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Research report

Games people play: How video games improve probabilistic learning

Sabrina Schenk*, Robert K. Lech, Boris Suchan

Institute of Cognitive Neuroscience, Department of Neuropsychology, Ruhr University Bochum, Universitätsstraße 150, D-44780 Bochum, Germany

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ABSTRACT

Recent research suggests that video game playing is associated with many cognitive benefits. However, little is known about the neural mechanisms mediating such effects, especially with regard to probabilistic categorization learning, which is a widely unexplored area in gaming research. Therefore, the present study aimed to investigate the neural correlates of probabilistic classification learning in video gamers in comparison to non-gamers. Subjects were scanned in a 3 T magnetic resonance imaging (MRI) scanner while performing a modified version of the weather prediction task. Behavioral data yielded evidence for better categorization performance of video gamers, particularly under conditions characterized by stronger uncertainty. Furthermore, a post-experimental questionnaire showed that video gamers had acquired higher declarative knowledge about the card combinations and the related weather outcomes. Functional imaging data revealed for video gamers stronger activation clusters in the hippocampus, the precuneus, the cingulate gyrus and the middle temporal gyrus as well as in occipital visual areas and in areas related to attentional processes. All these areas are connected with each other and represent critical nodes for semantic memory, visual imagery and cognitive control. Apart from this, and in line with previous studies, both groups showed activation in brain areas that are related to attention and executive functions as well as in the basal ganglia and in memory-associated regions of the medial temporal lobe. These results suggest that playing video games might enhance the usage of declarative knowledge as well as hippocampal involvement and enhances overall learning performance during probabilistic learning. In contrast to non-gamers, video gamers showed better categorization performance, independently of the uncertainty of the condition.

1. Introduction

Probabilistic categorization learning requires a coordinated interaction between declarative and non-declarative memory. Over the past 20 years, evidence has accumulated that probabilistic learning involves distinct anatomically and functionally segregated memory systems [1]. It has been discussed whether these systems interact in a competitive [2,3] or cooperative manner [4]. Brain regions which are involved in cognitive control, performance integration and reward learning [5–9] represent additional factors affecting the probabilistic categorization learning process. With respect to memory, the interplay of the medial temporal lobe [MTL] and the basal ganglia is in the focus of research [2]. Declarative memory involves the hippocampus which supports the acquisition of flexible knowledge in contrast to more rigid striatum-dependent memory systems [10,11].

The weather prediction task (WPT) is a well-known probabilistic learning task [5–7,2]. In this task, participants are asked to classify one to three (out of four) different cue cards into one of two weather categories (rain or sun) based on feedback they receive for their actions. The WPT is a well-established probabilistic categorization learning task that demonstrates the differential contributions of declarative (mediated by the hippocampus) and nondeclarative (mediated by the basal ganglia) memory processes [12]. Patients with basal ganglia disorders show reduced performances in the WPT, especially in the early probabilistic learning phase [5]. However, amnesic patients with damage to the hippocampus perform comparably to controls in the early phases of learning, presumably because the declarative memory system interferes with the nondeclarative regularities detected by the nondeclarative memory system [6].

Additionally, further studies focused on the contribution of declarative knowledge to WPT performance [8,13,9,14]. Schwabe and Wolf [9], for instance, demonstrated a positive correlation between WPT task performance and hippocampal activation. It seems that the hippocampus-based learning and the hippocampal activity play an important role in the categorization learning process and support the learning performance in a probabilistic learning task.

The hippocampal activity as well as the hippocampal based memory processing and hippocampal based behavior can be in turn modified by

* Corresponding author.
E-mail address: Sabrina.Schenk@rub.de (S. Schenk).

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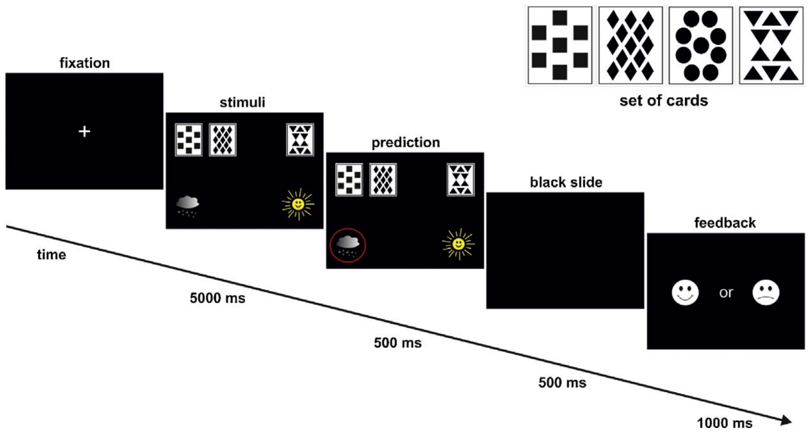

