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Cognitive neuroscience of episodic memory encoding

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Abstract

This paper presents a cognitive neuroscientific perspective on how human episodic memories are formed. Convergent evidence from multiple brain imaging studies using positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) suggests a role for frontal cortex in episodic memory encoding. Activity levels within frontal cortex can predict episodic memory encoding across a wide range of behavioral manipulations known to influence memory performance, such as those present during levels of processing and divided attention manipulations. Activity levels within specific frontal and medial temporal regions can even predict, on an item by item basis, whether an episodic memory is likely to form. Furthermore, separate frontal regions appear to participate in supplying code-specific information, including distinct regions which process semantic attributes of verbal information as well as right-lateralized regions which process nonverbal information. We hypothesize that activity within these multiple frontal regions provides a functional influence (input) to medical temporal regions that bind the information together into a lasting episodic memory trace. © 2000 Elsevier Science B.V. All rights reserved.

The question addressed in this paper is simple: why do certain events and experiences form episodic memories? This question can be answered at different levels of description. At one level, theories from cognitive psychology provide an account of

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how certain forms of processing facilitate episodic memory formation, outlining the conditions necessary to promote these forms of processing and the many variables that may influence retrieval of episodic memories after they have formed. At another level, evidence from neuroscience provides information about the neural structures that support encoding, and characterizes the operations carried out by these neural structures. The view of encoding presented here reflects a cognitive neuroscience approach that relates these two levels of description. The aim is to understand how encoding and its behavioral manifestations arise from the workings of underlying neural structures.

What follows is a review of recent results from brain imaging studies that suggests a cognitive neuroscience theory of how episodic memories form and why some experiences are more likely than others to establish a lasting memory trace. While the theory is incomplete, there is good evidence supporting the notion that certain types of encoding processes may onto neural activity within specific brain regions, and that evidence from neuroscience can inform and constrain studies of behavior and vice versa. Although several brain regions are likely to be involved in episodic memory formation, in this paper particular focus is placed on (1) the role of the frontal cortex in episodic memory encoding, and (2) how frontal regions may interact with medical temporal regions that play a well-established role in episodic (and semantic) memory formation. The main conclusion drawn is that for an episodic memory to form an event must encourage elaboration of information within specific frontal regions that provide a critical input to medical temporal cortex. Components of these ideas have been presented previously (e.g., for a highly overlapping explication see Buckner, Kelley, & Petersen, 1999; Buckner, 1999).

1. Brain imaging studies suggest specific left frontal regions contribute to verbal episodic encoding

The majority of data about human episodic memory encoding comes from studies using verbal materials. One manner of encoding words into episodic memory is *intentional* memorization. Brain imaging studies, using functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) have consistently demonstrated that specific regions within left frontal cortex are active when subjects intentionally memorize words (Fletcher et al., 1995; Kapur et al., 1996; Kelley et al., 1998).

However, many instances of episodic memory formation in everyday life occur *incidentally*, without any intention to remember. As studies in cognitive psychology have shown (cf. Postman, 1964; Hyde & Jenkins, 1973; Craik & Lockhart, 1972), episodic memories can form as a byproduct of certain kinds of information processing, independent of the intent to remember. For example, words that are deeply processed in terms of their meaning and how they relate to other items in memory are better remembered than words processed in a shallow fashion in which only surface characteristics are examined – the well-known levels of processing effect (e.g., Craik & Lockhart, 1972). Frontal regions active during *intentional* memori-

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