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Getting Stuck on Myself: The Cognitive Processes Underlying Mental Suffering

Marieke van Vugt

Many have demonstrated that we spend considerable time in task-unrelated spontaneous thought (Killingsworth and Gilbert 2010; Smallwood and Schooler 2015). While sometimes beneficial for skills such as creativity (Baird et al. 2012), such spontaneous thought can also impair performance and even lead to accidents. Moreover, when spontaneous thought takes a life of its own, as in the case of rumination, it becomes an important risk factor for depression and other forms of psychopathology. Diagnosed depression has a societal cost roughly equivalent to 1% of the total economy in Europe (Sobocki et al. 2006).

Milder forms of such ‘perseverative cognition’ may not lead to depression, but still cause impairments in concentration (e.g., van Vugt and Broers 2016). An important question is therefore: what turns innocuous and even beneficial spontaneous thought into impairing rumination? In this chapter, I will shed a new light on this process by looking at it through the lens of cognitive science with suggestions for how to study this process. I will then use that to suggest ideas for new interventions for preventing mind-wandering turning into rumination.

Perseverative Cognition and Rumination Defined

Clinical psychology has defined many terms referring to phenomena similar to rumination, e.g., cognitive reactivity, repetitive negative thinking, associative elaboration and perseverative cognition. Perseverative cognition is a more general term, defined as ‘repeated or chronic activation of the cognitive representation of one or more psychological stressors’ (Brosschot et al. 2006; Verkuil et al. 2010).

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Such psychological stressors could, for example, be fears about whether you do well enough at work, or memories of a fight at home. In contrast, ‘rumination’ refers to the more specific process of self-related negatively-valenced thinking that is repetitive and interfering with ongoing cognitive processes (Marchetti et al. 2016; Nolen-Hoeksema and Morrow 1991; Treynor et al. 2003). While rumination pertains to depressed patients, I refer to perseverative cognition as one that occurs in all people. Since I intend to look at rumination and associated phenomena through the lens of cognitive science, I will frame this chapter around ‘perseverative cognition’.

Theories of Perseverative Cognition and Rumination

There are many theories of how perseverative cognition and rumination arise, which I have summarised in three different classes. The first class of theories ascribe rumination to an increased attentional bias to negative-valence information (Dagleish and Watts 1990). This theory states that attentional focus is narrowed such that people are unable to engage with something else (Whitmer and Gotlib 2013). These theories are based, among others, on experiments that show that rumination is associated with quicker responses to negative information (Bradley et al. 1997) and that negative memories are retrieved more easily in people who suffer from depression (Clark and Teasdale 1982). A second class of theories suggests that rumination arises from a defect in inhibition, in particular inhibition of negative self-focused thought processes (Fox et al. 2015; Whitmer and Banich 2007). This theory is, among others, based on experiments in which participants have to switch tasks or suppress associations, and trait ruminators show impairments. This defect in inhibition then leads to a tendency to persevere: after attention has been captured, the person is not able to let go of negative information (Altamirano et al. 2010). This theory is supported by experiments that show that ruminators are better at maintaining the current task set, but have difficulty changing or updating working memory. A final version of this class of theory is the impaired disengagement hypothesis (Koster et al. 2011), according to which people are not able to let go of self-referring negative information. This has been supported by experiments in which people had to remove negative information from working memory (Joormann and Gotlib 2008). A third class of theories focuses more on the content of what is rehearsed during rumination: even with the same cognitive capacities, if habits of repetitive negative thinking are stronger, then one can get stuck in this repetitive negative thinking as if it were an attractor (Cramer et al. 2016). Similarly, neural data shows indirectly that ruminators have a more narrow network of associations that is evoked by task stimuli (Harel et al. 2016). While these three approaches all predict impairments in the ability to concentrate and perform a cognitive task (as has also been observed for depressed patients), they make different predictions about the relation between cognitive control capacity and task performance.

