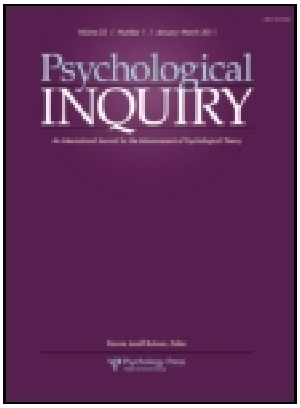

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Making Sense of It All? Cognitive and Behavioral Mechanisms Needing Clarification in the Meaning Maintenance Model

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Making Sense of It All? Cognitive and Behavioral Mechanisms Needing Clarification in the Meaning Maintenance Model

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It goes without saying that meaning, and maintaining it, is core to our existence. As such, studies of meaning and its maintenance reach far and wide, as Travis Proulx and Michael Inzlicht (this issue) eruditely review in their target article. Examples of sense-making and its mechanisms abound in all sorts of disciplines and can be readily found in popular press outlets. The July 23, 2012, edition of the *New Yorker* magazine, for instance, included a six-page article on forensic linguistics—the application of linguistic analysis to written and spoken evidence in legal cases—and at the center of the article was meaning maintenance:

> Words serve as catalysts, setting off sparks of potential meaning that the listener organizes into more specific meaning by observing facial expressions, body language. . . . We then employ another powerful tool: prior experiences and the storehouse of narratives that each of us carries—what linguists call "schema." . . . Meaning . . . is constantly bent by expectation. (Hitt, 2012, pp. 27–28)

Thus, we applaud Proulx and Inzlicht for their integrative efforts, distilling sense from multiple corners of psychology and neuroscience, and contributing to the defractionation of our field. Yet there are some shortcomings of the meaning maintenance model (MMM) with regard to explanations of the basic cognitive and behavioral mechanisms involved that we address herein. We approach this commentary from a mechanistic perspective, focusing on elemental levels of analysis in the hopes that future iterations of the MMM can further benefit from even stronger ties to basic behavioral and cognitive science and neuroscience. Specifically, we address five, interrelated shortcomings: (a) the meaning of meaning; (b) the range of expectancy violations and the role of the anterior cingulate cortex (ACC); (c) the role of emotion; (d) basic indices of "palliative efforts"; and (e) the place for existing concepts of somatic markers, motivational set points, the "interpreter," and negative reinforcement.

The Meaning of Meaning

Our first concern is with the MMM's definition of meaning. Although we greatly appreciate Proulx and Inzlicht's analysis of existing definitions of meaning, boiling them down, and offering a novel, simpler definition, the MMM could benefit from clarifying whether meaning, then, is equal to expectation and, furthermore, if meaning violations are, then, expectancy violations. Thus, do we need both terms if we can reduce meaning to expectation? If meaning is expectation, then perhaps we can abandon one or the other term in service of further parsimony. This may seem a picky point, but if meaning is expectation then perhaps Proulx and Inzlicht can rely further on basic behavioral and cognitive sciences, particularly those rooted in stimulus-response pairings and conditioning principles (for a review, see Berridge, 2001).

The Range of Expectancy Violations and the Role of the ACC

We cannot help but notice that Proulx and Inzlicht focus their MMM on negative expectancy violations, or violations of expectancy that signal something worse (or more odd) than expected. We doubt very much that meaning making and maintenance come about solely, or even primarily, when the organism detects a violation of expectation derived from a negative occurrence. We favor a more inclusive perspective here such that meaning, or expectancy, violations can be of any kind. In this way, the MMM could accommodate violations that are worse than expected, "pleasant surprises," and everything in between. It might also then be possible to abandon the term "palliative"—indicating a need to reduce unpleasantness—and, instead, adopt a more neutral term such as "adjustment" for the cognitive and behavioral events that follow from a violation of expectancy.

