The brain's braking system (and how to 'use your words' to tap into it)

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The brain's braking system (and how to 'use your words' to tap into it)

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'I dragged myself out of bed.'

'I made myself go to the gym.'

'I kept my cool and did not yell at my boss (even though I really wanted to).'

Our capacity for self-control is unquestionably one of the things that separates man from the beasts and yet, like most psychological capacities, it is typically taken for granted. This capacity is unique, complex, and responsible for most human accomplishments being accomplishments rather than half-baked ideas that never leave the drawing board. Self-control allows us to persist in the face of other appealing options and to adapt rather than being slaves to our impulses.

It may also get you into the college of your choice. In the 1970s, Walter Mischel ran a series of studies in which he confronted young children with a straightforward dilemma: 'you can have one marshmallow now or any time before I return by ringing this bell, or you can wait until I return and I'll give you two marshmallows.' There are adorable videos of the children doing everything they can to resist chowing down on the one marshmallow that is already sitting in front of them. Just like adults, children logically know that two is better than one and so they want to wait it out. But you can see they are fighting against something: themselves. And who wins this battle of the selves (the self who wants immediate gratification vs. the self who appreciates the big picture) has real consequences. Those children who were able to wait the full 15 minutes went on to score more than 200 points higher on their SATs a decade later than those who immediately gobbled up the first marshallow. Self-control at age five sets you on a career to greater or lesser success for the rest of one's life.

At first blush, the kind of self-control needed to resist marshmallows seems very different than the kind of self-control involved in performing well on standardized tests.

Motor self-control and perspective-taking self-control are as different as can be and yet both of these rely on the same neural mechanism.

However, neuroscientists are demonstrating how disparate forms of self-control all rely on a common neural mechanism. Indeed, the kinds of self-control that depend on this system vary much more widely than the marshmallow and SAT cases. Imagine driving in a foreign country where they drive on the opposite side of the road from you. This takes enormous motor self-control to override your normal driving habits. At the other extreme of the self-control spectrum, imagine watching a sporting event with someone who is rooting for the team you are rooting against. Trying to take this person's perspective on the event also involves great self-control as you try to inhibit your own way of seeing things. Motor self-control and perspective-taking self-control are as different as can be and yet both of these rely on the same neural mechanism.

Figure 1: The anatomical outlines of right ventrolateral prefrontal cortex (RVLPFC).

The rest of this paper will proceed in three sections. First, I will discuss the region that is common to various forms of self-control, a brain region called *right ventrolateral prefrontal cortex* (RVLPFC), and summarize some of the evidence demonstrating this region's contribution. Second, I will explore an unexpected consequence of this region's role in the *brain's braking system* in a study from our lab that suggests that when we try to engage in a targeted form of self-control (e.g. motor self-control), we may unintentionally induce self-control in other domains (e.g. emotional self-control) because the brain's braking system will regulate all kinds of impulses when it is active. Third, I will discuss how putting feelings into words can unintentionally tap into this RVLPFC self-control system, and how certain forms of mental training like meditative practice can improve the effectiveness of this system. From my own perspective, the first section highlights something that fMRI does particularly well; show that psychological processes that feel quite different from one another can share a common neural bases. This sets up and helps explain the interesting but paradoxical phenomena that follow.

Varieties of self-control

Motor self-control

The neural basis of self-control has been studied most extensively in the domain of motor self-control. Anytime your body seems to 'want' to do one thing but you know you need to do another, that's motor self-control. Driving on the opposite side of the road in foreign countries is certainly one kind of self-control, but scientists use a much simpler analog of this to study motor self-control within the confines of an MRI scanner. Typically, neuroscientists will use some variant of of a *go-nogo* task.

In a typical go-nogo task, participants see a series of letters appear on the computer screen one at a time (i.e. each letter replaces the one that was there before it). For any letter that appears other than one particular letter (e.g. 'R'), the participant is instructed to hit a button. These are the go trials and usually 80% or more of the trials in a go-nogo study are go trials. These occur about one every second and so a participant gets into a rhythm of tapping the same button once a second. In other words, a button pressing habit forms and the brain's tendency to want to keep pressing the button is described as a *prepotent response*. Nearly all forms of self-control involve overriding some kind of prepotent response (i.e. a response the brain assumes should follow and thus is prepared to make) and in motor self-control this is certainly the case. This is where the *nogo* trials come in. Every so often (but not too often), the 'R' appears and when this happens, the participant is instructed to not press a button. For the participant doing the task, this feels decidedly like withholding a response, the prepotent response that was all ready to go.

Anytime your body seems to 'want' to do one thing but you know you need to do another, that's motor self-control.