Using Mind-Wandering as a Theoretical Framework for Understanding Rumination

To compare these different explanations of perseverative cognition, it is helpful to cast them all in terms of the same computational cognitive theory. The most relevant domain for this is mind-wandering, given that rumination is a thought process that occurs spontaneously and is task-independent, just like mind-wandering (Christoff et al. 2016; Smallwood and Schooler 2015). The model is built on an integration of the most important theories of mind-wandering. One influential theory states that mind-wandering occurs whenever cognitive control fails (McVay and Kane 2010), i.e., a problem in goal management. On the other hand, there is also evidence that people can strategically mind-wander when the task allows them to do so, suggesting that mind-wandering can be a conscious choice (Smallwood et al. 2009). Yet other theories of mind-wandering suggest it is caused by failures of meta-cognition (allowing a process that is not intended to take over). This is based on experiments that show that when people indicate that they were not aware of where their attention was, mind-wandering is more prevalent (Mrazek et al. 2013). This has led to researchers to suggest that we need to distinguish between intentional and unintentional mind-wandering (Seli et al. 2016). Essentially, people can choose to strategically mind-wander when task demands are low. On the other hand, when task demands are high, people with low attentional control may still mind-wander, even though that is not adaptive, and they do not intend to mind-wander. Consequently, mind-wandering can be a person's goal. Mind-wandering often involves a shift of attention from the external world to the internal world—a phenomenon referred to as 'perceptual decoupling' (Smallwood et al. 2011). Such a shift may occur when there is very little stimulation in the external world, but also when internal stimuli are sufficiently powerful that they actively turn attention away from the internal world. For example, Klinger (1987) suggested that mind-wandering arises from a person's preoccupation with non-task goals and concerns—consistent with the idea of a competing mind-wandering goal. In short, there is a multitude of factors that could generate mind-wandering.

A Computational Theory of Mind-Wandering

To organise these different theories of mind-wandering, I have developed a computational theory of this model. Computational theories can help to arrive at a fine-grained understanding of a cognitive process, because they can make quantitative predictions about the consequences of different mental strategies. For example, Marewski and Mehlhorn (2011) used this approach to distinguish between different theories of how heuristics are involved in decision-making. Similarly, my computational model of mind-wandering (to my knowledge the first computational theory of this process), formalises some of the main theories of how mind-wandering arises (Taatsgen et al., submitted; van Vugt et al. 2015).

The main assumption of my model is that mind-wandering arises when the competition between the goals of mind-wandering and performing a task is won by the goal of mind-wandering. This assumption implements the idea that mind-wandering is driven by current concerns (which strengthen the mind-wandering goal), perceptual decoupling (which weakens the task goal), and intentional mind-wandering (consistent with the idea that not only the cognitive task but also mind-wandering can be a goal). The other main assumption of my model is that mind-wandering consists predominantly of retrieving items from memory, in line with some experimental findings (Ellamil et al. 2016) that demonstrate that at the moment that someone reports mind-wandering, there is an increase in neural activity in the medial temporal lobe, a system associated with memory retrieval. Mind-wandering in my model can be ended by retrieving a memory that reminds the model of the main task, which returns it to the cognitive task at hand. The memory that is being retrieved at a particular point in time is determined by the activation of the different memories of the model—the most active memory wins the competition. This memory will then spread activation to other memories that are associated, which affects what memory is being recalled next, and thereby shapes the series of memories (‘thoughts’) that are being retrieved. In other words, an individual’s associative memory architecture shapes the trajectory of mind-wandering that occurs.

This simple computational model of mind-wandering is implemented in the adaptive control of thought-rational (ACT-R) cognitive architecture (Anderson 2007). ACT-R is a computational theory of cognition that has to date been used to model many different tasks ranging from free recall to task switching, and driving a car. Its parameters and structure has been validated in all these previous applications, thereby providing constraints on my mind-wandering model.