To be fair, Proulx and Inzlicht acknowledge a range of expectancy violations; however, negative (e.g., personal tragedy) and neutral (e.g., Stroop effect) ones are given priority. Moreover, Proulx and Inzlicht propose aversive physiological arousal as the primary mechanism whereby meaning violations are registered, and, in turn, what motivates adjustments. Two problems arise from hanging one's hat on this mediation model: (a) There is little to no evidence showing that physiological arousal mediates the relationship between expectancy violations and adjustments, and (b) generic measures of arousal such as skin conductance are not very good at separating aversive from appetitive states, that is, skin conductance increases are found in response to unpleasant *and* pleasant stimuli (e.g., Bradley, 2008). Similarly, it seems relevant to point out that aversive states do not necessarily lead to expected adjustments. For instance, studies from our group (Moran, Taylor, & Moser, 2012; Moser, Moran, & Jendrusina, 2012) and others (Weinberg, Olvet, & Hajcak, 2010; see Olvet & Hajcak, 2008, for a review) examining the relationship between anxiety—an aversive state—and the error-related negativity—an electrophysiological index of ACC activation following mistakes—show that although anxiety is related to an enhanced error-related negativity, it does not relate to greater expected performance adjustments such as greater accuracy, posterror slowing (PES) or posterror accuracy (PEA; see also Weinberg, Riesel, & Hajcak, 2012). Although anxiety increases ACC activity, sounding the alarm does not lead to expected adjustments. Individual differences studies like this can help shed light on the mediational hypothesis of the MMM. We return to the ACC-behavioral adjustments relationship next.

We further harp on this point because the MMM situates the ACC at the nexus of detecting and correcting aversive arousal states resulting from expectancy violations. Although a reasonable brain region to include as a focal point—indeed, expectancy violations have long been associated with ACC activity across a range of measures (Hajcak, Moser, Holroyd, & Simons, 2007; Holroyd & Krigolson, 2007; Moser & Simons, 2009; Oliveira, McDonald, & Goodman, 2007; Somerville, Heatherton, & Kelley, 2006)—the primary functions of the ACC are hotly debated. The ACC has been implicated in conflict monitoring, error detection, emotional processing, error likelihood prediction, and reinforcement learning (for a review, see Shackman et al., 2011). Although Proulx and Inzlicht use this variety of functions to undergird their argument that the ACC is an ideal structure to register myriad expectancy violations and respond to them, more recent theories propose different notions of ACC function that should be handled in future versions of the MMM.

Alexander and Brown (2011), for instance, suggest that the ACC is responsible for signaling unexpected bad *and* good outcomes and, in particular, unexpected nonoccurrences of predicted outcomes (i.e., negative surprises) that could be bad or good. The functional role of the ACC is shifted from valence to surprise in their model, and thus the ACC would not necessarily be primarily responsible for eliciting aversive arousal states per se, as negative surprise could reasonably trigger disappointment, relief, or joy (Egner, 2011). Moreover, several studies demonstrate that modulation of ACC activity, including event-related brain potential indices of ACC activity and the dopaminergic system linked to the ACC, is greater to unexpected gains or rewards than losses and nonrewards (Carlson, Foti, Mujica-Parodi, Harmon-Jones, & Hajcak, 2011; Holroyd, Pakzad-Vaezi, & Krigolson, 2008). Phasic increases in dopamine occur when events are better than expected (Schultz, 2002), and these signals are proposed to train the ACC to improve performance (Holroyd & Coles, 2002). We find it difficult to reconcile how increases in dopamine—a rewarding neurotransmitter—would result in aversive arousal states in need of palliative/relief efforts. Rather, such increases motivate approach-related reward-seeking behavior (Zaghloul et al., 2009) in contrast to the focus of MMM on avoidance-related palliative efforts.

Holroyd and Yeung (2012) further complicate the role of the ACC for the MMM, as they suggested that the ACC has little to do with behavioral adjustments implemented during a task but rather selects and maintains task options, that is, "coherent behaviors over extended periods" (p. 123; Holroyd & Yeung, 2012). Thus, the ACC may have less to do with signaling the need for behavioral adjustments along the way, which poses a problem for MMM that contends that the ACC signals the need for palliative efforts. However, Holroyd and Yeung concluded their theory article with, "We propose that ACC is responsible for learning and selecting high-level behavioral plans that provide the meaning behind, and thus the motivation for, our moment-to-moment action" (p. 127). Perhaps with the right adjustments, then, MMM could accommodate this twist on ACC function.

Do We Need Emotion to Understand Expectancy Violations and Subsequent Adjustments?

As already mentioned, the MMM claims that "aversive arousal/affect" following meaning violations prompts compensatory, palliative behaviors aimed at reducing this aversive experience. However, can these compensatory behaviors be understood without some notion of "aversiveness" and/or negative emotional experience? We question here whether the "negative emotional" component is necessary for motivating compensatory behaviors following meaning/expectancy violations.

