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# Personality profiles of the Namaqua rock mouse (Micaelamys namaquensis), the Mozambique thicket rat (Grammomys cometes) and the woodland dormouse (Graphiurus murinus)

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# Personality profiles of the Namaqua rock mouse (*Micaelamys namaquensis*), the Mozambique thicket rat (*Grammomys cometes*) and the woodland dormouse (*Graphiurus murinus*)

by

**Nthabiseng Mampa**

**A dissertation submitted in fulfilment of the requirements**
**for the degree of MASTER OF SCIENCE (DISSERTATION)**
**in the Faculty of Science**
**at the University of the Witwatersrand**

September 2023

# Declaration

I declare that this dissertation is my own, unaided work. It is being submitted for the Degree of Master of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other university.



_____

02 September 2023

# Abstract

Personality is the variation in behaviour amongst individuals, which arises as a result of genetic differences and exposure to different environments. Although the term is usually associated with humans, multiple studies have found evidence for personality in other non-human taxa such as rodents, fish, reptiles, and primates, which ultimately showed that personality is ubiquitous. Personality determines how individuals react in different situations throughout their life, such as when they encounter stressors, interact with their conspecifics, prey and predators, how they select seeds and the distance to which they disperse, when displaying aggression, and when facing novel objects, their propensity to take risks, among other behaviours. Personality traits are most described using terms such as bold and shy, aggressive, docile, and avoidant. These terms relate to individual coping style, temperament, and correlated traits. Given the importance of personality, this study was aimed at studying personality in the woodland dormouse, Mozambique thicket rat and Namaqua rock mouse, in order to understand personality and how it varies among species and within species, i.e., between sexes. In consideration of the importance of genetic factors in the development of personality, it was expected that there would be differences among the three rodent species despite being exposed to similar environmental conditions. It was also expected that there would be differences between males and females within each species due to the influence of sex hormones on personality. Two standardised personality tests were conducted, namely the open-field and the novel object test to measure boldness, shyness, exploration, and avoidance when facing novelty by observing the frequency and duration of the behavioural responses exhibited during these tests. The study showed that rodents react to novelty by showing both shy and bold behavioural responses. However, the three species differ from each other in boldness and shyness. Males and females also showed differences in their behavioural responses to novelty. Overall, this study highlighted two strategies used for survival in nature. In consideration of this, it would be beneficial to preserve pristine forests to protect keystone structures that are crucial for preserving diversity in species and personality types. However, more studies on long-term trapping and correlation with personality tests could reveal more information on the personality profiles and their subsequent consequences.

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# Introduction

## 1. A broad overview of personality

### 1.1 What is personality?

Personality is the variation in behaviour amongst individuals, which is expressed in how they repeatedly behave in different situations, consequently contributing to their fitness (Wilson 1998; Sih *et al*. 2004; Gosling 2008; Koolhaas 2010). Previously, this variation was sometimes referred to as temperament, behavioural syndrome, and coping style; however, personality is a more widely accepted and used term for both humans and non-human taxa (Gosling 2008).

Coping style is defined as how individuals handle challenges or stressors that they encounter in their environment, and this varies amongst individuals (Koolhaas *et al*. 1999). An individual can either display a proactive or reactive coping style, depending on the level of aggression (Benus *et al*. 1991; Koolhaas *et al*. 1999; Koolhaas *et al*. 2008; Koolhaas *et al*. 2010). Individuals that have a proactive coping style tend to display overt aggressive behaviours, with shorter latency to attack (Benus *et al*. 1991; Koolhaas *et al*. 1999; Koolhaas *et al*. 2008). On the other hand, individuals with a reactive coping style are less likely to show aggression and have a longer latency to attack (Benus *et al*. 1991; Koolhaas *et al*. 1999; Koolhaas *et al*. 2008).

Personality traits are linked to each other, for example, aggression is linked with characteristics such as boldness, and similarly, non-aggression is linked with shyness (Sih *et al*. 2004). These links are observed in different situations and under different context; thus, they are referred to as behavioural syndromes (Mortez *et al*. 2004; Sih *et al*. 2004). The correlation between behavioural traits suggests that genes and hormones can influence more than one behavioural trait (Mortez *et al*. 2004). Furthermore, when the same behavioural syndrome is repeatedly observed in an individual across different situations and context, it is deemed as the individual's behaviour type, and it is therefore expected in all other different contexts as well (Sih *et al*. 2004).

Temperament refers to an individual's style of performing behaviours, which is a result of the personality traits that they have developed in the early stages of their life (Goldsmith *et al*.

1987). Due to the variation in temperament, individuals behave differently from each other even when the motivation is the same (Goldsmith *et al*. 1987; Réale *et al*. 2000). For example, bighorn sheep (*Ovis canadensis*) show differences in willingness to enter a salt-baited trap depending on their temperament (Réale *et al*. 2000). Sheep that are bold and less averse to taking risks, have a shorter latency in entering traps and struggle more when they are handled; while the shyer sheep, take longer to enter the baited trap and do not struggle as much when they are handled (Réale *et al*. 2000). Boldness, which is an individual's propensity to take risks, and their level of docility, are essential components of temperament (Réale *et al*. 2000). According to Gosling (2001), some researchers prefer to use the term 'temperament' over 'personality' because of its association with humans, although the concepts are very similar. However, personality is a more inclusive term (Goldsmith *et al*. 1987).

Personality is often described using terms such as bold and shy, depending on how an individual consistently behaves in various situations. For example, when they encounter novel environments and novel objects, when they interact with their conspecifics, when and how they display aggression, and lastly how they respond to stressors and other stimuli (Sih *et al*. 2004; Sih *et al.* 2012; Brehm 2018). Shy individuals are categorised as those that tend to be timid, avoidant, display relatively less aggressive and have an aversion to risky behaviours, whilst bold individuals are categorised as those that tend to display less aversion to novelty and threats, act more proactively and display dominance (Koolhaas *et al*. 1999; Mortez *et al*. 2004; Sih *et al*. 2004; Koolhaas *et al*. 2008; Rupia *et al*. 2016; Yuen *et al*. 2017). For example, Brehm (2018), found that personality affected seed choice as well as the distance and location for caching seeds in small mammal species such as deer mouse (*Peromyscus maniculatus*), southern red-backed vole (*Myodes gapperi*) and northern short-tailed shrew (*Blarina brevicauda*). Shy rodents preferred smaller seeds and dispersed them at shorter distances, while bold rodents selected larger seeds and dispersed them at longer distances; despite this, it also exposes them to a greater risk such as larger seeds require more handling time and travelling further exposes them to predators for longer (Brehm 2018).

### 1.1.1 Development of personality

Various proximate and evolutionary mechanisms work in cohorts during the development of personality in animals (Figure 1) (Sih *et al*. 2004). These mechanisms are highly influenced by genes, environmental factors, neuroendocrine mechanisms, and life experiences (Figure 1)

(Bouchard 1994; Koolhaas *et al*. 1999; Dingemanse *et al*. 2002; Sih *et al*. 2004; van Oers *et al*. 2005; Johnson *et al*. 2008; Stamps and Groothuis 2010; von Borell *et al*. 2016).

#### 1.1.1.1 Genetic influences on personality

Behavioural phenotypes are mostly stable or consistent, this suggests that personality is partially heritable (Kagan *et al*. 1988). Through twin (human) studies, researchers determined that genetic factors account for about 50% of the differences in personality traits and the rest arise due to the influence of environmental factors (Bouchard 1994; Johnson *et al*. 2008). Genes are important in the development of coping styles, which is an important component of personality (Koolhaas *et al*. 1999). Seeing that personality contributes to an individual's fitness, favourable traits are preserved through natural selection (van Oers *et al*. 2005). Existing literature clearly indicates that important components of personality such as whether an individual is shy or bold, exploratory, aversive, and aggressive or not, are heritable traits (Kagan *et al*. 1988; Dingemanse *et al*. 2002; Brown *et al*. 2007; Matzel *et al*. 2019). For example, Dingemanse *et al*. (2002), reported that exploratory behaviours in wild great tits (*Parus major*) are heritable, and in addition, how individuals react in novel environments is influenced by the characteristics inherited from their parents. Kagan *et al*. (1988), concluded from his studies that most animals that display an aversion to novelty from the early stages of development, which indicated that shyness is heavily influenced by genetics.

Similarly, Brown *et al*. (2007), also found evidence of heritability for shyness-boldness in fish (*Brachyraphis episcopi*), by comparing fish whose parents were caught from high-predation streams to those whose parents were from low-predation risk using behavioural tests. The results of this study revealed that fish whose parents were subjected to a high-predation risk showed a higher latency towards exploring novel environments (i.e., shy) when compared to fish whose parents had experienced low-predation risk (i.e., bold) (Brown *et al*. 2007). Seeing that their offspring show similar degrees of shyness or boldness, it seemed likely that these traits are heritable to some degree (Brown *et al*. 2007).

Aggression is important in the social hierarchy for survival because animals can defend themselves and their resources (Benus et al. 1991). Thus, it would be beneficial for this trait to be heritable (Benus *et al*. 1991; Koolhaas *et al*. 2008). Supporting evidence of this is reported by Benus *et al*. (1991) in wild house mice, (*Mus musculus domesticus*); whereby the mice that were selected from parents with a short latency to attack also had a short latency to attack, and similarly the mice that were selected from parents with a longer latency to attack

also displayed a longer latency to attack. This study thus revealed that the latency to attack, which is an indicator of aggression, is influenced by genetics (Benus *et al*. 1991). However, while some researchers use phenotypic stability as evidence for the heritability of individual behavioural differences, it is important to note that environmental factors can reinforce some differences in phenotypes in flexible individuals and they can also erase those differences; thus, heritability alone is not enough to explain the origin of differences in individuals (Kagan *et al*. 1988).

#### 1.1.1.2 Neuroendocrine mechanisms as drivers of personality.

Personality traits are inherited through genes, but their expression is modulated by the neuroendocrine systems through different hormone secretions (Benus *et al*. 1991). An example of how the neuroendocrine system influences personality can be seen in the levels of secretion of testosterone and oestrogen and their effects on aggression, which is an important component of coping style and personality (Albert *et al*. 1989; Benus *et al*. 1991; Koolhaas *et al*. 1999; Filby *et al*. 2012).

In most species, males tend to be more aggressive than their female counterparts; this suggests that high concentrations of androgens in males could be the drivers of aggression (Benus *et al*. 1991). For example, studies have shown that highly aggressive male brown rats (*Rattus norvegicus*) have higher testosterone concentration levels than their female counterparts (Koolhaas *et al*. 1999). Similar results were reported for highly aggressive male house mice (*Mus musculus domesticus)*, therefore suggesting that testosterone possibly regulates the expression of aggression in both rats and mice (Albert *et al*. 1989; Koolhaas *et al*. 1999). Oestrogen also has important consequences on personality in animals (Benus *et al*. 1991; Koolhaas *et al*. 2008). For example, exposure to oestrogen has an inhibiting effect on how dominant male zebrafish (*Danio rerio*) display aggression toward their conspecifics, specifically towards subordinate males and dominant females (Filby *et al*. 2012).

#### 1.1.1.3 Environmental factors shape personality.

Environmental factors are important in the development of an individual's personality and can also alter and shape personality traits at the later stages of development in an individual's life (Kagan *et al*. 1988; Bouchard 1994; Johnson *et al*. 2008; Matzel *et al*. 2019). Factors such as the level of predation risk, population density, the timing of natal dispersal, and anthropogenic alterations to habitats such as changes in land use and degradation, all expose

individuals to negative or positive cues in their early life, thus shaping the development of personality traits (Kagan *et al*. 1988; Bouchard 1994; Dingemanse *et al*. 2003; Johnson *et al*. 2008; Matzel *et al*. 2019). Experiences in the latter part of an individual's life can also alter their personality due to behavioural plasticity (Sih *et al*. 2004).

*a) Predation:* The level of predation risk in an individual's environment affects their temperament by exposing them to a negative stimulus which requires them to alter their behaviour (Wilson *et al*. 1993). A good example of this is shown in the studies by Brown and Braithwaite (2004), who found variations in temperament (shyness and boldness) amongst bishop fish (*Brachyrhaphis episcopi*) and its correlation with the level of predation risk in their environment. Fish from higher predation areas were bolder, compared to fish sampled from lower predation environments. Consequently, over time, the population moves towards one side of the shy-bold continuum due to having to develop characteristics that are best suitable for the level of predation in their environment (Wilson *et al*. 1993). Therefore, the effect of predation risk on personality differences is significant at the individual and population level (Wilson *et al*. 1993).

*b) Anthropogenic changes:* Changes to an environment due to human activities such as changes in land use for agriculture, most especially monoculture and other forms of habitat degradation, can cause individuals to alter their behaviour through phenotypic plasticity (Villegas-Ríos *et al*. 2017; Brehm *et al*. 2019; Wilson *et al*. 2020). Over time, these changes in behaviour result in the loss of some keystone structures, further influencing how personality types are distributed in one population (Villegas-Ríos *et al*. 2017; Brehm *et al*. 2019; Wilson *et al*. 2020). For example, personality studies by Brehm *et al*. (2019), on small species, such as deer mouse (*Peromyscus maniculatus*), southern red-backed vole (*Myodes gapperi*) and northern short-tailed shrew (*Blarina brevicauda*) revealed that the distribution of bold and shy individuals in a forest habitat is highly influenced by anthropogenic changes. The African striped mouse (*Rhadomys pumilio*) also shows plasticity in its social behaviours as a response to anthropogenic changes to the environment (Rymer *et al*. 2013). Anthropogenic changes to the environment cause and worsen habitat degradation, which in turn affects the population density of the striped mouse i.e., worse conditions support a lower population density (Rymer *et al*. 2013). To survive, the striped mice chose between a solitary and a communal rearing strategy depending on the population density at the time (Rymer *et al*. 2013).

*c) Population density*: The population density in the rearing environment also affects personality. For example, field crickets (*Gryllus integer*) reared in the presence of conspecifics are influenced by the acoustic sexual signals they hear in the early stages of life (DiRienzo *et al*. 2012). Calls from conspecifics were used to gauge population densities, hearing fewer calls from other crickets is indicative of low population density, which in turn means that there will be less competition for resources and mates (DiRienzo *et al*. 2012). Consequently, crickets could either be bold, if they anticipated having to compete with many conspecifics for resources or be shy if they did not anticipate having to fight with many conspecifics for resources (DiRienzo *et al*. 2012).

