

# **A Cognitive Neuroscience Approach to the Study of Attentional Deficits in Schizophrenia**

LUIS J. FUENTES, PHD

Dr Luis J. Fuentes is professor of Cognitive Neuropsychology in the Department of Experimental Psychology and Psychobiology at the University of Almería, Almería, Spain.

**Recent research has used a cognitive neuroscience approach to the study of the cognitive deficits in general, and the attention dysfunction in particular, that have been associated with schizophrenia. A main characteristic of this approach is that integrates convergence evidence coming from at least three sources: cognitive psychology, cognitive neuropsychology, and neuroimaging techniques.**

In the last decades cognitive psychologists have proposed some theoretical models of how cognitive functions work. These models contemplate cognitive abilities as a set of elementary operations that perform an orchestrated job to maximize subjects' performance. Each one of these elementary operations have been thought to be involved in a specific cognitive function. From the neurocognitive approach, it is assumed that these operations are strictly localized in the brain.

An optimal strategy to determine the neural circuitry involved in cognitive functions would involve two aspects. On one hand, the design of appropriate cognitive tasks, or model tasks, that subjects are asked to perform in a controlled environment. On the other hand, the use of patients with brain lesions and/or the simultaneous record of brain activity while they perform such cognitive tasks. The former will allow us to disentangle complex cognitive processes into elementary operations. The latter will allow us to determine the neural substrate that underlies to each operation.

## **The cognitive neuroscience of selective attention**

The aim of this article is to show how the use of such a strategy, as that described above, can help understand one of the main cognitive deficits researches have associated with schizophrenia: *selective attention*. However, first of all we need to define very clearly what we understand by selective attention.

The concept of attention has evolved since Williams James conceived of it as central to understand how individuals select relevant information to form part of our knowledge about the world around us. The development of modern neuroimaging techniques as well as the study of neurological and psychiatric patients have led authors to conceive of attention as a set of neural networks that perform very specific computations (for a review, see Posner & Raichle, 1994). So far, authors have proposed the existence of at least two attentional networks involved in the control of cognitive functioning: the *orienting network*, and the *executive network*.

The orienting network is involved in shifting attention from one location to another in searching for relevant information. Michael Posner designed a model task that shows in a simple way how these shifts of attention might occur (see Figure 1). In this task, a peripheral cue signals the most likely location of a target. Subjects will detect the target appearing in that cued location more rapidly than if the target is presented in a non-cued location. This advantage in responding to targets at cue compared with uncued locations has been termed the *validity effect*. For subjects to perform this cuing task, three simple operations are necessary: *disengage* attention from its current focus, *move*

attention to the location of the cue, and *engage* attention to the target appearing in that location. Patients' studies have revealed that the posterior parietal lobe, the superior colliculus, and the pulvinar nucleus of the thalamus are involved in these operations, respectively.

Visual orientation of attention not always produces benefits in subjects' detection responses. If attention is drawn to a location by the cue and then withdrawn by either using a second central cue or a long cue-target interval, detection responses are often slowed for targets presented at the original cued location. This is thought to reflect a bias in the attentional network to not return attention to previously attended locations. The disadvantage in responding to targets presented at cued locations compared with uncued locations has been termed *inhibition of return*. This spatial inhibition seems to involve some areas of the midbrain (e.g., the superior colliculus), on the basis of findings that patients with lesions in that part of the brain do not exhibit inhibition of return.

The executive attention network is associated with the selection of objects on the basis of high-level characteristics such as their meaning. The brain areas involved are the dorsolateral prefrontal cortex, midline frontal areas including the anterior cingulate cortex and the supplementary motor area, and some portions of the basal ganglia that supply dopamine to the frontal lobes. Positron emission tomography studies have found activation of the anterior cingulate during tasks that require attention-dependent semantic processing.

The involvement of executive attention in semantic processing is of special relevance here because some patients diagnosed with schizophrenia seem to have difficulties to maintain a coherent discourse when they speak. To study the involvement of executive attention in language processing, psychologists frequently use a lexical decision task. In this task, subjects are told to respond to the lexical nature of targets. In half of the trials the target is a word, and a non-word in the other half. When it is a word, the target can be preceded by either a related word (related condition), or an unrelated word (the unrelated condition) which is usually called the *prime* (see Figure 2). The classical results show facilitation in subjects' responses when prime and target are related compared with when they are not related. This effect has been termed *semantic priming*. By manipulating some characteristics of the model task such as the simultaneous performance of an auditory task, or the presence or absence of an intervening stimulus between the prime and the target, Fuentes and his colleagues have demonstrated the usefulness of this task to measure attention-dependent facilitatory as well as inhibitory semantic processing (Fuentes, Carmona, Agis, & Catena, 1994; Fuentes, Vivas, & Humphreys, 1999).

## **Attention deficits in Schizophrenia**

In this review I present recent data we have collected concerning the attentional deficits associated with schizophrenia within the framework of anatomically related attention networks. In our studies, we used a cuing task that is thought to tap the orienting network, and a semantic priming task that is thought to tap the executive network.