This task and others that are conceptually similar (e.g. stop-signal task) have now been examined dozens of times with fMRI. Results do vary a bit from study to study, but the one near constant across these studies is that RVLPFC is more active during nogo trials (when self-control is needed) than during go trials. Other regions have certainly been observed as well, including left ventrolateral prefrontal cortex (PFC), supplementary motor area and basal ganglia. As I discuss each different kind of self-control you should bear in mind that there are always networks of brain regions involved. My main point in this section is simply that the RVLPFC is the one brain region that seems to be present across all of the different kinds of self-control.

Demonstrating that particular brain regions are active during a particular form of self-control is important, but it does not tell us whether those brain regions are actually doing anything necessary to have successful self-control occur. Examining patients with brain damage; with lesions to particular brain structures, can help remedy this situation. Adam Aron conducted the best neuropsychological study of motor self-control to date in order to figure out what brain structures are truly necessary for motor self-control. Aron and colleagues (2003) examined behavior performance on a stop-signal task in a variety of patients with damage in different brain regions. The extent of damage in different brain regions was related to performance on the motor self-control task, and only damage in the RVLPFC predicted impaired performance on the task. No other damage in the brain was associated with task impairment.

Thus, the evidence for RVLPFC involvement in motor self-control is clear and uncontroversial. It shows up in nearly every fMRI study and it is the one region that has been causally linked to motor self-control deficits in patients with brain damage.

Cognitive self-control

There are fewer studies of cognitive self-control than there are of motor self-control. During cognitive self-control, individuals try to modulate their own thoughts in terms of what does or does not come to mind, or try to influence how one thought or belief might influence other cognitive processes that logically should be kept separate. At this point we can say that a number of these studies, though not all, suggest RVLPFC involvement in cognitive forms of self-control.

In one study (Mitchell *et.al,* 2007), participants were instructed to try not to think of a white bear. This turns out to be a very challenging task (try it!), but while participants were doing this, rather than engaging in free thinking, they generated increased activity in the RVLPFC. Similarly, in another study (Depue, Curran and Banich, 2007), individuals learned to associate pairs of pictures together and later were shown one picture and asked not to think of the other, and their success at this was associated with RVLPFC activity.

In a different kind of study, Goel and Dolan (2003) examined the capacity to inhibit a belief in order to provide the logical answer to a question. In their study, participants were shown syllogisms and had to indicate whether the conclusion logically followed from the premises. Critically, a conclusion can logically follow from the premises even if the premises are not actually true. For instance, if you were shown the syllogism: (1) Only expensive things are addictive, (2) Cigarettes are inexpensive, (3) Therefore, cigarettes are not addictive. Logically, the conclusion follows from the premises even though the first premise is false. In order to answer this question accurately, one must suppress the belief that the conclusion is factually false. When individuals in the study were able to suppress their belief and provide the correct answer regarding the logical flow of the argument, the only region that demonstrated increased activity in the brain was the RVLPFC.

During cognitive self-control, individuals try to modulate their own thoughts in terms of what does or does not come to mind...

Financial self-control

Adults are quite good at passing Mischel's marshmallow test, however they fail an analogous test easily. In studies of temporal discounting, individuals indicate whether they would prefer to receive $10 right now or $15 in a month. In these studies individuals reliably prefer the smaller, sooner reward to the larger, later reward, even when the best possible returns on one's investment could not match the increased financial benefit of waiting for the later reward. The first neuroimaging study to examine temporal discounting (McClure, Laibson, Loewenstein and Cohen, 2004) observed increased activity in the RVLPFC when individuals selected the larger, later rewards, presumably inhibiting the impulse to take the immediate reward. A subsequent study (Boettiger *et.al,* 2007) created an index for each participant based on their overall tendency to take one kind of reward or the other. In this study, the only region that was associated with the tendency to take the larger, later reward was the RVLPFC. Although there have only been a few studies on financial self-control, they suggest that the RVLPFC may play a key role.

Emotional self-control

Emotional self-control is more typically described as emotion regulation, and along with motor self-control, is one of the most researched forms of self-control both behaviorally and neurally. There are several different strategies that people apply in order to regulate their emotions including distraction, detachment, reappraisal, and suppression (Ochsner and Gross, 2008). Across the few dozen neuroimaging studies that have been conducted, three regions are pretty reliably associated with attempts at emotion regulation and the success of those attempts: RVLPFC, left ventrolateral PFC, and dorsomedial PFC. In one review of this literature (Berkman and Lieberman, 2009), the RVLPFC was found to be most frequently associated with emotion regulation processes.