#### 1.1.1.4 Life experiences as drivers of personality

Early life experiences with siblings, parents and other conspecifics, predators, and other environmental cues give the individual an idea of what to expect in future, therefore affecting the development of the personality (Stamps and Groothuis 2010; Hudson *et al*. 2011; DiRienzo *et al*. 2012). Field crickets develop personality traits based on the cues they receive from the environment; and this is indicative of how early life experience affects the development of personality in animals (DiRienzo *et al*. 2012). Experiences that take place later in life can alter personality as a change in the stimuli requires an individual to adapt to better suit the environment (Kandler and Bleidorn 2015). For example, rainbow trout (*Onchorhyncus mykiss*) modify their personality after winning or losing a fight against their conspecifics (Frost *et al*. 2006). Shy individuals that had won a fight behaved more boldly after winning, while individuals that were initially bold, became shyer after losing a fight (Frost *et al*. 2006). This change in personality as a response to experiencing positive or negative stimuli shows the plasticity of personality (Sinn *et al*. 2008).

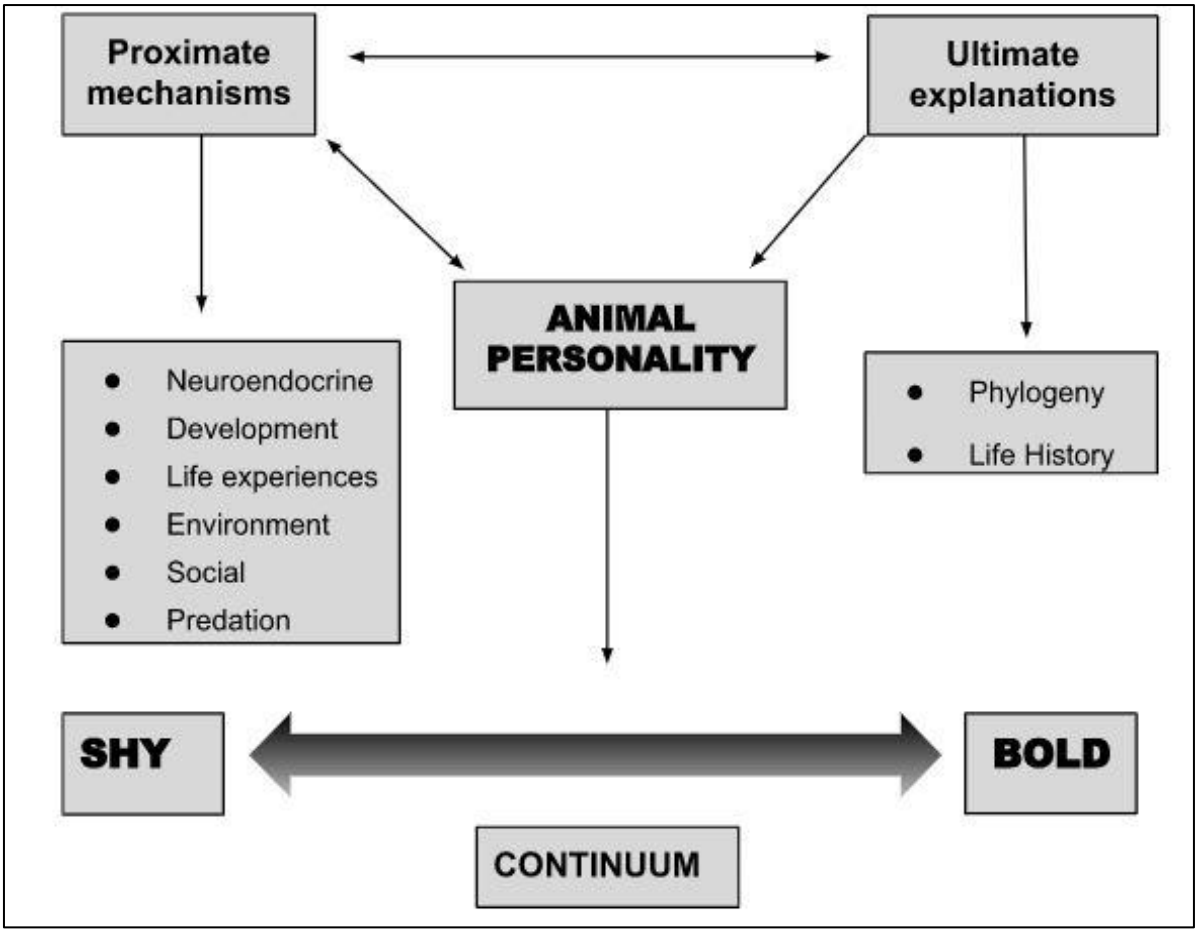


**Figure 1:** Schematic diagram of the proximate and ultimate explanations to animal personalities.

### 1.2 Rationale

Personality influences behaviours which contribute to an individual's survival rate; thus, it is crucial to study personality as this provides insight into how individuals will fare in their environment. Personality also has ecological consequences such as influence on seed choice and seed dispersal, natal dispersal behaviours which also affect social structures and the spread of diseases and social learning. Thus, getting insight into the personality profiles of rodent species in natural populations can help provide informed conservation plans. Planning conservation appropriately is crucial as while some species such as the Namaqua rock mice (*Micaelamys namaquensis*) and the four striped mouse (*Rhabdomys pumilio*) are resilient, other species may not be able to respond the same to potential stress caused by human activities (Rymer *et al*. 2013; Ramahlo *et al*. 2019).

### 1.3 Aim of the study

**Aim**

The aim of this study was to assess the personality of three rodent species and to understand how personality varies in rodent assemblages.

**Objectives**

a) To determine whether there were species-specific differences in the personality of the three rodent species.
b) To determine whether there were differences in the personality traits of the three rodent species, by looking at their propensity to explore novel environments using the open-field test.
c) To determine whether there were differences in the personality traits of the three rodent species, by measuring shyness and boldness as well as exploration and avoidance of a novel object using the novel object test.
d) To determine whether there were intersexual differences in the personality of the three rodent species.

**Predictions**

a) Personality traits are highly based on genetic factors and are influenced by the life history of the individual, I therefore expected that though the three species of rodents were exposed to similar environments, they would maintain species-specific individual behaviours (Kagan *et al*. 1988; Dingemanse *et al*. 2002; Brown *et al*. 2007; Matzel *et al*. 2019).
b) I expected that there would be intersexual differences in personality due to the effects of sex hormones on the regulation of certain behaviours (Koolhaas *et al*. 1999).

# 2. Material and Methods

## 2.1 Sampling sites

This study was conducted at the Great Fish River Nature Reserve (33°04'–33°09'S, 26°37'–26°49'E) and Kwandwe Private Game Reserve (33°08'38.5"S 26°38'08.5"E). The two sampling sites are protected areas located northeast of Grahamstown, in the Eastern Cape Province, South Africa. The Great Fish River Nature Reserve (GFRNR) is managed by the Eastern Cape Parks and Tourism Agency, while Kwandwe Private Game Reserve is a privately owned reserve.

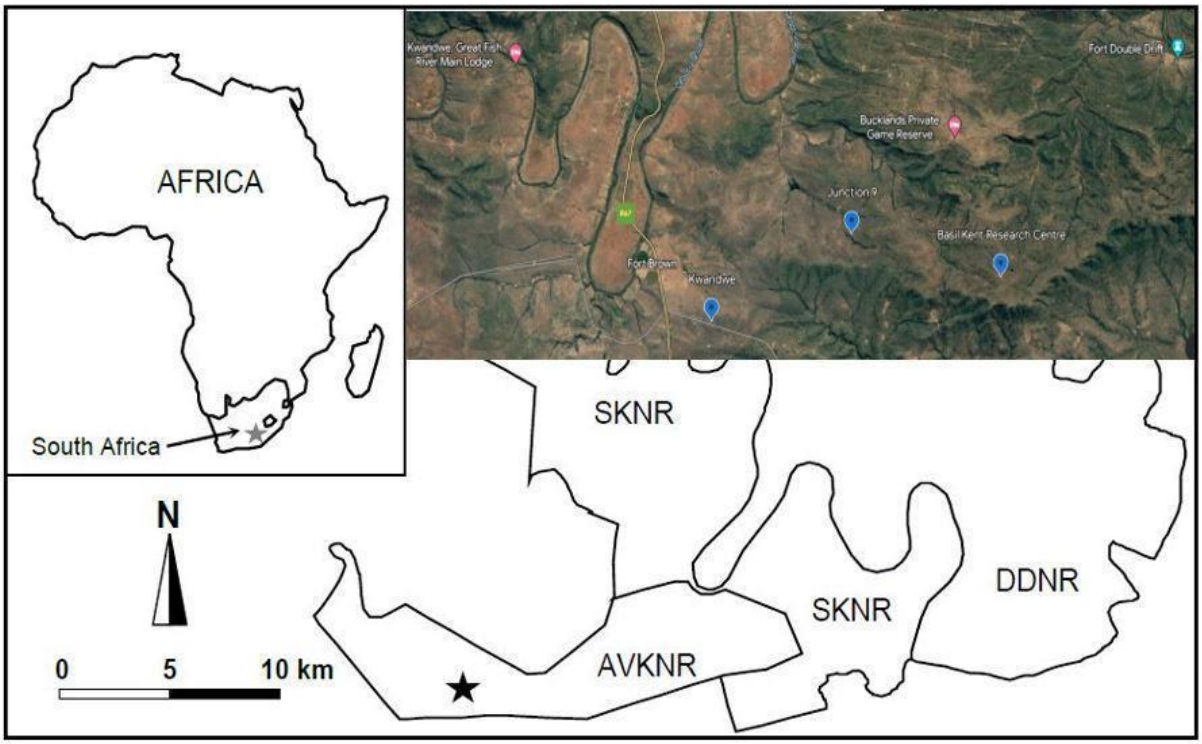


**Figure 2:** Map showing the location (small, grey-shaded star in the upper left-hand side inset) and the structure of the Great Fish River Nature Reserve. The location of the Junction 9 is indicated by a large black star. The upper right-hand side inset shows an aerial view of the two study areas at Junction 9 and Kwandwe, and the Basil Kent Research Centre. Great Fish River Nature Reserve sections: AVKNR: Andries Vosloo Kudu Nature Reserve; SKNR: Sam Knott Nature Reserve; DDGR: Double Drift Game Reserve. Adapted from Madikiza (2017).

### 2.1.1 Great Fish River Nature Reserve

The first sampling site for this study was at Junction 9 (Figure 2). It is located within a *Combretum* riverine forest, which occurs along a non-perennial channel. The forest has both tall trees, the African bushwillow (*Combretum caffrum*), and an understorey composed of acacia bushes (*Vachellia tortilis*), different types of grasses, a few flowering plants, and

woody interlays. The plant species found in this area range include the spekboom (*Portulacaria afra*), karoo boer-bean (*Schotia afra*), grewia (*Grewia* spp.), common guarri (*Euclea undulata*), Jade plants (*Crassula* spp.), sneezewood (*Ptaeroxylon obliquum*), and Wart-stem Whiteberry-bush (*Phyllanthus verrucosa*) (Maswoba 2019). Arboreal rodent species in this forest are known to be found nesting in the hollow parts of bushwillow trees that form when the trees rot from the inside (Kryštufek *et al*. 2008; Madikiza *et al*. 2011; Gebe 2014; Madikiza *et al*. 2016a, 2016b; Lagesse and Thondhlana 2016; Madikiza and Do Linh San 2020). This sampling site was selected in order to trap arboreal rodent species. Potential predators on this site include snakes, small carnivores, and nocturnal birds of prey (Lamani 2015).

### 2.1.2 Kwandwe Private Game Reserve

The second sampling site was located on Kwandwe Private Game Reserve (hereafter ‘’Kwandwe’’) (Figure 2). This part of the reserve is located adjacent to GFRNR; and at the time of the study, it was being used as grazing land for cattle and goats. The vegetation on this site is different in comparison to Junction 9; it is a *euphorbia* thicket, which mainly consists of Botha’s euphorbia (*Euphorbia bothae*), short grasses, sparsely distributed shrubs, and other succulents. This is likely due to being exploited by goats and cattle. Goats browse the lower parts of the plant, which over time, reduces the radius of the rooted area of the plant (Stuart-Hill 1992). This eventually results in a decline in the number of shrubs in the area (Stuart-Hill 1992), whilst the less preferred plants like the Botha’s euphorbia become more dominant. A previous study surveying small mammal species diversity on GFRNR and on this site, found that the Namaqua rock mouse also had a relatively high presence here (Lagesse and Thondhlana 2016). Thus, this sampling site was selected in order to trap the Namaqua rock mouse. Potential predator species at Kwandwe are similar to those found at Junction 9.

## 2.2 Live-trapping

Live-trapping took place between January and February 2022. I conducted live-trapping for a period of 22 days, in order to reach the minimum sample size for all three species. A total of 100 Sherman live traps (H. B. Sherman Traps, Tallahassee, Florida, USA; length × breadth × height: 23 × 8 × 9 cm) were deployed on each site.

At Junction 9, live-trapping was conducted over a period of four weeks. During this period, I selected 50 trap stations (marked locations where traps were placed) which were spaced ~ 10 - 15 m apart from each other. Each station was selected based on the presence of trees, and bushes. I initially set two Sherman traps at each station, with one trap placed above ground (~1 – 1.5 m), either on tree branches, in-between bushes or in a woody interlay. The second trap was placed directly on the ground and hidden under bushes. Over the 22 days, the number of traps and the area covered were progressively increased, in order to meet the minimum sample size for each species. All traps were set in the evening from 17h00 and checked early in the morning from 06h00 and in the afternoon at 15h30 and 17h00 consecutively.

The trapping session at Kwandwe was from 01 February to 08 February 2022, which was 7 nights in total. The 100 trapping stations were set up in a grid-like pattern, with the stations ~ 10 m away from each other. All traps were set directly on the ground depending on the availability of bushes to protect the traps from direct sunlight, and disturbance by humans and animals in the area. Traps were checked twice a day; in the mornings from 7h00 and from 15h30 in the afternoons. The Sherman traps were baited with rolled oats coated with sunflower oil.

### 2.3 Handling and Identification of animals

A total of 57 small mammals were caught at Junction 9, and 17 at Kwandwe (Table 1). This was made up of six rodent species (Junction 9), three rodent species and one shrew species (Kwandwe). These were the Mozambique woodland thicket rat (*Grammomys cometes*), woodland dormouse (*Graphiurus murinus*), Namaqua rock mouse (*Micaelamys namaquensis*), African four-striped field mouse (*Rhabdomys pumilio*), multimammate mouse (*Mastomys spp),* and the eastern rock elephant shrew (*Elephantulus myurus*). Trapped individuals were transferred directly from the trap into a pre-weighed, Ziploc® plastic bag.

