Brain and Cognition 77 (2011) 265–270

Contents lists available at SciVerse ScienceDirect

Brain and Cognition

journal homepage: www.elsevier.com/locate/b&c

Increased spreading activation in depression

Paul S. Foster [a,b,*], Raegan C. Yung [a], Kaylei K. Branch [a], Kristi Stringer [c], Brad J. Ferguson [d], William Sullivan [a], Valeria Drago [b,e]

[a] Middle Tennessee State University, Murfreesboro, TN, United States
[b] University of Florida, Gainesville, FL, United States
[c] University of Alabama at Birmingham, Birmingham, AL, United States
[d] University of Missouri, Columbia, MO, United States
[e] Laboratorio LENITEM, IRCCS San Giovanni di Dio Fatebenefratelli, Brescia, Italy

ARTICLE INFO

Article history:
Accepted 1 August 2011
Available online 1 September 2011

Keywords:
Spreading activation
COWAT
Animal Naming
Word frequency
Depression

ABSTRACT

The dopaminergic system is implicated in depressive disorders and research has also shown that dopamine constricts lexical/semantic networks by reducing spreading activation. Hence, depression, which is linked to reductions of dopamine, may be associated with increased spreading activation. However, research has generally found no effects of depression on spreading activation, using semantic priming paradigms. We used a different paradigm to investigate the relationship between depression and spreading activation, one based on word frequencies. Our sample included 97 undergraduates who completed the BDI-II and the Controlled Oral Word Association test as well as the Animal Naming test. The results indicated that the group scoring within the depressed ranged evidenced greater spreading activation as compared to those who scored within the normal range on the BDI-II. The implications of these results as they relate to creativity in depression is discussed.

1. Introduction

Collins and Loftus (1975) proposed a theory of spreading activation in which semantic memory nodes (e.g. cats) are organized into large networks consisting of concepts (e.g. animals). The nodes within the conceptual networks are highly interconnected through associative, bidirectional links such that activation of a node within a network is purported to spread along the associative links to related nodes or concepts. Further, the semantic nodes within a network (e.g. cats and dogs) are more strongly interconnected than semantic nodes from different conceptual networks (e.g. cats and screwdrivers). The strength of the connections between the semantic nodes within a conceptual network also varies, with some connections being stronger (e.g. cats and dogs) and other being weaker (e.g. cats and beavers). The strength of the connections between nodes is determined by production frequency norms, or the frequency of the use of the associations between nodes, which then determines the speed of the spreading activation. Hence, activation will spread more quickly through associated nodes that have been accessed more frequently, as compared to nodes that have been accessed or activated less frequently. The strength of connectivity is also likely related to the Hebbian principal that neurons (or the neuronal assemblies that comprise the semantic nodes) that fire together wire together. The extent or spread of activation is dependent on the strength of the initial activation of the node such that greater initial activation will result in greater spread of activation from that node. Activation of conceptual networks, however, decreases over time or with some intervening activity.

Dopamine may represent the source by which these networks are activated or deactivated. Specifically, through the role of dopamine as both a neurotransmitter and neuromodulator (Cepeda & Levine, 1998), dopamine may have a prominent role in the modulation of activation of the semantic and conceptual networks. The dopaminergic system originates in the cells of the substantia nigra and the ventral tegmental area, which then send projections to the striatum, limbic system, and the frontal lobes (Afifi & Bergman, 1998). Hence, through these projections to the basal ganglia and cortex, dopamine may play an important role in modulating activation of the areas within the frontal lobes that control activation of semantic and lexical networks. The specific action may be through modulation of 'the signal to noise ratio'. Specifically, Servan-Schreiber, Printz, and Cohen (1990) presented a model of the effects of catecholamines in a neural network such that catecholamines have the effect of improving the signal detection performance of the network, by dampening weak signals while simultaneously amplifying stronger signals.

* Corresponding author. Address: Middle Tennessee State University, Psychology Department, 1500 Greenland Drive, Murfreesboro, TN 37132, United States. Fax: +1 615 898 5027.
E-mail address: pfoster@mtsu.edu (P.S. Foster).

0278-2626/$ - see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.bandc.2011.08.001

The role of dopamine as a neuromodulator in spreading activation has received support in numerous investigations. Kischka et al. (1996), by integrated the spreading activation theory of Collins and Loftus (1975) with the model of Servan-Schreiber et al. (1990), proposed that whereas a high signal-to-noise ratio would result in decreased spreading activation, a low signal-to-noise ratio would result in increased spreading activation. The results indicated that dopamine significantly reduced the indirect semantic priming effect but only marginally affected direct semantic priming. These results were interpreted as supporting the hypothesis that dopamine increases signal-to-noise ratio in semantic networks by reducing spreading semantic activation. Other investigations have supported these findings using similar paradigms (Angwin et al., 2004; Roesch-Ely et al., 2006). Additionally, patients with Parkinson's disease (PD) have been found to possess increased spreading activation (Angwin, Coplan, Chenery, Murdoch, & Silburn, 2006), which is expected since PD is associated with a depletion of dopamine (Braak & Braak, 2000; Mink, 1996).

