to mask the specific hypothesis of interest. These tasks included a page of Sudoku puzzles, a memory task involving matching faces of individuals to their biographies, and a series of personality questionnaires that were not analyzed as part of the study.

Mortality-salience manipulation. Next, participants completed the standard-mortality salience manipulation: They wrote either two paragraphs about what will happen to their body after they die and how they feel about it or two paragraphs about dental pain (Burke et al., 2010). The rationale behind using dental pain as a control is that it should be aversive, but should not create an experience of violated expectations or uncertainty, and thus should not lead to affirmation responses (McGregor et al., 1998). This control condition has been used in the past to help rule out negative mood as an explanation for compensatory affirmation, (Burke et al., 2010). However, it is widely accepted that individuals typically cannot recall past physical pain, and are sensitive to bias based on the amount of pain they are currently in (Eich, Reeves, Jaeger & Graff-Radford, 1985; Erskine, Morley, & Pearce, 1990; Kent, 1985) suggesting that a pain recall question is in fact quite benign, and unlikely to evoke either a clear memory of distress or negative mood in general. Interestingly, in a study that happened to focus on dental pain, participants' memory of the pain months later tended to be more associated with their expected pain prior to the operation, compared to what they reported immediately after the experience, again suggesting that physically painful experiences are difficult to recall in a visceral manner (Kent, 1985).

Positive and Negative Affect Schedule. After the mortality-salience manipulation, participants completed the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988; $\alpha = .79$ for positive items and $\alpha = .75$ for negative items in this sample). This measure identifies the state of affect an individual is experiencing, using 20 different affect descriptors. Participants are asked to report how well each descriptor matches how they are feeling at the moment. This scale is often used to create a delay between the mortality-salience manipulation and the task assessing the dependent variable, and it typically reveals that the manipulation does not influence either positive or negative affect (Burke et al., 2010).

Social judgment survey. Finally, participants read a hypothetical arrest report about a prostitute and were asked to set the amount of the bail (on a scale from \$0 to \$999). This is the same measure that was used in Study 1 and 3, and has been used in a number of other meaning violation studies (Proulx & Heine, 2008; Proulx et al., 2010; Randles et al., 2011; Rosenblatt, Greenberg, Solomon, Pyszczynski, & Lyon, 1989).

Results

During debriefing, participants were asked to guess which capsules they had consumed. Fifty-five percent claimed that they had no idea; of those who guessed, 57% were correct (not different from chance, $p < .50$). Data from 5 participants who did not complete the materials were removed from analysis.

Planned orthogonal contrasts were used to test the hypothesis. I chose this analysis because I was expecting one particular pattern of effects: that participants in the mortality-salience/placebo group would show higher compensatory affirmation compared with participants in the other three groups. In cases with multiple groups and a priori

predictions, planned orthogonal comparisons maximize power to detect an effect, while eliminating the possibility of capitalizing on unpredicted effects that may be spurious (Bobko, 1986). As predicted, only participants who had experienced a meaning violation and had taken the placebo showed evidence of increased affirmation. Participants in the mortality-salience/placebo group ($M = 443.19$, $SD = 299.15$) punished the norm violator by a significantly larger amount than the other three groups did (Control/placebo: $M = 277.61$, $SD = 268.46$; control/acetaminophen: $M = 301.87$, $SD = 298.26$; mortality-salience/acetaminophen: $M = 313.89$, $SD = 253.66$; see Fig. 1; $t_{(112)} = 2.33$, $p < .05$, $d = 0.52$ ($CI_{.975}[-.08-.96]$ ⁶; See Figure 4.1). Participants in the mortality-salience/acetaminophen group showed no compensatory affirmation compared with those in the two control groups, $t(112) < 1$, $d = 0.09$, $CI_{.975}[-.36-.54]$. The two control groups did not differ from each other, $t(112) < 1$, $d = 0.09$, $CI_{.975}[-.41-.59]$. As in previous meaning-threat studies, self-reported positive and negative affect did not differ between conditions (all $ts < 1$).

Study 6

In Study 5, I employed the most commonly used manipulation of existential anxiety, mortality salience. To test whether acetaminophen affects uncertainty more broadly defined, I used a different and novel manipulation in Study 6. Specifically, I turned to an artistic tradition that is known precisely for its ability to provoke feelings of discomfort and unease: surrealism. The surrealist tradition involves the juxtaposition of unfamiliar elements in familiar settings. Past research has found that surrealist art forms,

⁶ Point and interval estimates for Cohen's d are based on recommendations in Robey (2004).

including literature, paintings, and humor, lead to compensatory responses (Proulx & Heine, 2009; Proulx et al., 2010). The work of surrealist filmmaker David Lynch seemed especially apt for my needs. As his biographer Rodley (2005) noted, “the indefinable ‘mood’ or ‘feeling’ Lynch seeks to convey is linked to a form of intellectual uncertainty—what he calls being ‘lost in darkness and confusion’” (p. x, preface). Whether because of nonlinear dream imagery, the unsettling juxtaposition of the beautiful alongside the horrifying, or the surreal disconnect between the events and characters’ reactions, Lynch’s films have the ability to “disturb, offend or mystify” (Rodley, 2005, p. 245).

Method

Students were recruited through the same methods as in Study 5. Of the 236 who were recruited, 8 failed to complete the study because of technical problems, and the data from 21 participants were removed because they reported during an open-ended debriefing that they had participated in previous MMM experiments or had guessed that we were interested in their responses to Lynch’s film (The key effects still remained significant when these 21 participants were included in the analyses.). This left 207 participants (124 women, 83 men), who were predominantly of European (52%), East Asian (25%), and South Asian (7%) descent.

The procedure was identical to that in Study 5, with two differences. First, the manipulation was changed. Participants in the meaning violation condition watched three films. The first was a 2-min clip from a Donald Duck cartoon, designed to ease participants into the task. They then watched a 4-min clip from the short film *Rabbits*, created by David Lynch (2002). The film, which at first resembles a sitcom, consists of a

series of non sequiturs, with seemingly random laugh and applause tracks separated by long portentous pauses, an eerie soundscape, a complete absence of a narrative, and characters inexplicably dressed in rabbit costumes. The clip is ominous, although it contains no reference to disturbing or unpleasant topics. After the *Rabbits* clip, participants watched a 2-min clip from a Snoopy cartoon, designed to serve as a distraction and delay. As we were concerned that participants would identify *Rabbits* as critical to the study, we included an additional distractor beyond the PANAS ($\alpha = .77$ for positive items and $\alpha = .54$ for negative items in this sample) to help reduce suspicion. Participants in the control condition saw the same videos except that the *Rabbits* clip was replaced with a 4-min clip from an episode of “The Simpsons”.

I also changed the dependent measure.

This study was conducted 3 to 6 months after a well-publicized local riot that followed the Vancouver Canucks’ loss in their bid for the Stanley Cup, and I suspected that most students held a negative view of the riot. Thus, I expected that after a meaning violation, participants would affirm this view by calling for stronger punishment for the rioters. Participants were informed that people were debating whether the rioters should be given sentences more lenient than those for comparable individual acts of vandalism, because the rioters had acted impulsively, or should be given stiffer sentences, because they had taken advantage of the city while it was vulnerable. Participants then marked a spot on a line from 0% to 200%. They were told that 0% indicated that rioters should not be punished, that 100% indicated that rioters should receive a normal punishment, and that 200% indicated that rioters should receive a doubled punishment.

Results

Participants were unable to correctly identify whether they had taken acetaminophen or a placebo. Fifty-three percent claimed that they had no idea; of those who guessed, 45% were correct (not different from chance, $p < .50$). Participants in all conditions set the fine for the rioters at a higher value than the court would normally set (all $ps < .001$), which confirms my expectation that most students in our sample found the behaviors unacceptable.

As in Study 1, I used planned orthogonal contrasts to test whether participants in the violation-placebo group showed more compensatory affirmation than participants in the other three groups. Again, only participants who had experienced a meaning violation and had taken the placebo showed evidence of increased affirmation (see Fig. 4.2).