**Table 1:** Number of individuals caught per species at Junction 9 and Kwandwe.

| Species | Site | |
|---|---|---|
| | Junction 9 (GFRNR) | Kwandwe |
| | Number of individuals caught | |
| *Grammomys cometes* (Mozambique thicket rat) | 17 | 0 |
| *Graphiurus murinus* (Woodland dormouse) | 26 | 0 |
| *Micaelamys namaquensis* (Namaqua rock mouse) | 4 | 8 |
| *Rhabdomys pumilio* (Four striped mouse) | 5 | 2 |
| *Mastomys spp.* (Multimammate mouse) | 1 | 0 |
| *Elephantulus spp.* (Elephant shrew) | 0 | 1 |
| *Micaelamys spp.* (Rock mouse) | 4 | 6 |
| Total | 57 | 17 |

Individuals were then identified to species level and weighed with a 60 g or 100 g spring balance (Pesola, Baar, Switzerland). To determine the sex of each individual, a visual inspection of the ano-genital distance was recorded, which is shorter in females. The presence of testes for males, and nipples for females following Madikiza (2010), was observed and recorded. The reproductive status of each individual was observed and categorised following Madikiza (2010) as well. For males, presence of descended testes, and for females a perforate or imperforate vagina, visible pregnancy, or presence of nipples, were used to categorise the reproductive status of each individual. Due to low sample size, only three species of rodents were considered for analysis (i.e., woodland dormouse, Mozambique thicket rat and Namaqua rock mouse). All the other species were therefore released at the trap station after handling.

Each individual was then marked with a unique fur-clipping on the back for identification purposes. The juveniles were distinguished from the adults by body mass following Madikiza (2010); individuals with a body mass < 20 g were classified as juvenile, while individuals with a mass between 20 - 25 g were classified as sub-adult, and lastly individuals with a mass > 25 g were classified as adult. Any unique features such as a tear on the ears and length of tail were noted. The date and the trap station number at which the animal was caught was recorded on a protocol sheet.

For the behavioural studies, individuals that were selected to participate in the personality tests were each transferred from the Ziploc® plastic bag into a clear Perspex® glass cage (l × b × h: 26 × 20 × 14 cm) with a stainless-steel wire bar lid to prevent possible escapes. Each

cage was marked with an ID code (i.e., location and pattern of the fur clip) of the individual, and the trap station at which each individual was caught. Only adult males and females were considered in this study, in order to avoid the confounding effects of age on personality. All handling of animals were conducted according to the procedure approved by the Animals Research Ethics Committee (AREC) of the University of the Witwatersrand (clearance certificate number: 2021/04/08/B).

### 2.4 Animal maintenance and housing conditions

For the staged personality tests, I observed 10 Namaqua rock mice, 13 Mozambique thicket rats and 23 woodland dormice (Table 2). After handling and processing, the test animals were transported to the Basil Kent Research Centre, using a research vehicle. The research centre is located within the GFRNR between 2.5 and 4 km from Junction 9 site (Figure 2). The rodents were kept in a quiet room with natural lighting until the personality experiments were conducted. The base of each cage was covered with ~5 cm of wood shavings for bedding. Each individual was provided with food (i.e., a slice of apple and a handful of mixed pellets and seeds) prior to experiments. Plastic water bottles with lids were placed above cages and water was provided to animals *ad libitum*. Each individual spent a maximum of two nights at the research house. Each individual participated in the personality tests once. All animals were then released at the exact capture site within the two reserves.

**Table 2:** Individuals observed for staged personality tests.

| | **Species** | | |
|---|---|---|---|
| | *Grammomys cometes* (Mozambique thicket rat) | *Graphiurus murinus* (Woodland dormouse) | *Micaelamys namaquensis* (Namaqua rock mouse) |
| Males | 9 | 16 | 6 |
| Females | 4 | 7 | 4 |
| Total | 13 | 23 | 10 |

## 2.5 Experimental Design

The open-field test and novel object test were used to study the personality of the three species of rodents. The open-field test (OFT) is a personality test used in rodent behavioural studies to test boldness and exploration by observing how they react to novel environments (Walsh and Cummins 1976). Novel object test (NVO) measures rodents' reaction to novel environments and unfamiliar objects to get insight into how personality traits such as, propensity to explore novel environments and stimuli (Mettke-Hofmann *et al*. 2006).

### EXPERIMENT 1: Observation of personality traits using the open-field test.

The first experiment was conducted indoors, in a separate room at the research house during day or night-time depending on the circadian rhythms of the species. During the first test, a clear rectangular plastic tank (LXBXH 38 x 57 x 30 cm) was used as a test arena. The floor of the arena was marked with a black masking tape to divide it into nine quadrants in order to observe how each individual used the space in the test arena i.e., whether they stayed in the periphery or spent some time in the centre of the arena during the two personality tests. A plexiglass slab (60 x 40 cm) was then placed above the tank partially covering the tank to prevent the rodents from escaping during the tests, as well as to allow for air flow during testing. A video camera (Canon, Legria HFR806 HD) was then mounted on a tripod stand, at a height of ~1m above floor level and at a distance of 40cm from the tank.

During the night, a red lamp (5W 230V 50Hz) was used for nocturnal species such as dormice and Mozambique thicket rats. The lamp was angled away from the arena to prevent overheating. All the experiments during the night took place during the most active times of the species (from 19h00 - 22h00) following Madikiza (2017).
During the daytime, the experiments took place between 12h00 and 14h00.

At the start of the experiment, an animal would be removed from their housing cage and placed inside the test arena. The video camera and timer would then be started. A piece of paper displaying the individual's identification code and the name of the test would be flashed in front of the camera. The behaviours of each individual were then videotaped for a period of 15 minutes without the observer present. At the end of the test, the observer would enter the room. The behaviours recorded during this test were sitting, running, jumping, rearing, grooming, scent-marking, and sniffing (Table 3).

**EXPERIMENT 2: Observation of personality traits using the novel object test.**

Prior to starting the novel object test, the novel object was prepared by placing a few drops of lavender oil on a tennis ball. The tennis ball was then placed in the arena away from the test individual. The behaviour of each test subject was then recorded for a period of 15 minutes. The behaviours recorded during this test were sitting, running, jumping, rearing, biting, grooming, scent-marking, and sniffing (Table 3). The behaviours were grouped into three broad behavioural categories according to whether they were indicative of shyness, exploration, or aggression (Table 4). At the end of the 15 minutes, the recording would be stopped. A Sherman trap would then be used to transfer the rodent from the test arena to the housing cage. Food and water were provided again. The animal would remain in the housing cage until they were released again the next morning at the capture site.

After transferring the rodent to the housing cage, the arena and glass slab were cleaned with alcohol (99% ethanol) and a clean cloth or toilet paper to prepare it for the next individual and to avoid scent transfer between individuals.

**Table 3**: Behavioural categories and their related behavioural components scored during the open-field test and the novel object tests.

| **Behavioural categories** | **Behavioural components** |
|---|---|
| *OPEN-FIELD TEST* | |
| Sitting | Remaining mostly stationary or making minimal movement in place. |
| Running | Moving around the arena (ambulating). |
| Jumping | Taking a leap to try and escape from the arena. |
| Grooming | Licking, scratching, or cleaning itself. |
| Sniffing | Inspecting by smelling around the arena. |
| Rearing | Standing on hind legs with front legs against the walls of the arena. |

| | |
|---|---|
| Scent-marking | Defecating in the arena or rubbing cheeks and body against the floor of the arena. |
| *NOVEL OBJECT TEST* | |
| Sitting | Remaining mostly stationary or making minimal movement in place. |
| Running | Moving around the arena (ambulating). |
| Jumping | Attempting to leap out of the arena and leaping onto the novel object (tennis ball). |
| Grooming | Licking, scratching, or cleaning itself. |
| Sniffing | Inspecting by smelling the novel object (tennis ball) and around the arena. |
| Biting | Nibbling the novel object (tennis ball). |
| Rearing | Standing on hind legs with front legs against the walls of the arena. |
| Scent-marking | Defecating in the arena or rubbing cheeks and body against the floor of the arena. |

**Table 4**: Broad behavioural categories and their related behavioural components scored during the open-field test and the novel object tests.

| **Behavioural categories** | **Behavioural components** |
|---|---|
| Shy | Sitting and grooming itself individuals are reluctant to interact with or investigate the environment and the novel object. |
| Exploration | Jumping and rearing, attempting to escape the arena. Running and sniffing. Investigating the environment (the arena) and the novel object. |
| Aggression | Biting the ball and scent-marking. |

## 2.6 Data analysis

Trapping and behavioural data were transferred to an Excel spreadsheet. For the personality tests, I scored behaviours according to the ethogram, where I noted the start time of each behaviour and the end time of each behaviour, using one-zero sampling. Behaviours were scored as "event" behaviours (these were the behaviours that were recorded as a frequency or the number of times the animal performed a certain behaviour) and/or "state" behaviours (these were the behaviours that were recorded as the duration or how long it took for the animal to perform a certain behaviour).

All statistical analyses were conducted with IBM SPSS Statistics 28.0 (SPSS Inc.). I considered a significance level of $p \leq 0.05$ level for all my tests. I tested my data for normality using both Kolmogorov-Smirnov test and Shapiro-Wilk test, ($p < 0.05$) normality tests. A Chi-square test of independence and homogeneity test were used to test for potential inter-species and intra-sexual differences in the frequencies of behaviours in the open-field test and the novel object test. To investigate potential differences between sexes in the duration of behaviours, I used a non-parametric Mann-Whitney *U* test, and a Wilcoxon matched-pair test. The Kruskal-Wallis signed ranks test was used to investigate differences in duration of behaviours between the three species.

# 3. Results

## SPECIES DIFFERENCES IN BEHAVIOURAL RESPONSES

From the personality tests, the absolute occurrence of the behaviours, as well as the duration that individuals spent performing the behaviours were observed.

### 3.1 Behavioural response of Mozambique thicket rats (Gc), woodland dormice (Gm) and Namaqua rock mice (Mn) in an Open-field Test

Overall, the three species performed similar behaviours. However, they significantly differed from each other in the frequency to perform the observed behaviours ($\chi^2 = 378.136$, df = 12, $p < 0.001$; Figure 3). As shown in Figure 3, woodland dormice (Gm) sat, groomed, and sniffed around the arena significantly more often than Namaqua rock mice (Mn) and Mozambique thicket rats (Gc). Mozambique thicket rats (Gc) ran, jumped, reared and scent-marked the arena significantly more often than woodland dormice (Gm) and Namaqua rock mice (Mn) in the open-field test (Figure 3).

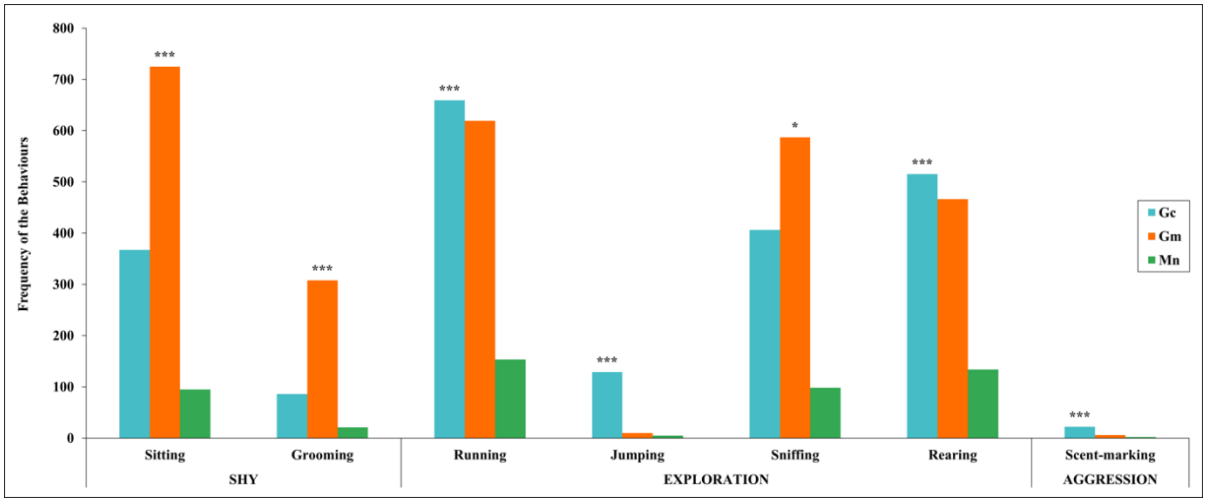


**Figure 3:** Comparisons of the absolute frequencies of occurrence of behavioural categories exhibited by the three rodents Mozambique thicket rat (Gc), woodland dormouse (Gm) and Namaqua rock mouse (Mn) in an open-field test. Behavioural categories that differed significantly among the three species (Chi-square test of independence) are indicated with * = $p < 0.05$; *** = $p < 0.001$.

A chi-square test of homogeneity was performed (Table 5) and it was found that the Mozambique thicket rat (Gc) reared and ran around the arena more often than expected by chance; however, they groomed, jumped and scent-marked less often than expected by

chance. Woodland dormice sat, ran, and sniffed more often than expected by chance; however, they jumped and scent-marked less often than expected by chance (Table 5). The Namaqua rock mice (Mn) ran, sniffed, and reared in the arena more often than expected by chance; however, they groomed, jumped and scent-marked less often than expected by chance (Table 5).

**Table 5:** Chi-square tests of homogeneity to investigate whether the three species of rodents (Mozambique thicket rats (Gc), woodland dormice (Gm) and Namaqua rock mice (Mn) exhibited specific behaviours more or less than expected according to a theoretical homogeneous distribution during the Open-Field Test. Observed values which are at least 25% larger or smaller than expected values are highlighted in bold. Expected values in parentheses.

| Categories | Sitting | Grooming | Running | Jumping | Sniffing | Rearing | Scent-marking | Chi-square test |
|---|---|---|---|---|---|---|---|---|
| **Gc observed** | 367 (312) | **86 (312)** | **659 (312)** | **129 (312)** | 406 (312) | **515 (312)** | **22 (312)** | $\chi^2$ = **1096.615, df = 6, *p* < *0.001*** |
| **Gm observed** | **725 (389)** | 308 (389) | **619 (389)** | **10 (389)** | **587 (389)** | 466 (389) | **6 (389)** | $\chi^2$ = **1306.408, df = 6, *p* < *0.001*** |
| **Mn observed** | 95 (73) | **21 (73)** | **153 (73)** | **5 (73)** | **98 (73)** | **134 (73)** | **2 (73)** | $\chi^2$ = **325.165, df = 6, *p* < *0.001*** |

Significant differences were further observed between the three species in the time spent performing behaviours such as sitting (H = 9.986, df = 2, $p$ = .007, Figure 4), rearing (H = 6.669, df = 2, $p$ =.036, Figure 4), running (H = 6.544, df = 2, $p$ = .038, Figure 4), and sniffing (H = 11.545, df = 2, $p$ =.003, Figure 4).