Research on spreading activation has typically used a lexical decision task, or semantic priming paradigm, to examine how activation spreads through semantic and/or lexical networks. We have proposed and used a different paradigm based on the average word frequencies from the words generated on the Controlled Oral Word Association Test (COWAT). The COWAT is a measure of verbal fluency that requires the individual to generate as many words as possible, within 60 s, that begin with a specified letter (usually F, then A, then S). Research using lexical decision tasks has indicated that the reaction time for identifying high frequency words is significantly faster than for low frequency words (Allen, McNeal, & Kvak, 1992; Allen, Smith, Lien, Weber, & Madden, 1997; Allen, Wallace, & Weber, 1995). Hence, given the longer reaction time for low frequency words, it may be deduced that the adequate activation of the nodes that represent lower frequency words require greater spreading activation. Essentially, greater spreading activation is required to activate words that have lower frequencies, i.e. are further out in the semantic/lexical network. We conducted an investigation using this new paradigm to investigate spreading activation in patients with Parkinson's disease (PD). Since PD is associated with reduced levels of dopamine, our hypothesis was that PD would be associated with increased spreading activation. The findings indicated that PD patients exhibited a significantly lower average word frequency than the controls, indicating greater spreading activation in the PD patients (Foster et al., 2008).

Research has also associated the dopaminergic system with depression (Dailly, Chenu, Renard, & Bourin, 2004; Malhi, Parker, & Greenwood, 2005). Lower concentrations of metabolites of dopamine, such as homovanillic acid, have been found in the cerebrospinal fluid of depressed patients (Roy, de Jong, & Linnoila, 1989). As mentioned previously, the dopaminergic system projects to the frontal lobes and there also are greater concentrations of dopamine in the left hemisphere relative to the right hemisphere (De la Fuente-Fernandez, Kishore, Calne, Ruth, & Stoessl, 2000; Glick, Ross, & Hough, 1982). Repetitive transcranial magnetic stimulation (rTMS) is an effective treatment for depression (Martin et al., 2003) and research has indicated that rTMS applied over the left dorsolateral prefrontal region releases endogenous dopamine in patients with major depression (Pogarell et al., 2006). The left frontal lobe may also be involved in spreading activation. Specifically, relative to high frequency words, low frequency words generate significantly greater activation at the left frontal lobe (Carreiras, Mechelli, & Price, 2006; Halgren et al., 2002; Joubert et al., 2004).

Taken together, the aforementioned research suggests that depression may be associated with enhanced spreading activation. However, research has indicated that depressed patients do not differ from normal, healthy controls in spreading activation. Specifically, no differences between depressed patients and controls have been reported in research using a lexical decision task (Besche-Richard, Passerieux, & Hardy-Bayle, 2002; Georgieff, Dominey, Michel, Marie-cardine, & Dalery, 1998). Further, Dannlowski et al. (2006) used a word pronunciation task to measure spreading activation and also found no differences between depressed patients and normal controls. Given this discrepancy between the purported effects of dopamine on spreading activation in depressed individuals and the findings of the relevant research, we sought to investigate whether this relationship existed using our different paradigm for measuring spreading activation. Our hypothesis was that depressed individuals would be associated with significantly lower average word frequencies on the COWAT and the Animal Naming tests, i.e. greater spreading activation. Additionally, we sought to determine whether a relationship exists between the initial activation and the extent of the subsequent spreading activation.

2. Methods

2.1. Participants

The participants included 97 (31 men and 66 women) undergraduate students from Middle Tennessee State University with an age range of 18–37 years ($M = 20.90$; $SD = 3.52$). To be considered for inclusion the participants had to exhibit a preference for the right hemibody as indicated by their score on the Coren Porac and Duncan Laterality Questionnaire (CPD). Specifically, the participants had to obtain a positive score on the CPD, although a total of six of the participants indicated a preference for using the left hand even though their total CPD score was positive. The participants had no history of significant head injury, psychological illness, or neurological diseases. All participants were treated in accordance with the ethical principles of the American Psychological Association and provided written informed consent.

2.2. Apparatus

2.2.1. Animal Naming (AN)

The AN test requires the individuals to name as many different animals as possible within 60 s. The dependent variable consisted of the average word frequency for all animals named.

2.2.2. Beck depression inventory – II (BDI-II)

The BDI-II (Beck, Steer, & Brown, 1996) is a 21 item self-report questionnaire used for measuring the severity of depression. The items of the BDI-II address problems related to numerous psychological, cognitive, and physiological symptoms. Each item is rated by the patient on a scale of 0–3, with a range of possible scores from 0 to 63.

2.2.3. Coren Porac and Duncan Laterality Questionnaire (CPD)

The CPD (Coren, Porac, & Duncan, 1979) is a self-report questionnaire consisting of 13 questions assessing lateral preference for the hand, foot, eye, and ear. Responses are scored as +1 for "right", −1 for "left", and 0 for "both". Thus, the range of scores possible on the CPD are from −13 to +13.

2.2.4. Controlled Oral Word Association Test (COWAT)

The COWAT is a measure of lexical fluency to confrontation requiring the individual to name as many words as possible within 60 s that begin with a specified letter (F, A, and S were used in this investigation). The participants were restricted from using proper nouns, numbers, and stem words with different endings. The primary dependent variable consisted of the average word frequency for the words generated on all three target letters.