Available online at www.sciencedirect.com
ScienceDirect
International Journal of Psychophysiology 62 (2006) 193 – 202
INTERNATIONAL JOURNAL OF PSYCHOPHYSIOLOGY
www.elsevier.com/locate/ijpsycho

Event-related potential (ERP) evidence for sensory-based action memories

P. Andrew Leynes [a,*], Jeremy A. Grey [a], Jarret T. Crawford [b]

[a] The College of New Jersey, United States
[b] Rutgers University, United States

Received 8 September 2005; received in revised form 11 April 2006; accepted 21 April 2006
Available online 12 June 2006

Abstract

Memory for performed and motioned actions was measured on source recognition and source recall tests in order to investigate memory for actions or output monitoring (OM). Event-related potentials (ERPs) were recorded during the source recognition test to provide insight into the basis of OM. Source identification and recall of performed actions was greater than motioned actions indicating that sensory characteristics provide unique information for action memories. The ERP data supported this interpretation because the brain activity elicited by performed actions differed from motioned and new actions. Early parietal ERP differences suggest that sensory information leads to selective recollection of performed actions or that more sensory information was activated by performed actions during remembering. A large late posterior negativity (LPN) was also observed in the absence of frontal ERP differences, which are typically observed during source monitoring. This pattern of ERP differences is evidence that frontal ERPs and the LPN reflect distinct source monitoring processes. Based on the available data, we argue that frontal ERPs reflect general decision processes that evaluate diagnostic information, whereas the LPN reflects processes that are engaged when a detailed inspection of information is required by the context.

Keywords: Source memory; ERP; Actions

People must be able to remember past actions (i.e., retrospective memory) and maintain intentions for future actions (i.e., prospective memory) in order to function in many contexts. Failures in these forms of cognition can range from mild (e.g., forgetting to put one's car in park) to serious (e.g., leaving a sleeping infant in a hot car). Prospective memory has been the subject of a number of studies (see Henry et al., 2004 for a recent review) and a separate body of work has focused on retrospective memory for actions (see Engelkamp, 1998 or Zimmer and Cohen, 2001 for reviews). However, there is obvious overlap between these two areas of research because prospective memory can fail when a search of retrospective memory leads one to believe that the action has been completed (Leynes and Bink, 2002; Leynes et al., 2005b; Schaefer et al., 1998). As a result, one way to integrate the literature is to investigate the factors that affect retrospective memory for actions in an effort to understand how the safety and quality of life may be compromised in many situations.

The majority of retrospective action memory studies have used a paradigm in which participants perform simple actions in the laboratory (e.g., roll the ball), which are called subject performed tasks. Recognition or recall of these actions is typically superior to memory for actions that are performed by the experimenter or actions that are learned verbally (the "enactment effect"). Theories explaining this effect have been advanced including a view that the motor information in the memory trace creates this effect (Engelkamp, 2001) or that actions create a rich integration of the information and the person (Kormi-Nouri and Nilsson, 2001). As a result, many studies in this field have attempted to distinguish between competing explanations for the enactment effect, which also furthers an understanding of the basic organization of memory.

Although this body of work has yielded many important and interesting findings, Leynes and colleagues (Leynes and Bink, 2002; Leynes et al., 2005b) have focused on the factors that affect retrospective memory for actions. They argue that discriminating

* Corresponding author. Department of Psychology, The College of New Jersey, P.O. Box 7718, Ewing, NJ 08628-0718, United States. Tel.: +1 609 771 2624; fax: +1 609 637 5178.
E-mail address: leynes@tcnj.edu (P.A. Leynes).

0167-8760/$ - see front matter
doi:10.1016/j.ijpsycho.2006.04.003

between different types of actions (e.g., performed versus imagined actions) can be viewed as a special case of source monitoring (i.e., memory for the origin of information; Johnson et al., 1993). According to this argument, actions that have been performed are one source of information, whereas other types of actions (imagined or other performed actions) are another source of information. Leynes and colleagues referred to these cases of source monitoring as output monitoring (OM) to connect to related work that investigates other situations in which people make judgments concerning their own output (see Marsh and Hicks, 2001). The advantage of this approach is that the theory that describes source monitoring, the Source Monitoring Framework (Johnson et al., 1993), can be used to guide and interpret additional studies of action memory (Hornstein and Mulligan, 2004).