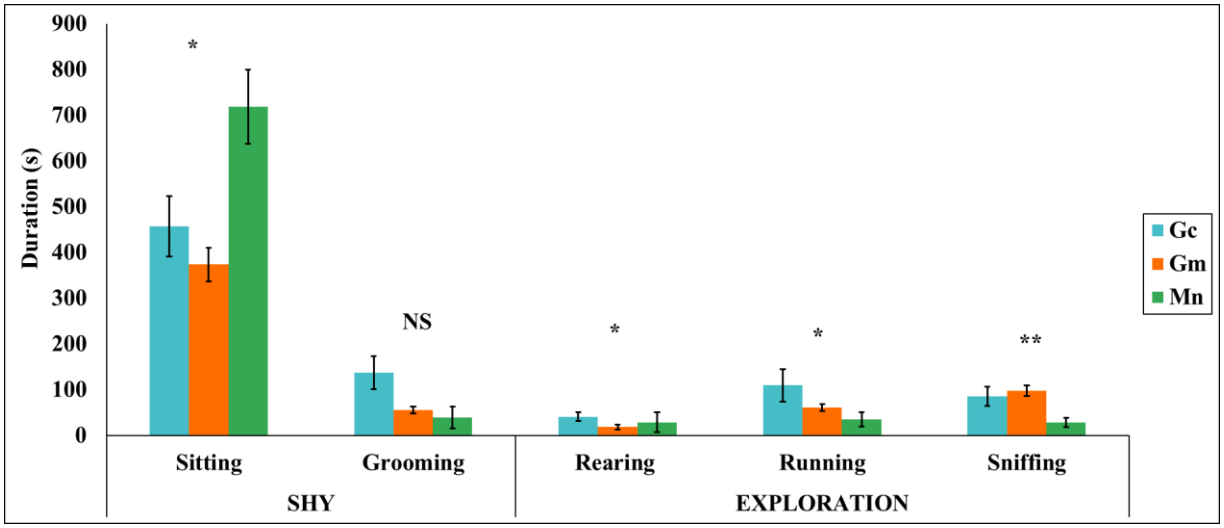


**Figure 4:** Duration (mean ± SE) of the behavioural categories recorded during 15-min open-field test between the three species: Gc ($n$ = 13), Gm ($n$ = 23) and Mn ($n$ = 10) (Kruskal-Wallis test: $p < 0.05$); * = $p < 0.05$; ** = $p < 0.01$; NS = non-significant.

### 3.2 Behavioural response of Mozambique thicket rats (Gc), woodland dormice (Gm) and Namaqua rock mice (Mn) in a Novel Object Test

Overall, similar behaviours were observed in all the three species, except for biting, which was not observed in the Namaqua rock mice (Mn). However, the frequency at which these behaviours were performed was significantly different among the three species ($\chi^2 = 370.103$, df = 12, $p < 0.001$; Figure 5). Mozambique thicket rats (Gc) ran and jumped significantly more often in compared to the other two species, woodland dormice (Gm) and Namaqua rock rats (Mn). While woodland dormice (Gm) sat, groomed, sniffed the novel object, and reared in the arena significantly more often than the other two species, Mozambique thicket rats (Gc) and Namaqua rock rats (Mn) (Figure 5). No differences were found in the frequency of scent-marking.

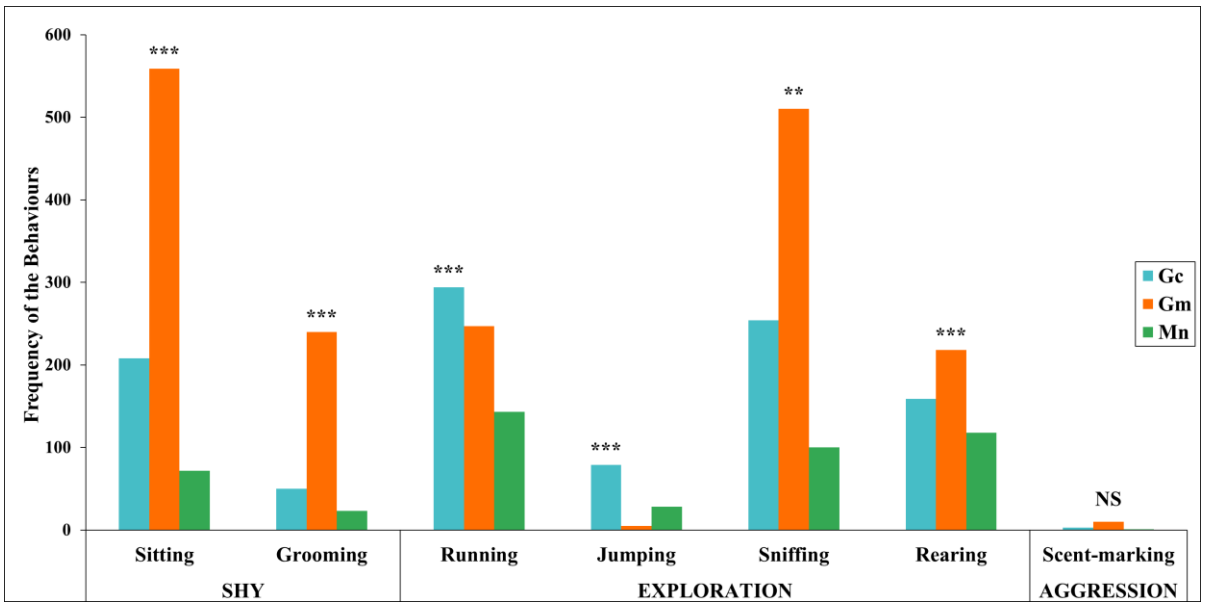


**Figure 5:** Comparison of the absolute frequencies of occurrence of behavioural categories exhibited by the three rodents Mozambique thicket rat (Gc), woodland dormouse (Gc), Namaqua rock mouse (Mn) in a novel object test. Behavioural categories that differed significantly among the three species (Chi-square tests of independence) ** = $p < 0.01$; *** = $p < 0.001$; NS = non-significant.

The chi-square test of homogeneity results showed that there were significant differences in all the behaviours performed (Table 6). Mozambique thicket rats (Gc) deviated from the expected values for all the behaviours except for rearing (Table 6). Mozambique thicket rats (Gc) ran and sniffed more often than expected; however, they sat, groomed, jumped and scent-marked less often than expected (Table 6). Woodland dormice (Gm) sat and sniffed more often than expected; however, they jumped and scent-marked less often than expected

(Table 6). Namaqua rock mice (Mn) also deviated from the theoretical homogenous distribution for all the observed behaviours except for sitting (Table 6). Namaqua rock mice (Mn) ran, sniffed around, and reared more often than expected; while grooming, jumping, and scent-marking took place less often than expected (Table 6).

**Table 6:** Chi-square tests of homogeneity to investigate whether male Mozambique thicket rats (Gc), woodland dormice (Gm) and Namaqua rock mice (Mn) exhibited specific behaviours more or less than expected according to a theoretical homogeneous distribution during the NVO. Observed values which are at least 25% larger or smaller than expected values are highlighted in bold. Expected values in parentheses.

| Categories | Sitting | Grooming | Running | Jumping | Sniffing | Rearing | Scent-marking | Chi-square test |
|---|---|---|---|---|---|---|---|---|
| **Gc observed** | **208 (150)** | **50 (150)** | **294 (150)** | **79 ( 150)** | **254 (150)** | 159 (150) | **3 (150)** | **$\chi^2$ = 479.007, df = 6, $p$ < 0.001** |
| **Gm observed** | **559 (256)** | 240 (256) | 247 (256) | **5 (256)** | **510 (256)** | 218 (256) | **10 (256)** | **$\chi^2$ = 1102, df = 6, $p$ = 0** |
| **Mn observed** | 72 (69) | **23 (69)** | **143 (69)** | **28 (69)** | **100 (69)** | **118 (69)** | **1 (69)** | **$\chi^2$ = 254, df = 6, $p$ = 0** |

In terms of the time spent on the behaviours between the three species, there was a significant difference in the duration that the three species spent on sitting (H = 17.174, df = 2, $p$ < .001; Figure 6). However, there was no difference in duration for the behaviours such as grooming (H = 1.948, df = 2, $p$ = .378; Figure 6), jumping: (H = 1.423, df = 2, $p$ = .491; Figure 6), rearing (H = 2.233, df = 2, $p$ = .327; Figure 6); running (H = 3.828, df = 2, $p$ = .147; Figure 6), sniffing (H = 4.235, df = 2, $p$ = .120; Figure 6), biting (H = 2.304, df = 2, $p$ = .316; Figure 6) and scent-marking (H = .000, df = 2, $p$ = 1.000; Figure 6).

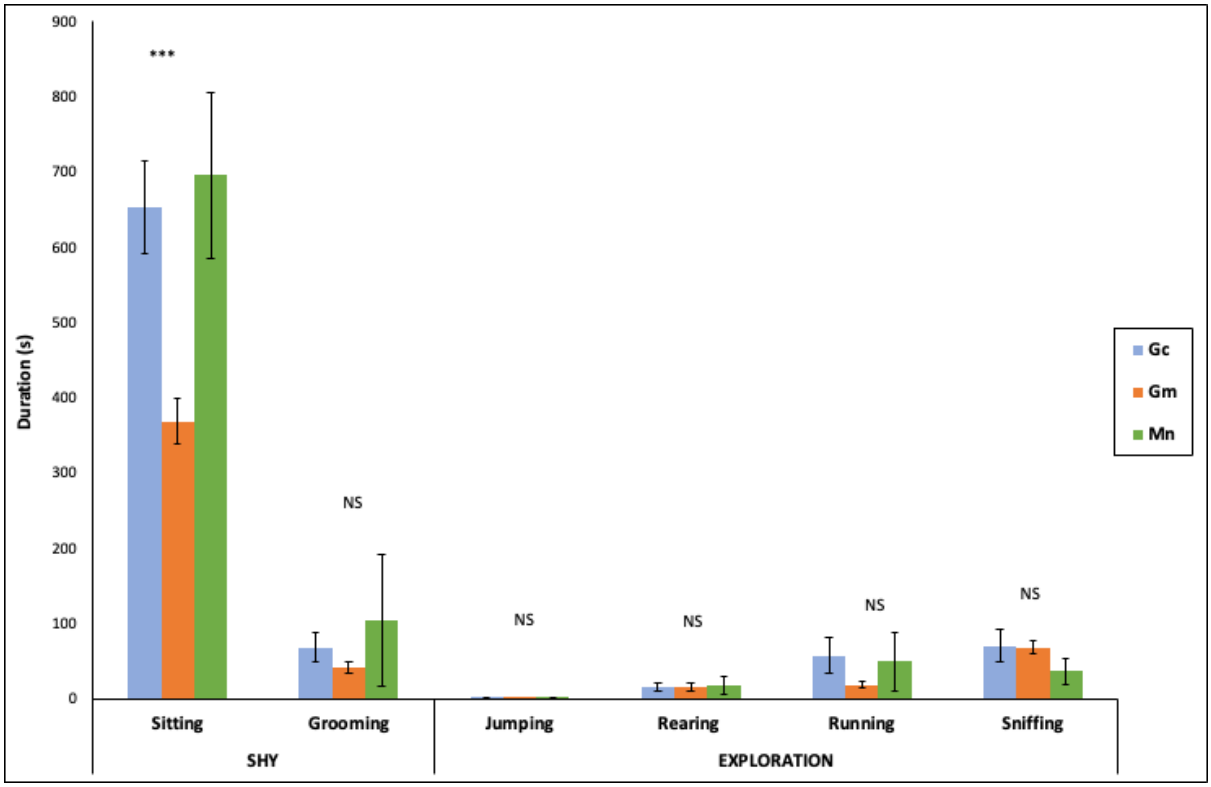


**Figure 6:** Duration (mean ± SE) of the behavioural categories recorded during 15-min novel object test Gc ($n$ = 13), Gm ($n$ = 23) and Mn ($n$ = 10). (Kruskal-Wallis test) * = $p < 0.05$; *** = $p < 0.001$; NS = non-significant.

## SEX DIFFERENCES IN BEHAVIOURAL RESPONSES

### Namaqua rock mouse (*Micaelamys namaquensis*)

### 3.3 Behavioural responses of male and female Namaqua rock mice an Open-field test

Male and female Namaqua rock mice expressed similar behaviours during the open-field test. However, they did not differ in the frequency of any of the types of behaviours recorded during the open-field test ($\chi^2$ = 5.633, df = 5, $p$ = 0.34; Figure 7).

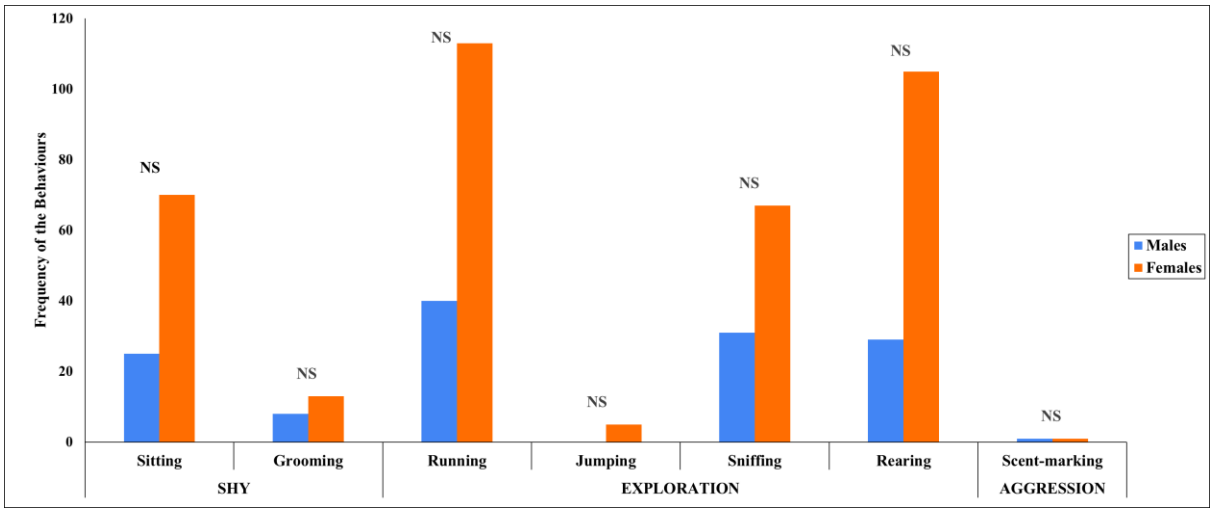


**Figure 7:** Comparisons of the absolute frequencies of occurrence of behavioural categories exhibited by male and female Namaqua rock mice (*Micaelamys namaquensis*) in an open-field test. Behavioural categories did not differ significantly between males and females (Chi-square tests of independence: $p > 0.05$); NS = non-significant.