In general, we feel the MMM may be strengthened by not splitting up emotional and cognitive processes. This dichotomy already abounds in psychological research (e.g., "cold cognitive processes" vs. "hot emotional states") and has several problematic implications. For example, the implicit consensus among researchers is that cognition is superior to and more methodologically accessible than emotion

(Miller, 1996). In the case of the MMM, the implicit story is that negative emotions must be “corrected” by the superior palliative efforts initiated by cognitive processes. If, instead, we interpret affect as cognition and treat the distinction between the two as phenomenological rather than ontological (Duncan & Barrett, 2007), MMM may further accommodate instances of expectancy violations in which the negative emotional response is not entirely clear or admittedly absent. By understanding palliative behaviors as efforts to return to some basic motivational state—independent of emotional responses arising from deviations from that state—perhaps the theory could account for more psychological phenomena, as described next.

As Proulx and Inzlicht point out, the ACC is activated during “low-level” conflict between response tendencies such as that brought about by the color Stroop task (e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001; Carter et al., 1998). The conflict-monitoring theory claims that conflict prompts the ACC to recruit additional resources in order to improve performance on subsequent trials (Botvinick et al., 2001). In this way, conflict is operationalized as the simultaneous activation of multiple mutually incompatible response tendencies (Botvinick, Cohen, & Carter, 2004). It is not clear from the MMM how conflict would be affectively aversive, as the concept of emotion is entirely absent from the conflict-monitoring theory (e.g., Botvinick et al., 2001). Indeed, the vast majority of conflict studies use neutrally valenced stimuli (e.g., “>><>>”) to elicit ACC activity and behavioral adjustments following conflicts and errors. It is unclear, then, why we need negative emotion/aversive arousal to explain compensatory behaviors when these behaviors are already accounted for by computational models built on purely cognitive mechanisms.

Instead, it may be that affective responses to conflicts and errors are already built into existing cognitive models. Perhaps the autonomic affective reactions reported after conflicts and errors (e.g., Hajcak, McDonald, & Simons, 2003) simply reflect what it feels like to make an error (Yeung, 2004). There is no question that there is significant overlap between “cognitive” and “subjective emotional” experiences of expectancy violations; the dorsal ACC is sensitive to both response errors and the subjective frustration that accompany them (Spunt, Lieberman, Cohen, & Eisenberger, 2012). Given that neural mechanisms respond to conflicts and errors within milliseconds, it is very difficult to parse out the differences between “cognitive” and “affective” reactions to these types of violations (Yeung, 2004). In sum, the MMM should consider treating cognitive and affective reactions to meaning violations as one in the same (McClure, Botvinick, Yeung, Green, & Cohen, 2007). Next, we consider the palliative behaviors/adjustments directly.

What Are Indicators of Palliative Behaviors/Adjustments?

Again, a central tenet of MMM is that meaning violations initiate compensatory behaviors that act as palliative efforts to reinstate familiarity by reducing aversive states/meaninglessness. Although Proulx and Inzlicht describe the ACC’s role in regulating *physiological and somatic* responses to violations, less attention is given to how this regulation carries over and influences overt *behavioral* responses. We turn to cognitive neuroscience studies of error monitoring, in which subjects perform simple two-choice tasks designed to elicit conflicts and errors (e.g., Eriksen & Eriksen, 1974), to address this missing link. We believe error-related phenomena are well suited for the MMM, because errors often reflect expectancy violations and elicit neural and behavioral responses thought to reflect “compensatory efforts.”

Here, we focus on two behavioral adjustments that follow errors: PES and PEA (see Danielmeier & Ullsperger, 2011, for a review). PES refers to the widely reported increase in reaction time following an error (Rabbitt, 1966). PES has long been considered a compensatory response to improve accuracy on the subsequent trial (e.g., Botvinick et al., 2001; Gehring, Goss, Coles, Meyer, & Donchin, 1993); the general line of thought has been that PES reflects the adoption of a more “cautious” response strategy. In this way, PES would seem an excellent candidate as a basic palliative response within the context of the MMM. PEA (obviously) reflects accuracy after mistakes, which provides a clear indication of how well the system rebounds or compensates. Thus, PEA also seems quite appropriate to understand from the perspective of the MMM.

