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Behavioural Brain Research 159 (2005) 127–133
BEHAVIOURAL BRAIN RESEARCH
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Procedural memory in Korsakoff's disease under different movement feedback conditions

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Received 11 August 2004; received in revised form 15 October 2004; accepted 18 October 2004
Available online 24 November 2004

Abstract

Within the field of cognitive neuroscience, it has become widely accepted to distinguish between declarative and nondeclarative memory, with different neurobiological substrates subserving these memory structures. This distinction has been inferred from the study of amnesic patients, including those suffering from Korsakoff's syndrome. It is commonly agreed that Korsakoff patients demonstrate intact memory for motor and perceptual skills (nondeclarative) whereas memory of various forms of factual knowledge (declarative) is severely impaired. In the present study, Korsakoff patients and a group of age-matched controls learned a new bimanual motor skill whereby performance was assessed in the presence and absence of augmented visual information feedback. Findings demonstrated that Korsakoff patients were able to learn and retain this skill when directive augmented information feedback was provided while no learning occurred at all in the absence of this information. These observations shed new light on the conditions required for preserved memory in amnesic patients and challenge the classic view that nondeclarative memory is invariably preserved. Instead, the quality of memory across both motor and cognitive dimensions appears to depend on the availability of task-specific information to guide performance, presumably allowing amnesic patients to bypass affected brain areas. This prompts for a reevaluation of current notions about procedural memory capacity in Korsakoff patients.

Keywords: Korsakoff; Motor learning; Memory; Bimanual coordination; Procedural versus declarative

1. Introduction

Current theories on the neurobiology of memory are profoundly influenced by dissociations in performance, as exhibited on various learning tasks in amnesic patients [1–3]. Multiple memory systems are postulated to account for these performance discrepancies. Distinctions have been made between declarative (knowing that) and procedural memory (knowing how) [4], later redefined as declarative and nondeclarative memory [5] and explicit and implicit memory [6,7]. Declarative memory refers to the storage and retrieval of material that is available to consciousness and that can therefore be expressed by language, that is, knowledge we usually know we have. Non-declarative memory is expressed through performance without affording access to any conscious memory content, allowing the gradual development of new skills and habits [5,7]. Previous work has shown that amnesic patients, including those suffering from Korsakoff's syndrome, show severe deficits in declarative memory whereas nondeclarative memory is largely preserved. Motor skill has traditionally been considered as one of the typical examples of nondeclarative memory that is invariably preserved in these patients.

However, a reevaluation of published motor learning and memory research in amnesic patients reveals that the available evidence is scarce, that the tasks studied so far did not require the acquisition of a new movement form, and that external information was usually available to guide motor performance [8–11]. For example, pursuit rotor learning [8,9] or serial reaction time tasking [10,11] are characterized by visual information that strongly guides the required move-

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doi:10.1016/j.bbr.2004.10.009

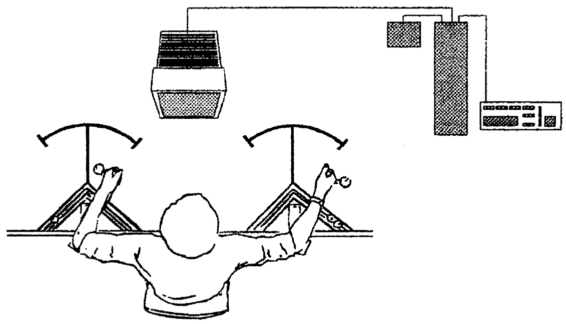

Fig. 1. Top view of the experimental apparatus.

ments. The performer has to improve the stimulus response associations whereas less emphasis is placed on the acquisition of a new movement form or coordination pattern. Such extrinsic information reduces the need to intrinsically generate movement from memory representations. Accordingly, the widely accepted notion that procedural memory is intact in Korsakoff patients lacks solid experimental verification. This may have consequences for the presumed dissociation between declarative and nondeclarative memories.

