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Research report

Sequential behavior in the rat: A new model using food-reinforced instrumental behavior

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Abstract

Sequential behavior, probably reflecting procedural learning, has intensively been investigated in humans. This work has mainly been done using so-called serial reaction time tasks. In such tasks, subjects have to respond rapidly to simple visual stimuli appearing at one of four locations by pressing a corresponding response key. Unknown to the subjects, these stimuli can follow a specific repeating sequence. Learning of such a sequence is typically inferred from faster reaction times to sequence as compared to random blocks of stimuli. In contrast to human subjects, the analysis of sequential behavior has received considerably less attention in rodents, possibly due to the lack of analogous animal models there. In order to establish such a model, a method was developed in rats to investigate serial reactions under conditions of random or sequential stimulus presentation. Operant testing chambers were used which consisted of four nose-poke holes with cue lights. These holes were arranged in a square fashion with a pellet receptacle in the center. The task of the rat was to rapidly respond to an illuminated hole by poking into it in order to obtain food. The stimulus locations varied permanently, and these changes pursued either a random or serial order. In three experiments with differing methodological details, responding under such conditions was analyzed with sequences consisting of 6, 12 or 13 positions. Evidence was obtained that rats can improve their performance under sequence as compared to random conditions, for example, with respect to the percentage of reinforcements obtained, or with respect to reaction times. Furthermore, methodological factors, like response requirements, were addressed which may critically affect experimental outcome. Together, this new kind of instrumental task might be useful to analyze sequential performance in the rat, and the brain mechanisms by which it is mediated.

Keywords: Sequence learning; Serial reaction time task; Fixed ratio; Procedural learning

1. Introduction

Nissen and Bullemer [1] have introduced the serial reaction time (SRT) task, which is a modification of tests formerly used in neuropsychological studies of attention [2]. In this SRT task, the human subjects have to perform rapid keyboard responses with their fingers in correspondence to varying visual stimulus locations on a computer screen. Unknown to the subjects, the order of stimuli displayed, and thus, that of the corresponding responses, is either random or sequential. Performance, usually measured in terms of reaction times, typically improves when stimuli are presented in a sequential fashion. This improvement is taken as a measure of learning, and a wealth of studies in normal subjects, patients with brain damage or neurodegenerative diseases has dealt with the psychological details of this kind of learning and its possible brain mechanisms. In short, such work has shown that sequence performance in SRT tasks can be viewed as a form of procedural, or implicit learning, to which explicit mechanisms can, but need not, contribute. Thus, this form of learning can occur without the awareness of the subjects, and can be preserved in amnesic patients [3–5]. Furthermore, neuropsychological and brain imaging studies have shown that certain brain systems are involved in se-

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quential learning and performance, which include parts of the basal ganglia, cerebellum, and frontal cortex (for review see [6,7]).

Although such work in humans has provided substantial scientific evidence, the feasibility of research in humans is limited, especially with respect to the experimental analysis of neural mechanisms. Therefore, animal models are necessary; however, compared to humans, sequential learning has been rather poorly investigated in animal subjects, and here, monkeys have often been used [8–10]. Work in rodents is comparably sparse, and the tasks investigated so far are usually dissimilar from the classical human SRT task, like sequential behavior of rats in various mazes, during odor discrimination, or grooming [11,13–19,31].

Here, we describe the development of an instrumental task in rats. The main goal of our study was to devise a test in rats similar to the classical human SRT task [1], which would then allow us to study implicit sequence learning phenomena in rodents. To achieve this goal, we adopted an instrumental approach used in attentional research of rats or mice (5-choice serial reaction time task; for review see [20]) and modified it in order to make it applicable for the analysis of sequential behavior. In the following, we describe several behavioral experiments, which show how rats perform in this task under different conditions of random or sequential stimulus presentation.