Participants in that group wanted to punish the norm violators by a significantly larger amount than those in the other three groups did, $t(203) = 2.64$, $p < .01$, $d = 0.43$ (CI_{.975}[.11 - .74]). Participants in the threat-acetaminophen group showed no compensatory affirmation compared with those in the two control groups, $t(203) < 1$, $d = 0.05$, CI_{.975}[-.29 - .39]. There was no difference between the two control groups, $t(203) < 1$, $d = 0.09$, CI_{.975}[-.26 - .44]. Again, there was no difference among the groups in self-reported positive or negative affect (all $ts < 1.2$, $ps > .23$).

Discussion

Two studies show that acetaminophen interrupts the typical compensatory responses to meaning violations. In the first study, I found a typical mortality-salience reaction in the placebo condition, but participants in the mortality-salience condition who had taken acetaminophen responded in ways similar to those who had not contemplated their mortality. In the second study, this pattern of findings was replicated using a surreal

video clip and a novel dependent measure; participants who had watched the David Lynch clip and taken a placebo were more punitive than those who had watched the same clip but consumed acetaminophen or who had watched the control video. In neither study were there any group differences in self-reported positive or negative affect, which renders it unlikely that the effects were simply due to people becoming more punitive because they were in a bad mood. Rather, we argue that a particular type of distress associated with expectancy violation (originating from the dACC) and a failure to correctly identify or be able to accommodate to the source of that distress led to this affirmation. These results are consistent with the notion of a domain-general process for expectancy violation.

These findings imply that the similarities between physical pain and belongingness threats may not be specifically due to both kinds of threats triggering something akin to pain; rather, the similarities may arise because both typically involve a violation of expectations. This is not to say that uncertainty is a necessary feature of pain, but it is possible that pain (and social failure) are often brought about by unexpected consequences to behaviors or actions. In reviewing the literature on the dACC, Shackman et al. (2011) argued that “the core function common to negative affect, pain and cognitive control is the need to determine an optimal course of action in the face of uncertainty” (p. 160).

However, one disconnect between the present findings and current data on the dACC is that the manipulations I used, and indeed many manipulations of uncertainty or existential anxiety (e.g., Burke et al., 2010), do not lead to changes in self-reported affect as measured by the PANAS. Studies that have measured dACC activation following

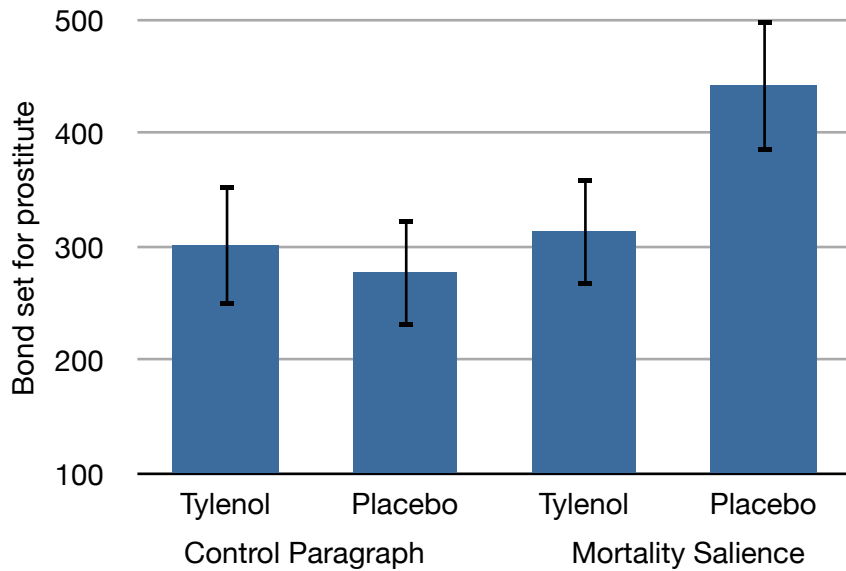
physical pain, social pain, and frustration have found an association with self-reported negative affect (e.g., DeWall et al., 2010; Eisenberger & Lieberman, 2004; Spunt, Lieberman, Cohen, & Eisenberger, 2012), and a recent meta-analysis of brain-imaging studies found that the dACC was activated in response to manipulations that induced fear, anger, or disgust (Shackman et al., 2011). There are several possible reasons for this disconnect. It could be (a) that the PANAS does not tap into the kinds of negative affect associated with expectancy violations, (b) that asking participants about how they are generally feeling at the moment is less likely to reveal measurable differences between conditions compared to asking how they felt about the threat in particular (Spunt et al., 2012), or (c) that people do not always have conscious access to the arousal elicited from expectancy violations (Lang, 1968; Lang, Bradley, Cuthbert, 1998). I partially address this concern with Study 7 in Chapter 5.

These studies have a number of limitations and suggest several future research directions. First, it is unclear how well the findings would generalize to other samples. However, research on terror management theory finds effects in the same direction across a broad array of samples, although Americans and college students show stronger effects than other samples (Burke et al., 2010). I therefore anticipate that the findings would replicate, possibly with a weaker magnitude, in other samples. Second, acetaminophen affects a number of brain regions, some of which are not directly related to physical or social distress (Toussaint et al., 2010). Therefore, these findings could have been due to acetaminophen (a) reducing participants' felt arousal when they witnessed violations, (b) interrupting the trigger for the affirmational response without affecting participants' experience of arousal, (c) making participants less attentive so they never noticed the

violation to begin with, or (d) affecting some of the cognitive processes involved in completing the dependent measures. Although these studies were inspired by the neuroscience research on physical pain, social pain, and expectancy violation, further work will be needed to confirm that overlapping brain regions are involved. A more complete understanding could be achieved through employing alternative measures of distress, in particular neurological evidence that perceptions of violated expectations are in fact reduced by acetaminophen. The following chapter presents evidence that more directly addresses this question.

Figure 4.1

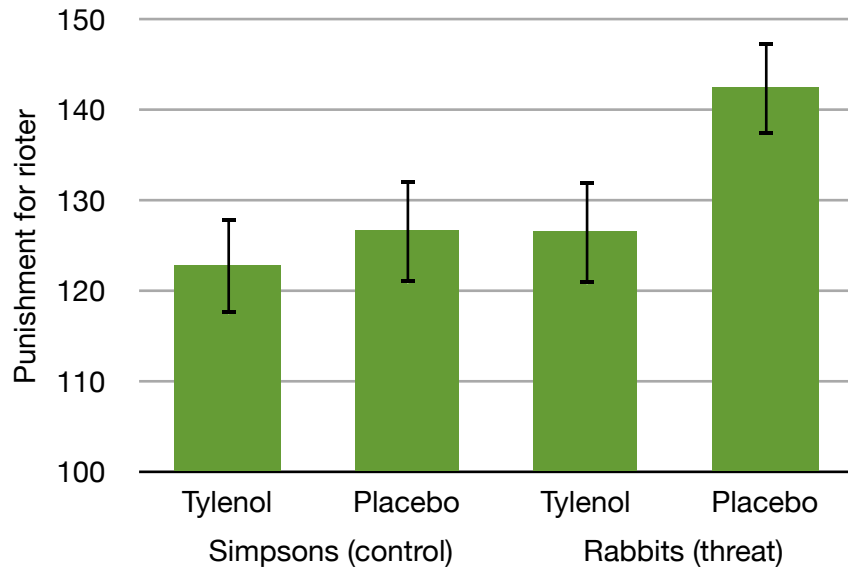
Bond values set for prostitute described in social judgment survey



Results from Study 5. Mean bond value set for the prostitute as a function of group (mortality-salience vs. control condition crossed with placebo vs. acetaminophen condition). The scale ranged from \$0 to \$999. Error bars represent the standard error for each group.

Figure 4.2

Increased penalty percentage (fine or jail time) for someone convicted of vandalism or theft during the Vancouver hockey riot.



Results from Study 6. Mean preference for the penalty to be given individuals convicted of vandalism or theft during the Vancouver hockey riot as a function of group (threat vs. control condition crossed with placebo vs. acetaminophen condition). The rating scale ranged from 0% (no fine for a conviction), through 100% (a normal fine), to 200% (a doubled penalty). Error bars represent the standard error for each group.