Fig. 1. Modified version of the weather prediction task.

the environmental enrichment [15–17]. This effect might be mediated by enhanced visual exploration of enriched environments, which in turn promotes hippocampal neuroplasticity and hippocampus-dependent learning and declarative memory. Based on these findings a modification of the environmental enrichment or a visual exploration training should enhance hippocampal-based learning and behavior as well as the related hippocampal activity. Since the hippocampus responds to both the real and the virtual environment in a comparable way [18,19], it should be possible to use video games as an effective training method to enhance hippocampal-based learning and behavior as well as the related hippocampal activity.

In previous research, playing video games has already been linked to improved attention resources, visual imagery, problem solving, visual processing, response speed [20–22] and cognitive flexibility [23]. Moreover and in accordance with the positive effect of the environmental enrichment, Clemenson and Stark [17] demonstrated that video games provide a strong environmental enrichment, which leads to enhanced memory performance on a task that is thought to tax hippocampal processing. All these cognitive functions, which can be improved by video games, are important factors within the probabilistic categorization learning process.

Using the WPT, the current study investigated the effects of video game playing on the performance in a probabilistic categorization task, the related usage of learning and memory processes as well as other cognitive functions and its neural correlates, which represents a widely unexplored area in gaming research up to now. We used a modified version of the WPT (see [9]) that include an equal condition (50/50% probabilities) as well as more certain (probabilities in the 80/20% range) and less certain conditions (probabilities in the 70/30% and 60/40% range). In contrast to the uncertain conditions, which should address the nondeclarative learning and activate the implicit memory system (mediated by the basal ganglia), the certain condition should be related to a more pronounced usage of declarative knowledge and should additionally activate the explicit memory system (mediated by the MTL, especially the hippocampus).

Based on previous findings, we expected that video gamers show better categorization performances due to a more pronounced usage of declarative knowledge, hippocampus-dependent learning and memory processes. More specifically, we aimed to investigate to which degree probabilistic categorization learning is positively mediated by the assumed enhanced hippocampus-depending learning of video gamers that is due to the strong environmental enrichment of video games. To measure these effects of video game playing the categorization performance in the WPT, the brain activity and the explicit knowledge of the task and their relation to each other were assessed.

2. Materials and methods

2.1. Participants

The current study included fifteen healthy right-handed video gamers (13 male and 4 female; mean age: 24.6 years; SD: 3.0 years) and fifteen healthy right-handed non-gamers (13 male and 4 female; mean age: 27.5 years; SD: 4.1 years). The subjects were recruited through advertisements at the Ruhr University and in local newspapers. The group membership was defined on the basis of a screening questionnaire. Video gamers were characterized by playing more than 15 h of video games like "starcraft" or other action-based videogames per week. Non-gamers, with low or without any video game experience, were defined by playing less than 4 h per week.

All participants had normal or corrected to normal vision and no current or past mental illnesses. The study was performed in accordance with ethical standards laid down in the declaration of Helsinki and written informed consent was obtained from all subjects. The investigation was approved by the local Ethics Committee of the Psychological Faculty of the Ruhr University Bochum, Germany.

2.2. Stimuli and task

Subjects were scanned while performing a modified version of the WPT ([5,6,2]; see Fig. 1). The experiment was performed using Presentation® software (Neurobehavioral Systems, Inc., Albany, CA, USA) and MRI-suitable LCD video goggles (Resonance Technology Company, Inc., Northridge, CA, USA) with a resolution of 800 × 600 pixels, registering the responses with an MRI-suitable keypad.

Before the WPT started, participants were instructed that on each trial one to three (out of four) different cue cards will appear and that they should learn to predict the weather based on the presented cards. Participants classified card stimulus sets as predictions of the weather (sun/rain) and got feedback (positive/negative) accordingly to their choice. Each card pattern was associated with fixed probabilities for more/less probable weather outcomes (probabilities of 50/50%; 60/40%; 70/30%; 80/20%). The different card combinations and positions were randomly presented and associated with the two possible weather outcomes. The experiment consisted of two sessions of 100 trials each, resulting in 200 trials over the course of the experiment (see [9]). After completion of the WPT, the participants answered a self-designed post-experimental questionnaire to assess cue usage and declarative knowledge about the WPT. The questionnaire was completed outside the scanner and contained 14 items that assessed explicit task knowledge about the WPT. For example, participants were asked which card or card combinations were most strongly associated with the two weather possibilities. For 12 items, one point was given for each correct answer. For the remaining two items that contained two sub-questions up to two points were given. The score reached in the post-experimental