However, the chi-square test of homogeneity revealed that both sexes deviated significantly from the theoretical homogenous distribution ($\chi^2$ = 49.224, df = 5, $p < 0.001$; Table 7). Male Namaqua rock mice walked, ran, and sniffed around the arena more than expected; while they groomed themselves and marked the arena with their scent less than expected. Similarly, female Namaqua rock mice walked, ran, jumped, and reared more than expected; and they groomed and scent-marked less than expected ($\chi^2$ = 178.321, df = 5, $p < 0.001$, Table 7).

**Table 7:** Chi-square test of homogeneity to investigate whether male (M) and female (F) Namaqua rock mice (*Micaelamys namaquensis*) exhibited specific behaviours more or less than expected according to a theoretical homogeneous distribution during the OFT. Observed values which are at least 25% larger or smaller than expected values are highlighted in bold. Expected values in parentheses.

| Categories | Sitting | Grooming | Jumping & Rearing | Running | Sniffing | Scent-marking | Chi-square test |
|---|---|---|---|---|---|---|---|
| **M observed** | 25 (22) | **8 (22)** | 29 (22) | **40 (22)** | **31 (22)** | **1 (22)** | **$\chi^2$ = 49.224, df = 5 $p$ < 0.001** |
| **F observed** | 70 (62) | **13 (62)** | **110 (62)** | **113 (62)** | 67 (62) | **1 (62)** | **$\chi^2$ = 178.321, df = 5, $p$ < 0.001** |

In terms of the duration of the behaviours (Figure 8), male and female Namaqua rock mice did not differ the duration of any of the behavioural components recorded during the open-field test ($p > 0.05$ in all the behaviours).

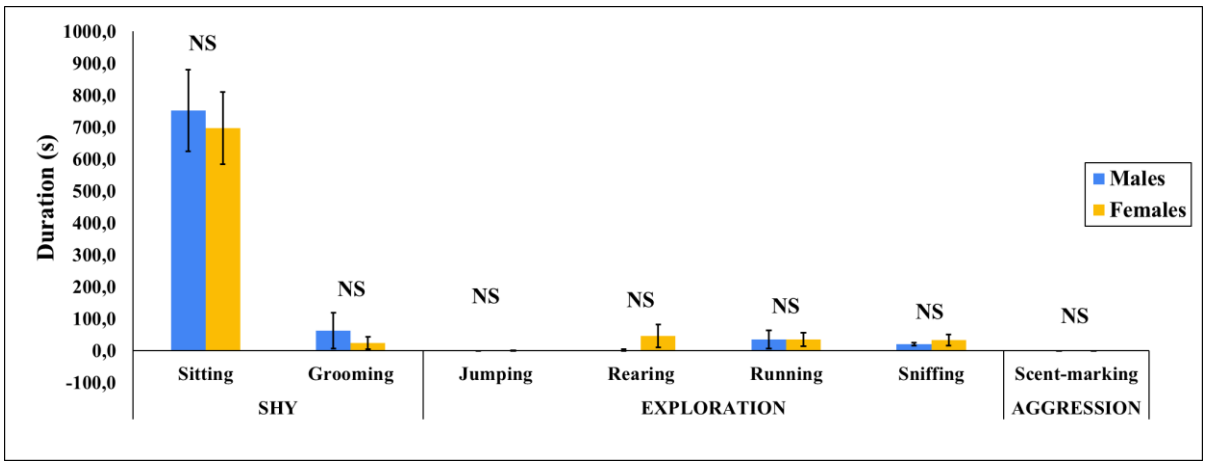


**Figure 8:** Duration (mean ± SE) of the behavioural categories recorded during 15-min open-field test male ($n$ = 6) and female ($n$ = 4) in Namaqua rock mice (*Micaelamys namaquensis*). Values did not differ significantly between males and females (Mann-Whitney $U$ tests: $p > 0.05$); NS = non-significant.

### 3.4 Behavioural response of male and female Namaqua rock mice in a Novel Object Test

Male and female Namaqua rock mice expressed similar behaviours during the novel object test (Figure 9). However, the frequency which these behaviours were expressed, differed significantly ($\chi^2 = 129.778$, df = 5, $p < 0.001$, Figure 9). Male Namaqua rock mice jumped, ran, sniffed and reared significantly more often than female Namaqua rock mice (Figure 9). Female Namaqua rock mice on the other hand, sat and groomed significantly more often than male Namaqua rock mice.

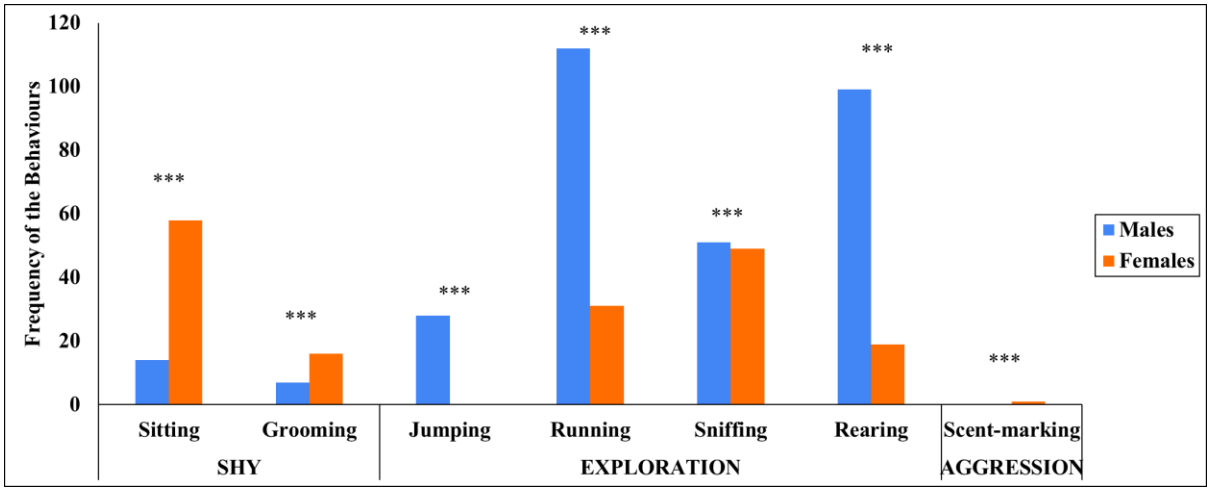


**Figure 9:** Comparisons of the absolute frequencies of occurrence of behavioural categories exhibited by male and female Namaqua rock mice (*Micaelamys namaquensis*) in a novel object test. Behavioural categories that differed significantly between males and females (Chi-square tests of independence) are indicated with *** = $p < 0.001$.

In addition, the homogeneity test analysis further showed that both sexes deviated significantly from the theoretical homogenous distribution (Table 8). Male Namaqua rock mice ran and walked more often than expected. However, they sat, sniffed, jumped/reared and scent-marked less often than expected ($\chi^2 = 190.125$, df = 5, $p < 0.001$; Table 8). Female Namaqua rock mice sat and sniffed more often than expected; however, they groomed, jumped/reared and scent-marked less often than expected ($\chi^2 = 81.671$, df = 5, $p < 0.001$; Table 8).

**Table 8:** Chi-square tests of homogeneity to investigate whether male (M) and female (F) Namaqua rock mice (*Micaelamys namaquensis*) exhibited specific behaviours more or less than expected according to a theoretical homogeneous distribution during the NVO. Observed values which are at least 25% larger or smaller than expected values are highlighted in bold. Expected values in parentheses.

| Categories | Sitting | Grooming | Jumping | Running | Sniffing | Rearing | Scent-Marking | Chi-square test |
|---|---|---|---|---|---|---|---|---|
| M observed | **14 (52)** | **7 (52)** | **28 (52)** | **112 (52)** | 51 (52) | **99 (52)** | **0 (52)** | $\chi^2$= 190.125, df = 5, $p < 0.001$ |
| F observed | **58 (29)** | **16 (29)** | **0 (29)** | 31 (29) | **49 (29)** | **19 (29)** | **1 (29)** | $\chi^2$ = 81.671, df = 5 $p < 0.001$ |

Observations on the duration of the behaviours performed during the novel test, showed that male and female Namaqua rock mice did not differ in how long they performed the behaviours ($p > 0.05$; Figure 10).

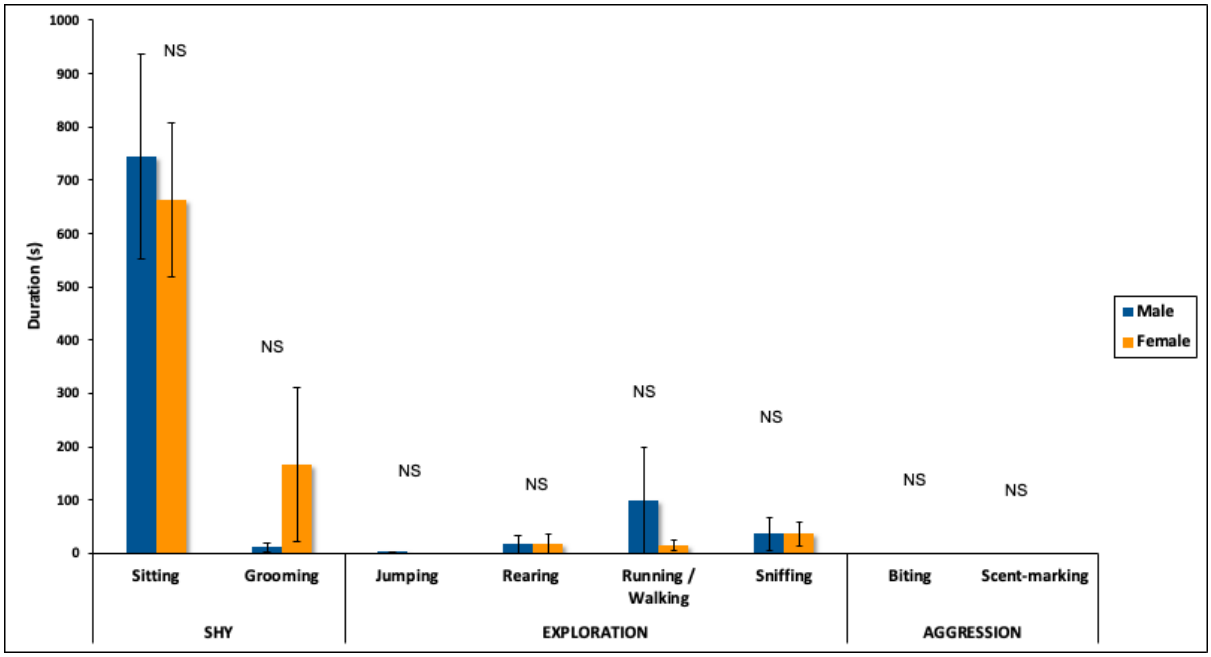


**Figure 10:** Duration (mean ± SE) of the behaviours recorded during 15-min novel object test male ($n = 6$) and female ($n = 4$) in Namaqua rock mice (*Micaelamys namaquensis*). Values did not differ significantly between males and females (Mann-Whitney *U* tests: $p > 0.05$). NS = non-significant.

**Mozambique thicket rat (*Grammomys cometes*)**

### 3.5 Behavioural response of male and female Mozambique thicket rats in an Open-field Test

Male and female Mozambique thicket rats expressed similar behaviours during the open-field test. However, they differed significantly in the frequency to perform the observed behaviours ($\chi^2$ =35.894, df = 6, $p < 0.001$; Figure 11). During the test, male Mozambique thicket rats groomed, jumped, sniffed, reared and scent-marked significantly more often than the female Mozambique thicket rats (Figure 11).

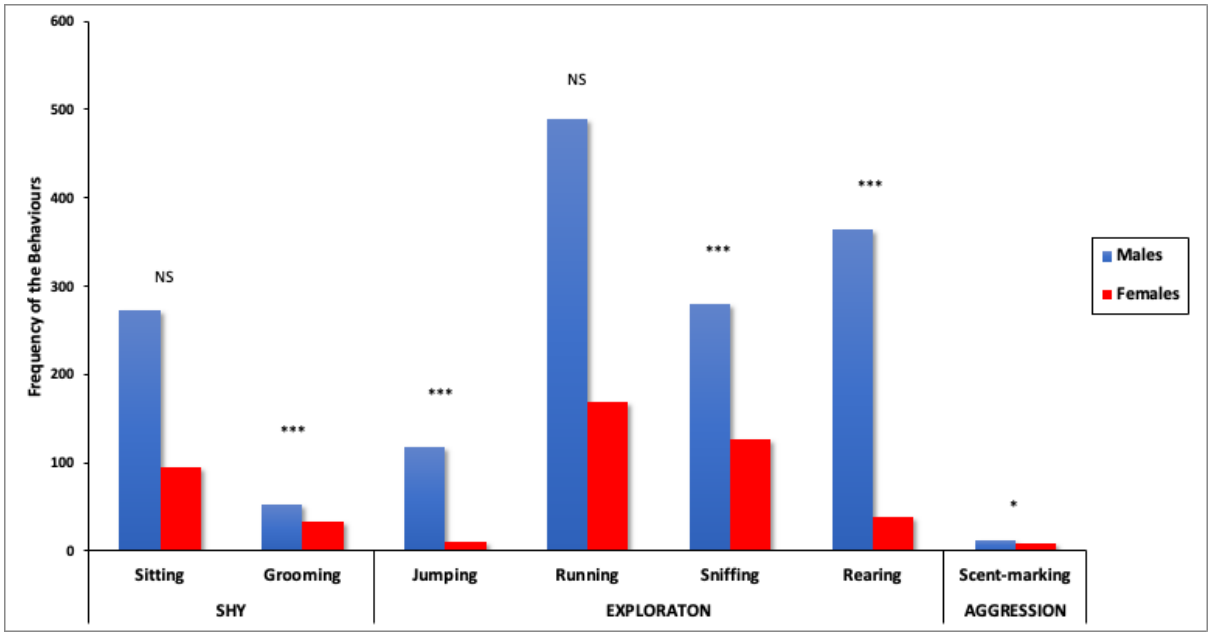


**Figure 11:** Comparisons of the absolute frequencies of occurrence of behavioural categories exhibited by male and female Mozambique thicket rats (*Grammomys cometes*) in an open-field test. Behavioural categories that differed significantly between males and females (Chi-square tests of independence) are indicated with * = $p < 0.05$; *** = $p < 0.001$; NS = non-significant.

