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Research report

Rats exhibit reference-dependent choice behavior

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HIGHLIGHTS

- The origin of reference dependence will help delineate the neural mechanism of choice.
- We developed 'a novel paradigm' based on a modification of the "T" maze.
- Rats showed reference-dependent behavior by avoiding the option framed as a loss.
- Reference dependence is likely a conserved from the emergence of mammals.

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ABSTRACT

Human preferences depend on whether a chosen outcome appears to be a loss or a gain compared with what had been expected, *i.e.*, in comparison to a reference point. Because reference dependence has such a strong influence on human decision-making, it is important to uncover its origins, which will in turn help delineate the underlying mechanisms. It remains unknown whether rats use reference points in decision-making, and yet, the study of rats could help address the question of whether reference dependence is evolutionarily conserved among mammals and could provide a nonhuman animal model to investigate the neural mechanisms underlying this important cognitive process. The aim of the current study was to determine whether rats show reference-dependent choice behavior. We developed a novel paradigm by modifying the "T" maze by installing "pockets" to the left and right of the "T" stem that held reward pellets so rats would potentially develop reference values for each option prior to choice. We found that the rats were indeed sensitive to the way alternatives were presented. That is, they exhibited reference-dependent choice behavior by avoiding the choice option framed as a loss (*e.g.*, having four reward pellets in the pocket, but receiving only one), at least under conditions with certain outcomes and clear differences between the reference and outcome quantities. Despite the small number of rats in this study, this species-level capacity suggests that reference dependence in general and loss aversion in particular may be conserved traits that evolved at or before the emergence of mammals.

1. Introduction

According to expected utility theory [1], the preference between choice options should depend only on the utility received from each option; however, substantial evidence suggests that human preferences are affected by other factors. For example, our preferences depend on whether outcomes appear to be losses or gains compared with what had been expected, *i.e.*, in comparison to a reference point [2]. Moreover, people avoid loss, even in cases when the actual outcome is better than other alternatives. Because decision-making based on reference points can lead to suboptimal and thus apparently irrational choices, and because such behavior can have a wide-ranging impact on human economic and social behavior, it is important to understand the underlying causes of this cognitive strategy.

On the one hand, the use of reference points in decision-making could result from the complexities of human society, culture, and language; on the other hand, it could instead reflect an evolved cognitive architecture that conferred a selective advantage to our evolutionary ancestors, *i.e.*, it could be an adaptation sculpted by natural selection. To delineate its origins, it is important to conduct a comparative analysis that can test these general possibilities by

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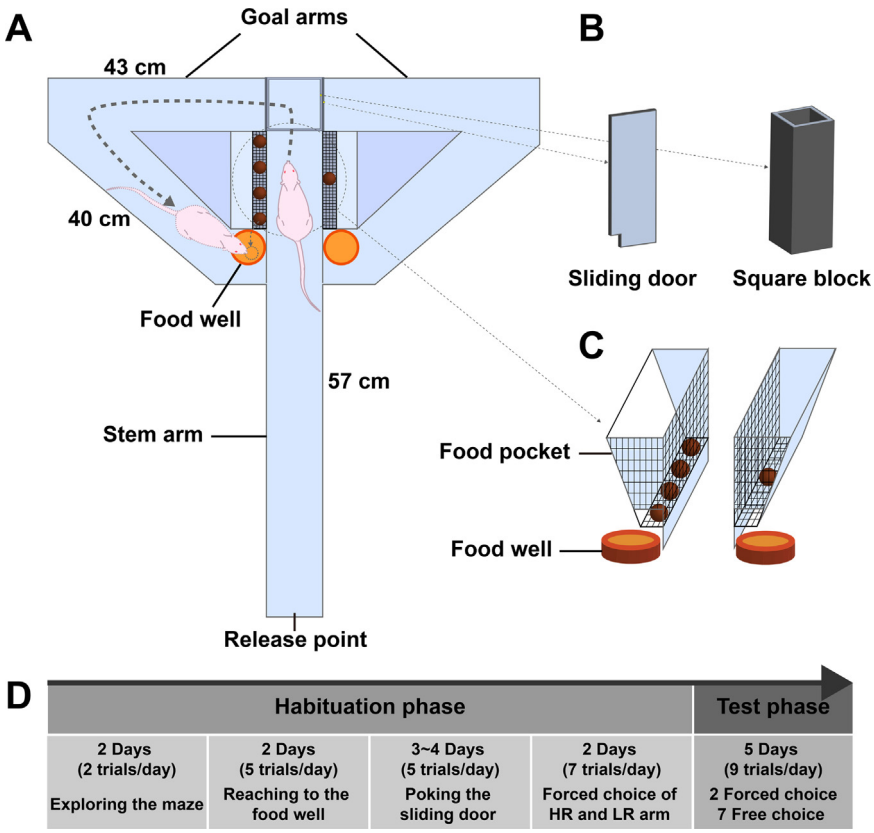