My model reproduces some hallmark phenomena in the mind-wandering literature satisfactorily: it roughly gets the proportion of off-task thinking correct and it reproduces the increase in response time variability before off-task responses relative to on-task responses (Fig. 1). It also reproduces other features of behaviour, such as the proportion of errors, average response times, and the proportion of

Fig. 1 Computational model of mind-wandering can predict increase in response time variability when off-task (left) and fraction of off-task responses (right). White Empirical data, grey model. Striped On-task; open off-task

thoughts about the past, present and future. In short, on the basis of two main assumptions and leaving most parameters at their defaults, my model can simulate introspection.

Reframing Theories of Perseverative Cognition in a Computational Model

We can now recast the three classes of theories of perseverative cognition in terms of this mind-wandering model. Attentional bias theories posit that rumination is the result of an increased focus on negative information. In my model, that could be implemented as an increase in the activation of negative-valence memories, making them more likely to be retrieved when a person is mind-wandering. Inhibition-based theories posit that rumination arises from an inability to disengage from negative information or conversely, the tendency to persevere in negative self-referential thinking. In other words, this theory is about a defect in task switching (where the tasks are the cognitive task on the one hand, and ruminating on the other). In general, switching between tasks has previously been modelled in cognitive architectures as requiring the execution of a task-preparation step (Sohn and Anderson 2001), which takes some time, and thereby explains the delay that is generally observed in task performance when participants switch tasks relative to when they stay with the same task. If this task-preparation step is more difficult to perform (in the model this would be implemented as a lower activation for the task-preparation action) then switching from the mind-wandering/rumination process to the main task becomes more difficult. As switching to the cognitive task becomes more difficult, the person will persevere more in ruminating. The third class of theories posits that rumination arises from particular habits of thought. In my model (which is reported in more detail in van Vugt and van der Velde 2017), the habits of thought are modelled by the activations of memories as well as the pattern of associations between them. Memories that are more often used (and therefore stronger habits) have higher activations, and are therefore more easily retrieved again. Memories can also spread activation to other memories (making the other memories easier to retrieve), thereby

Fig. 2 Model simulations of a computational model of rumination based on manipulating habits of thought. *Left* Ruminating model is more frequently mind-wandering. *Right* Ruminative model has a longer duration of mind-wandering. Ruminative model: *green*; Healthy model: *red*

modelling the associations between memories. The associative network can be configured such that one gets stuck in repeatedly retrieving negative, self-related memories (Bar 2009; Harel et al. 2016). In a preliminary implementation of that mechanism (Fig. 2), I showed that the depressed model (green) is mind-wandering more often than the control model (red), and the duration of mind-wandering is longer. What is remarkable is that the increase in mind-wandering and associated reduction in task performance automatically fell out when we modelled rumination by changing the model’s associative network.

Distinguishing Theories of Perseverative Cognition Based on Cognitive Control

While each of the theories of perseverative cognition has been developed to explain a different set of behavioural data, it may be possible to distinguish these theories of perseverative cognition empirically by examining how the duration of perseverative mind-wandering responds to changes in cognitive control (Koster et al. 2011; Marchetti et al. 2016). It is known that cognitive control is an important factor affecting rumination and depression and we will see below that the three classes of theories predict different effects of cognitive control on the duration of mind-wandering for each of these (Table 1). In the modelling framework I am using, cognitive control is implemented as the tendency to check whether the current goal is in line with the intended goal (goal monitoring), and preparing for upcoming tasks when possible (O’Reilly et al. 2010; Taatgen et al. 2009). This means that changing cognitive control would not be associated with any changes in (perseverative) mind-wandering according to theories that focus on an attentional bias towards negative information. The inhibition account of perseverative cognition instead predicts that when there are more cognitive control resources, this helps to strengthen the current task focus, and any spare time is used to prepare upcoming tasks. Together, these control strategies prevent mind-wandering from occurring (Hertel 1997). In this theory, even when mind-wandering occurs, this ensures that the task goals are on general more active, and therefore it is easier to return to the main task, which means that the duration of mind-wandering will be briefer when cognitive control resources increase. In contrast, the habits of thought account suggests that additional cognitive control resources can be used both by the main task and by the mind-wandering [in accord by previous studies of craving: Andrade et al. (2012) and rumination:

Table 1 Predictions of different theories of perseverative cognition

Theory	Cognitive control resources used by MW	Incidence of MW when more cognitive control	Duration of MW when more cognitive control
Attentional bias	No	No change	No change
Problem in inhibition	No	Less	Shorter
Habits of thought	Yes	No change	Longer

MW = Mind-wandering

Altamirano et al. (2010)]. When cognitive control resources are used by the mind-wandering process, this causes the mind-wandering to persevere even longer.