CHAPTER 5 – THE EFFECT OF ACETAMINOPHEN ON EEG ERROR-RELATED NEGATIVITY AND POSITIVITY POTENTIALS

In chapter 3, I made the claim that any activation of the ACC, what Shackman et al. (2011) calls the adaptive control system, might be sufficient to trigger compensatory affirmation. That is, in a state of aroused attention due to ACC activation, people may be more motivated to emphasize and affirm importantly held beliefs merely as a result of the state they are in. Many of the paradigms discussed in chapter 3 reliably generate ACC activation in response to errors, including the Stroop task, Flanker task and Go/NoGo task. The study presented here attempts to answer two questions. The first is whether acetaminophen inhibits awareness of errors in conflict tasks, as it appears to inhibit awareness of meaning violations. The second is whether making mistakes during a sterile cognitive paradigm can lead to increased compensatory affirmation.

When using electroencephalographic (EEG) recording equipment, cognitive conflict and errors reliably generate a neural response. The signal, referred to as an evoked response potential (ERP), is isolated by anchoring to a participant's response to a stimulus and tracking the subsequent EEG recording for a fixed window of time. This signal includes both a negative-going inflection distributed at the fronto-central scalp region, termed the error-related negativity (ERN), and a subsequent positive-going inflection distributed at the parietal-central region, termed the error positivity (Pe; Falkenstein, Hoormann, Christ, & Hohnsbein, 2000; Hohnsbein, Falkenstein, Hoormann, & Blanke, 1991). Using source-localization techniques during ERP experiments, the ERN has been most consistently localized to the ACC, most likely in the dACC (M. J. Herrmann, Römmler, Ehlis, Heidrich, & Fallgatter, 2004; Pourtois, 2010). Additionally,

damage to the dACC leads to reduced ERNs following errors, and obsessive-compulsive disorder patients exhibit greater ERNs in response to any conflict, a finding that parallels their relatively greater ACC resting activity (Graybiel & Rauch, 2000). Although less work has focused specifically on the Pe, it likely also originates in the ACC, though the more rostral region (M. J. Herrmann et al., 2004; Taylor, Stern, & Gehring, 2007; van Veen & Carter, 2002), and may be associated with physiological reactions after error, such as increased skin conductance (Hajcak, McDonald, & Simons, 2003).

Although both components of the wave follow from errors, they are at least partially independent. Awareness of an error is often uniquely predicted by the Pe, even though the ERN is triggered by both aware and unaware errors (Endrass, Franke, & Kathmann, 2005; Overbeek, Nieuwenhuis, & Ridderinkhof, 2005). Additionally, while both waves are associated with post-error slowing, the relationship emerges more consistently for the Pe (Frank, D'Lauro, & Curran, 2007; Hajcak et al., 2003). Although typically the ERN always precedes the Pe, at least one study has found that Pe activation can emerge in the absence of a robust ERN when participants report that they are uncertain whether they made an error or not (relative to a certain error, in which both the ERN and Pe are present; Hewig, Coles, Trippe, Hecht, & Miltner, 2011). Interestingly, lesions of the dACC often reduce the ERN yet leave error-detection largely intact (cf. Tyalor 2007), suggesting that the ERN represents only one of a number of signals that communicate conflict, and that the Pe is more critical for ultimately receiving these signal and acknowledging mismatch (Hughes & Yeung, 2011; Steinhauser & Yeung, 2010). This perspective fits with the role of dACC as primarily responsible for aggregating response outcomes and communicating mismatch to other regions (possibly within the

ACC) when sufficiently deviant events occur (Orr & Hester 2012; Wessel et al., 2011). Despite this support for at least partial independence, researchers tend to ignore the Pe and focus exclusively on the ERN when observing error responses (C. S. Herrmann & Knight, 2001; Inzlicht & Al-Khindi, 2012; Inzlicht & Tullett, 2010; Ma, Shu, Wang, Dai, & Che, 2008), possibly on the general assumption that the Pe is mostly a downstream artifact (Orr & Carrasco, 2011).

In the previous study, it was noted that I couldn't distinguish whether acetaminophen prevented awareness of a meaning violation or whether it prevented the motivation to affirm. In this study I will directly observe the effect of acetaminophen on the ERN and Pe. If acetaminophen is able to inhibit these signals after an error, it provides supporting evidence that the effect is primarily one of inhibiting awareness of anomaly. Additionally, this study tests whether errors in a sterile cognitive paradigm are sufficient to cause compensatory affirmation. Shackman et al., (2011) note for instance, that while the current data strongly implicates the dACC in both emotional and cognitive processing, future technology may allow for more refined and detailed analyses, possibly revealing non-interacting neurons for different processes within the area. Assuming that there is overlap, errors on this task may be sufficient for generating compensatory affirmation.

Study 7

Participants

Sixty-two student participated (44 women, mean age = 19.42 SD = 1.85) were recruited from an Eastern Canadian university. Participants were pre-selected on the basis of holding prior negative attitudes towards prostitution. Pre-selection was used to

hopefully decrease noise caused by individual differences and maximize the likelihood of seeing a difference on the affirmation measure, despite the smaller sample. The measure of compensatory affirmation was the same social judgment survey used in studies 1, 3, and 5, but given the smaller sample of this study, pre-screening was used to help minimize noise and increase the likelihood of detecting a significant effect. Six participants ERP data were unusable due to equipment failure, excessive blinking or high impedance levels throughout the study. Additionally two participants' data were removed because a number of channels produced mean ERP scores 3+ standard deviations from the mean, and visual inspection of the EEG revealed persistent artifacts. All 62 participants were used for analyses that only require self-report measures.

Stimuli

The Go/NoGo task was the primary measure of error. This is a commonly used paradigm in cognitive psychology, where participants quickly hit a button in response to a stimulus, but withhold their response if a similar-looking but different stimulus is presented. In this study the stimuli used were the letters F and E, counter-balanced between participants regarding which stimulus was “go” and which was “no go”. Each trial consisted of a fixation dot presented for 200-600ms (random jitter), followed by stimulus presentation for 100ms. Participants have up to 600ms from the target's appearance to respond, after which an inter-trial interval of 0-200ms occurs (random jitter) and the next trial begins. Stimulus presentation was anchored to the previous stimulus presentation and not participant response, such that there was always between 800-1400ms between stimulus presentations. Errors were recorded but no feedback was given to participants.

Self-report measures

After the Go/NoGo task, participants completed the PANAS (described in Study 3 and 5). This measure was administered twice; once immediately after the Go/NoGo task ($\alpha = .87$ for positive and $\alpha = .77$ for negative items) and again at the very end of the study ($\alpha = .88$ for positive and $\alpha = .87$ for negative items). The 1st version asked participants to report how they were generally feeling now (i.e. typical wording of instructions) while the 2nd version asked participants to report how they felt specifically while completing the Go/NoGo. This was done to address concerns raised by Spunt, Lieberman, Cohen, & Eisenberger, (2012) that people are better able to articulate their feelings relative to an actual event. Participants also completed the social judgment survey (described in study 3) as a measure of compensatory affirmation.

Procedure

After giving consent, participants consumed the two capsules assigned to their participant number. This was a double-blind procedure, where each participant's dose was assigned a unique ID prior to the study and placed in a separate container with that ID number. This method was used instead of bottles with condition codes to enhance the double-blind protocol and prevent researchers from developing suspicions about which condition-coded bottles contained the acetaminophen. Kirkland brand Fast Acting Acetaminophen was used.

After a brief waiting period (around 30 minutes) the researcher fitted the participant into an EEG cap and placed them in front of a monitor to begin the Go/NoGo task. This task always began an hour after consuming the pills. When this task was completed, participants completed the PANAS, social judgment survey, a number of

materials not related to this study, and finally suspicion-check items, followed by the 2nd administration of the PANAS.

