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Resolving Conflict in Mind and Brain

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Derek Evan Nee received his B.A. in Cognitive Science and Computer Science from Dartmouth College and is currently a doctoral student in Psychology at the University of Michigan. His research focuses on executive processes and working memory through the use of behavioral and neuroimaging techniques. Recently, he has been studying mechanisms of conflict-resolution.

There is a common theme that threads its way through a number of phenomena. Consider just three examples.

- A one-year old child is shown an attractive toy in location A and then the toy is moved to location B in plain view of the child. The child, wanting the toy, reaches for it...but in location A, not B (Diamond, 1988).
- A patient with a lesion to the lateral part of frontal cortex is confronted with a task in which he has to produce as many words as possible beginning with the letter "S." He begins the task successfully, but then he keeps on repeating the same words over and over rather than producing new ones (Banich, 1997).
- Many depressed or dysphoric patients engage in rumination about negative self-referenced thoughts such that this rumination becomes a "habit of thought" (Hertel, 2004). Rumination is sufficiently powerful that it impairs the ability to engage in many tasks of daily life because of its consuming nature.

What these phenomena share in common is that they all represent cases in which conflict has to be resolved between a prepotent thought or response and one that is appropriate for the current occasion. In the case of the child, the conflict is between the recent salient location of the toy and its new location. In the case of the patient, it is between the high familiarity of recent responses and the need to search memory for new responses. In the case of depressed patients, it is between the recurring negative thoughts and the thoughts that they should focus on to engage in daily activities. Even brief consideration of these and other phenomena makes clear that they are ubiquitous. We are constantly faced with situations in which we have to resolve conflict in order to behave appropriately. What are the mechanisms that help us resolve conflict? Is there but one, or are there many? What regions of the brain are recruited in the service of conflict-resolution? We have devoted some energy to addressing these questions using various techniques all focusing on a small set of tasks that model conflict-resolution in well-controlled experimental environments. Of course, what we learn from these contrived tasks only begins to tell us about conflict-resolution mechanisms; what we learn must then be applied to the sorts of situations that normal individuals and brain-compromised individuals face. But we are making a start.

At first glance, it may seem quite unlikely that there is any single common mechanism that could underlie all cases of interference resolution. For example, we know that generally, the correlations among performance in various interference-resolution tasks are quite low (Kramer et al., 1994; Stoltzfus et al., 1993; Fan et al., 2003). Also, there is evidence from brain-imaging data that appear to suggest no coherence among interference-resolution mechanisms (Fan et al., 2003). We have conducted a meta-analysis of brain-imaging results from 41 published papers using various interference-resolution tasks, and the gross data are shown in Figure 1a (Nee, Jonides, and Wager, 2004). Each of the points in the figure represents a region of reliable activation from one or another study of the go/no-go task, the Stroop task, the flanker task, the stop-signal task, the Simon task, and tasks that require incompatible responses to stimuli. In each case, the activations

reported are from contrasts comparing an interference condition with a non-interference control. The most impressive feature of the figure is that the activations are spread throughout the brain with seemingly little systematicity.

Despite this seeming heterogeneity, is there any evidence that there are some common mechanisms involved in the resolution of conflict? A closer look indicates that there may be. On the behavioral front, Friedman and Miyake (2004) have shown that there is some orderliness among some interference-resolution tasks, with tasks involving inhibition of responses being related to tasks involving resistance to distractors, and both of these being distinct from resistance to proactive interference. On the brain-imaging front, the apparent chaos in Figure 1a is, in fact, orderly when one conducts a clustering analysis on the points in the figure. Such a clustering analysis reveals that the anterior cingulate cortex, dorsolateral prefrontal cortex, inferior frontal gyrus, insula, and posterior parietal cortex are common sites of activation in the six interference-resolution tasks that were analyzed. This is shown in Figure 1b in which the common sites are shown on superior and frontal views of a brain.

Beyond this, we have also explicitly compared brain activations that arise from three tasks that require interference-resolution: the flanker task, the go-no/go task, and the stimulus-response compatibility task (Sylvester et al., 2003). In a single experiment, a group of participants completed all of these tasks while they underwent scanning using functional MRI. In each case, we compared a version of the task that demanded a good deal of interference-resolution with one that required less. For the flanker task, this required comparing the effects of incongruent versus congruent flankers; for the go-no/go task it required examining trials in which a response had to be withheld after a series of trials in which a response was executed; for the stimulus-response task, it required comparing trials in which there was an incompatible mapping between stimuli and responses versus a compatible mapping. We then examined the brain activations to see whether there were regions of overlap among the tasks. Indeed, there were; and many overlapped with those found in the meta-analysis described above. Again, insula cortex, dorsolateral prefrontal cortex, and parietal cortex were featured prominently. In addition, there was common activation in anterior prefrontal and premotor cortices.

