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Review

Neural correlates of local contextual processing across stimulus modalities and patient populations

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ABSTRACT

The objective of the current review is to integrate information from a series of studies, employing a paradigm that evaluates local contextual processing using electrophysiological measures. Collectively these studies provide an overview of how utilization of predictive context changes as a function of stimulus modality and across different patient populations, as well as the networks that may be critical for this function. The following aspects of local contextual processing will be discussed and reviewed: (i) the correlates associated with contextual processing that have been identified in healthy adults, (ii) stimulus modality effects, (iii) specific alterations and deficits of local contextual processing in aging and across different neurological and psychiatric patient populations, including patients with prefrontal cortex lesions, Parkinson's disease, schizophrenia, and major depressive disorder, (iv) the potential for utilizing the correlates of local context as biomarkers for frontal cognitive dysfunction and (v) the role of frontal networks in the processing of contextual information. Overall findings show that behavioral and neural correlates associated with processing of local context are comparable across stimulus modalities, but show specific alterations in aging and across different neurological and psychiatric disorders.

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1. Introduction

Contextual processing is a cognitive function that is associated with processing of goal-directed task-relevant information that is used to guide a future action. On a daily basis we constantly extract relevant information from our environment in order to plan our actions and behavior. This type of contextual, goal-directed task-relevant information is used to guide, plan and select appropriate responses (Cohen and Servan-Schreiber, 1992). In other words, context may be seen as information that is transferred into a representational form or "context representation" so that it can subsequently be used to mediate appropriate task behavior (Barch et al., 1997, 2001; Barch and Ceaser, 2012; Cohen and Servan-Schreiber, 1992). Contextual information may include a set of task instructions or the processing of specific prior stimuli (Cohen and Servan-Schreiber, 1992). Processing of goal-directed contextual information facilitates the selection of appropriate responses so we can flexibly adapt our behavior according to the different requirements of particular goals and tasks that we need to perform. Thus, contextual processing sub-serves a range of higher cognitive functions, including reasoning and language.

1.1. Contextual processing and working memory

Contextual processing is considered to be an executive function and a subcomponent of working memory (Barch et al., 2001; Cohen and Servan-Schreiber, 1992). When there is a delay between task-relevant stimuli and a response, contextual information is maintained over time and plays a facilitatory role in working memory (Cohen and Servan-Schreiber, 1992; Hemsley, 2005). In our daily environment series of events that are separated in time are integrated and actively maintained on-line in working memory in the form of information that helps guide a future action (Mesulam, 1998). In the current review contextual information is also regarded as a series of events that are separated in time, which are then integrated and maintained by working memory in the form of predictive goal-relevant information. The goal-relevant information is a short predictive sequence of stimuli preceding a target event. This predictive information evolves over time, so that its predictive value is provided after the sequential display of a set of stimuli in a particular order. This information is considered "local" since it occurs directly before the delivery of a target event. Thus, serial events are detected, integrated and actively maintained on-line in working memory, in the form of predictive information that signals the occurrence of a subsequent target. In summary, local context may be defined as the occurrence of a short predictive series of stimuli that signals the delivery of a subsequent target event. The performance of this task consists of multiple stages. In order to perform the task subjects need to detect stimuli, extract information from task-relevant stimuli (predictive), manipulate and translate this information into a self-guided cue, and finally utilize this information to facilitate detection of predictable targets. Within the framework of Baddeley's model of working memory (Baddeley, 2000) context can be seen as sequential visual stimuli that are stored in the spatial sketch pad (parietal cortex) and are subsequently manipulated and transformed by the central executive system (dorsolateral prefrontal cortex) into goal-relevant predictive information. This is also in line with the proposition that working memory has a restrospective function of retention and a prospective function of anticipating and preparing for forthcoming actions, in posterior perceptual and frontal executive areas, respectively (Fuster and Bressler, 2012). In relation to local contextual processing this would mean that predictive information provided by the predictive sequence is maintained for the future activation of goal-directed behavior related to target detection. These predictive cues may enhance performance and transfer of perceptual representations in to working memory (Gazzaley and Nobre, 2012; Posner, 1980).

1.2. Contextual processing and prefrontal cortex

Neuroimaging and model data have demonstrated the important role of prefrontal cortex (PFC), specifically the dorsolateral PFC, and frontal networks in contextual processing (Barch et al., 2001; Huettel et al., 2005; MacDonald et al., 2000; Mesulam, 1998; Miller and Cohen, 2001). Furthermore, contextual processing deficits have been associated with PFC dysfunction in schizophrenia and in prefrontal lesioned patients (Barch et al., 2001; MacDonald et al., 2005; Fogelson et al., 2009b, 2013). PFC has characteristics ideally suited for a function such as contextual processing: (i) it is involved in top-down processing, modulating activity in other task-relevant areas and allowing for the selection of appropriate responses; (ii) PFC is highly interconnected with other cortical and subcortical areas such as parietal cortices, temporal lobes and the basal ganglia (Mesulam, 1998; Miller and Cohen, 2001). PFC is thought to have a key role in the transformation and maintenance of context representations (Barch et al., 1997, 2001; Cohen and Servan-Schreiber, 1992; MacDonald et al., 2000) and in the resolution of short term uncertainty (Huettel et al., 2005). Contextual information is proposed to influence working memory processes supported by the lateral PFC, by extracting regularities such as goals and task rules so that information is recoded into context representations (Barch et al., 1997; Cohen and Servan-Schreiber, 1992; MacDonald et al., 2000; Miller and Cohen, 2001). These context representations, which are thought to be multi-modal in nature (see Section 3) are maintained in PFC and can be used to bias both motor and sensory processing, via frontal–parietal networks, to allow for the selection and execution of appropriate actions (Miller and Cohen, 2001). Thus, stimulus recognition may be facilitated by predictive contextual information through top-down mechanisms involving