EEG recording and analysis

Continuous EEG was recorded during the task using 64 active electrodes (BioSemi Active-Two amplifier system). Recordings were digitized at 256 Hz with two additional electrodes (common mode sense and drive right leg) positioned over the medial-parietal cortex to serve as grounds. Data was digitally filtered offline between .1 and 30 Hz (fast Fourier transform implemented, zero phase-shift Butterworth filter). EEG was corrected for vertical electrooculogram artifacts at 200 μ V (Gratton, Coles, & Donchin, 1983), unless visual inspection of the data revealed additional eye-blink artifacts, in which case the filter was reduced by 25 μ V until artifacts were not present or a minimum of 100 μ V was reached. An average of 13.34% (SD = 12.94%) of the total number of correct trials across participants and 21.62% (SD = 19.7%) of the incorrect trials were rejected due to these signal artifacts. The percentage of trials rejected did not significantly differ between the acetaminophen and placebo conditions (both $t_s < 1$, $p_s > .5$). Epochs were defined as 800ms windows, beginning at stimulus response and were baseline-corrected by subtracting the average voltage during the time period 200-50ms prior to response. This baseline window was used to avoid subtracting out the ERN component, which often is visible up to 50ms prior to recording of the response (e.g. Inzlicht & Al-Khindi, 2012). Data for these epochs were averaged within participants independently for correct button-presses (i.e. correct “go”s) and incorrect button presses (incorrect “nogo”s) and then grand-averaged across participants within the respective conditions.

The ERN was defined as the average of the minimum deflection between 0-100ms post-response. Based on general consensus, I defined this wave solely by the output from channel FCz (Hajcak et al., 2003; Inzlicht & Al-Khindi, 2012; Santesso, Segalowitz, & Schmidt, 2005; Steinhauser & Yeung, 2010). The Pe was recorded as the average of the positive deflection from 180-350ms. Although less research has focused specifically on this component, it is sometimes recorded using CPz as the sole channel (Steinhauser & Young, 2010), though Cz and Pz are also consistently used, either alone or as an aggregate (Hajcak et al., 2003; Moser, Schroder, Heeter, Moran, & Lee, 2011; Santesso et al., 2005). I present the Pe here as an aggregate of the difference waves at CPz and Pz (the more parietal channels) though all three electrodes correlate $r > .85$ (all $ps < .001$). I wanted to assess the activity following an incorrect button press, controlling for activity generated by any button press. To accomplish this, I calculated the difference waves by subtracting the ERPs for correct presses from the incorrect press ERPs (Luck, 2005).

Results

As a check of the double-blind protocol, I asked participants what type of pill they believed they had received, and whether they were confident in this guess. Only 6.7% claimed they were confident (3 in the acetaminophen group, and 1 in the placebo group), and guesses were correct 56.45% of the time (not different from chance, $p < .50$). Neither group was more accurate at guessing their condition ($p > .5$) but there was a marginally significant correlation between being confident in your guess and being correct, $r = .23$, $p < .10$, suggesting that for a small minority (possibly those experiencing mild pain before

the study) it was at least somewhat possible to detect whether they had been given a placebo or the drug.

The main hypothesis was that acetaminophen would inhibit the ERN and Pe following an error. First, there was a clear ERN/Pe composite following incorrect button presses for both the placebo group (Figure 5.1) and the acetaminophen group (Figure 5.2). Comparing the two conditions, there was no significant difference in the ERN measured at FCz ($t_{(52)} = 1.54, p < .50, d = .45$ CI_{.975}[-.13 - 1.03]), but a significant reduction in the magnitude of the Pe measured at CPz/Pz for the acetaminophen condition ($t_{(52)} = 2.32, p < .05, d = .64$ CI_{.975} [.09 - 1.2]); See Figures 5.3, 5.4). The results suggest that acetaminophen has no effect on early conflict detection, but may inhibit the conscious perception that an error was made.

Regarding behavioral outcomes, it seemed possible that if participants were less likely to consciously detect an error, they would fail to correct their behavior via post-error slowing. To test this, I used a 2X2 repeated measures model, contrasting reaction time after a correct NoGo inhibition with RT after a NoGo error, crossed with condition. If the participant failed to respond to a Go trial before the timeout, their reaction time was capped at 600ms. Although a clear post-error slowing effect emerged ($F_{(1,58)} = 87.1, p < .001$) there was no difference between conditions ($F_{(1,58)} = 1.63, p < .50$; See Table 5.1). Further, there was no correlation with post-error slowing between either magnitude of the ERN ($r = -.01, p > .50$) or Pe ($r = -.08, p > .50$) difference waves. This latter finding is at odds with past literature, and is explored more in the discussion.

To assess effects on the number of errors made, I used negative binomial regression with a log link function for all analyses. This analysis employs a distribution

that fits count data well (such as errors made), anticipating a distribution that is extremely right-skewed and over-dispersed (i.e. the variance of errors is greater than the mean).

Regarding errors of commission, I did not find that acetaminophen predicted more erroneous button presses; in fact numerically this group made *fewer* errors ($\chi^2_{(1,58)} = 1.46$, $p < .50$, $\ln(b) = -.127$ CI_{.975}[-.332 - .079; See Table 5.1 for error rates). Nor were erroneous button presses predicted by the magnitude of an individual's ERN ($\chi^2_{(1,58)} = .23$, $p > .50$, $\ln(b) = .01$ CI_{.975}[-.02 - .03]) or Pe ($\chi^2_{(1,60)} = .06$, $p > .50$, $\ln(b) = -.01$ CI_{.975}[-.02 - .02]). However, the acetaminophen group made significantly more errors of *omission*. That is, they allowed a larger number of "go trials" to pass by without entering a response ($\chi^2_{(1,58)} = 14.99$, $p < .001$, $\ln(b) = .87$ CI_{.975} [.43 - 1.30]). This difference was exclusively driven by missed Go trials that were immediately preceded by a Go trial. That is, after either a successful or unsuccessful NoGo trial, participants in both conditions showed similar missed Go trials. However, after a Go trial, participants in the acetaminophen condition missed a significantly larger number of subsequent Go trials ($\chi^2_{(1,58)} = 19.38$, $p < .001$, $\ln(b) = 1.08$ CI_{.975} [.60 - 1.56]). Because I didn't anticipate this difference, I ran an additional follow-up test. I removed the five most extreme scores (all five in the acetaminophen) because there was a gap in the distribution of errors separating these five from the rest of the sample. Re-running the analysis on the total number of omission errors (i.e. not just those after Go trials) produced a result that was not meaningfully different than before, with the acetaminophen group still showing more errors of omission ($\chi^2_{(1,58)} = 6.00$, $p = .01$, $\ln(b) = .60$ CI_{.975} [.12 - 1.07]). This result is thus not caused by extreme scores or a violation of statistical assumptions, and is very unlikely to have emerged by chance. Additionally, individual differences in Pe magnitude

(controlling for condition) predicted fewer errors of omission as magnitude increased ($\chi^2_{(1,51)} = 4.93, p < .05, \ln(b) = -.04$ CI_{.975}[-.08 - (-).01]), although no interaction was present between Pe magnitude and condition ($\chi^2_{(1,51)} = .17, p > .05$). Likewise, individual differences in ERN magnitude failed to predict these errors condition ($\chi^2_{(1,51)} = .04, p > .05$). Although I did not initially consider looking at reaction time for Go trials that followed a Go trial, these results encourage doing so. The acetaminophen group shows a small but non-significant increase in reaction time ($t_{(60)} = 1.60, p < .50$). However, when I remove the trials with no response, this difference disappears completely ($p > .50$, See Table 5.1 for means). The implication is that these errors of omission are not occurring as a result of overall slower reaction time or greater inhibition, but occur for other reasons, possibly due to stochastic mind wandering or some other distraction. I discuss this below.

Regarding conscious change in affect, there were no differences between conditions regarding positive or negative affect, regardless of whether the PANAS was presented immediately after the Go/NoGo task, or whether it was presented later and had the participant report their mood during the Go/NoGo task (all t s $< .5$), nor was there any correlation between Pe magnitude and either positive or negative affect (all p s $> .54$). While this is normal for meaning violation studies, one might have anticipated that conscious awareness of error lead to greater negative affect.

The final question is whether making errors on a somewhat sterile task is sufficient to motivate compensatory affirmation, and whether acetaminophen can inhibit this. In both cases, the answer appears to be negative. There was no difference between conditions on the amount of money assigned in the social judgment survey (Mean acetaminophen = 372.21, SD = 289.28; placebo = 406.48, SD = 266.53; $t_{(58)} = .473, d =$

.12 CI_{.975}[-.65 - .40]). The sample size for this study was low and I anticipated not having power to detect a difference on the bond between conditions, though the direction of the effect is sensible (the placebo group set a higher fine). However there was additionally no significant correlation between the bond score and the ERP waves, or number of errors, which I did anticipate adequate power to detect. Again, although non-significant, in each case the numerical trend was sensible, where participants set a higher bond if they made more errors or produced larger ERPs (ERN $r_{(52)} = -.24, p < .10$; Pe $r_{(52)} = .07, p > .50$; errors of commission $r_{(58)} = .12, p = .37$, errors of omission $r_{(58)} = .01, p > .50$).

