International Journal of Psychophysiology 87 (2013) 189–199

Contents lists available at SciVerse ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

Variations in retrieval monitoring during action memory judgments: Evidence from event-related potentials (ERPs)

P. Andrew Leynes *, Bhavika Kakadia

The College of New Jersey, United States

ARTICLE INFO

Article history:
Received 11 July 2012
Received in revised form 17 December 2012
Accepted 2 January 2013
Available online 9 January 2013

Keywords:
ERP
Action memory
Source memory
Recollection

ABSTRACT

The present study investigated the neuroscience of memory for actions using event-related potentials (ERPs). Actions were performed, initiated but not completed (i.e., interrupted), or watched while the experimenter performed the action during encoding. Memory was assessed in a reality monitoring (RM) test (performed vs. watched actions), as well as in an internal source monitoring (ISM) test (performed vs. interrupted) while ERPs were recorded. Behavioral measures provided evidence of robust old/new recognition for all actions, but the analysis of source errors revealed that interrupted actions were often confused with performed actions. The ERP correlate of recollection, the parietal "old/new" effect (700–900 ms), was observed for all actions. The right frontal "old/new" effect (1500–1800 ms) that correlates with general memory monitoring was observed in RM but not in ISM. Instead, ISM was associated with the late posterior negativity (LPN) that has been connected to more specific memory monitoring. This pattern of ERP findings suggest that, in this context, general monitoring was used to discriminate self- versus other-performed actions, whereas more specific monitoring was required to support the discrimination of completed and interrupted actions. We argue that the mix of general/specific monitoring processes is shaped by the global retrieval context, which includes the number of memory features that overlap and the combination of sources being considered among other factors.

1. Introduction

Accurate memory for actions is a key process for everyday functioning, and it is arguably the most common form of remembering. Failures of action memory can range in severity from mildly disconcerting (e.g., forgetting to lock your car) to deadly (e.g., forgetting a child in a hot car). This type of remembering overlaps other memory processes, such as prospective memory (remembering to fulfill a future intention) and false memory. For example, forgetting to lock your car might result from a failure of prospective memory if you simply forget to fulfill the intention; however, that same action memory failure can also result from a false memory that you already locked your car (Leynes and Bink, 2002). Indeed, Guard and Gallagher (2005) found that memory failures contributed to the majority of cases (54%) in which children were left in a hot car and died during an eight-year period in the United States. Accurate action memory also has important legal applications because failures to accurately remember real actions can drive false confessions, and eyewitness recollection of crime-relevant actions is subject to confusions from internal (e.g., imaginations) and external sources (e.g., other eyewitness accounts; Loftus, 2011). Therefore, investigating the neural mechanisms of action memory has a wide range of applications to everyday functioning, legal situations, and to the functioning of those who suffer traumatic brain injuries and might experience deficits in remembering actions (e.g., Schwerdt and Dopkins, 2001).

Johnson and colleagues argue that these types of discriminations can be characterized as a form of source monitoring in the Source Monitoring Framework (SMF; Johnson et al., 1993; Mitchell and Johnson, 2009). Source monitoring refers to the processes that are used to discriminate between information with different origins or sources, such as discriminating between seen and heard information. The SMF identifies three basic types of source discriminations: (a) discriminating between two sources external to the person remembering (e.g., seen vs. heard information), (b) discriminating between an external source and thoughts/actions that originate from the person remembering (a discrimination called reality monitoring) or (c) discriminating between two sources that originate from the person remembering (e.g., discriminating between thoughts and actions; a discrimination called internal source monitoring). Action memory and source monitoring converge when one discriminates between actions of different types or sources (Leynes and Bink, 2002; Leynes et al., 2005b, 2006). Discriminating between performed actions and actions that were imagined (Leynes and Bink, 2002), motioned (Leynes et al., 2006), or interrupted (Leynes et al., 2005b) captures situations where one must make an internal source judgment between the two types of actions originating from oneself. The SMF was developed largely on cognitive behavioral measures and discriminations between typical stimuli (e.g., words and pictures) because these studies require fewer resources to execute.

* Corresponding author at: Psychology Department, The College of New Jersey, Ewing, NJ 08628-0718, United States. Tel.: +1 609 771 2624.
E-mail address: leynes@tcnj.edu (P.A. Leynes).

0167-8760/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.ijpsycho.2013.01.004

According to the SMF, source monitoring decisions involve activation of the qualitative characteristics stored in the memory trace (e.g., perceptual, semantic, temporal, kinesthetic, and thoughts at the time of encoding) and the evaluation of those characteristics (Johnson et al., 1993). The activated features in the memory trace can be evaluated using heuristic or systematic decision processes. Heuristic decisions tend to be fast and based on the average difference in qualitative characteristics. For example, remembering more visual detail serves as an indicator that the information was seen rather than heard. Systematic decisions are slower, based on more extended reasoning or retrieval of additional supporting memories. Although systematic decisions are more complex, there have been recent attempts to further characterize these processes (e.g., Gallo, 2010; Gallo et al., 2010). Whether decision processes are heuristic, systematic, or some mixture of both kinds of processes depends upon the combinations of qualitative characteristics that differentiate the sources being considered and the agenda of the decision-maker.

1.1. Neuroscience of source memory

Neuroimaging evidence from Functional Magnetic Resonance Imaging (fMRI) indicates that several key brain regions support source monitoring, including medial temporal lobe (MTL) structures, areas within the prefrontal cortex (PFC), and regions in the parietal lobes (see Mitchell and Johnson, 2009 for a review). MTL structures are critical for binding or consolidating qualitative characteristics into complex memories and for relatively automatic reactivation of these features during remembering. PFC areas appear to support various types of monitoring processes (i.e., heuristic or systematic processes). Additionally, parietal areas appear to support attention to specific features re-activated in memory (Cabeza, 2008; Cabeza et al., 2008; Mitchell and Johnson, 2009), which support the experience of recollection when features are sufficiently strong (Vilberg and Rugg, 2009).

