Brain Imaging Investigation of the Impairing Effect of Emotion on Cognition

Gloria Wong[1,2], Sanda Dolcos[1,3], Ekaterina Denkova[1], Rajendra A. Morey[4,5], Lihong Wang[4,5], Nicholas Coupland[1], Gregory McCarthy[6] & Florin Dolcos[1,2]

[1]Department of Psychiatry, [2]Centre for Neuroscience, [3]Department of Psychology, University of Alberta, Edmonton (AB), Canada

[4]Brain Imaging and Analysis Center, Duke University, Durham (NC), USA

[5]Department of Psychiatry and Behavioral Sciences, Duke University, Durham, NC 27710 USA

[6]Department of Psychology, Yale University, New Haven, CT 06520 USA

Running Title: *Brain Imaging & Emotional Distraction*

Short abstract: We present a protocol that allows investigation of the neural mechanisms mediating the detrimental impact of emotion on cognition, using functional magnetic resonance imaging. This protocol can be used with both healthy and clinical participants.

Keywords: *Emotion-Cognition Interaction, Cognitive/Emotional Interference, Task-Irrelevant Distraction, Neuroimaging.*

# of Figures & Movies: 2 + 2

Corresponding Author:

Florin Dolcos, PhD
Department of Psychiatry
University of Alberta
1E1.01 Mackenzie Centre
Edmonton, Alberta
Canada, T6G 2R7

Email: fdolcos@ualberta.ca
Phone: 780 492-8657
Fax: 780 492-3260

Acknowledgements: FD was supported by a Young Investigator Award from the US National Alliance for Research on Schizophrenia and Depression and a CPRF Award from the Canadian Psychiatric Research Foundation.

Long Abstract / Introduction

Emotions can impact cognition by exerting both *enhancing* (e.g., better memory for emotional events) and *impairing* (e.g., increased emotional distractibility) effects. Complementing our recent JoVE protocol describing a method that allows investigation of the neural correlates of the memory-enhancing effect of emotion (see also reviews by [1, 2, 3]), here we present a protocol that allows investigation of the neural correlates of the detrimental impact of emotion on cognition. The main feature of this method is that it allows identification of reciprocal modulations between activity in a *ventral neural system*, involved in 'hot' emotion processing, and a *dorsal system*, involved in higher-level 'cold' cognitive/executive processing, which are linked to cognitive performance and to individual variations in behaviour [4]. Since it's initial introduction [4], this design has proven particularly versatile and influential in the elucidation of various aspects concerning the neural correlates of the detrimental impact of emotional distraction on cognition, with a focus on working memory (WM) performance, and of coping with such distraction [5,4], in both healthy [6, 7, 8, 9] and clinical participants [10].

I. Task Design, Stimuli, and Experimental Protocol

1. The basic task of this protocol is a delayed-response WM task, where novel task-irrelevant emotional and neutral distracters are presented during the delay interval between the memoranda and probes (see Figure 1 for diagram illustrating the task); event-related fMRI data are recorded while participants perform this task. Scrambled versions of the actual distracters can also be used as perceptual controls, which have identical basic properties (e.g., spatial frequency and luminance).

   [Figure 1 about here]

   Figure 1. General Diagram of the Delayed-Response Working Memory Task with Distraction. (from [4] with permission). Three faces are used in the memoranda in order to strongly engage the dorsal executive system**,** and pairs of novel distracters are used in order to increase the impact of emotional distraction on WM performance and brain activity. The impact of emotional distracters can also be increased by presenting the pictures in color (not shown). Participants are instructed to maintain their focus on the WM task while still processing the distracters, and to make quick and accurate responses to the probes by pressing a response button (1 = Old, 2 = New). For stimulus presentation, we used CIGAL (http://www.nitrc.org/projects/cigal/). All stimuli are presented in colors.
2. It is advised that the sex of the faces in the memoranda has balanced proportions of males (50%) and females (50%). Similar balanced proportion is also advised for the *Old* (50%) and *New* (50%) probes. The difficulty of the WM task can be varied by changing these proportions and/or by varying other factors - e.g., the similarity of the facial features among faces from same memorandum and their similarity with the probes, and by manipulating the presence/absence of extrafacial features in the memoranda (compare memoranda from Figure 1 and movie # 1).

3. Variation of the distracters type also contributes to the versatility of this design, by adapting it according to the goals of investigations and the targeted populations. Emotional and neutral distracters in the original design [4] were selected from the International Affective Picture System [11], but similar effects can be obtained with other novel stimuli that are effective as distracters (), and/or with manipulations that increase the sensitivity of the WM task in detecting behavioral differences (e.g., by also assessing the participants' confidence in their responses) (see movie # 1 and [9]).
4. In a recent study in post-war veterans with or without post-traumatic stress disorder (PTSD), the emotional IAPS pictures inducing general negative emotions were replaced with combat-related pictures. These pictures were expected to induce emotions that are more specifically linked to combat-related traumas and thus be more effective distracters in this cohort, particularly in the PTSD group.
5. Moreover, stimuli that induce specific emotions (e.g., anxiety) may also be used as distracters in healthy participants. For instance, faces displaying fearful expressions could induce social anxiety, and thus be effective in investigating the impact of transient anxiety-inducing distraction on WM (see movie #2).
6. Finally, in conjunction with other measures (e.g., behavioral- and personality-related) this paradigm can also be used to investigate relationships between brain activity and individual differences in various aspects that affect cognitive performance in this task [6, 8, 9].