Table 1 summarises these predictions for how the different classes of theories of perseverative cognition would respond to changes in cognitive control. Note that the three classes of theories make qualitatively different predictions for the duration of mind-wandering episodes (last column). This suggests that we can determine what mechanism is generating perseverative cognition by measuring the duration of mind-wandering. I will next review methods to measure mind-wandering, and discuss how those could be used to measure the duration of this cognitive process.

Methods for Measuring Mind-Wandering in the Laboratory

Since mind-wandering is a spontaneous—rather than task-driven—process, it is a challenge to measure it in the lab, and doing so requires triangulating between different measures. The most common approach is to intersperse self-report questions in a cognitive task, in which participants are asked whether they were mind-wandering at the moment the prompt appeared, and what the mind-wandering was about. Using these methods, it has been demonstrated that participants make more errors and their response time is more variable (Bastian and Sackur 2013) in the periods prior to off-task responses relative to on-task responses.

The problem with thought probe responses is that they effectively create another task within the task, and are only taken at discrete moments, thereby making it impossible to track mind-wandering duration. For that purpose, we would need more continuous neural or physiological measures. In functional magnetic resonance (fMRI) studies, mind-wandering has been associated with activation of the default mode network (Christoff et al. 2009; Mason et al. 2007), a network of brain areas, including the medial prefrontal cortex, posterior cingulate and medial temporal lobe, that are more active during resting periods than during demanding cognitive tasks. EEG studies have most robustly associated mind-wandering with a phenomenon called ‘perceptual decoupling’—reduced event-related potentials to external stimuli (Smallwood et al. 2008), but also to increased 9–14 Hz alpha oscillations (Baird et al. 2014; Braboszcz and Delorme 2011).

Although these findings are promising, there is considerable heterogeneity in the observed relations between mind-wandering and brain activity. Such heterogeneity is also evident in physiological findings, in which mind-wandering has sometimes been associated with less phasic pupil responses, and a higher tonic pupil size (Jonathan Smallwood et al. 2011; Unsworth and Robison 2016), but other studies contradict that. Altogether this suggests that we need a more fine-grained understanding of mind-wandering, and the level of perseverativeness of mind-wandering may be a crucial distinction.

Fig. 3 Elastic net classifier trained on thought-probe-derived samples of intracranial EEG classifies degree of mind-wandering across the whole task for a case study of a single patient

If we have a way of experimentally manipulating perseverativeness, then we can compare neural and physiological activity between perseverative and regular mind-wandering conditions. On the basis of this contrast, we can train machine learning classifiers to distinguish normal and regular mind-wandering on a single-trial level, similar to previous work that has distinguished between on- and off-task thinking on a single-trial level (Mittner et al. 2014). Having trained this classifier, we can then run it on the continuous data and obtain for each moment in time an estimate of whether a person is engaging in mind-wandering or perseverative cognition (Fig. 3). On the basis of these estimates, it will be possible to derive the average duration of mind-wandering.

Methods for Manipulating Perseverative Cognition in the Lab

To create sufficient trials to train a classifier on, we need to be able to manipulate perseverative cognition experimentally. My colleagues and I have recently developed ways to trigger perseverative cognition in the laboratory, in the context of a mind-wandering task and a complex working memory task (Daamen et al. 2016). In this task, participants memorise letters, and the memorisation is interspersed by a task in which they either think about themselves or make other semantic judgments. A robust finding is that self-related thought is associated with a reduction in memory accuracy. A reasonable explanation is that that impairment is caused by a lingering thinking about the self—indeed, perseverative cognition. In line with that idea, participants in this task report thinking more about the words they have to judge when they are in the self-referential condition relative to the control condition.