These findings from fMRI are consistent with event-related potential (ERP) measures taken during source memory. ERPs are electrical recordings of neuronal activity at the scalp that are time-locked to the presentation of a stimulus. ERPs complement fMRI evidence because fMRI has a superior ability to localize areas that are active, whereas ERPs have superior ability to resolve millisecond changes in activity. Memory-related ERP components reflect memory processes because old and new items produce differences in ERP amplitudes ("old/new effects") that are distinguished by temporal onset (i.e., time after the test probe) and spatial location (i.e., electrodes where the effect is present or maximal).

Old/new effects appear soon after the onset of the probe (about 300 ms) when recognition is based on fluency (e.g., Leynes and Zish, 2012) or on familiarity (see Rugg and Curran, 2007 for a review; but see Paller et al., 2012 for a differing view). Source monitoring tends to be based on more differentiated information (i.e., recollection; Johnson et al., 1993); consequently, the earliest old/new ERP difference tends to emerge later (approximately 500–800 ms after the onset of the probe). This ERP tends to be largest at left parietal electrode sites for words (often called the "parietal old/new effect"; parietal effect hereafter; e.g., Wilding and Rugg, 1996), and it has been linked with activation in left inferior parietal cortex (Vilberg and Rugg, 2009) that supports recollection when task-relevant details are activated (Leynes, 2012).

The second old/new ERP difference has a later onset (approximately 800 ms after the probe) and typically has a right-frontal distribution. Based on many ERP findings, the "right frontal old/new effect" has been hypothesized to reflect post-retrieval processes (e.g., Mecklinger, 2000; Wilding and Rugg, 1997) or more general monitoring processes (Hayama et al., 2008) that are comparable to heuristic decision processes described by the SMF (Leynes and Phillips, 2008).

A third old/new ERP difference, called the "late posterior negativity" (LPN hereafter), has been reported in some source memory studies (see Johansson and Mecklinger, 2003 for a review; Friedman et al., 2005; Herron, 2007; Leynes, 2012; Leynes et al., 2006; Leynes and Phillips, 2008). The LPN emerges approximately 1000 ms after the probe, and it is largest at the posterior electrode sites. The available evidence suggests that it reflects additional inspection of retrieved feature conjunctions that can support difficult source discriminations (Johansson and Mecklinger, 2003; Mecklinger et al., 2007), which is similar to systematic monitoring as described by the SMF (Leynes and Phillips, 2008).

1.2. Neuroscience of action memory

Discriminating between action and non-action memories has been investigated using ERP (Heil et al., 1999), positron emission tomography (PET; Nilsson et al., 2000; Nyberg, et al., 2001), and magnetoencephalography (MEG; Masumoto et al., 2006). The consistent result across these studies is that remembering actions initiates additional activation of the motor cortex (but see Senkfor et al., 2008 for contradicting evidence). This result is taken as evidence that motor information is reactivated during the remembering of actions.

Other ERP studies have examined source memory for actions by asking participants to discriminate between performed and other types of actions or information. Senkfor and colleagues measured ERPs during source memory tests for actions (Senkfor, 2008; Senkfor et al., 2002, 2008). However, these studies provide limited contributions to understanding source monitoring of actions because two of these studies did not include any new items on the memory test (Senkfor, 2008; Senkfor et al., 2002) and the other study focused on the differences between performed and cost encoded actions (i.e., stimuli with no action relevance; Senkfor et al., 2008). More relevant to understanding internal source monitoring (ISM) are the ERP studies that have contrasted memories for what one has done (performed actions) with imagined actions (Leynes and Bink, 2002), actions enacted without touching or manipulating the objects (i.e., motioned actions; Leynes et al., 2006), or actions initiated without completing the full action (i.e., interrupted actions; Leynes et al., 2005b). These studies contrast two internal, action-related memories in an effort to understand the cognitive processing that governs these types of everyday decisions. These studies generally observe the traditional old/new ERP effects reported in source memory ERP studies (i.e., parietal effect, right frontal effect, and LPN) that use words or other stimuli, and observing similar patterns of ERPs indicate that the SMF is a good theoretical match for action discriminations.

Despite the general similarity of ERP activity between action and source discriminations, some important variations in ERP components were observed in these three studies. Performed actions elicited the parietal effect in all three studies; however, the topography was shifted towards central electrode sites versus the left-parietal topography elicited by word stimuli. Originally, Leynes and Bink (2002) suggested that the more central topography was consistent with the argument that remembering actions reactivated motor information in the memory trace (see Senkfor et al., 2002 for a similar argument). However, Masumoto et al. (2006) provide evidence that motor reactivation occurs earlier (about 150 to 250 ms) and that left and right parietal areas are active during action memory. Consequently, the additional activation of right parietal areas might produce the more central ERP topography during action memory.

The amplitude of the parietal effect in these action memory studies has varied. Leynes and Bink (2002) reported that planned actions elicited the parietal effect; however, interrupted (Leynes et al., 2005b) and motioned actions (Leynes et al., 2006) did not elicit the parietal effect. Based on a variety of evidence, Leynes (2012) argued that the absence of the parietal effect reflects strategic recollection in which the source judgment is based on the recovery of targeted features or on the absence of these features (see also Rosburg et al., 2011a, 2011b).

The late effects (i.e., the right frontal effect and LPN) have varied across action memory studies much like they vary across source memory