Fig. 1. Schematic of the apparatus and behavioral experiment design. (A) Schematic top view of the modified T-maze. The rats were allowed to explore the reward presented in the food pockets located in the stem arm just before the junction. After exposure to the presented reward, the rats could then choose one arm. (B) Rectangular removable block (right) and the rectangular-piece removable sliding door (left). The two components were designed to provide the rats with more opportunity to explore the presented reward before an actual decision was made and to prevent impulsive choices. (C) Magnified view of the food pocket. Food rewards were presented in meshed food pockets to provide potential reference points for each arm option. Each food pocket had an exit hole (3 × 3) for providing the selected food when the rats arrived at the food well. (D) Experimental procedure. The habituation and test phases of the experimental procedure are depicted.

determining whether the ability is shared with other species that do not share our complex society, culture and language. Recent nonhuman animal studies have found behavioral biases similar to those in humans [3–8]. Most of these species are relatively large-brained, however, and we know that their last common ancestor had a relatively small brain [9,10]. Thus, it remains unclear whether the behavioral biases in question are homologous (*i.e.*, inherited from a common ancestor) or result instead from parallel evolution under similar selection pressures. Further comparative work is therefore necessary to clarify the origins of these heuristics and biases such as reference dependence in decision-making. To this end, it is useful to study a species that closely resembles a common ancestor of humans to determine when the trait may have arisen in the human lineage. With respect to our mammalian lineage, the rodent appears to be a reasonable extant species that resembles an early mammalian ancestor that could help address the question of whether reference dependence is shared among mammals and thus evolved at or before the emergence of mammals.

Several laboratory studies have shown that rats exhibit economic behaviors similar to humans' in terms of consumer demand, value theory and labor supply [11–13]. These results, together with recent findings in decision-making under risk [14,15] and intertemporal choice [16] in rats, suggest the potential presence of behavioral biases that reflect some comparable cognitive strategies to those of humans. However, whether the rat actually exhibits reference dependence remains unknown. In fact, it has been suggested that rats may not be able to learn a task that can test for such higher-cognitive phenomena [11–13].

Therefore, the aim of the current study was to investigate whether rats exhibit behavioral biases in their economic decisions that depend on the problem setting (*i.e.*, how the problem is *framed*) and resultant reference points that are formed. To do so, we developed a novel paradigm to study framing effects based on the problem structure that may lead to reference points in rodent decision-making. We modified a conventional T-maze that controlled for impulsivity and provided a means to display different amounts of food items on either wall of the "T" stem to allow the potential development of reference points prior to choice. We then examined whether the rats' preferences reflected the influence of reference points based on whether the choice options were perceived as gains or losses as in humans and other select nonhuman animals [17]. A further motivation for developing this paradigm to study rats is that they provide an excellent nonhuman animal model that can be used to delineate the specific behavioral, cognitive and neural mechanisms underlying important and ubiquitous heuristics and biases [18,19].

2. Methods

2.1. Subjects

Nine seven-week-old male Sprague-Dawley rats weighing 250–350 g were used in this study. All procedures were approved by the KAIST Institutional Animal Care and Use Committee. After arrival from the supplier (Koatec, Pyeongtaek, South Korea), the rats were housed in transparent Plexiglas cages at 22 °C with 50–60% humidity. They were maintained on a 12-h light/dark cycle. Food