Another relevant paradigm that has been developed to manipulate perseverative cognition is the current concerns mind-wandering task—a go/no-go paradigm in which a participants’ personal concerns (Klinger 1987) are embedded (McVay and Kane 2013; van Vugt and Broers 2016). The hypothesis is that the concerns trigger local increases in off-task thinking, frequently about these concerns. While there is some evidence for that, it is not always consistent (McVay and Kane 2013; van Vugt and Broers 2016). Nevertheless, when we distinguished the thought probes on the basis of self-reported ‘difficulty to disengage from the thought’ (Verplanken et al. 2007), we observed an increase in the variability of response time and proportion of off-task thinking.

The last task that could be used to trigger perseverative cognition in the lab is free recall with emotionally-valenced words. In this task, participants memorise lists of positive, negative and neutral words. When people are asked to recall these words in any order, the way in which they organize their recall gives information about how their thought patterns are organised (Howard and Kahana 1999). Moreover, searching for items in memory may in itself trigger certain patterns of mind-wandering that are primed by the memory recalls. Indeed, I showed that depressed patients tend to perseverate on recalling negative information, and that that tendency is reduced after Mindfulness-Based Cognitive Therapy (van Vugt et al. 2012). In this task, we can then designate the period in which people persist in recalling negatively-valenced information as perseverative cognition, and compare that to periods in which they recall more freely. In short, at least three different kinds of tasks can be used to create periods of perseverative cognition in the lab.

Is It Likely That Neural and Physiological Measures Distinguish Between Perseverative Cognition and Mind-Wandering?

Even if we are able to manipulate perseverative cognition in the laboratory, how likely is it that neural or physiological activity can distinguish between perseverative cognition and more general mind-wandering? Several lines of research suggest that perseverative cognition has a unique signature. For example, heart rate variability seems to track perseverative cognition (Ottaviani et al. 2016). Recently, Christoff et al. (2016) suggested that perseverative cognition differs from more general mind-wandering in the pattern of connectivity between default mode network areas and frontal cortex, with a reduced frontal influence during perseverative cognition. Similarly, EEG studies have shown differences in oscillatory activity between depressed patients and controls (e.g., Fingelkurts and Fingelkurts 2015; Henriques and Davidson 1991; Pollock and Schneider 1990), although that has not been linked directly to behaviour. Temporally more precise theories of perseverative cognition should we able to allow us to develop more precise neural signatures as well.

How Could Research on Perseverative Cognition Impact the World?

If, through the methods I discussed above, we are able to determine when and how perseverative cognition occurs, and through which mechanism, then what can we do with it? Once we better understand through what mechanism perseverative cognition occurs, this can inform interventions. Currently, there are many interventions for depression, including anti-depressant medication, cognitive behavioural therapy, and Mindfulness-Based Cognitive Therapy (MBCT, Segal et al. 2002). MBCT consists of mindfulness techniques in which people learn to observe their mental patterns in combination with cognitive restructuring exercises derived from cognitive therapy. It is currently the treatment of choice recommended by the United Kingdom's National Health Services. While MBCT has been very helpful in treating depression and preventing relapse, it also has its limitations and does not work for every individual. Could there be other approaches to target perseverative cognition?

Since mindfulness appears to be a promising ingredient of interventions for depression, it is worthwhile investigating other contemplative techniques as well (Dahl et al. 2015). One of the contemplative practices that may be particularly relevant to changing habits of thought is analytical meditation, a practice I have recently started to investigate. This practice may be particularly well-suited to changing habits of thought that are associated with perseverative cognition. Analytical meditation consists of contemplating philosophical ideas (especially those related to the nature of the 'self' and reality) repeatedly, interspersed with resting meditation, in which insights are consolidated, and with testing one's understanding in dyadic debate. Monastic debate is a core activity of life in Tibetan monasteries (Dreyfus 2003; Perdue 1992). The objective of this debate is to reduce excessive self-focus. The debate tackles the perspectives of different philosophers in the Buddhist tradition about what 'self' actually means: is it the body? Is it the mind? When did it start? When did it end? (Epstein 2008; Siderits et al. 2013) Carefully contemplating these (and more) questions slowly causes a realisation to dawn that while the self is usually a focus point of our thinking, and we act as if it is permanent and independent from everything else. In fact, however, it is very difficult to delineate where your 'self' ends and someone else's 'self' begins. This realisation is useful because previous studies have shown that excessive self-focus is associated with rumination, and therefore reducing it should reduce rumination (Ayduk and Kross 2010).