II. Preparing the Subject for the Scan

All participants provide written informed consent prior to running the experimental protocol, which is approved by an Ethics Board.

Prior to Entering the Scanning Room

1. On the day of scanning, participant's current state of mind is assessed, to control for the effect of mood on the WM task with distraction. In conjunction with post-scanning assessments, these initial evaluations can be also used to screen for changes in mood as a result of participating in the study.
2. Prior to the scan, the participant is informed in detail of the scan procedures, and is given specific instructions for the behavioral task. The participant also completes a short practice session to familiarize with the task.

Entering the Scanning Room

3. The participant lies supine on the scanning bed, with additional cushioning for the head, to ensure comfort during the scan and minimize movement. To further minimize head movement, the non-adhesive side of a length of tape may be wrapped lightly around the subject's forehead. Subjects are

given ear protection as well as isolation headphones to communicate with the experimenter during the MRI scan.

4. The subject's right hand is positioned comfortably on the response box. Before starting data collection, it is critical to make sure that the response buttons work properly and that the subject can see the screen projection clearly for stimulus presentation. An emergency stop button is also placed nearby, so that the subject may indicate any urgent need to stop the scanner.

Following the Scanning Session

5. Additional tasks may be used for further behavioural assessments - e.g., to determine participants' sensitivity to the distracters, by rating the emotional intensity of distracters and/or the subjectively perceived distractibility of the distracters. Individual differences in those ratings can be used to investigate their influence on the neural mechanisms mediating the detrimental effect of emotion on cognition [4, 6].
6. Assessments of personality traits (e.g., trait anxiety, emotional reactivity) can also be made after the MRI scanning, if not performed prior to scanning.

III. Data Recording and Processing

Scanning Parameters

In the original study [4], we collected MRI data using a 4 Tesla General Electric scanner for MRI recordings, but for the more recent versions of the task we were also successful in collecting MRI data with a 1.5 T scanner [9]. In the 4T scanner, series of 30 functional slices (voxel size = 4x4x4 mm) were acquired axially using an inverse-spiral pulse sequence (TR = 2000 ms; TE = 31 ms; field of view = 256x256mm), thus allowing for full-brain coverage. High-resolution three-dimensional spin-echo structural images were acquired for each functional slice in axial orientation (in-plane resolution = 1 mm^2; anatomical-functional ratio = 4:1).

Data Analysis

We use Statistical Parametric Mapping (SPM: http://www.fil.ion.ucl.ac.uk/spm/) in combination with in-house Matlab-based tools. Pre-processing involves typical steps: quality assurance, TR alignment, motion correction, co-registration, normalization, and smoothing (8 mm^3 Kernel). Individual and group-level statistical analyses involve comparisons of brain activity according to distracter type (emotional vs. neutral, distraction). Moreover, correlations of brain imaging data with subjective or objective measures of distractibility (e.g., emotional and distractibility ratings and working memory performance) and/or scores indexing personality measures (e.g., trait anxiety) can also be performed, to investigate how brain activity co-varies with individual differences in those measures. Analyses in all of our studies using this protocol have typically focused on activity observed during the delay interval, when the distracters are presented, but activity time-locked to other events (e.g., probes) can also be investigated.

IV. Results

[Figure 2 about here]

Figure 2. Opposite pattern of activity in the ventral vs. dorsal brain system in the presence of emotional distraction (from [4] with permission). Emotional distracters produced enhanced activity in ventral affective brain regions (red blobs), such as the ventrolateral prefrontal cortex (vlPFC) and amygdala (not shown), while producing decreased activity in dorsal executive brain regions (blue blobs), such as dorsolateral prefrontal cortex (dlPFC) and lateral parietal cortex (LPC). This dorso-ventral dissociation was linked to impaired WM performance in the presence of emotional distraction [4], has been systematically replicated [6, 10, 7, 8, 9], and was shown to be specific to emotional distraction [6,12]; see also movie # 2. The central image shows activation maps of the direct contrast between the most vs. the least distracting conditions (i.e., emotional vs. scrambled), superimposed on a high-resolution brain image displayed in a lateral view of the right hemisphere. The color horizontal bars at the bottom of the brain image indicate the gradient of *t* values of the activation maps. The line graphs show the time course of activity in representative dorsal and ventral brain regions (indicated by color-coded arrows). The grey rectangular boxes above the x-axes indicate the onset and duration of the memoranda, distracters, and probes, respectively. FFG = Fusiform gyrus.

V. Discussion

This experimental design provided initial brain imaging evidence that the detrimental effect of emotional distraction on the ongoing cognitive processes entails reciprocal modulations between the *ventral affective* and *dorsal executive* neural systems. Given its versatility, this protocol and its variant can be used in the investigation of the neural correlates of responding and coping with emotional distraction in both healthy and clinical groups. In the latter cohort, it allows identification of the mechanisms underlying the exacerbated impact of emotional distraction observed in anxiety disorders, which are associated with increased emotional distractibility (e.g., PTSD, social phobia). The success of this protocol relies on the possibility to simultaneously explore activity in emotion- and cognition-related brain regions and of their interactions, as well as on its adaptability to select the specificity of emotional distraction according to the goals of investigations.

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