Behavioural Brain Research 328 (2017) 178–185

Contents lists available at ScienceDirect

Behavioural Brain Research

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

Impulsivity in spontaneously hypertensive rats: Within-subjects comparison of sensitivity to delay and to amount of reinforcement

Vladimir Orduña[a,*], Eduardo Mercado III[b]

[a] Universidad Nacional Autónoma de México, Mexico D.F., 04510, Mexico
[b] Department of Psychology, Park Hall, University at Buffalo, The State University of New York, Buffalo, NY, 14260, United States

ARTICLE INFO

Keywords:
ADHD
Behavior dynamics
Delay discounting
Impulsivity
Spontaneously hypertensive rat

ABSTRACT

Previous research has shown that spontaneously hypertensive rats (SHR) display higher levels of impulsive choice behavior, which is accompanied by a higher sensitivity to the delay of reinforcement, and by a normal sensitivity to the amount of reinforcement. Because those results were based on three different samples of subjects, in the present report we evaluated these three processes in the same individuals. SHR and WIS rats were exposed to concurrent-chains schedules in which the terminal links were manipulated to assess impulsivity, sensitivity to delay, and sensitivity to amount. For exploring impulsivity, a terminal link was associated with a small reinforcer (1 pellet) delivered after a short delay (2 s) while the other terminal link was associated with a larger reinforcer (4 pellets) delivered after a longer delay (28 s). For assessing sensitivity to delay, both alternatives delivered the same amount of reinforcement (1 pellet) and the only difference between them was in the delay before reinforcement delivery (2 s vs 28 s). For assessing sensitivity to amount, both alternatives were associated with the same delay (15 s), but the alternatives differed in the amount of reinforcement (1 vs 4 pellets). In addition to replicating previously observed effects within-subjects, we were interested in analyzing different aspects of the regularity of rats' actions in the choice task. The results confirmed that previous findings were not a consequence of between-group differences: SHR were more impulsive and more sensitive to delay, while their sensitivity to amount was normal. Analyses of response regularity indicated that SHR subjects were more periodic in their responses to levers and in their feeder entries, had a higher number of short-duration bouts of responding, and made a substantially higher number of switches between the alternatives. We discuss the potential implications of these findings for the possible behavioral mechanisms driving the increased sensitivity to delay in SHR.

1. Introduction

As an animal model of Attention Deficit Hyperactivity Disorder (ADHD), spontaneously hypertensive rats (SHR) have been evaluated in several behavioral procedures focused on different characteristics of ADHD, including inattention, hyperactivity, and impulsivity [for a review, see [1]]. Impulsivity, in particular, has received much attention in the validation of the SHR strain. Impulsivity is a complex, non-unitary construct [2] that can be divided into at least two broad categories: impulsive action and impulsive choice [3]. ADHD patients show signs of both impulsive action [4], and impulsive choice [5,6]; for this reason, SHR frequently have been evaluated in both kinds of impulsivity task. SHR often show signs of impulsive action [7–10], although exceptions have also been reported [11]. With regard to impulsive choice, the picture is less clear because about half of past studies have found higher impulsive choice [12–15], whereas the other half found impulsivity comparable to that of control strains [16–19]. A possible reason for these discrepant results is an unusually high within-strain variability related to two SHR subpopulations [19], one impulsive and one non-impulsive [18].

In most of the studies that have assessed impulsivity in SHR, rats must choose between a small reinforcer delivered after a short delay versus a larger reinforcer delivered after a longer delay. Past explanations of impulsive choice emphasize the concept of temporal discounting. However, the fact that alternatives differ in both amount of reinforcement and delay to reinforcement suggests at least two possible mechanisms of impulsive choice: an increased sensitivity to delay, and/or a diminished sensitivity to amount. In order to distinguish between these possibilities, Orduña [20] recently conducted three experiments, with different rats participating in each. For exploring impulsive choice, the animals chose between 1 pellet delivered after a short delay (2 s), and 4 pellets delivered after a longer delay (28 s). For assessing

* Corresponding author.
E-mail address: vladord@unam.mx (V. Orduña).

http://dx.doi.org/10.1016/j.bbr.2017.04.033
Received 28 January 2017; Received in revised form 6 April 2017; Accepted 17 April 2017
Available online 21 April 2017
0166-4328/

sensitivity to delay, rats were exposed to five different conditions; during each of them the alternatives differed exclusively in delay and the amount of reinforcement was kept constant. For assessing sensitivity to amount, in each of five conditions, the alternatives were associated with different magnitudes of reinforcement, while the delay was kept constant. The results showed a remarkably higher impulsivity in SHR, a higher sensitivity to delay in SHR, and the same sensitivity to amount in SHR and Wistar (WIS) rats.

Orduña [20] concluded that the impulsivity observed in SHR is related to an increased sensitivity to delay, discounting the alternative possibility that decreased sensitivity to amount led to impulsive choices. It remains possible, however, that in the sample of rats studied, the impulsive sub-population of SHR was over-represented in Experiments 1 and 2, while in Experiment 3 this subpopulation was under-represented. In order to overcome this potential confound, the first objective of the present experiment was to compare impulsivity, sensitivity to delay, and sensitivity to amount across SHR and WIS strains using a within-subjects design. WIS rats were selected as a control strain rather than Wistar Kyoto rats to avoid certain complications associated with the latter. Specifically, behavior in Wistar Kyoto rats exhibits some aspects of depression [21,22], making it difficult to attribute differences in impulsivity or hyperactivity to increased values in SHR.