Several lines of evidence indicate that PES is not always related to increased cognitive control on the subsequent trial, however. First, PES has been dissociated from PEA in a number of studies, such that increased PES bears no relationship to PEA (Carp & Compton, 2009; King, Korb, Von Cramon, & Ullsperger, 2010) or goes along with *decreased* PEA (Fiehler, Ullsperger, & Von Cramon, 2005; Laming, 1979). Second, the relationship between PES and PEA is likely influenced by task dynamics such as changing response-stimulus intervals (Jentzsch & Dudschig, 2009; Schroder, Moran, Moser, & Altmann, in press). Specifically, if the time between the initial error and the subsequent trial is too short, the erroneous response creates too much interference, causing the subsequent response to be slower and less accurate. The extent to which PES is “palliative” is therefore unclear at present.

A recent account suggests that, rather than an increase in cognitive control, PES reflects an orienting response to novel or infrequent events (i.e., errors) that inhibits subsequent responses (Notebaert et al., 2009;

Nunez Castellar, Kuhn, Fias, & Notebaert, 2010). In this view, PES reflects the by-product of an array of autonomic responses to novelty, including heart rate deceleration, pupil dilation, and increased skin conductance (Ullsperger, Harsay, Wessel, & Ridderinkhof, 2010). Of interest, PES is largest when participants are aware that they made an error (Nieuwenhuis, Ridderinkhof, Blom, Band, & Kok, 2001) or when they "feel" as if they did (Hajcak et al., 2003). Therefore, PES may be most prominent when novel/infrequent events become consciously processed and encoded. Taken together, these findings imply that PES might reflect an automatic orienting response to novel events, the adaptiveness of which is likely dependent on the task context. Thus, PES may, instead, be aimed at *facilitating* subsequent top-down efforts to improve accuracy on posterror trials rather than reflecting a palliative behavior in and of itself (Danielmeier & Ullsperger, 2011).

Some phenomena from error-monitoring studies may therefore be particularly important for MMM to consider, especially with regards to how ACC-mediated responses to inconsistencies promote compensatory *behavior* brought about to regain a sense of control. Moreover, the MMM would greatly benefit from incorporating how the orienting response initiates and/or guides behaviors following a range of expectancy violations. Specifically, the MMM should consider the nuanced relationship between autonomic/orienting behaviors (e.g., PES) and truly adaptive efforts to maintain meaning/adequate performance (e.g., PEA). Not all postexpectancy violation behaviors are palliative and not all palliative efforts are created equal. PEA—which is *always* adaptive—may be a more reliable index of a palliative behavior, for instance.

Finally, we note that individual differences in implicit beliefs may play an important role in mediating posterror compensatory behaviors. Decades of research by Dweck and colleagues suggest that individuals who believe their intelligence is malleable outperform those who believe it is fixed when performance is challenged (i.e., after mistakes; Dweck, 2006). Our group (Moser, Schroder, Heeter, Moran, & Lee, 2011) and others (Mangels, Butterfield, Lamb, Good, & Dweck, 2006) have demonstrated that those who believe intelligence is malleable demonstrate enhanced attention allocation to erroneous responses, which predicts their superior ability to bounce back on subsequent trials. These findings suggest that subconscious beliefs about ability play a role in how meaning/expectancy violations are experienced and responded to, at the neural and behavioral level. The MMM may benefit from considering how implicit beliefs play into promoting palliative behaviors/adjustments following meaning violations.

Missing: Somatic Markers, Motivational Set Points, Interpreter, Negative Reinforcement

In this final section we turn to existing concepts in the literature that we feel are quite relevant to the MMM but that Proulx and Inzlicht did not incorporate. First, to follow from our previous comments on the ACC, the mechanisms underlying meaning maintenance in the MMM remind us of the somatic marker hypothesis proposed by Damasio and colleagues (Damasio, 1994; Naqvi, Shiv, & Bechara, 2006). In short, this theory suggests that decision making is guided by emotional body states that "mark" behaviors as advantageous or disadvantageous based on past experience. These body states are proposed to be maintained by activity in the prefrontal cortex, including the ACC, during deliberation of behaviors with uncertain outcomes, and thus bias decision making depending on the representation of the choice as good or bad. It seems to us that this theory could help further elaborate the MMM in terms of fleshing out how interactions between brain and body maintain order and guide behavior.