The emphasis on critical reasoning is what analytical meditation differs from mindfulness practices, which focus more on the training of attention and an attitude of non-judgementality. Analytical meditation also differs from (mindfulness-based) cognitive therapy in that it is not directly focused on a person's destructive thought habits, but rather on the underlying assumptions about the nature of the self as something that needs to be protected at all costs against an outside world with which it competes. Potentially, radically changing a person's view of their self can leave maladaptive thought patterns (which depend crucially on the self, since they are self-referential) without basis.

Further Deconstructing the Self in Debate

The individual contemplation of the nature of the self is complemented by dyadic or group debates. In their debate practice, monastics use reasoning accompanied by a highly stylised physical form to deconstruct habitual patterns of self-focus. Our preliminary discussions with the monks suggest that this physical form helps to powerfully turn the intellectual understanding into embodied experience.

Debates centre around the interaction between one or more challengers and one or more defenders. The challenger (or ‘clarifier of reasoning’ (Lempert 2012)) has the objective of making the defender contradict him- or herself. While the challenger is allowed to say anything, the defender is bound to be consistent with his previous assertions (Liberman 2008). The topic of the debate is decided by the challenger, who will often prompt the defender to start by quoting the relevant part of the text under discussion. After both agree on this, the challenger will derive consequences from this quoted text and earlier statements that the defender can either agree with, state that the reason is not established, or ask the challenger to explain himself. The debate continues back and forth in this way, and both parties are not allowed to spend a long time thinking, otherwise they run the risk being ridiculed (Liberman 2015). If one party needs more time to think, they may rehearse earlier statements to keep up the pace of the debate. In this way, debating helps to solidify the relevant lines of reasoning and deepen conviction in the conclusions of one’s reasoning (Dreyfus 2003)—in other words, debate can serve to change habits of thought through extensive reasoning.

The emphasis on developing new habits of thought make debate an interesting target of investigation. Preliminary results from the first studies we have done with the monastics suggest that during the debate, prefrontal 4–9 Hz theta oscillations, frequently associated with concentration (Gevins et al. 1997; Yamamoto and Matsuoka 1990), increase over time, demonstrating that the debate is an attention training (van Vugt et al., in preparation).

Conclusions

In this chapter, I have looked at perseverative cognition, a process of negative self-referential thinking that is associated with psychopathology such as depression, through the lens of computational cognitive science. I have outlined the different theories that exist to explain perseverative cognition: a bias in attending to negative information, a defect in inhibition, or habits of thought that make one get stuck in rehearsing negative patterns of thinking. I have translated these theories into a computational cognitive theory, and demonstrated that they can be distinguished by looking at how cognitive control increases would affect the perseveration of mind-wandering. Interestingly, the perseveration of thinking is what makes it so harmful and interfering with cognition and wellbeing. As a result of this

perseveration, new perspectives and external perceptions are discounted or ignored. Instead of planning ahead for the next trial of a task, or adapting to circumstances, people spend their time internally focused, rehearsing the same thought patterns over and over. This means that interventions that reduce perseverative cognition are important. I suggested that analytical meditation practices, inspired by age-old contemplative practices of Tibetan monks, may hold promise as interventions for reducing perseverative cognition. The main reason for this suggestion is that negative self-referential thinking lies at the core of perseverative cognition, and monks are experts at deconstructing self-referential thought, one of the key ingredients of perseverative cognition. Maybe in the future, some of these methods will allow people to be less of a victim of their own self-referential thinking, thereby unlocking the potential of their minds.

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