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Research report

Impulsivity and sensitivity to amount and delay of reinforcement in an animal model of ADHD

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HIGHLIGHTS

- Spontaneously hypertensive rats (SHR) and Wistar rats were evaluated in three choice tasks.
- Impulsivity, sensitivity to delay and sensitivity to amount of reinforcement were measured.
- SHR were found to be more impulsive, and more sensitive to delay.
- SHR and Wistar rats were found to be equally sensitive to amount of reinforcement.

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ABSTRACT

Previous research has been inconclusive about the degree of impulsivity displayed by spontaneously hypertensive rats (SHR), an animal model of Attention Deficit Hyperactivity Disorder (ADHD). In the present set of experiments, concurrent-chains schedules were employed in order to explore SHR's impulsivity, sensitivity to delay, and sensitivity to amount of reinforcement; Wistar rats (WIS) were used as comparison group. In the three experiments – performed with different subjects – non-independent variable interval 30 s schedules were presented in the initial links; the difference between experiments was in the terminal links. For exploring impulsivity, one of the terminal links (SS) was associated to a short delay (2 s) and a small reinforcer (1 pellet), whereas the other terminal link (LL) was associated to a longer delay (28 s) and a larger reinforcer (4 pellets). The results indicated a remarkably higher impulsivity in SHR. Because this impulsivity may have as potential mechanisms an increased sensitivity to delay and/or a decreased sensitivity to the amount of reinforcement, in experiments 2 and 3 these possibilities were examined. For assessing sensitivity to delay, the following pairs of fixed interval (FI) schedules were used in the terminal links in five conditions: 2–28, 6–24, 15–15, 24–6, 28–2 s; the magnitude of reinforcement was 1 pellet in all conditions for both alternatives. For assessing sensitivity to amount, in five conditions the alternatives were associated with different magnitudes of reinforcement: 1–5 pellets, 2–4, 3–3, 4–2 and 5–1 in left–right alternatives, respectively; the delay to reinforcement was controlled by a FI 15 s in all conditions and for both alternatives. The sensitivity to delay and the sensitivity to amount were calculated according to the Generalized Matching Law. The results indicated a higher sensitivity to delay in SHR, and the same sensitivity to amount in SHR and WIS rats. These results suggest that the increased sensitivity to delay influences the high level of impulsivity observed in SHR.

1. Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a psychiatric disorder with a high prevalence in both children [1] and adults [2]. One aspect of the disorder that has received great attention is impulsivity, which is now recognized as a non-unitary construct [3] that at least can be divided into two broad categories: impulsive action and impulsive choice [4]. Impulsive action refers to the inability to withhold a prepotent response [4]; impulsive choice is characterized by the selection of a smaller more immediate reward in preference of a larger delayed one [5]. Although these two aspects of impulsivity have been demonstrated to be unrelated in both humans and rats [6], it has been shown that ADHD patients show signs of both, impulsive action [7] and impulsive choice [8,9].

In order to find an adequate animal model of ADHD that mimics the aspects of impulsive action and choice observed in ADHD

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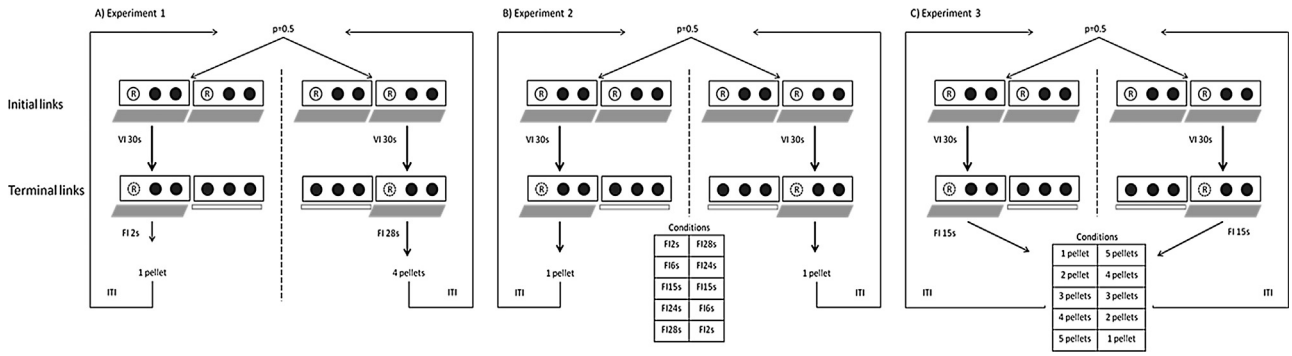

Fig. 1. Diagrams of the procedure used in the different experiments. With $p = .5$, the left or right initial link were selected to deliver reinforcement, but both alternatives were available and signaled by a discriminative stimulus (R). The first response in that alternative after a randomly chosen sub-interval resulted in the presentation of the terminal link stimulus, and in the removal of the alternative lever and its associated stimulus. When the terminal link's FI requirement was satisfied, the reinforcer was delivered, and a variable-length ITI began, after which another trial initiated. In Experiment 1 (left panel) the alternatives differed in both, the delay to reinforcement and its amount. In Experiment 2 (central panel), the alternatives were associated to the same amount of reinforcement, and only differed in the delays, which were varied across conditions. In Experiment 3 (right panel), the alternatives were associated to the same delay to reinforcement, and only differed in the amount of reinforcement, which was varied across conditions.