The chi-square test of homogeneity further revealed that both male and female Mozambique thicket rats deviated significantly from the theoretical homogenous distribution (Table 9). Male Mozambique thicket rats ran and reared more often than expected. However, they groomed, jumped and scent-marked less often than expected ($\chi^2$ = 795.683, df = 6, $p < 0.001$; Table 9). Similarly, female Mozambique thicket rats deviated from the expected values for all the observed behaviours. They sat, ran, sniffed, and reared more often than expected; however, they groomed, jumped and scent-marked less often than expected ($\chi^2$ = 337.813, df = 6, $p < 0.001$, Table 9).

**Table 9:** Chi-square tests of homogeneity to investigate whether male (M) and female (F) Mozambique thicket rats exhibited specific behaviours more or less than expected according to a theoretical homogeneous distribution during the OFT. Observed values which are at least 25% larger or smaller than expected values are highlighted in bold. Expected values in parentheses.

| Categories | Sitting | Grooming | Jumping | Running | Sniffing | Rearing | Scent-marking | Chi-square test |
|---|---|---|---|---|---|---|---|---|
| M observed | 272 (227) | **53 (227)** | **118 (227)** | **490 (227)** | 279 (227) | **364 (227)** | **13 (227)** | $\chi^2 = 795.683$, df = 6, $p < 0.001$ |
| F observed | **95 (69)** | **33 (69)** | **11 (69)** | **169 (69)** | **127 (69)** | **151 (69)** | **9 (69)** | $\chi^2 = 337.813$, df = 6, $p < 0.001$ |

There were no significant differences between male and female Mozambique thicket rats in the duration of the observed behaviours ($p > 0.05$; Figure 12).

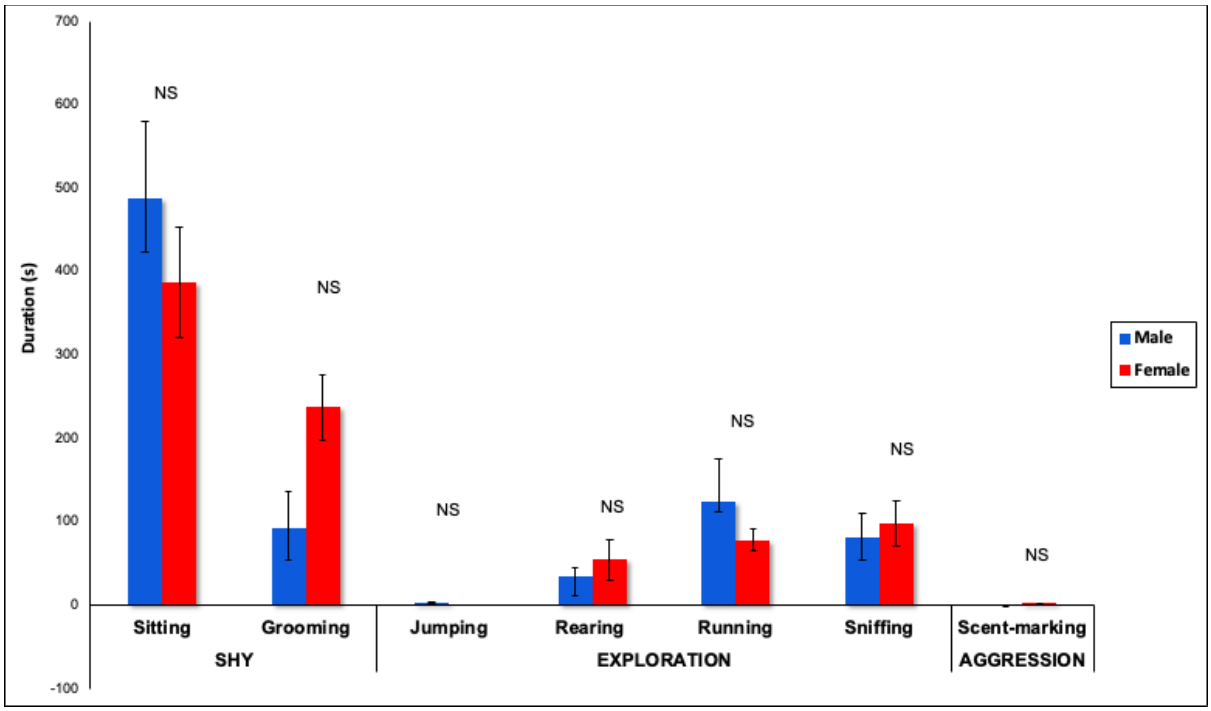


**Figure 12:** Duration (mean ± SE) of the behavioural categories recorded during 15-min open-field test male ($n = 9$) and female ($n = 4$) in Mozambique thicket rats (*Grammomys cometes*). Values did not differ significantly between males and females (Mann-Whitney *U* tests: $p > 0.05$). NS = non-significant.

### 3.6 Behavioural response of male and female Mozambique thicket rat in a Novel Object Test

Male and female Mozambique thicket rats differed significantly in the frequency of the behaviours observed during the novel object test ($\chi^2 = 85.846$, df = 6, $p < 0.001$; Figure 13). The results showed that male Mozambique thicket rats jumped, sniffed, and reared more often than the female Mozambique thicket rats (Figure 13). Female Mozambique thicket rats on the other hand, groomed and scent-marked slightly more often than the male Mozambique thicket rats during the novel object test (Figure 13).

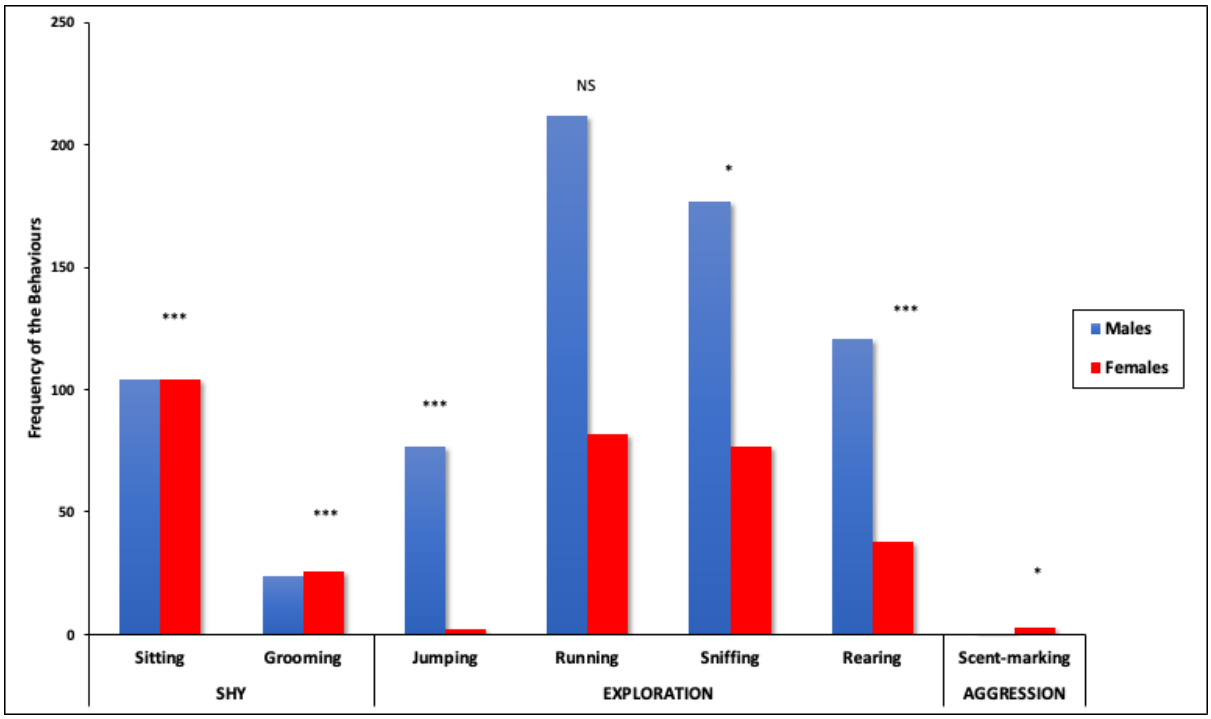


**Figure 13:** Comparisons of the absolute frequencies of occurrence of behavioural categories exhibited by male and female Mozambique thicket rats (*Grammomys cometes*) in a novel object test. Behavioural categories that differed significantly between males and females (Chi-square tests of independence) are indicated with * = $p < 0.05$; *** = $p < 0.001$; NS = non-significant.

Male and female Mozambique thicket rats did not perform the observed behaviours at the same frequency (Table 10). Male Mozambique thicket rats ran/walked, sniffed, and reared more often than expected, whilst they groomed and jumped less often than expected ($\chi^2 = 242.501$, df = 6, $p < 0.001$; Table 10). Female Mozambique thicket rats deviated from the theoretical homogenous distribution in all the observed behaviours. Female Mozambique thicket rats sat, ran/walked, and sniffed more often than expected; and they jumped, reared and scent-marked less often than expected ($\chi^2 = 166.183$, df = 6, $p < 0.001$; Table 10).

**Table 10:** Chi-square tests of homogeneity to investigate whether male (M) and female (F) Mozambique thicket rats exhibited specific behaviours more or less than expected according to a theoretical homogeneous distribution during the NVO test. Observed values which are at least 25% larger or smaller than expected values are highlighted in bold. Expected values in parentheses.

| Categories | Sitting | Grooming | Jumping | Running | Sniffing | Rearing | Scent-marking | Chi-square test |
|---|---|---|---|---|---|---|---|---|
| **M observed** | 104 (102) | **24 (102)** | **77 (102)** | **212 (102)** | **177 (102)** | 121 (102) | **0 (102)** | **$\chi^2$ = 242.501, df = 6, $p$ < 0.001** |
| **F observed** | **104 (47)** | **26 (47)** | **2 (47)** | **82 (47)** | **77(47)** | **38 (47)** | **3 (47)** | **$\chi^2$ = 166.183, df = 6, $p$ < 0.001** |

Observations on the duration of the behaviours performed during the novel test showed that, there were no differences between male and female Mozambique thicket rats ($p > 0.05$; Figure 14).

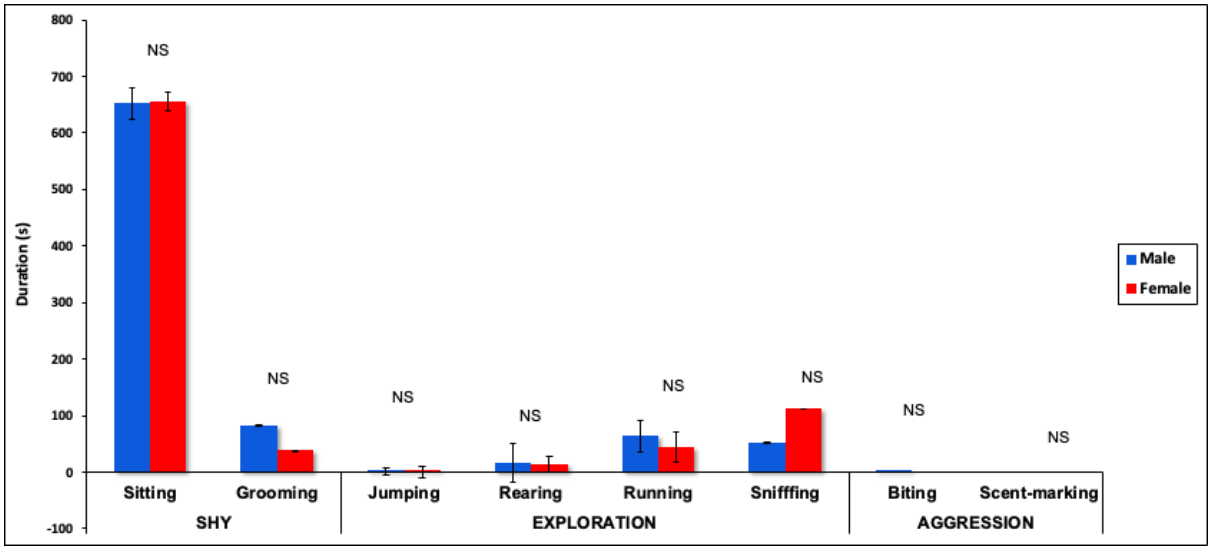


**Figure 14:** Duration (mean ± SE) of the broad behavioural categories recorded during 15-min novel object test male ($n$ = 9) and female ($n$ = 4) in Mozambique thicket rats (*Grammomys cometes*). Values did not differ significantly between males and females (Mann-Whitney $U$ tests: $p > 0.05$). NS = non-significant.

**Woodland dormouse (*Graphiurus murinus*)**

### 3.7 Behavioural response of male and female woodland dormice in an Open-field Test

In the open-field test, both male and female woodland dormice performed similar behaviours (Figure 15). However, there was a significant difference in the frequency with which the behaviours were performed during the open-field test ($\chi^2$ = 24,2875, df = 6, $p < 0.001$; Figure 15). Male woodland dormice groomed, jumped, and sniffed the arena more often than female woodland dormice (Figure 15). There was no difference in the frequency of sitting and running between male and female woodland dormice (Figure 15).