What these analyses reveal is that there are some common mechanisms among various tasks of interference resolution. This is not the complete story, however. It is important to note that there are also brain activations that are unique to one interference task or another. What might cause these differences? One possibility is that interference-resolution mechanisms are tailored to the stage of processing at which they apply. We have entertained the hypothesis that there may be identifiably different processes of interference resolution that operate at the time of encoding material versus storing material in working memory versus responding. Hasher and Zacks (1988; see also Hasher, Zacks and May, 1999) proposed this hypothesis some years ago, but evidence about it has previously come from very different tasks in different contexts.

We have taken a different approach to this issue. Our strategy is to study processes of interference-resolution in a single task to see if they are dissociable. In one such study, we have found a dissociation between resolution processes that operate on responses versus those that operate on working memory processes (Nelson et al., 2003). Participants were given a set of four target letters to hold in memory followed after a 3-second retention interval by a probe letter. The probe either matched one of the letters of the target-set or it did not. The interesting feature of the experiment concerned those trials on which there was not a match. On some of these trials, the mismatching letter had not appeared recently in the experiment. On others, although it did not match the current target-set, it did match one of the letters of the previous target-set. On these trials, then, the probe had a high familiarity because of its recent appearance, and this was intended to produce conflict among representations in working memory. That is, there was conflict between the high activation of an item based on its recent presentation and the demand to recognize that this item was not present in the current target-set. On yet other trials, not only did the probe letter match one of the letters of the previous target-set, the letter that it matched had in fact been the probe for the previous target-set as well, so that it had resulted in a positive response. So, these trials had not only the high familiarity due to the recent appearance of a probe, they also had a competition for responses as well: On the previous trial, participants had properly responded positively to this item while on the current trial, they had to respond negatively. The comparison among these two types of negative trials on which there was competition, one due to high familiarity and one due to response disagreement, revealed two different patterns of brain activation. The conflict due to familiarity led to activation in inferior frontal gyrus in the left hemisphere, a result that we have found previously in a task of this sort (Jonides et al., 1998). The conflict due to response competition led to activation in the anterior cingulate cortex, a result that has been found by others for tasks in which there is response conflict (Botvinick et al., 2001). These two regions of activation were doubly dissociated leading to the conclusion that response competition and competition in working memory are mediated at least in part by different processes.

More recently, we have been examining potential differences between mechanisms involved in suppressing irrelevant information during encoding versus when it is already in working memory and must be removed. The experiment also used an item-recognition task and participants had to either ignore stimuli presented for encoding or they had to remove encoded stimuli from working memory. We have found evidence suggesting two separable processes (Nee and Jonides, 2004). One keeps information from entering working memory if that information is irrelevant to the current task. The other is responsible for getting information that has entered working memory out when that information is no longer relevant to the task. Although previous research has suggested two such processes (Hasher et al., 1999), demonstrating them in the context of a single task is an important step to documenting their separability.

Study of model experimental paradigms of this sort has revealed that there are separable mechanisms involved in suppressing prepotent responses or memories, but that these mechanisms share some common properties as well. The heavy lifting that is now required will involve specifying what the processing characteristics are of each mechanism and how these are implemented in the brain.