2. General methods

2.1. Subjects

Male Wistar rats (Harlan-Winkelmann, Borchen, Germany) were used which were housed singly during the experiment. They were kept in an animal-room with a 12:12 h light/dark cycle (light on at 07:00) with water available ad libitum. During the experimental phases, the animals received food only during (food pellets, see below) and after (Altromin rat chow, up to 60 min) daily testing. These experimental periods took place between 11.00 and 17.15 of the light phase. The rats were weighed daily before the test to insure that they were maintained above 85% of free-feeding weights.

2.2. Apparatus

Two standard operant chambers (28 cm L × 26 cm W × 28 cm H, working area; Med Associates), placed in separate sound-attenuated cubicles, were used. In each chamber, four light-equipped nose-poke holes (2 cm in diameter, 1 cm deep) were arranged in a square (side length: 17 cm apart from hole center to hole center) with a pellet receptacle in the middle of the square, a house-light and a speaker above it (see Fig. 1). The four holes (see Fig. 1) were numbered as follows: upper left: 1, upper right: 2, bottom left: 3, bottom right: 4. The pellet receptacle was connected to a dispenser, which delivered the food pellets (dustless precision pellets, 45 mg each, Bioserve, Bilaney Consultants, Germany) in an adjustable way. Infrared devices detected entries into the nose-poke holes or the receptacle. The whole system was controlled and monitored by a Med-PC soft-

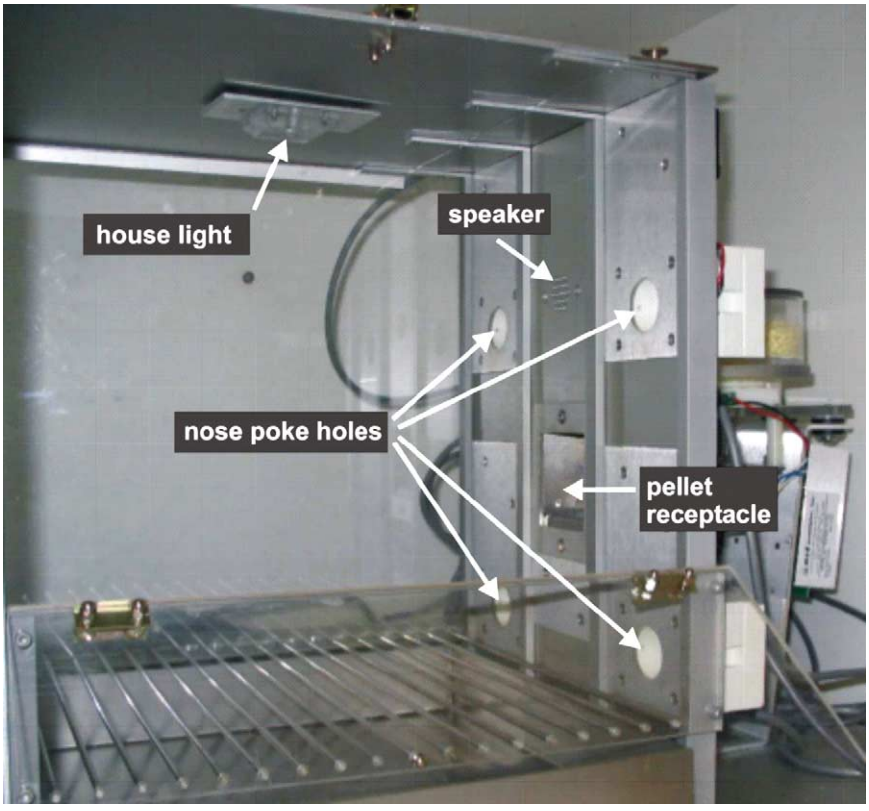

Fig. 1. The apparatus used to implement the serial reaction time task (for further details see Section 2). The nose-poke holes, which were arranged in a square-shaped manner, were labeled as follows: upper left – 1, upper right – 2, lower left – 3, lower right – 4.