Discussion

In the previous chapter, I identified that it wasn't clear whether acetaminophen affected compensatory affirmation by either inhibiting awareness of the anomaly, or the motivation to affirm. Results of this study, in combination with past work, suggest that the former is more likely to be true. I found that although acetaminophen has little to no impact on low-level conflict detection via the ERN, it significantly inhibits the Pe, which is viewed as an index of conscious awareness of error (e.g. Hewig et al., 2011). It is possible that conflict information is being passed to regions of the ACC responsible for Pe activation (Hewig et al., 2011; Ullsperger, Harsay, Wessel, & Ridderinkhof, 2010), and that what is being inhibited is the ability to integrate this information and signal an error.

Regarding actual performance, there was no difference in reaction time between conditions for any type of trial, including the post-error slowing effect that clearly emerged whether participants had taken acetaminophen or a placebo. Additionally, participants in the two conditions made the same number of commission errors,

suggesting that the reduced Pe activity neither prevented post-error slowing, nor increased the likelihood of a NoGo error. However, participants in the acetaminophen group made significantly more errors of omission. That is, this group failed to press the button on “go” trials more often than the placebo group, a result that appeared to be at least partially mediated by inhibited Pe activity. This result appears robust, though omission errors are not typically focused on with the Go/NoGo. Given that this effect doesn't appear to be driven by an over-all slower reaction time or greater inhibition, it is somewhat of an open question regarding what process lead to these errors. One possibility is that acetaminophen is increasing the frequency of mind wandering, or moments of distraction and disengagement with the task.

In general though, there is not always a consistent link between Pe activity, or conscious detection of error, and improved performance. Hester, Nestor, & Garavan, (2009) for instance, found that chronic cannabis users (average 8 years) showed reduced awareness of errors, which correlated with reduced ACC activity, even though this had no impact on performance. However a different study found that those with a growth mindset (tendency to embrace error and learn from mistakes) produced a larger Pe after errors, which, in turn, did predict improved performance on trials immediately following the error (Moser et al., 2011). Both of these studies use tasks that require responses for every trial, such as the stroop or flanker task; in general, the Go/NoGo is probably the wrong task to use if change in actual performance is the main hypothesis of interest. Future studies that extend this work should use a conflict task that is more directly comparable to the literature on post-error slowing. Additionally, since this result could be

replicated with only behavioral measures, a larger sample size in a behavior-only paradigm would increase confidence in the results.

Although the Pe was reduced by acetaminophen, I did not see a coinciding reduction in either positive or negative affect as measured by the PANAS. This was true whether the questions were phrased about how the person felt in general right now, or how they felt in particular while completing the Go/NoGO task (although this was asked several minutes later just before debriefing). This result perhaps speaks to the concerns of Spunt et al., (2012) and highlights the need to find more sensitive measures of arousal, affect, or mood when running experiments on meaning violations and uncertainty. If overall frustration or poor performance on a task is insufficient to provoke negative affect as measured by the PANAS, then the PANAS is likely the wrong tool for these types of paradigms. Unfortunately, I did not have a self-report measure of conscious awareness of errors, but these results speak to the need to use such a measure. Even asking participants at the end of the study to estimate their errors would have been good, but also employing methods such as Orr et al. (2012), where participants are expected to monitor their error performance online while completing the task.

Finally, I did not find support for the prediction that any task that leads to increased ACC activity will increase a person's motivation to affirm any available belief. When considering this question across conditions, there was no significant difference between groups. Further, when collapsing across conditions, there was no significant correlation between either the number of errors made or magnitude of the ERN/Pe components and affirmation. Given that participants were all in a highly novel and somewhat uncomfortable environment (i.e. fitted to EEG testing equipment) performance

on a sterile task such as the Go/NoGo appears to be insufficient to generate noticeable increases in the motivation to affirm. To fully answer this question however, it would be helpful to have data using a typical meaning violation, adjusted to work in an ERP paradigm. Previous work with dissonance reduction using fMRI paradigms (van Veen, et al., 2009; Kitayama, et al, 2013), suggest that such adjustments are possible.

In general, these results speak to the theoretical perspective that a single error detection mechanism is used to first address any anomaly. Acetaminophen not only inhibits pain, social rejection and violations of meaning, it also inhibits the Pe, which is associated with conscious detection of error. This finding converges with other work showing that a broad range of unsettling events (e.g. social rejection, violations of meaning) all lead to compensatory affirmation. However, the fact that I didn't see affirmation in this context, suggests that it is not just ACC activity that leads to this motivation. In past work, affirmation has been shown to require misattribution of felt arousal, as having an explanation for one's arousal reduces both the motivation to affirm (e.g. Proulx & Heine, 2008), and interestingly, also the magnitude of ERN responses after a Go/NoGo error (Inzlicht & Al-Khini, 2012). It may be that an EEG testing experience is explicitly arousing enough that the individual feels no need to attribute their subjective state to the materials being completed, however past work successfully producing dissonance in more aggravating conditions (i.e. fMRI) speaks to the Go/NoGo simply as being insufficient to motivate affirmation. Again, extending this work with a behavior-only paradigm and larger sample might help to resolve the confound, as would using a meaning violation that could be fit to an ERP paradigm.

Table 5.1
Reaction time and number of errors for different trial types

| Event Type | Placebo | Acetaminophen |
|---|----------------|------------------|
| Errors on NoGo trial (Errors of commission) | 20.46 (6.40) | 18.03 (0.05) |
| Errors on Go trial (Errors of omission) | 5.61 (4.76) | 13.31 (12.10)*** |
| Omission errors only if preceded by a Go trial | 2.79 (2.73) | 8.24 (8.13)*** |
| Reaction time on all Go trials | 203.07 (30.04) | 216.12 (39.69) |
| Reaction time excluding omissions error trials | 197.14 (30.26) | 201.36 (34.36) |
| Post-error slowing | 91.35 (86.26) | 91.54 (15.93) |

Note: Mean values are presented, standard deviations are in brackets. Post-error slowing is the difference between the reaction time on a Go trial following a NoGo error, vs. reaction time on a Go trial following a NoGo success. Asterisks refer to a significant difference between the placebo and acetaminophen conditions.

