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Exploration of a novel object in late adolescence predicts novelty-seeking behavior in adulthood: Associations among behavioral responses in four novelty-seeking tests

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ABSTRACT

The sensation/novelty seeking behavioral trait refers to the exploration/preference for a novel environment. Novelty seeking increases during late adolescence and it has been associated with several neurobehavioral disorders. In this experiment, we asked whether inbred Roman high- and low-avoidance (RHA-I, RLA-I) rats (1) differ in novelty seeking in late adolescence and (2) whether late adolescent novelty seeking predicts this trait in adulthood. Thirty six male RHA-I and 36 RLA-I rats were exposed to a novel object exploration (NOE) test during late adolescence (pnd: 52–59; Dependent variables: contact latency, contact time, contact frequency). Head-dipping (hole-board, HB), time and visits to a novel-arm (Y-maze), and latency-in and emergence latency (emergence test) were registered in adulthood (pnd: 83–105). The results showed strain differences in all these tests (RHA-I > RLA-I). Factor analysis (RHA-I + RLA-I) revealed two clusters. The first one grouped HB and emergence test measures. The second one grouped NOE and Y-maze variables. Time exploring a novel object (NOE) was a significant predictor of novel arm time (RHA-I + RLA, RHA-I); contact latency was a significant predictor of novel arm frequency (RLA-I). Present results show consistent behavioral associations across four novelty-seeking tests and suggest that late adolescent novelty seeking predicts this genetically-influenced temperamental trait in adult Roman rats.

1. Introduction

In animal behavioral research, trait is defined as a pattern of specific behavior which differs among individuals, but which is relatively constant within subjects across time and situations (Gosling, 2001). Behavioral traits resemble types, temperaments or personalities in humans, and have been proposed as critical for individual adaptive capacity, as well as for vulnerability or resistance to various pathologies (Steimer and Driscoll, 2005).

Several methodological approaches have been developed to analyze inter-individual differences in behavior in non-human animals (see Pawlak et al., 2008, for review). One of the most commonly used involves selectively breeding animals on the basis of divergent behavioral dispositions such as addiction proneness, exploration, fearfulness or novelty seeking, among others. The results of this psychogenetic selection is the creation of strains of animals showing consistent and stable patterns of behaviors over generations, providing a useful tool to study the biological basis of personality (Driscoll et al., 2009; Steimer and Driscoll, 2005). One of the behavioral traits most extensively studied by using this approach is sensation seeking. In humans, it is described as the need for varied, novel, complex and intense sensations and experiences, and willingness to take physical and social risks for the sake of such experiences (Zuckerman, 1994). The parallel concept in

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research with nonhuman animals, novelty or sensation seeking, has been used to describe high levels of exploratory activity in response to novel environments and unknown objects or stimuli (Bardo et al., 1996). A distinction has been recently proposed between "sensation seeking" tests (based on exposure to inescapable novel environments) and "novelty seeking" tests (involving preference for novelty in free-choice tasks; see Flagel et al., 2014). The locomotor activity exhibited in a novel environment from which there is no escape (e.g., horizontal activation in a circular corridor or vertical activation—rearing-in an open field) is frequently measured in sensation seeking tests (Piazza et al., 1989; Pawlak and Schwarting, 2002). By contrast, novelty seeking is commonly defined as a preference for a novel context (or object) compared with a familiar context (Pelloux et al., 2004, 2006, 2015; Pisula, 2003; Dellu et al., 1996), thus usually involving two-trial testing procedures (and, thus, learning/habituation processes) and giving animals a choice to either approach or avoid novelty (Bardo et al., 2013; Meyer et al., 2010). Finally, the hole-board (HB) test consists in an open field apparatus with equidistant holes in the floor in which head-dipping behavior is used as an index of novelty reactivity (File and Wardill, 1975). This test has been conceptualized both as an inescapable and a free-choice-based novelty test (Bardo et al., 2013).

Mixing findings have been found in the literature with respect to the relationship between sensation and novelty seeking, suggesting that these tests may be measuring different aspects of novelty seeking that are mediated by partially different neurobiological processes (Beckman et al., 2011). In this regard (a) elevated reactivity to inescapable novelty (in terms of locomotor activity) is frequently unrelated to preference for novel environments (Cain et al., 2004; Beckman et al., 2011; Flagel et al., 2014; Meyer et al., 2010); (b) whereas exploratory behavior in forced novelty tests seems to be a good predictor of the initial proneness to take drugs (Belin et al., 2008; Flagel et al., 2014), preference for novelty in free-choice tasks correlates with compulsive drug taking and severity of addictive behavior (Belin et al., 2011; Belin and Deroche-Gamonet, 2012; Flagel et al., 2010); and (c) although both sensation and novelty seeking are related to the mesolimbic dopaminergic system (Bardo et al., 2013), only responses to inescapable novelty seem to elevate corticosterone levels and are associated with activation of the stress axis (Bardo et al., 1996; Kabbaj, 2006), suggesting that inescapable novelty may represent a stressful rather than positive incentive value experience in rodents (Norbury and Husain, 2015). Overall, this evidence suggests that novelty/sensation seeking is not a unitary neurobehavioral trait, but one that includes some behaviors differentially associated to a variety of neurobehavioral disorders (Duclot et al., 2011; Flagel et al., 2014; Norbury and Husain, 2015). Nevertheless, this conclusion deserves further investigation considering that discordant results with this sensation/novelty seeking distinction have also been reported (e.g., Dellu et al., 1996; Kabbaj, 2006; Kabbaj et al., 2000).