The Source Monitoring Framework describes the cognitive processes that govern remembering the origin of information. Source memory is not directly retrieved; rather, source judgments are supported by the information in memory that is activated (qualitative memory characteristics) after which the activated information is evaluated by a complex set of decision processes in order to determine the source. Qualitative memory characteristics include the many features that become bound into memory when the information is encountered (e.g., perceptual details, spatial and temporal information, semantic detail, affective information, motor information, and cognitive operations). After qualitative characteristics are activated, heuristic or systematic decision processes govern the evaluation of memory characteristics to render a source judgment (Johnson et al., 1993).

Johnson et al. (1993) suggested that the type of processes used in many source monitoring (and by extension OM situations) may differ somewhat from those used when recalling or recognizing actions because source judgments rely on more differentiated information and the decision processes may vary depending on the context. This hypothesis, as it relates to action memory, has already received some support. For example, Kormi-Nouri (2000) reported that recall of performed and imagined actions did not differ, whereas Leynes and Bink (2002) found that more performed than imagined actions were recognized and recalled when participants determined whether actions were “performed”, “imagined”, or “new.” Furthermore, some novel predictions arise when action memory is considered as source memory. For example, Hornstein and Mulligan (2004) found that enhancing visual information did not affect the enactment effect (item memory), but more visual information led to more source confusions. Because increasing the similarities between the sources creates more source confusions in many other contexts (Johnson et al., 1993), these results suggest source monitoring can successfully guide research on action memory when people are asked to discriminate between different types of actions.

Recently, event-related potentials (ERPs) have provided insight into the cognitive processes that are used when discriminating between different types of actions because several studies have examined ERPs during other types of source monitoring (e.g., Rugg et al., 1998; Senkfor and Van Petten, 1998; Wilding, 1999; Wilding and Rugg, 1996). In one study, Leynes and Bink (2002) asked participants to perform some actions and to imagine and plan to perform another set of actions at study. ERPs were recorded during a source recognition test that asked participants to determine if the test probe was a performed action, an imagined action, or was new. They observed ERP effects that were similar to other source monitoring ERP studies because about 600 ms after the probe both old sources elicited more positive ERPs than new (an old/new effect). Most source monitoring and recognition studies (which have predominantly used verbal materials) report an old/new effect around 600 ms which tends to be largest at parietal electrodes. This effect has been hypothesized to reflect recollection of information stored in memory (e.g., Paller and Kutas, 1992; Paller et al., 1995; Wilding, 2000; Wilding and Rugg, 1996). The old/new difference in the Leynes and Bink study tended to have a more central distribution; consequently, the authors suggested the more central distribution reflected activation of the motor cortex when sensorimotor information associated with imagining or performing actions was reactivated during the test (see Senkfor et al., 2002 for a similar claim). This interpretation is consistent with a positron emission tomography study of memory for actions that reported increased activation in right motor cortex when performed actions were recalled (Nilsson et al., 2000) as well as the claim that motor information contributes to the enactment effect (Engelkamp, 2001).

Leynes and Bink (2002) also observed later ERP differences at frontal electrode sites as well as a late posterior negativity (LPN). The frontal ERP differences have been observed in many source monitoring studies and are presumed to reflect post-retrieval processing (Mecklinger, 2000; Ranganath and Paller, 2000; Wilding, 1999; Wilding and Rugg, 1997) or source monitoring decision processes (Leynes, 2002; Leynes and Bink, 2002; Leynes et al., 2003, 2005b,). The LPN has also been observed in many studies and it has been hypothesized to reflect a search for additional attributes in memory (see Johansson and Mecklinger, 2003 for a review).

Recently, Leynes, Crawford, and Bink (2005b) investigated the effect of interrupting actions on OM. In their study, participants completed some actions and began to complete another set of actions when the experimenter interrupted the completion of these actions. They argued that initiating (but not completing actions) would make the actions more similar to performed actions because the memory trace would also contain some sensorimotor information, which should lead to more source confusions (Hornstein and Mulligan, 2004; Johnson et al., 1993). The behavioral data supported this prediction because more interrupted actions were misattributed to performed actions. The ERP data suggested that memories for performed actions differed from interrupted actions because amplitude differences in the early parietal ERPs were observed (i.e., performed ERPs were more positive than interrupted ERPs and new ERPs).

Although the results of Leynes, Crawford, and Bink (2005b) study suggest that different types of information can be activated and consulted to support OM, our understanding of action memory can be furthered by similar studies that investigate how various kinds of information impact OM. For example, performed