Figure 5.1
ERPs following an error of commission for the placebo group

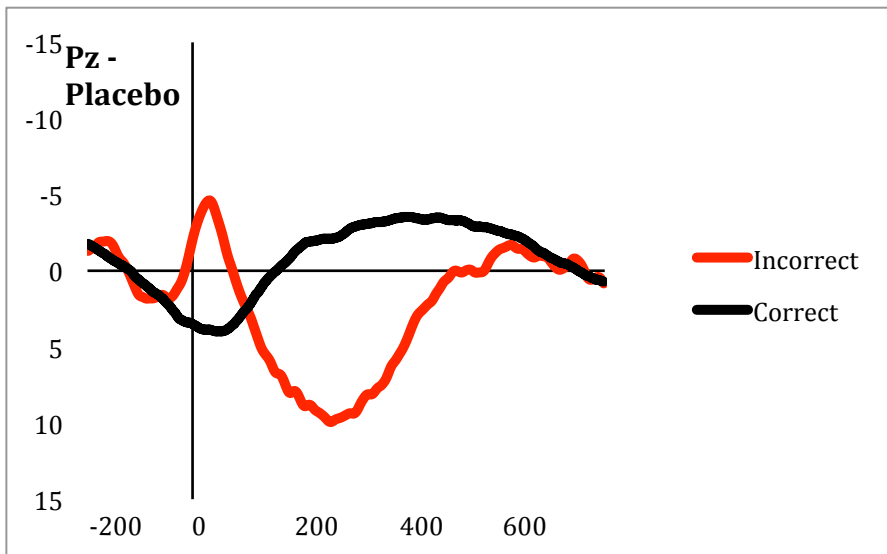
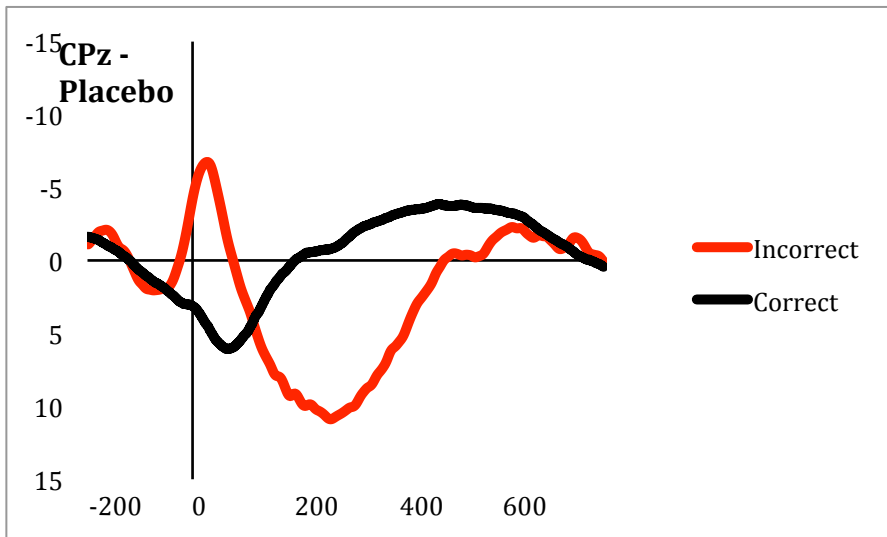
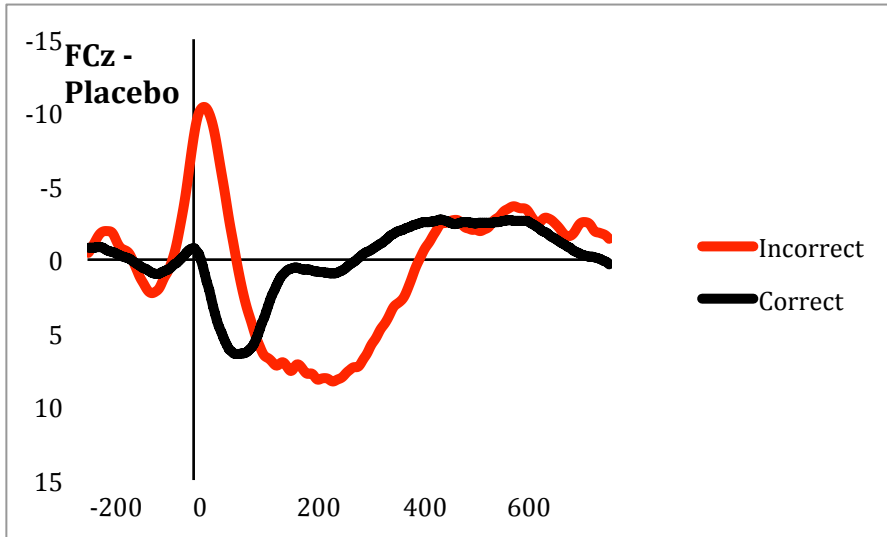


Figure 5.2
ERPs following an error of commission for the acetaminophen group

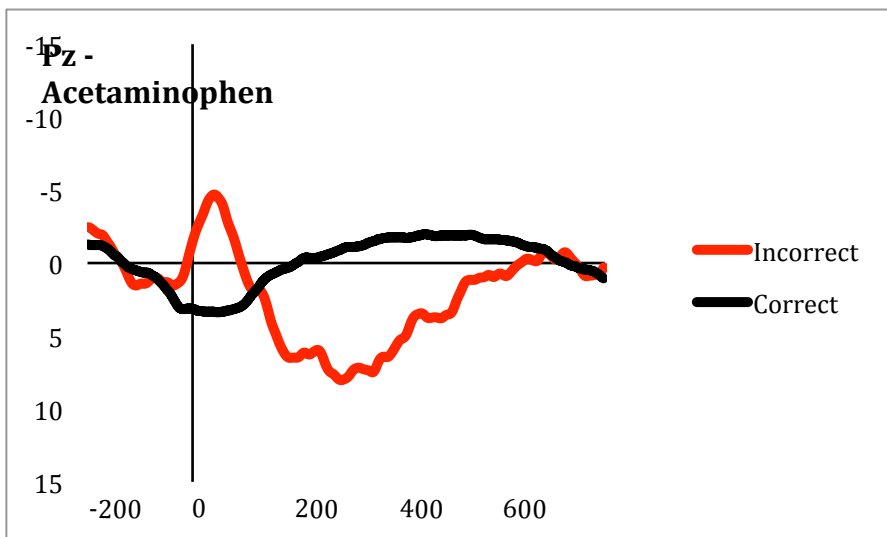
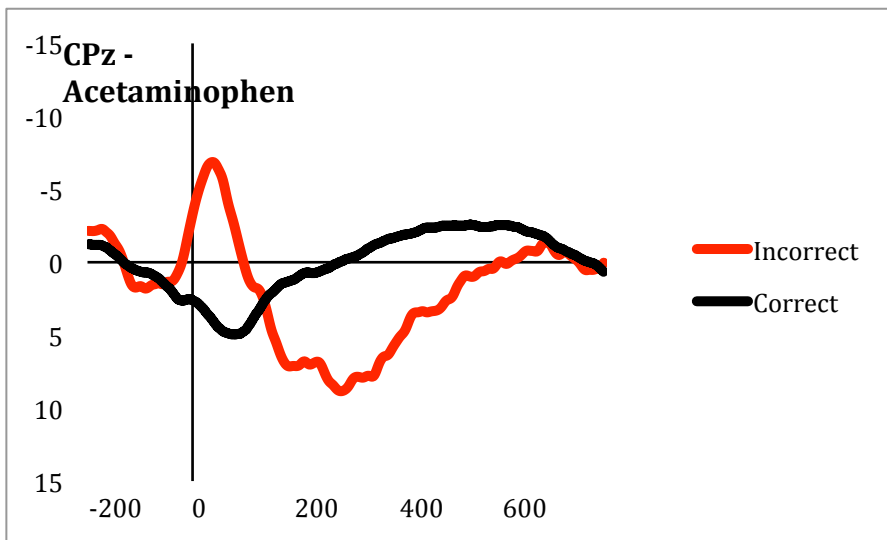
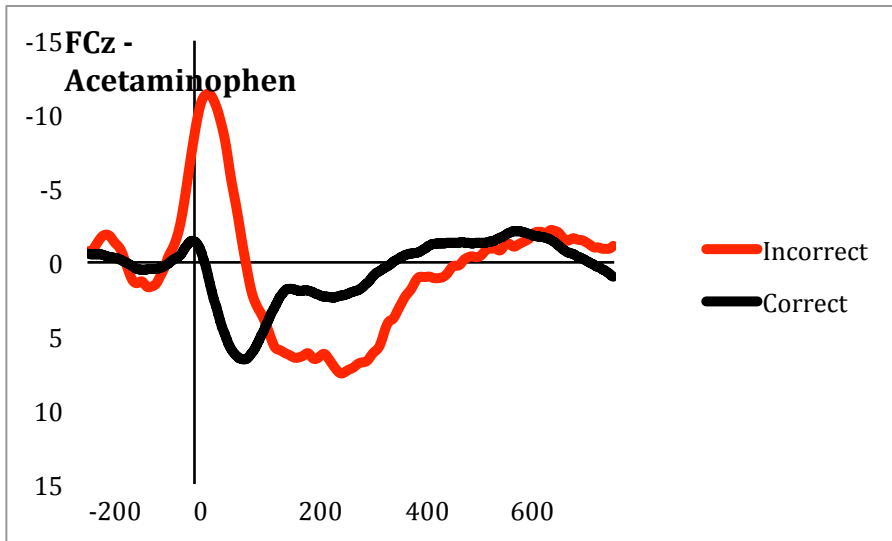
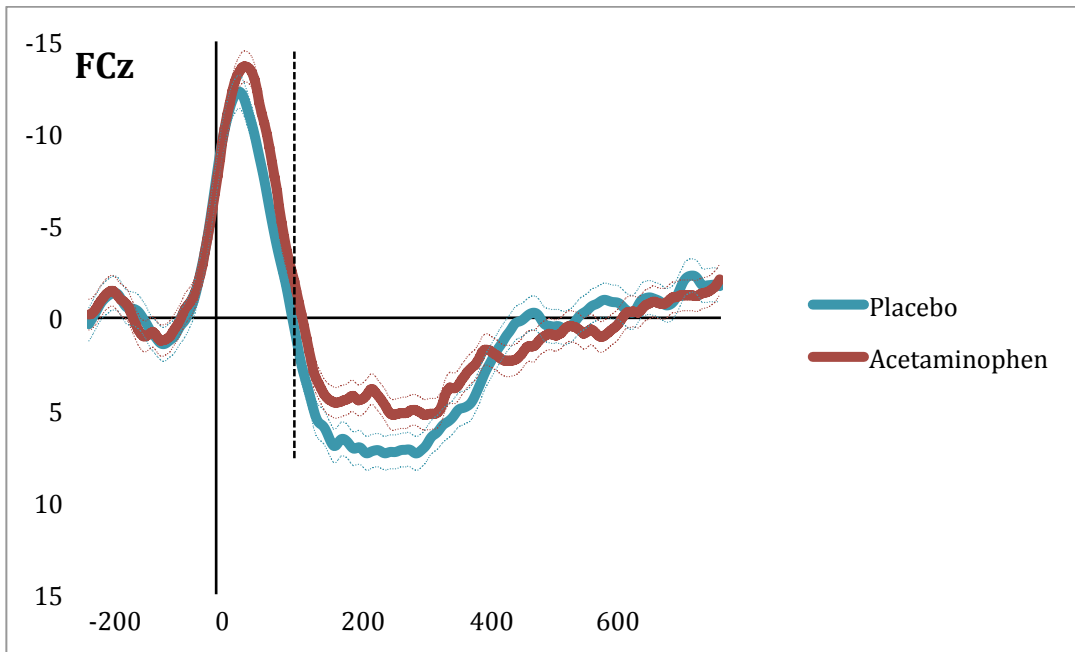