References

- Banich, M.T. (1997). Breakdown of executive function and goal-directed behavior. In M.T. Banich (Eds.), *Neuropsychology: The neural bases of mental function* (pp. 369-390). Boston, MA: Houghton Mifflin Company.
- Botvinick, M.M., Braver, T.S., Barch, D.M., Carter, C.S., and Cohen, J.D. (2001). Conflict monitoring and cognitive control. *Psychological Review*, 108:3, 624-652.
- Diamond, A. (1988). Abilities and neural mechanisms underlying A not-B performance. *Child Development*, 59, 523-527.
- Hasher, L., Zacks, R.T., and May, C.P. (1999). Inhibitory control, circadian arousal, and age. In D. Gopher and A. Koriat (Eds.), *Attention and Performance* (pp. 653-675). Cambridge, MA: MIT Press.
- Hertel, P.T. (2004). Memory for emotional and nonemotional events in depression: A question of habit? In D. Reisberg and P. Hertel (Eds.), *Memory and Emotion* (pp. 186-216). New York: Oxford University Press.
- Kramer, A.F., Humphrey, D.G., Larish, J.F., Logan, G.D., and Strayer, D.L. (1994). Aging and inhibition: Beyond a unitary view of inhibitory processing in attention. *Psychology and Aging*, 9, 491-512.
- Friedman, N.P., and Miyake, A. (2004). The relations among inhibition and interference control functions: A latent variable analysis. *Journal of Experimental Psychology: General*, 133, 101-135.
- Jonides, J., Smith, E.E., Marshuetz, C., and Koeppe, R.A. (1998). Inhibition in verbal working memory revealed by brain activation. *Proceedings of the National Academy of Sciences* 95, 8410-8413.
- Nee, D.E., Jonides, J., and Wager, T. D. (2004). A meta-analysis of interference-resolution tasks. 2004 Meeting of Cognitive Neuroscience Society.
- Nee, D.E., and Jonides, J. (2004). Dissociating information-suppression during encoding versus working memory. Paper to be presented at the Meeting of the Psychonomic Society.
- Nelson, J.K., Reuter-Lorenz, P.A., Sylvester, C-Y. C., Jonides, J., and Smith, E.E. (2003). Dissociable neural mechanisms underlying response-based and familiarity-based conflict in working memory. *Proceedings of the National Academy of Sciences*, 100, 11171-11175.
- Stoltzfus, E.R., Hasher, L., Zacks, R.T., Ulivi, M., and Goldstein, D. (1993). Investigations of inhibition and interference in younger and older adults. *Journal of Gerontology*, 48, 179-188.
- Sylvester, C.C., Wager, T.D., Jonides, J., Lacey, S.C., Cheshin, A., and Nichols, T.E. (2003). Processes of interference resolution as revealed by functional magnetic resonance imaging. 2003 Meeting of Cognitive Neuroscience Society.
- Wager, T.D., Phan, K.L., Liberzon, I., and Taylor, S.F. (2003). Valence, gender, and lateralization of functional brain anatomy in emotion: a meta-analysis of findings from neuroimaging. *Neuroimage*, 19, 513-531.

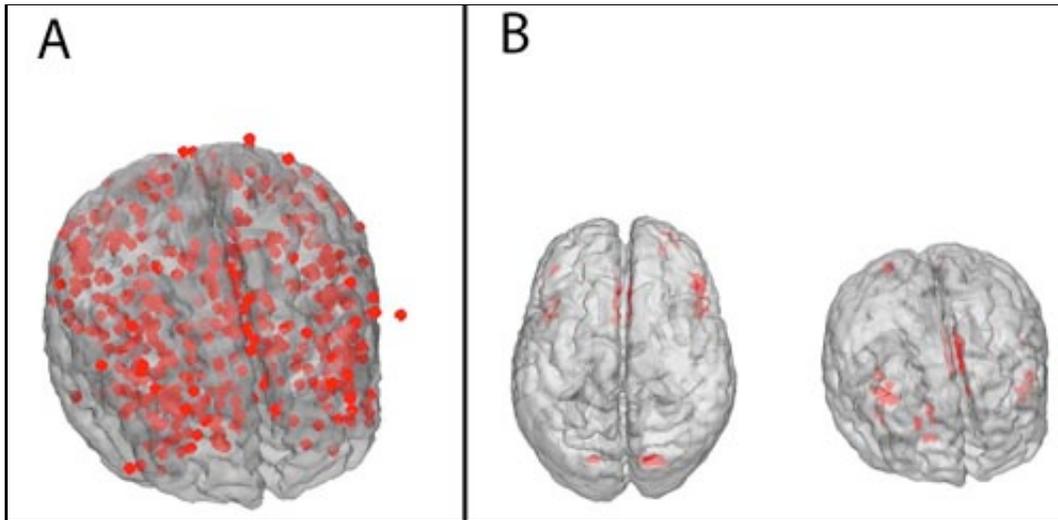


Figure 1.

A) A plot of all peaks from 41 neuroimaging studies of interference-resolution tasks. The peaks show seemingly little systematicity. B) The results of a density analysis (Wager et al., 2003) on the peaks shown in A, which reveal clusters of activity in posterior parietal, medial frontal, dorsal lateral prefrontal, and inferior frontal regions.

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