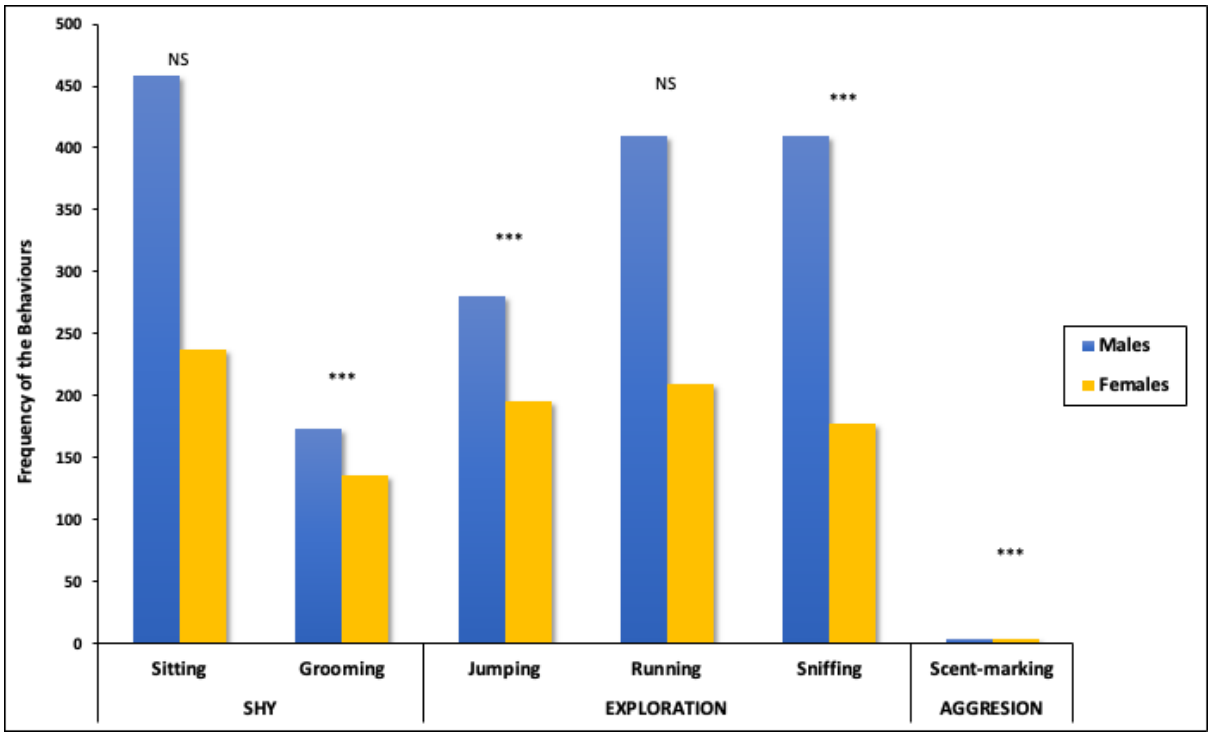


**Figure 15:** Comparisons of the absolute frequencies of occurrence of behavioural categories exhibited by male and female woodland dormice (*Graphiurus murinus*) in an open-field test. Behavioural categories that differed significantly between males and females (Chi-square tests of independence) are indicated with *** = $p < 0.001$; NS = non-significant.

It was further observed that there were significant differences in the propensity of performing the observed behaviours in the chi-square homogeneity test (Table 11). Male woodland dormice sat, ran/walked, and sniffed more often than expected; and they groomed and scent-marked less often than expected ($\chi^2$ = 529.656, df = 5, $p < 0.001$, Table 11). Female woodland dormice sat and ran/walked more often than expected; and they scent-marked less often than expected ($\chi^2$ = 220.389, df = 5, $p < 0.001$, Table 11).

**Table 11:** Chi-square tests of independence to investigate whether male (M) and female (F) woodland dormice exhibited specific behaviours more or less than expected according to a theoretical homogeneous distribution. Observed values which are at least 25% larger or smaller than expected values are highlighted in bold. Expected values in parentheses.

| Categories | Sitting | Grooming | Jumping & Rearing | Running | Sniffing | Scent-Marking | Chi-square test |
|---|---|---|---|---|---|---|---|
| **M observed** | **458 (289)** | **173 (289)** | 281(289) | **410 (289)** | **410 (289)** | **3 (289)** | **$\chi^2 = 529.656$, df = 5, $p < 0.001$** |
| **F observed** | **237 (159)** | 135 (159) | 195 (159) | **209 (159)** | 177 (159) | **3 (159)** | **$\chi^2 = 220.389$, df = 5, $p < 0.001$** |

Observations on the duration of the behaviours during the open-field test, showed that male and female woodland dormice did not differ in how long they performed the behaviours ($p > 0.05$; Figure 16).

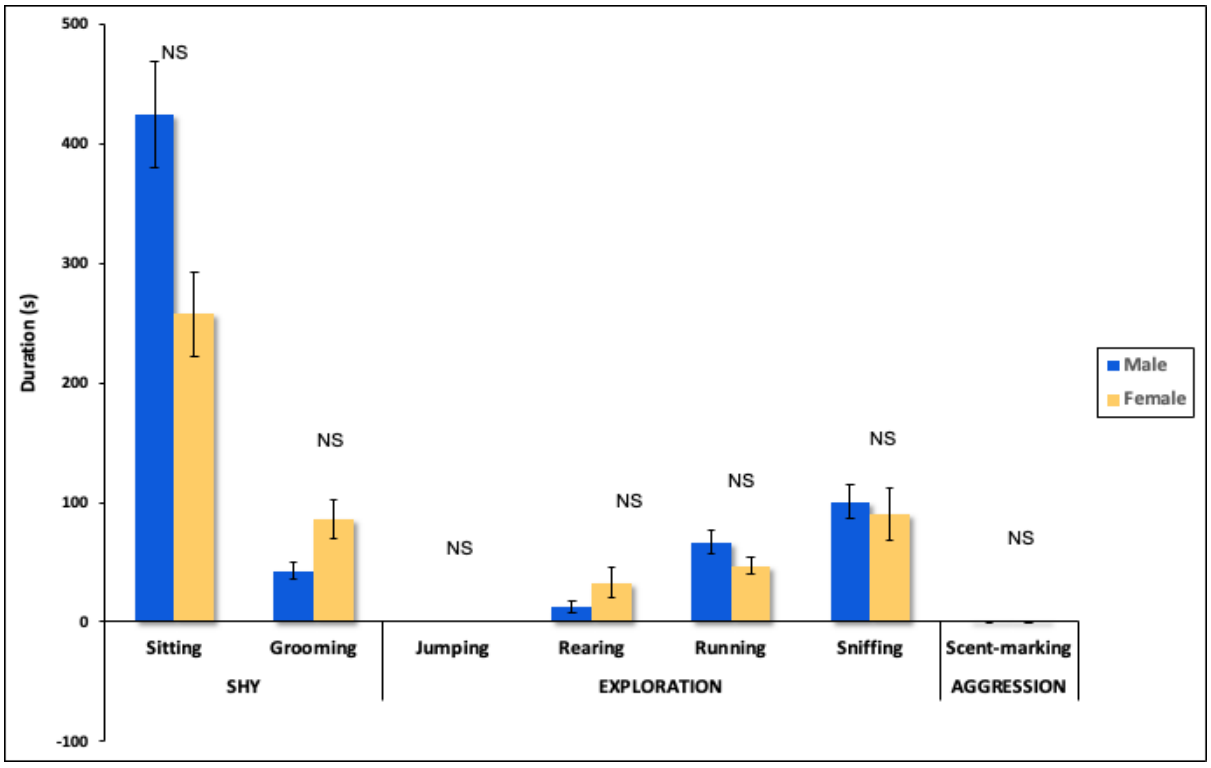


**Figure 16:** Duration (mean ± SE) of the behavioural categories recorded during 15-min open-field test male ($n = 16$) and female ($n = 7$) in woodland dormice (*Graphiurus murinus*). Values did not differ significantly between males and females (Mann-Whitney *U* tests: $p > 0.05$). NS = non-significant.

### 3.8 Behavioural response of male and female woodland dormice in a Novel Object Test

In the novel object test, male and female woodland dormice displayed similar behaviours. However, there was a significant difference in the frequency with which the behaviours were performed ($\chi^2 = 73.462$, df = 6, $p < 0.001$; Figure 17). Male woodland dormice sat and sniffed more often than female woodland dormice (Figure 17). On the contrary, female woodland dormice ran, reared, and bit the novel object significantly more often than male woodland dormice (Figure 17).

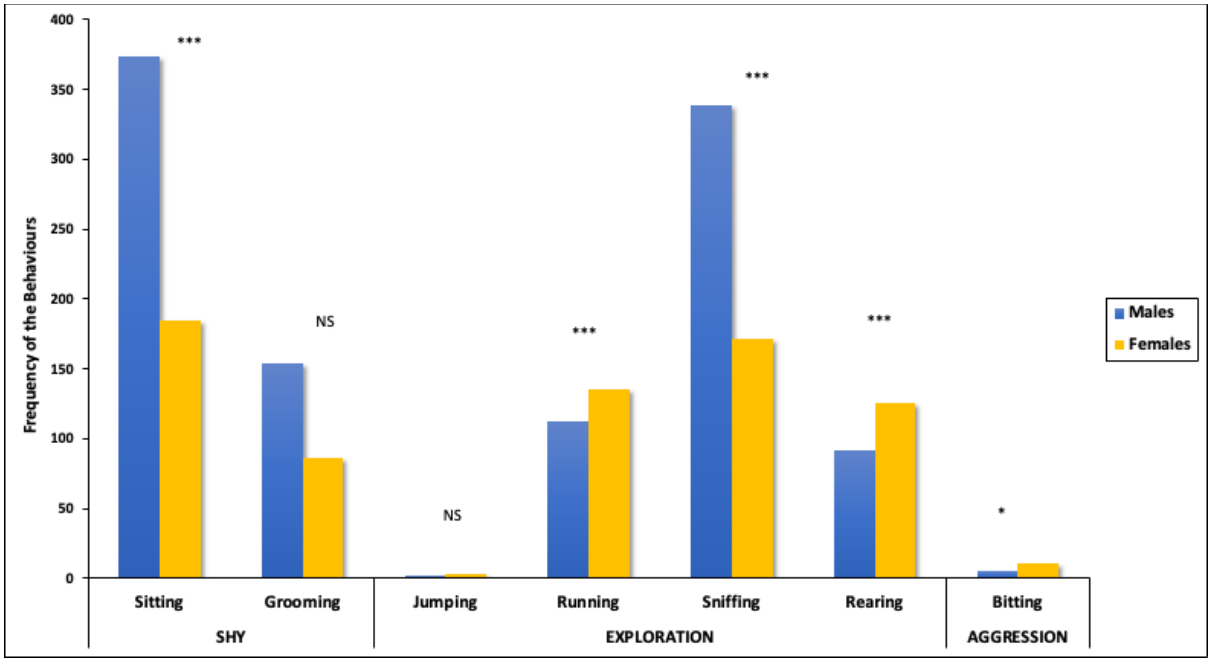


**Figure 17:** Comparisons of the absolute frequencies of occurrence of behavioural categories exhibited by male and female woodland dormice (*Graphiurus murinus*) in a novel object test. Behavioural categories that differed significantly between males and females (Chi-square tests of independence) are indicated with * = $p < 0.05$; *** = $p < 0.001$; NS = non-significant.

There were significant differences in the propensity of performing the observed behaviours (Table 12). Based on the chi-square homogeneity test, male woodland dormice sat, ran, and sniffed more often than expected; and they jumped, ran, reared, and bit the novel object less often than expected ($\chi^2 = 867.130$, df = 6, $p < 0.001$, Table 12). Female woodland dormice sat and sniffed more often than expected; and they jumped and bit the novel object less often than expected ($\chi^2 = 309.013$, df = 6, $p < 0.001$, Table 12).

**Table 12:** Chi-square tests of homogeneity to investigate whether male (M) and female (F) woodland dormice exhibited specific behaviours more or less than expected according to a theoretical homogeneous distribution during the NVO test. Observed values which are at least 25% larger or smaller than expected values are highlighted in bold. Expected values in parentheses.

| Categories | Sitting | Grooming | Jumping | Running | Sniffing | Rearing | Biting | Chi-square test |
|---|---|---|---|---|---|---|---|---|
| **M observed** | **374 (152)** | 154 (152) | **2 (152)** | **112 (152)** | **339 (152)** | **92 (152)** | **5 (152)** | **$\chi^2$= 867.130, df = 6, $p$ < 0.001** |
| **F observed** | **185 (102)** | 86 (102) | **3 (102)** | 135 (102) | **171 (102)** | 126 (102) | **11 (102)** | **$\chi^2$= 309.013, df = 6, $p$ < 0.001** |

The results showed that there were no significant differences between male and female woodland dormice in the duration for performing the observed behaviours ($p > 0.05$; Figure 18).

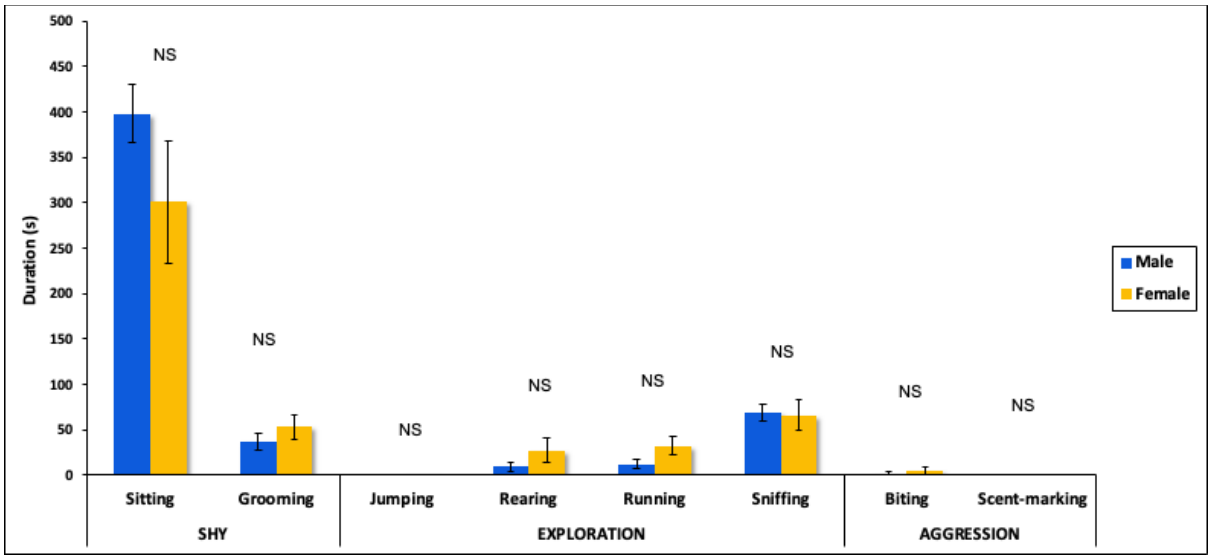


**Figure 18:** Duration (mean ± SE) of the behavioural categories recorded during 10-min novel object test male ($n$ = 16) and female ($n$ = 7) in woodland dormice (*Graphiurus murinus*). Values did not differ significantly between males and females (Mann-Whitney $U$ tests: $p > 0.05$). NS = non-significant.

# 4. Discussion

The overarching aim of this research was to study the personality of three arboreal rodent species namely, the woodland dormouse (*Graphiurus murinus*), Mozambique thicket rat (*Grammomys cometes*) and the Namaqua rock mouse (*Micaelamys namaquensis*) by observing species-specific and inter-sexual differences in behaviours using well known personality tests such as the Open-field test and the Novel object test.