patients, spontaneously hypertensive rats (SHR) have been evaluated. It is generally accepted that SHR show signs of impulsive action [10–13], although some exceptions have been reported [14]. Regarding impulsive choice, the evidence is less clear, as the same number of studies has reported either greater impulsivity in SHR or equal impulsivity as the controls. The delayed reinforcement task [15] has been extensively employed to study impulsive choice; in this procedure, animals are offered a choice between 1 pellet immediately, and four pellets with a delay that starts in 0 s, and is progressively increased across blocks of a session, or across sessions. Impulsivity is reflected in a faster decay of the preference for the larger magnitude alternative. Using this procedure, Fox et al. [16] reported that SHR have a higher preference for the smaller immediate alternative than Wistar Kyoto (WKY) rats (see also [17]). This finding has been replicated by Ibias and Pellon [18], and extended to the use of Wistar (WIS) rats as control group. However, in a posterior study by the same research group [19], the same level of preference was found for the larger magnitude across delays in the majority of the evaluations performed (e.g. see their Figs. 1a and 2a). This same trend was found by Pardey et al. [20], who found the same degree of preference in SHR vs WKY for the larger magnitude alternative in the majority of the 8 sessions in which the procedure was conducted. A normal level of impulsivity in SHR compared to WKY was originally reported by Adriani et al. [21]. The impulsivity in SHR has also been measured using the adjusting delay schedule. In this procedure, subjects are offered a choice between a single pellet obtained immediately, and three pellets obtained after a delay (e.g., 3 s), which is adjusted depending on the subject's previous choices according to the following rules: (a) if the subject prefers the smaller alternative, the adjusting delay is decreased, (b) if subject prefers the larger magnitude alternative, the adjusting delay is increased, and (c) if subject is indifferent, the adjusting delay is not changed. The dependent variable in this schedule is the value of the adjusting delay in stability, with smaller values representing higher levels of impulsivity. Using this schedule, it has been reported higher impulsivity in SHR vs WKY, but the same impulsivity in SHR than in Sprague Dawley [22], and WIS rats [19]. The analysis of the results of other procedures does not

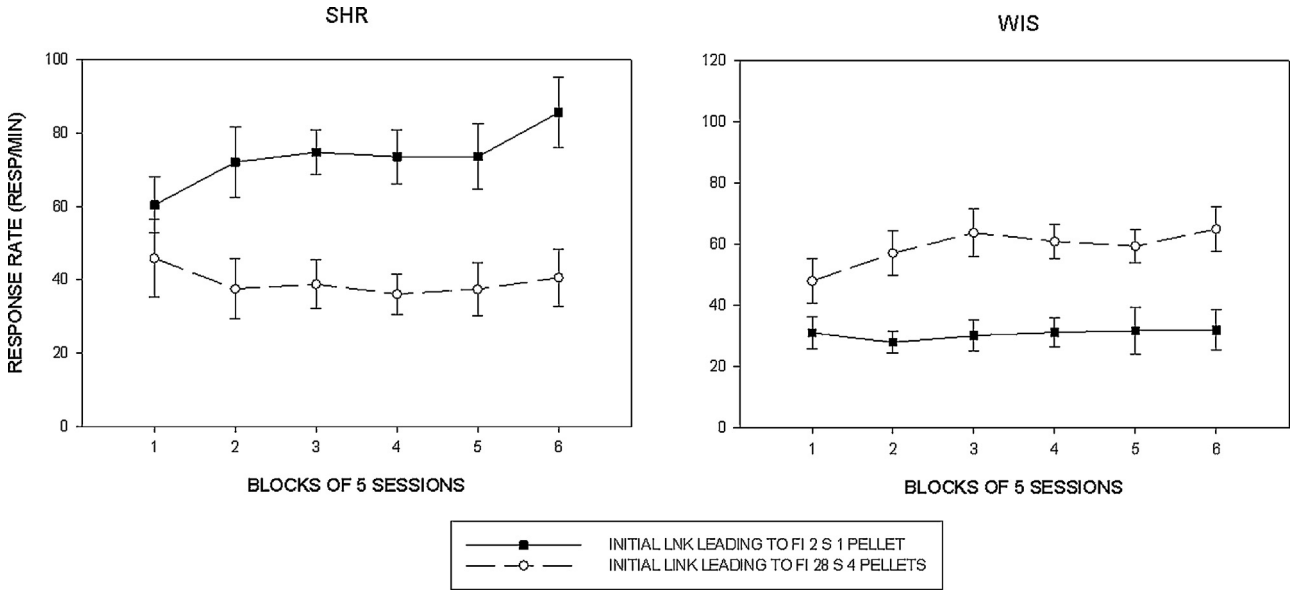

Fig. 2. Data points represent group mean ± SEM of the absolute response rate in the initial links of the concurrent-chains schedule during the 30 sessions of the experiment. Closed symbols represent the response rate in the initial link leading to the terminal link associated with FI 2 s and one pellet as the reinforcer; open symbols represent the response rate in the initial link leading to the terminal link associated with FI 28 s and four pellets as the reinforcer. Left panel shows data from SHR; right panel shows data from WIS rats.