In the present study, we investigated the acquisition and retention of a new cyclical bimanual coordination task in Korsakoff patients and normal controls under different conditions of feedback information. The task required subjects to coordinate the forelimbs such that one limb was 90° out-of-phase with the other (see Fig. 1) [12–16]. This coordination mode requires building a new movement form and is located in between the preexisting preferred in-phase (symmetrical arm movements) and anti-phase (asymmetrical arm movements) coordination modes that subjects can perform easily without prior practice [17–21]. Conversely, the 90° out-of-phase task is not normally part of the intrinsic motor repertoire and requires practice before the movement can be produced successfully and consistently. Subjects practiced the skill across two days with concurrent feedback provided on a computer screen in the form of a Lissajous figure of both displacement signals. Successful performance was characterized by appearance of a real-time circular configuration on the screen, thereby guiding performers toward the correct coordination mode. At regular intervals during practice, participants also performed the task without this augmented feedback but with normal vision of the moving limbs, or, while being blindfolded. The latter conditions forced subjects to guide performance on the basis of an internal representation as external stimulus information was lacking. Following the acquisition phase, a retention test was held one week later.

The goal of the present study was two-fold. First, we assessed whether motor learning and memory is preserved in Korsakoff patients when a new movement form has to be acquired. Second, to establish to what extent procedural memory capacity is dependent on environmental cues that guide performance, memory for the skill was tested in the presence and absence of augmented information feedback. Whereas the former condition allows the performer to guide action on-line with the help of extrinsic augmented information, the latter requires more focus on internally guided or memory driven monitoring of action. These questions have not been addressed in the literature yet.

2. Method

2.1. Subjects

Subjects consisted of a group of Korsakoff patients ($n = 11$), with a mean age of 50 years (S.D. = 5.09 years, range between 38 and 60 years) and a control group ($n = 11$) without any neurological deficit or alcoholic history. Controls matched the Korsakoff patients with respect to age (49.2 years, S.D. = 6.15 years, range = 39–62 years), gender (1 female, 10 males), hand preference and degree of education (12.63 versus 13 years). Korsakoff patients were recruited from a psychiatric institution. All patients were screened by a neurologist and showed severe anterograde amnesia and retrograde amnesia with a temporal gradient. The study was approved by the biomedical ethics committee of K.U.Leuven. Informed consent was obtained from all participants.

2.2. Apparatus and task

Two horizontal metal levers (43 cm long) were attached to virtually frictionless vertical axles that could be moved toward and away from the body midline (Fig. 1). An adjustable handle was located at the distal end of each lever. Incremental shaft encoders (Tamagawa FA-Coder, 4096 increments per revolution), mounted at the base of the axles, determined elbow displacement, sampled at 150 Hz. The subject was seated behind the apparatus such that the body was aligned between the levers. The forearms rested on the levers and a distal handle was firmly grasped. The elbow was positioned just above the lever's axis of rotation.

Subjects performed cyclical, horizontal bimanual forearm movements, coincident with the beating of an electronic metronome (KORG DTM-12, 66 beats per min), such that one complete movement cycle was performed on every beat. They were required to produce oscillations of each limb with the same frequency (1 Hz) and amplitude (60° peak-to-peak displacement) but with a phase offset between the limbs of 90° (see Fig. 2). The duration of each trial was 15 s. The limbs always started in mid-position prior to movement initiation. The reversals in direction at peak flexion and peak extension were made at vertical targets (width = 4°), located behind the movement path. A PC sampled and recorded the data, signalled the start and end of the trial, and controlled the onset and offset of the metronome.

The essence of this motor skill is the acquisition of a new spatiotemporal relationship between the limbs. When one limb is reversing direction at peak position, the other limb is located midway between peak extension and flexion and this offset (i.e., a quarter of a movement cycle) has to be maintained at all times. The orthogonal plot of both angular displacement patterns results in a circle configuration (Fig. 2a). This mode is located in between the preferred preexisting in-phase and anti-phase coordination modes. The former mode requires the limbs to flex and extend simultaneously whereas the latter mode requires one limb to flex while the other extends, or vice versa. There are two critical advantages of this task. First, it involves the acquisition of a new movement form that subjects can