Figure 5.3

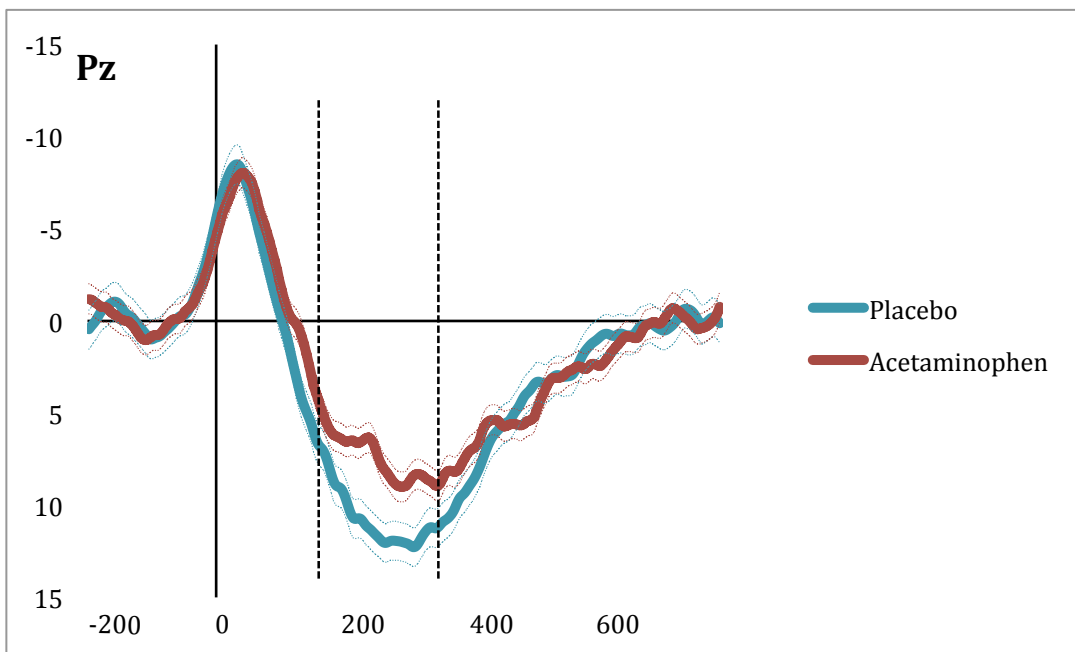
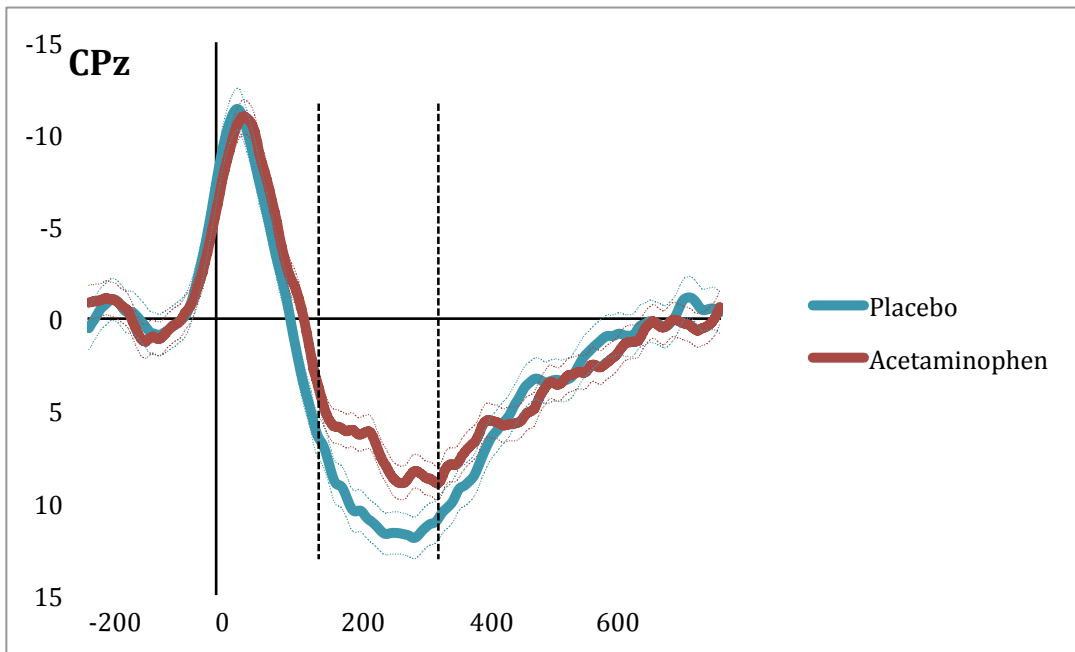
Difference waves by condition at FCz



Waves are constructed by subtracting the ERP for a correct button press from the ERP for an incorrect button press. Dashed lines represent standard error. Mean measurement for the ERN is from 0ms - 100ms.

Figure 5.4

Difference waves by condition at CPz and Pz



Waves are constructed by subtracting the ERP for a correct button press from the ERP for an incorrect button press. Dashed lines represent standard error. Vertical dashed lines indicate the window used for the mean Pe values, 180ms-350ms.

CHAPTER 6 – GENERAL DISCUSSION

The studies presented here are generally supportive of theories that argue for a broad monitor of mismatch between one's mental model and the world. In particular, that humans possess a single domain-general process for perceiving and interpreting violations of meaning, goal frustrations, social rejections, dissonance, and any other type of experience that could be described as a challenge to one's meaning frameworks. In Chapter 2, I presented four studies highlighting the overlap between Cognitive Dissonance Theory and the Meaning Maintenance Model. Dissonance was shown to not only motivate resolution of the current dilemma, but cause affirmation of completely unrelated beliefs and heightened motivation to abstract new patterns, as predicted by the MMM. Chapter 4 reports two of the first studies to explicitly test whether meaning violations might involve the dorsal anterior cingulate cortex and what Shackman, et al. (2011) call the adaptive control process. I found that acetaminophen, which has been shown to inhibit physical pain and feelings of social rejection via the dACC, also inhibits compensatory affirmation following meaning violations. This study provided the first indirect evidence that meaning violations employ the dACC. In Chapter 5, I tested a novel prediction that emerged from the previous chapter; acetaminophen should inhibit any detection of errors, not just those associated with social dilemmas or uncertainty broadly defined. While it was unclear from this study if dACC function was altered, the error-positivity associated with the rostral ACC was significantly inhibited by acetaminophen.