A second objective of this experiment was to evaluate different aspects of the regularity of actions performed in the choice task [23] that could potentially increase our understanding of impulsivity in SHR. In particular, we were interested in quantifying sequential patterns in response selection and timing, as well as the periodicity of responding by the different strains during task performance. We predicted that impulsivity in SHR would be associated with atypical temporal patterns of responding that might contribute, at least in part, to their aberrant choice behavior.

2. Method

2.1. Intertemporal task

2.1.1. Subjects

Subjects were seven SHR and eight WIS rats, all experimentally naïve, female, and approximately 90 days old. After habituating rats to the conditions of the animal housing room, food intake was gradually decreased during seven days so that rats' body weights were reduced by 15%. During the experiment, rats had free access to food for 45 min after each experimental session ended, maintaining subjects at approximately 85% of their free feeding weight. Water was available ad lib in the home cage.

2.1.2. Apparatus

Nine operant conditioning chambers (MED Associates, Inc., Model ENV 008-VP) served as the experimental spaces. Each operant chamber measured 30.5 cm (long) × 24.1 cm (wide) × 21.0 cm (tall), and was enclosed in a sound-attenuating cubicle (MED Associates, Inc., Model ENV-022 M). The floor was a stainless steel grid comprised of nineteen 0.48 cm diameter bars (MED Associates, Inc., Model ENV-005). Each chamber had two retractable response levers (MED Associates, Inc., Model ENV-112CM) located 10.5 cm above the floor, in the front wall. Each lever was 4.8 cm wide. The visual stimuli used were a 28-V, 100-mA house light (MED Associates, Inc., Model ENV-215 M) situated 1.3 cm below the top of the chamber, at the center of the back wall, and two triple stimulus displays, each of them situated 1.5 cm above each lever. Each triple stimulus display consisted on a bar of acrylic mounted on an aluminum bar with three apertures of 1 cm of diameter and separated by .6 cm and it could project (from left to right) red, white and blue light via ultrabrillant LEDs. A 5.1 cm × 5.1 cm pellet receptacle (MED Associates, Inc., Model ENV-200R2 M), outfitted with a head-entry detector (ENV-254-CB), was located in the center of the front wall, 2.5 cm above the floor, and received, according to the schedule, 45 mg food pellets (Bio-Serv, Product F0165) from a circular modular pellet dispenser (MED Associates, Inc., Model ENV-203 M). The presentation of stimuli and the collection of data were controlled by personal computers using the Medstate programming language (Med-PC-IV, MED Associates, Inc.).

2.1.3. Procedure

2.1.3.1. Habituation, magazine training, and lever response training. When subjects were at 85% of their ad lib weight, they were habituated to the operant box over a 30 m session, during which there were 40 pellets available in the magazine. Habituation was considered finished when the subject ate all the pellets in a session. During the next two sessions, the white lights above both levers were turned on, and a pellet was dispensed every 45 s or whenever the rat pressed any lever. Most of the subjects pressed the lever during this procedure, and were then switched to a continuous reinforcement schedule. Subjects that did not press the lever were hand-shaped after two sessions of magazine training.

When subjects earned 80 reinforcers in any of the levers during a 30 m session, a random-interval 15 s schedule was introduced for responses in one of the levers. In this schedule, in each second there was a probability of 0.067 that a reinforcer would be available for the next response. The next day, this training was replicated in the other lever. The order in which subjects were trained in the different levers was counterbalanced. When subjects earned 50 reinforcers for two consecutive sessions in each lever, the value of the random-interval schedule was changed to 30 s; after two consecutive sessions in which subjects obtained 50 reinforcers, the pretraining was finished and the final procedure began the next session.

2.1.3.2. Concurrent-chains schedule. A concurrent-chains schedule with non-independent [24] VI 30 s schedules in the initial links and a 2 s Changeover Delay was employed. The 12 subintervals composing the VIs were derived using the Fleshler and Hoffman [25] progression. The discriminative stimuli for the initial links were the red/left lights from the triple stimulus displays. When one of the schedules was satisfied, the terminal link schedule began, the stimulus over the associated lever began to blink (0.25 s on, 0.25 s off), and the other lever was retracted and its corresponding light turned off. When either of the terminal links schedules was satisfied, the reinforcer was delivered. The differences between the two terminal links were the delay for delivering the reinforcer (associated to FI schedules completion) and/or the magnitude of reinforcement (see below). After reinforcement delivery, an intertrial interval (ITI) began, whose duration was adjusted so that there were 60 s from the time of entry to the terminal link, to the beginning of the next trial. During the ITI, all stimuli were turned off. After the ITI, this cycle continued until 40 trials were completed, which defined the end of the session.

This concurrent-chains schedule was employed to assess the impulsivity, the sensitivity to delay, and the sensitivity to amount, in three different conditions that were presented to the subjects in a counterbalanced order (always with strain equated). All subjects participated in the three conditions.

a Impulsivity Task: For assessing impulsivity, the terminal links presented the subjects two schedules of reinforcement that differed in both, the delay to and the amount of the reinforcer. In particular, one of the terminal links was associated to a fixed interval (FI) 2 s that delivered one pellet as the reinforcer (Smaller Sooner alternative, SS), while the other terminal link was associated to a FI 28 s and delivered 4 pellets as the reinforcer (Larger Later alternative, LL)

b Sensitivity to delay: The main difference from the previous condition was that the magnitude of reinforcement was kept constant between alternatives (one 45 mg pellet), so that the only difference