A lesser appreciated model of the role of ACC in decision making and expectancy violations was proposed by Luu and Tucker (2004) in which they argued that the ACC represents motivational set-points, or adaptive goals, that, when violated, engages regulatory processes to meet or adjust the set-point of the organism. Luu and Tucker's view is unique in that they integrate the concepts of motivation, emotion, homeostasis, dynamical systems, and self-regulation. In this way, Luu and Tucker had much the same motivation as Proulx and Inzlicht to integrate across boundaries of different sciences. It may therefore be helpful to Proulx and Inzlicht to consider the role of set-points and self-regulation in the MMM.

Beyond more basic cognitive processes, the higher order phenomenon that Gazzaniga (e.g., 1998) refers to as the "Interpreter" also seems quite relevant to the MMM. Years of studying split-brain patients lead Gazzaniga to conclude that the Interpreter is our brain's reflexive storyteller, housed in our left hemisphere. Specifically, the Interpreter creates order and reason and meaning for each and every one of us by stringing together the bits of our internal and external lives—emotions, thoughts, and behaviors—and writes a coherent narrative that gives rise to our sense of self and wholeness. We find it an interesting point of connection that the Interpreter resides in the left hemisphere, where Proulx and Inzlicht propose palliative efforts are motivated (p. 24). Thus, meaning maintenance behaviors such as accommodation and affirmation may be further understood as henchmen of the Interpreter.

Finally, we draw connections between the MMM and the basic behavioral principle of negative reinforcement. The function of palliative efforts to decrease aversive states following meaning violations bears a striking resemblance to the process of negative reinforcement. Negative reinforcement is an operant conditioning principle whereby a behavior is reinforced, or increased, because it removes an aversive state. Thus, in Proulx and Inzlicht's MMM, palliative efforts can be construed as negatively reinforced behaviors. Negatively reinforced behaviors are generally thought of as being avoidance-, not approach-, motivated—that is, negatively reinforced behaviors aim to avoid, or take away, bad feelings. Perhaps Proulx and Inzlicht's meaning-making behaviors could be reconceptualized as avoidance-motivated.

Two-stage models of avoidance learning in anxiety disorders further make this point (Dollard & Miller, 1950; Mowrer, 1939, 1960). Specifically, anxiety-related disorders are thought to develop and persist because distress becomes associated with some particular event, which in turn motivates behaviors to reduce the anxiety that are largely construed as avoidance behaviors. Avoidance behaviors are maintained over time by negative reinforcement—that is, they remove aversive states. Palliative—avoidance—behaviors in anxiety models are generally thought of as maladaptive, or rather, their persistence is theorized to be maladaptive because it prevents new learning—that is, incorporation of corrective information—that feared situations are not as bad as they seem (Foa & Kozak, 1986). Put another way, palliative efforts to reduce aversive states may subserve short-term, rather than long-term, utility functions. It is important for the MMM to consider when certain palliative efforts are helpful versus unhelpful following the violation of various expectations. As an example, Proulx and Inzlicht discuss trauma and the resultant palliative efforts that are engaged to assimilate or accommodate extremely negative unexpected events. Some of these efforts following trauma are helpful (e.g., thinking bad things sometimes happen to good people) whereas others are not (e.g., thinking the world is dangerous so certain things, people, or places should be avoided in order to stay safe)—although both are palliative in that they are aimed at reducing aversive arousal. Negative reinforcement and avoidance learning theories may therefore provide interesting perspectives on the range and effectiveness of different meaning maintenance behaviors.

Concluding Remarks

Proulx and Inzlicht's MMM surely represents the kind of integrative theorizing that has the potential to unite thinkers from various areas of science and lead to meaningful innovation and advances. We are very supportive of this broad goal of the MMM. Our intention with this commentary was to provide a foundation for further expanding the scope of the MMM by highlighting some of its shortcomings regarding delineation of the basic cognitive and behavioral mechanisms involved. Some of the concerns we raised could easily be accommodated by the MMM (e.g., integration of the "Interpreter" concept), whereas others may require some depth of thought as to how cognitive and behavioral mechanisms in the MMM may have to be changed or retooled (e.g., the specific roles of aversive arousal and the ACC). We look forward to further development of the MMM and to its ability to shed new light on a range of biopsychosocial phenomena.

Note

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