Fuentes, Boucart, Alvarez, Vivas, and Zimmerman (1999) explored facilitation and inhibition processing in a cuing task similar to that presented in Figure 1. Schizophrenic patients and a group of healthy adults were told to detect the presence of a target stimulus that could appear at the cued or at the uncued location. We varied the interval between the cue and the target at two levels: 200 ms and 1200 ms. With the long interval there were two conditions. In one condition we presented only the peripheral cue (single-cue condition). In the other condition, we included a second central cue between the peripheral cue and the target (double-cue condition). The comparison between the single- and double-cue conditions is important because in the former it is the subject who endogenously re-orient attention to the central box before the target is presented, whereas in the latter, attention is

re-oriented to the center automatically by the central cue. Schizophrenic patients showed validity effects in the short interval, and inhibition of return effects in both cue conditions similar to those exhibited by healthy adults. Thus, we concluded that both facilitatory and inhibitory processing associated with the orienting network is preserved in schizophrenia.

In other study, Fuentes and Santiago (1999) used a semantic priming procedure similar to that of Figure 2. Schizophrenic patients and healthy adults were presented with a prime word in the center of the screen. The target (a word or non-word), appearing either to the left or the right, followed the prime. When it was a word, it could be related or unrelated to the prime. This procedure produces facilitatory semantic priming, which seems to be preserved in schizophrenia, however, if a intervening word that belongs to a different category is presented between the prime and the target, the facilitatory semantic priming becomes inhibitory; that is, now related targets produce slower responses than unrelated targets. The intervening word could result in attention being withdrawn from the category of the prime, so that when a related target is presented, attention returns to the previous category that might already be inhibited, producing a sort of semantic inhibition of return effect that we called *semantic inhibition*.

The results showed that whereas the healthy adult group showed semantic inhibition when targets were presented either to the left or right visual field, the schizophrenic patients showed semantic inhibition when presented to the left visual field (involving the right hemisphere), but semantic facilitation when presented to the right visual field (involving the left hemisphere).

These results suggest that the schizophrenic patients showed a lateralized deficit in the semantic inhibition effect associated with the anterior attention network. In addition, the positive semantic effect observed when the left hemisphere was involved suggests that schizophrenic patients activated prime word representations in the memory system.

## **Conclusion**

To conclude, inhibitory processing associated with the midline areas of the brain (e.g., the cingulate cortex) appears to be affected in schizophrenia. This left hemisphere dysfunction associated with attentional executive control, seems to last in time because the schizophrenic patients that participated in the Fuentes and Santiago's study had relatively long periods of illness (ranging from 4 to 23 years), and were medicated as soon as they were registered and diagnosed in the hospital.

This executive attention deficit observed with our semantic inhibition procedure, relates to other deficits found in previous research using executive tasks. For instance, schizophrenic patients perform poorly in the Wisconsin Card Sorting Test, a test that requires intact frontal lobe functioning; and showed abnormal activation of remote associated during indirect semantic priming, an effect that is modulated by dopamine, which is supplied to the cingulate cortex by some portions of the basal ganglia.

The failure in executive control operating in the semantic network might account for some characteristic symptoms underlying schizophrenia. Auditory hallucinations might arise because the semantic areas are hyperactive due to poor control from the anterior attention network and dopamine dysregulation. Thought disorders might be caused by impairments in inhibiting distracting information.

Thus, by looking at the pattern of results when patients perform cognitive tasks, we expect to better understand the cognitive impairments of schizophrenia. Our studies showed preserved cognitive operations that depend on the orienting network, but dysfunction of the executive network that takes place in the left hemisphere.

## IN THE LITERATURE

Fuentes LJ, Boucart M, Alvarez R, Vivas AB, Zimmerman MA. Inhibitory processing in visuospatial attention in healthy adults and schizophrenic patients. *Schizophrenia Research*. 1999; 40: 75-80.

Fuentes LJ, Carmona E, Agis I, Catena A. The role of the anterior attention system in semantic processing of both foveal and parafoveal words. *Journal of Cognitive Neuroscience*. 1994; 6: 17-25.

Fuentes LJ, Santiago E. Spatial and semantic inhibitory processing in schizophrenia. *Neuropsychology*. 1999;13: 259-270.

Fuentes LJ, Vivas AB, Humphreys GW. Inhibitory mechanisms of attentional networks: Spatial and semantic inhibitory processing. *Journal of Experimental Psychology: Human Perception and Performance*. 1999; 25:1114-1126.

Posner MI, Raichle ME. *Images of mind*. New York: Scientific American; 1994.

### Figure captions

Figure 1. The visual orientation task. Detection responses are required to targets (an asterisk) located at the cued or uncued location.

Figure 2. The semantic priming task. Lexical decision responses are required to targets, which can be related or unrelated to the previous prime word.