Perspective-taking self-control

In some ways, the self-control involved in certain forms of perspective-taking is the most intriguing form of self-control to consider. It is intriguing because it is so different from the others forms of self-control and could easily be forgotten as a form of self-control. A good deal of perspective-taking does not involve self-control, but at least one relatively common form of perspective-taking does. Self-control is involved when you, the perspective-taker, have a competing perspective with the person you are trying to take the perspective of.

The data on this is still very sparse, with the main finding coming from a single study with a patient who has selective damage to the RVLPFC. This patient was tested on various forms of perspective-taking and its clear that his basic capacity for perspective-taking is intact. However, when the patient has his own immediate perspective on something that needs to be inhibited in order to appreciate someone else's perspective that differs from his own, he is at a loss. For instance, if he is told that two people are watching a soccer match and Ben is rooting for Team A whereas Dan is rooting for Team B, he has no problem at all identifying how each would feel after Team A scores a goal – as long as he has no stake in the outcome. If it turns out that Team A is the team that he himself roots for, he then mistakenly believes that both Ben and Dan will feel the same way he feels when Team A scores. So he can engage in perspective-taking, but only if it does not require setting aside his own perspective on things. Given that his damage is almost exclusively to the RVLPFC, this is important evidence that the RVLPFC is involved in this rather abstract form of self-control.

A recent fMRI study backs up the results of the patient study. In this new study, participants looked at images of needles or cotton swabs being applied to another person's hand. The needles look like they would hurt whereas the cotton swabs do not, however on some trials of the experiment, participants were told that the hand was anesthetized and thus the needle would not hurt, and on other trials participants were told that the cotton swabs contained a chemical that would be painful to the skin. So on most trials, one's own perspective is aligned with and would not compete with the target's – needles hurt and cotton swabs do not. However on some trials, the participants needed to inhibit their own immediate response to be able to empathize with those receiving the painful cotton swab and to not be so concerned over the needle going into the anesthetized hand. On these latter trials, there was increased RVLPFC activity. In other words, when participants needed to inhibit their own pre-reflective responses to appreciate another's perspective, they recruited the same brain region involved in all the other forms of self-control that we have considered.

The brain's braking system

The results across all of these domains of self-control clearly point to the RVLPFC as a hub involved in virtually every form of self-control, no matter how different the forms of self-control feel or how distinct the demands necessary to achieve self-control in each. Consequently, it is appropriate to refer to the RVLPFC as the *brain's braking system*. As I mentioned earlier, there are different brain regions involved in each type of self-control, however only the RVLPFC seems to be involved in every identified form of intentional self-control.

> *The results across all of these domains of self-control clearly point to the RVLPFC as a hub involved in virtually every form of self-control...*

If this account is correct, it suggests that each time we engage in self-control we are activating a system that might cause several kinds of self-control simultaneously. Turning on this system might put the brakes on any prepotent responses or cognitions that are currently active. Of course, this is not how self-control feels. When we try to inhibit one of our responses, it feels like we target just that response to be controlled and others are unaffected. Elliot Berkman, Lisa Burklund and I (2009) conducted a study to find out what was really happening.

In our study, participants performed a go-nogo task similar to the one's described earlier. On some trials, participants were trying to inhibit a motor response and on some trials they were not. Instead of using letters to cue go and nogo trials, we used faces; in any block of trials, one gender was the go cue and other gender was the nogo cue. Critically, the faces were emotionally expressive and thus likely to produce limbic activity (e.g. amygdala activity). At no time were participants trying to inhibit their emotional response to the pictures, and the emotionality of the pictures had nothing to do with the go-nogo task (i.e. paying attention to the emotions would not help a participant figure out if the trial was a go or nogo trial). Nevertheless, when participants saw a nogo cue that happened to include a negative emotional expression, their attempt at inhibiting their motor response produced an unintentional side effect – their amygdala response to the negative expression was also inhibited. Moreover the magnitude of the amygdala decrease was associated with the magnitude of the RVLPFC response during motor inhibition.

Thus, even though participants felt like they were only inhibiting a motor response, they unintentionally inhibited their emotional response as well. This finding makes perfect sense if the RVLPFC is seen as a common mechanism in the brain's braking system. Turning on the braking system for any reason is likely to have broad self-control effects beyond the particular response one is hoping to inhibit.

Putting feelings into words turns on the brakes

Using your words

If turning on the brain's braking system can have effects beyond those intended, then perhaps turning on the braking system completely by accident could set self-control processes in motion as well. Parents and teachers have long told children to 'use your words' because it is assumed to help calm the child down when they are overly emotional or overaroused. It turns out this is surprisingly good advice.

...putting feelings into words turns on the brain's braking system.