Together, these findings empirically point to the recent theoretical arguments of a number of social psychologists (Hart, 2014; Hirsh, Mar, & Peterson, 2012; McGregor, et

al., 2010; Proulx et al., 2012). Rather than the human mind possessing a number of separate systems to track mismatches in physical expectations, social expectations, goals (including avoiding death), and internal inconsistency, one general process may constantly monitor all systems and use context from the situation to attribute the system arousal to its correct target. My results suggest that it is possible to describe this system in a way that can be interpreted across a range of psychological sub-disciplines, and that doing so will yield important new hypotheses on topics ranging from learning and development, through prejudice and stereotyping, to the all-consuming question of why anyone born in the last twenty years knows the lyrics to “Rock Around the Clock,” or finds it nostalgic (Krumhansl & Zupnick, 2013). The work here points to the advantage of drawing on multiple perspectives, and highlights the need of continuing to do so. To the degree that dissonance, cognitive conflict and social strife all employ similar processes, research efforts would want to focus on integrating any new findings from one of these sub-areas into the broader context of the others.

I, for one, have found these results, and the general thrust of these theoretical arguments to be quite exciting. New tools are becoming increasingly available, and with them the potential to make big leaps in our understanding of the mind. The advancement of social neuroscience and Big Data is giving us opportunities to test these theories with resources that simply were not available even a decade ago. But these are just tools, for psychology to make important leaps in the decade ahead, it needs integrated theories that can draw from and speak to all its sub-disciplines. This need is not actually new, of course. Bruner (1990), who was also writing on the topic of meaning, hoped that such integration was emerging twenty years ago:

“I have written it [this book] at a time when psychology, the science of mind as William James once called it, has become fragmented as never before in its history. It has lost its center and risks losing the cohesion needed to assure the internal exchange that might justify a division of labor between its parts. And the parts...have become specialties whose products become less and less exportable. This self-sealing risks making each part...ever more remote from other inquiries dedicated to the understanding of mind and the human condition.” (page ix, preface)

Bruner felt that meaning should, in fact, be the central topic of concern for psychologists, a topic that would allow for even greater bridging with the other social sciences and humanities. All of this is not to say that highly specific hypotheses are not valued or necessary, but that they should fit within or directly challenge the broader theoretical context they find themselves in. A number of such questions have emerged from the data I presented here, and are discussed below.

Limitations and future directions

Which violations are most important to an individual?

Although there are undoubtedly individual differences in what constitutes a violation of meaning, there are likely also categories of meaning that people in general may be more sensitive to. The emphasis of early work on the MMM was towards describing a system that could accommodate a wide range of violations (Heine, Proulx, & Vohs, 2006; Proulx & Heine, 2006), but other theoretical perspectives (and recently the MMM as well; Proulx & Inzlicht, 2012) have tried to keep this question one of central

focus. Reactive Approach Motivation and Cognitive Dissonance (Festinger, 1957; Harmon-Jones et al., 2009) for instance, argue that the function of this process is to moderate goal-directed behavior, and thus only goal-relevant conflicts should be able to trigger a response from individuals. This was one of the core arguments of dissonance theory, that the experienced distress could never be more than the perceived importance of the less important dissonant cognition, because the distress will lead to abandoning the less important cognition (pg. 25, Festinger, 1957). An implicit extension of this thinking is that if both cognitions are unimportant, almost no dissonance should be felt.

Supporting the argument for goal-relevant conflict, Nash et al. (2011) and Aronson (1999) have shown that priming goals before blocking them leads to an enhanced compensation effort, while priming unrelated goals minimized the effect of frustration. Additionally, neuroscience studies have found that the ACC appears to respond most strongly to anomalies that lead to a response-conflict (Botvinick, Cohen, & Carter, 2004) and to events where larger rewards on the line (Amiez, 2006; Aronson, 1999), suggesting that conflicting information that is not relevant to current goals may not trigger activation as strongly. These effects suggest that goals that are made more salient, do in fact become more important when monitoring for conflict. However, compensation efforts also emerge when participants experience subliminally presented mortality threats or incongruent word-pairs (e.g. turn-frog; Randles et al., 2011), when the experimenter is inconspicuously switched with a different person (Proulx & Heine, 2008), or when participants are exposed to absurd or surreal narratives (Proulx & Heine, 2009; Randles et al., 2012), none of which appear to directly threaten a goal-state. One possible synthesis for the data is that all inconsistency has the capacity to trigger error-detection, but that

inconsistencies being directly attended to may be more potent than those perceived peripherally or subliminally, and that inconsistencies which are related to important goal-states may have the most potency. Sorting this issue out to satisfaction will likely be benefitted by an emphasis on effect sizes and relative impact of manipulations (Cumming, 2014), rather than hypotheses built around whether an effect is present at all, as has historically been the strategy.

Is meaning maintenance an affective or motivated state?

In Chapter 2, I express some surprise that individuals who have first affirmed an unrelated belief are still motivated to reduce dissonance, and perhaps more surprisingly, that after attempting to reduce dissonance, compensatory affirmation likewise still occurs. These results were unexpected, because typically affirmation is seen as satisfying a need, be it to buffer existential anxiety, maintain meaning, or regain certainty or control. An alternative framing of this effect, is that rather than meaning violations triggering a motivation to satisfy a need, they trigger a drive state that is itself not satisfied by anything other than time and the absence of additional violations. This question of need vs. drive is probably one of the least understood in terms of process, and likely a fruitful direction for further inquiry.

One interpretation to consider is whether the need to maintain meaning is subjectively experienced as an increased drive to behave in a normative fashion. Heatherton (2011) has identified that many of the regions involved in expected violations (particularly the ACC) further activate regions associated with self-reference and self-regulation. That is, people affirm beliefs not as a palliative that only exists as a by-product of goal regulation (McGregor et al., 2010), but because

they feel a strong motivation to act in accordance with normative rules, beliefs and behaviors. Affirmation then, may hint at a functional response to uncertainty for humans; if one is aware that something anomalous has occurred, the most adaptive response may be to strictly adhere to normative behavior until the uncertainty is resolved. This approach to affirmation actually moves closer to Terror Management Theory, though rather than focus on satisfying a latent need, it argues that self-regulation is adaptive when feeling uncertain, because it minimizes the likelihood of being ostracized or causing further strife within the group during a tense event (Heatherton, 2011). Some affirmation findings clearly fit with this interpretation, such as avoidance of taboo behavior, increased prestige bias (Landau, Greenberg, Solomon, Pyszczynski, & Martens, 2006a; Landau et al, 2006b; Shephard et al., 2011) and greater antagonism towards rule-breakers (e.g. Studies 1, 3, 5-6). Likewise affirmation in the form of increased inter-group hostility makes sense, to the degree that one's in-group is generally at odds with the offending out-group. Other results are not so clear. For instance does an increase in racist behavior following a violation indicate adherence to one's internally held norms of their culture, or an affirmation of a belief that is personally important, even though it's at odds with one's larger community? Some work has suggested that either could be considered self-regulation (or affirmation) depending on which aspect of a person's identity is primed during the experiment (e.g. Jonas et al., 2008). Further work should explore this question, as no consensus exists concerning the function, if any, of compensatory affirmation.

At what point does specificity emerge?

In Chapters 4 and 5, I presented some evidence suggesting that the human mind is not especially sensitive regarding whether a violation occurs in domains of physical pain, social rejection, error or uncertainty more broadly defined. While this may be true, at one level, it is equally true that each of these domains generate robustly different effects that do not appear to overlap. As noted by others, although many drugs that inhibit physical pain and feelings of rejection show an overlapping effect, social “wounds” often remain deeply painful and are easily recalled, whereas physical pain is typically forgotten as soon as it ceases to be present (Eisenberger, 2012a; 2012b; Hester, 2011). Future work will likely continue to elaborate on the specificity of this process, but doing so will hopefully be more successful in the context of the broader cognitive system that appears to be relevant to all these domains.

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