Although substantial behavioral consistency across life cycle has been observed (Ray and Hansen, 2005), responses involving novelty seeking seem to reach a peak in adolescence (especially in the late period), and then decline (Laviola et al., 1999; Spear, 2002). Interestingly, adolescence constitutes a life cycle period in which different patterns of normal but maladaptive outcomes are common, and mental illnesses often manifest (Compas et al., 1995; Sturman and Moghaddam, 2011); for example, increased negative affect, higher sensitivity to stressful events, increased impulsivity, and a greater propensity to take risks, including the use of psychoactive agents (Milivojevik and Covault, 2013; Steinberg, 2004). Therefore, identifying individual differences in sensation seeking during adolescence could be used as a risk marker for vulnerability to psychopathology with basic and clinical implications.

In this experiment, we asked whether inbred Roman high- and low-avoidance (RHA-I, RLA-I) rats (1) differ in novelty seeking in late adolescence and (2) whether late adolescent novelty seeking predicts this trait in adulthood. Although initially selected and bred on the basis of their good (RHA-I) vs. poor (RLA-I) acquisition of the two-way active—shuttle box- avoidance response, the Roman rat lines/strains also show divergent profiles in a host of correlated behavioral traits, including anxiety/fearfulness (Driscoll and Bättig, 1982; Driscoll et al., 1998, 2009; Escorihuela et al., 1999; Fernández-Teruel et al., 1997; López-Aumatell et al., 2009), reactivity to frustration (Gómez et al., 2009; Rosas et al., 2007), impulsivity (Klein et al., 2014; Moreno et al., 2010), coping styles in novel/stressful environments (Díaz-Morán et al., 2012, 2013; Escorihuela et al., 1999; Estanislau et al., 2013; Fernández-Teruel et al., 1992a, 2002a; Giorgi et al., 2003; Piras et al., 2010, 2014; Pisula, 2003; Steimer and Driscollk 2003), consumption of palatable tastes (Fernández-Teruel et al., 2002a; Razafimanalina et al., 1996), vulnerability to addiction (Giorgi et al., 2007), sexual behavior (Sanna et al., 2015) and novelty seeking (Driscoll et al., 2009; Escorihuela et al., 1999; Fernández-Teruel et al., 1992a, 2002a; Giorgi et al., 2007; Guitart-Masip et al., 2006a). Within this respect, both outbred and inbred adult RHA rats exhibit more novelty seeking responses than their RLA counterparts in a variety of behavioral tests based on both inescapable and free-choice situations, including head-dipping in the HB, preference for a novel arm in the Y-maze, and preference for novelty introduced in a familiarized environment, among others (Escorihuela et al., 1999; Fernández-Teruel et al., 1992a, 2002a; Guitart-Masip et al., 2006a; Manzo et al., 2014; Pisula, 2003; Steimer et al., 1998). Strain differences have also been observed in young animals (pnd: 30–40) exposed to novelty-based situations, including the dark-light hexagonal tunnel maze and the timidity test (Escorihuela et al., 1999; Fernández-Teruel et al., 1991, 1992b, 2002b). Many of these strain differences have been shown to be enduringly abolished by neonatal handling (e.g., Fernández-Teruel et al., 1991, 1992a,b, 2002b; Río-Alamos et al., 2015), suggesting that genetically-influenced behavioral traits can be modulated by environmental events (Fernández-Teruel et al., 1997, 2002b).

Based on the evidence reviewed above, indicating behavioral consistency across age and sensation/novelty seeking tests in Roman rats, we predicted that (1) RHA-I rats would exhibit more novelty seeking responses than RLA-I when tested in late adolescence; and (2) novelty seeking in late adolescence would predict novelty seeking behavior in adulthood. Present study will also allow us to identify associations in behavioral responses across four novelty-seeking tests.

2. Method

2.1. Subjects

The subjects were 72 inbred male rats (36 RHA-I, 36 RLA-I) obtained from the colony established at the Autonomous University of Barcelona, Spain. Animals were housed in pairs with free access to food and water throughout the experiment, in a room kept at 22–23 °C, and subjected to a 12:12 h light cycle (lights on at 08:00 h). Animals were tested between 9:30–13:00 a.m. The experiment was conducted following the European Union directive guidelines for the use of animals in research (2010/63/EU) and the Spanish Law (RD 53/2013).

2.2. Apparatus

In order to assess novelty seeking behavior during late adolescence (pnd: 52–59), a novel object exploration (NOE) test was conducted (see also Río-Alamos et al., 2015). This involved the assessment of the exploratory responses of Roman rats when a