We conducted a study (Lieberman *et.al,* 2007) in which we showed emotional pictures to participants. Sometimes they were asked to choose an emotion word that described the target's emotion *(affect labeling)*, sometimes they chose a gender appropriate name *(gender labeling)* and sometimes they just looked at the picture *(observe)*. What we found is that a single region of the brain; the RVLPFC, was more active during affect labeling compared to gender labeling (see Figure 2). In other words, putting feelings into words turns on the brain's braking system. Indeed we also found evidence that affect labeling led to self-control effects. When people engaged in affect labeling, RVLPFC activity increased, but activity throughout the limbic system in general and in the amygdala in particular, diminished. Putting feelings into words diminished participants' emotional responses to emotional pictures, even though putting feelings into words involves attending to the emotional aspects of the pictures. This is a paradoxical result, but it makes sense once we understand the role of the RVLPFC in the brain's braking system and in putting feelings into words. In the absence of this neural connection such results sound a bit magical, but neuroscience allows us to the see the brain's trick behind the magic.

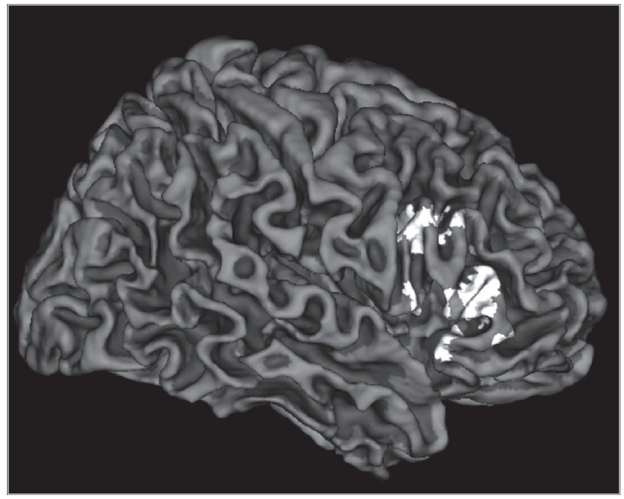

Figure 2: RVLPFC activity during affect labeling.

Unintentional emotion regulation

The affect labeling data suggests that putting feelings into words is a form of emotion regulation. The problem with this account is that affect labeling does not *feel* like emotion regulation. When you try to suppress your emotions you know you are doing it – it is quite conscious. Although people sometimes put their feelings into words in order to generate new insights and improve their emotional well-being, we often put our feelings into words without any expectation that mere affect labeling will have an emotional benefit. Indeed, in three studies now (Lieberman, Inagaki, Tabibnia, & Crockett, under review) we have found that people predict that looking at an emotionally evocative image will be more distressing if they are asked to label it. This has led us to conclude that affect labeling is a form of unintentional emotion regulation.

Learning to use your words

Can we learn to regulate our emotions better through 'using our words'? The evidence suggests that we already do as we go through the preschool years. As students improve in their ability and tendency to use emotional words to describe their feelings, they evidence fewer emotional outbursts and gain a range of benefits from classroom popularity to better academic performance (after statistically controlling for general language improvements).

What about us adults? Can we make meaningful strides in this area? There is only a little bit of data in this area, but the results are promising. We have been examining whether mindfulness meditative practice can increase the neurocognitive benefits of putting feelings into words. Mindfulness involves a non-judgmental awareness of what one is thinking, feeling and experiencing, which bares some strong resemblances to affect labeling. In our first study (Creswell, Way, Eisenberger, & Lieberman, 2007), we found that those who report being higher in dispositional mindfulness showed greater RVLPFC activity and less amygdala activity while affect labeling compared to those reporting being lower in dispositional mindfulness. We are following this up in a second study during which we are providing mindfulness training to individuals who are not experienced in this form of meditation, and thus far it appears that those getting the training are showing increased RVLPFC activity from pre- to post-training, whereas those not getting the training are not showing increases.

Conclusions

In this review, we have examined work that together suggests that the RVLPFC is a central part of the brain's braking system, supporting self-control in its various forms. Neuroscience makes an important contribution here because the different forms of self-control feel so different from one another that it would be easy to assume that the underlying processes supporting self-control in each case have little in common. We have also demonstrated evidence suggesting that putting feelings into words serves as an unexpected gateway into the brain's braking system, setting self-control processes in motion without the individual intentionally trying to engage in self-control.

...the RVLPFC is a central part of the brain's braking system, supporting self-control in its various forms.

Lastly, we have found some promising evidence that people can strengthen the impact of putting feelings into words through mindful meditative practice. Of course we may just be scratching the surface. The fact that mindfulness training may produce benefits in no way means that this is the only route or the best route towards improving the functioning of this process. Nevertheless, it's important to find out that this process is malleable, allowing for future investigations to examine other ways in which the brain's braking system can be made to work to our benefit.

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