### *Species differences in the Open-field Test*

The first objective of this study was to determine whether there were differences in the personality traits of the three rodent species, by evaluating their propensity to explore novel environments using the open-field test. The first prediction was that, even though the rodents are exposed to similar environments, they would still maintain species-specific individual characteristics. The results revealed that the three species expressed similar behaviours in the open-field test (Table 5). However, there were significant differences in the rate at which the behaviours were performed (Figure 3), as well as in the time spent performing the behaviours (Figure 4). This suggests that despite experiencing similar environmental factors in their habitat, for example climate conditions, level of predation risks, and food availability, etc.; the three rodent species maintained their individualised species-specific personality traits. These results (Figure 3 and 4) further suggested that the characteristics that make up personality, might have a genetic component. Indeed, personality traits are inherited through genes (Benus *et al*. 1991). These findings (Figure 3 and 4; Table 5) were similar to observations made by Pastorino *et al*. (2019) in a study conducted on three species of penguins (*Pygoscelis papua, Aptenodytes patagonicus* and *Eudyptes moseleyi*), which revealed that the three species of penguins had similar personality traits but differed in the rate of expression or intensity of the observed traits. A more detailed examination of the rate (Figure 3 and Table 5) and duration (Figure 4) of the different behaviours showed that the woodland dormouse spent more time expressing shy behaviours and to some extent exploratory behaviours during the open-field test. The preference for sitting, grooming, and sniffing around the arena, suggests that woodland dormice are likely more cautious and less inclined to explore novel and open spaces. Furthermore, these results (Figure 3 and 4; Table 5) could suggest that woodland dormice are potentially shyer than the other rodent species when exposed to novel environments. In a broader context, it is plausible that in natural environments, woodland dormice avoid or are reluctant to explore novel and open spaces in

the forest. Indeed, shy animals are categorised as those animals that tend to show timidity, avoidance, relatively less aggressive and aversion to risky behaviours (Koolhaas *et al*. 1999; Mortez *et al*. 2004; Sih *et al*. 2004; Koolhaas *et al*. 2008; Rupia *et al*. 2016; Yuen *et al*. 2017). In addition to this, it is possible that woodland dormice may have an aversion to open spaces as a study on microhabitat use by woodland dormice at the Great Fish River Nature Reserve found that they prefer the parts of the forest that had dense canopy cover rather the open spaces (Lamani 2015). Indeed, in habitats where animals are exposed to dense vegetation cover, as at Great Fish River Nature Reserve, animals tend to rely on crypsis as a form of predator avoidance (Wilson 1975). Contrary to the above, the results (Figure 3 and 4; Table 5) revealed that the Mozambique thicket rats spent more time performing exploratory behaviours and ritualised aggression in the arena. The preference for running, jumping, rearing and scent-marking behaviours by the Mozambique thicket rats, could suggest that this species is behaviourally motivated to explore novel and open spaces. In addition, the higher rates of ritualised aggression in the form of scent-marking could be interpreted as a form of territoriality or social dominance. Similarly, the results (Figure 3 and 4; Table 5) showed that Namaqua rock mice showed a preference for running, sniffing, and rearing. This shows that there was active exploration of the arena, as these behaviours are associated with activity and exploration (Archer 1975; Mortelliti and Brehm 2020). These results (Figure 3 and 4; Table 5) coupled with the relatively low preference for grooming and scent-marking could suggest that this species is behaviourally motivated to explore novel environments. Indeed, novelty is known to elicit exploration in rodents (Wilson *et al*. 1994; Mettke-Hoffman *et al*. 2006). Overall, these findings (Figure 3 and 4; Table 5) suggest that Mozambique thicket rats are possibly bolder in personality than the other species of rodents in this study. Higher rates of exploratory behaviours in novel environments have been associated with boldness (Wilson *et al*. 1993; Sih *et al*. 2004), higher ability to gather information (Brown and Braithwaite 2004), and higher assessment of risks involved (Bonn *et al*. 2008). The expression of ritualised aggressive behaviours could be associated with territorial aggression (Guillette *et al.* 2009; Tebbich *et al.* 2009) or social dominance (Dahlbom *et al.* 2011). Indeed, bold individuals in animals are categorised as those that tend to display less aversion to novelty or threats, and more proactive and dominant behaviours (Koolhaas *et al*. 1999; Mortez *et al*. 2004; Sih *et al*. 2004; Koolhaas *et al*. 2008; Rupia *et al*. 2016; Yuen *et al*. 2017). The results however are not supported by microhabitat use studies done by Gebe (2014) in the same study site, who showed that Mozambique thicket rats have a higher preference for dense canopy covers, as a means of predator avoidance.

Pooled together, the results (Figure 3 and 4; Table 5) show that in comparison, the Mozambique thicket rat is the boldest species in novel, open environments, followed by the Namaqua rock mouse, and lastly the woodland dormouse.

### *Species differences in a Novel Object Test*

The second objective of this study was to determine whether there were differences in the personality traits of the three rodent species, by measuring shyness and boldness as well as exploration and avoidance to a novel object using a novel object test. Complementary to the open-field test results above, there were similarities in the behaviours that were expressed by the three species in the novel object test. However, the rate (Figure 5) and the duration (Figure 6) for performing the behaviours observed in the novel object test was significantly different. Again, observing behavioural similarities at varying intensities among the three rodent species, is consistent with findings by Pastorino *et al*. (2019). Pastorino *et al*. (2019), studied three species of penguins (*Pygoscelis papua, Aptenodytes patagonicus* and *Eudyptes moseleyi*), and they found that the three species of penguins showed similar personality traits but differed in the rate of expressing the observed traits. In addition to this, the differences in the level of responses shown towards the novel object could be indicative of different coping styles in the three species, and this is an important component of personality (Benus *et al*. 1991; Koolhaas *et al*. 1999, 2008). A more detailed examination of the species-specific behaviours (Figure 5 and 6; Table 6) revealed that the Mozambique thicket rat had a higher propensity for exhibiting exploratory behaviours when exposed to the novel object. The relatively high rates observed for running and jumping (Figure 5, Table 6) during the novel object test, could be interpreted as exploration of the novel object by the Mozambique thicket rats. This is consistent with findings by Martin and Réale (2008), who also associated jumping with exploration in chipmunks (*Tamias striatus*). Based on these results (Figure 5 and 6; Table 6), it appears that this species is behaviourally motivated to investigate and gather information about the novel object in the arena. Overall, these results (Figure 5 and 6; Table 6) could also be indicative of boldness as these behaviours were performed in front of a novel object. Indeed, bold individuals are typically more explorative than shy individuals even when faced with the same situation (Wilson *et al*. 1993). Woodland dormice on the other hand, exhibited a combination of shy, and exploratory-avoidance behaviours when exposed to the novel object (Figure 5 and 6; Table 6). The relatively high rates (Figure 5; Table 6) observed for sitting and grooming in front of the novel object, could be interpreted

as the woodland dormice being shyness and aversive towards the novel object. In addition, the relatively high rates (Figure 5; Table 6) observed for sniffing and rearing, could be interpreted as exploration and as active avoidance of the novel object. Explanations of the shy behaviours expressed by woodland dormice could be linked to cautionary measures towards a novel object that might be perceived as a danger. According to Mortelliti and Brehm (2020), rearing is a form of vertical exploration. Thus, it is possible that the woodland dormice reared to find a way to escape from the novel object, hence this behaviour could be classified as a form of 'active' avoidance or an escape response. Alternative explanations could be linked to the biology of the species, woodland dormice are nocturnal rodents that inhabit dense forests (Madikiza 2010), therefore, are less likely to see their predators and hence they depend heavily on their olfactory senses. This could explain the relatively high rate of occurrence (Figure 5 and 6; Table 6) observed for sniffing. Interestingly, in terms of duration, the Namaqua rock mouse spent more time on shy behaviours such as sitting more than the other species did (Figure 6). Similarly, the relatively longer duration (Figure 6) spent sitting away from the novel object by the Namaqua rock mouse could also be interpreted as being avoidant of the perceived threat. Again, these behaviours are highly associated with being shy (Koolhaas *et al*. 1999; Mortez *et al*. 2004; Sih *et al*. 2004; Koolhaas *et al*. 2008; Rupia *et al*. 2016; Yuen *et al*. 2017).

Pooled together, the results (Figure 5 and 6; Table 6) show that in comparison, the Mozambique thicket rat is the boldest species when facing a novel object, followed by the woodland dormouse, and lastly the Namaqua rock mouse.

### *Differences between males and females in each species*

The third objective of this study was to determine whether there were any personality differences between males and females of the same species. The prediction was that there would be inter-sexual differences in personality due to the influence of sex hormones. Overall, the observed differences in the frequencies of performed behaviours during the staged personality tests, suggest that there are personality differences between males and females.

### *Differences between male and female Namaqua rock mice in an Open-Field Test*

The results (Figure 7 and 8, Table 8) show a general pattern in the behavioural responses of male and female Namaqua rock mice in a novel, open environment. However, contrary to

what was expected, the results (Figure 7 and 8, Table 8) indicate that this stimulus does not elicit any sex-specific behavioural responses in this species. These results (Figure 7 and 8, Table 8) could further indicate that, when exposed to novel, open environments both male and female Namaqua rock mice actively explore the environment. Indeed, exploration is a common behavioural response to being introduced to novel environments (Walsh and Cummins 1976; Mettke-Hofmann *et al*. 2006). Exploration is necessary to gain information about the new environment, as it allows animals to learn about possible threats and benefits in this new environment (Mettke-Hofmann *et al*. 2006).
Pooled together, the results (Figure 7 and 8, Table 8) suggest that there are no differences between male and female Namaqua rock mice in the open arena.

***Differences between male and female Namaqua rock mouse in a Novel Object Test***

Male and female Namaqua rock mice showed similar behavioural responses in the novel object test (Figure 9). However, there were clear sex differences in the rate (Figure 9) at which the behaviours were performed. The results (Figure 9; Table 8) suggest that the motivation to perform certain behaviours when facing a novel object, could be different for each sex. In comparison, male Namaqua rock mice spent more time (Figure 10) performing exploratory behaviours, while female Namaqua rock mice spent more time (Figure 10) performing shy behaviours. These results highlight the different strategies utilised by the male and female Namaqua rock mice. Similar findings on sex differences were reported by Pisula (1997; 2000), they showed that males laboratory rats approached novel sources more often than female laboratory rats did. Indeed, female rodents tend to freeze when facing novel stimuli (Archer 1975). Female Namaqua rock mice sitting and grooming in the corners of the arena, could indicate that the presence of a novel object caused them to be stressed and anxious (Komorowska and Pisula 2003; Díaz-Morán *et al*. 2014). This avoidance of an unfamiliar stimulus shown by female Namaqua rock mice, could indicate that the novel object was perceived as a threat (Barnett 1963; Calhoun 1963). The exploratory behaviours showed by male Namaqua rock mice (Figure 9 and 10; Table 8) could also be linked to high circulating blood concentrations of testosterone in males (Jardí *et al*. 2008). Jardi, *et al*. (2008) found that the hormone testosterone increases activity levels in male mice. High levels of activity are associated with exploration (Archer 1975). In natural populations, male Namaqua rock mice have been reported to have larger home ranges than females (Fleming

and Nicolson 2004) this could possibly explain their exploratory behaviours and boldness (Figure 9 and 10; Table 8).

Pooled together, the results (Figure 9 and 10; Table 8) show that male Namaqua rock mice are bolder and confront novel situations and stimuli, while female Namaqua rock mice are shyer and aversive towards exploring novel environments and stimuli. Additionally, these results (Figure 9 and 10; Table 8) could possibly highlight the motivation or inclination to prioritise certain behaviours when confronted with novel stimuli. Thus, further emphasising the dichotomy between bold and shy individuals.

***Differences between male and female Mozambique thicket rats in an Open-Field Test***

Male and female Mozambique thicket rats showed similar behavioural responses in the open-field test (Figure 11 and 12; Table 9). However, they differed in the rate of expressing some of the behaviours observed during the open-field test (Figure 11). In comparison to the female Mozambique thicket rats, male Mozambique thicket rats showed a relatively higher preference for grooming and behaviours associated with exploration (running and rearing) and aggression (scent-marking) (Figure 11). However, no differences were observed in the duration of performing any of the behaviours (Figure 12). A review of the open-field test showed that scent-marking is a behaviour that is commonly exhibited by male rodents during the open-field test Archer (1975). In nature, male mice use scent-marking as a means of chemical communication with their conspecifics, to mark their territory (Arakawa *et al*. 2008), in order to protect the territory and their mates from competitors as these are limited resources (Gosling and Roberts 2001). Thus, the relatively higher rate of scent-marking observed in male Mozambique thicket rats could be indicative of territorial behaviour (Figure 11). Similarly, male Mozambique thicket rats showed a relatively higher rate of behaviours associated with exploration (Figure 11), which is crucial for discovering new resources and information in novel environments (Brown and Braithwaite 2004; Mettke-Hofmann *et al*. 2006). Given that, in the natural population, male Mozambique thicket rats have 2-5 times larger home ranges than female Mozambique thicket rats do (Macata 2023 unpublished), it is likely that male Mozambique thicket rats are more inclined to explore new environments, as the results suggest (Figure 11 and Table 9). Indeed, higher exploratory behaviours in an open-field test have been positively correlated with different movement patterns of animals in nature e.g., movement distance and home range size (Boon *et al*. 2008; Kobler *et al*. 2009; van Overveld and Matthysen 2009).

Pooled together, these results (Figure 11 and 12; Table 9) show that in comparison, male Mozambique thicket rats are bolder than female Mozambique thicket rats as boldness is associated with being less aversive to novelty and a greater willingness to explore; while shyness is associated with being aversive towards novelty, being timid, avoidant and relatively less aggressive (Koolhaas *et al*. 1999; Mortez *et al*. 2004; Sih *et al*. 2004; Koolhaas *et al*. 2008; Rupia *et al*. 2016; Yuen *et al*. 2017).

***Differences between male and female Mozambique thicket rats in a Novel Object Test***

Male and female Mozambique thicket rats showed similar behavioural responses in the novel object test (Figure 13 and 14; Table 10). However, they differed in the rate of expressing some of the behaviours observed during the novel object test (Figure 13). However, no differences were observed in the duration of performing any of the behaviours (Figure 14). Male Mozambique thicket rats performed exploratory behaviours more frequently than female Mozambique thicket rats did (Figure 13). Female Mozambique thicket rats performed behaviours associated with shyness and avoidance more frequently than male Mozambique thicket rats did (Figure 13). Interestingly, female Mozambique thicket rats showed a relatively high preference for scent-marking (Table 10). This behaviour could be interpreted as a sign of anxiety, or a fearful response induced by the novel object (Bailey and Crawley 2009); or as a sign of territorial behaviour as a response to the stress induced by the novel object. Indeed, studies on female rodents have shown that stressed females tend to be more aggressive and territorial (Solomon *et al*. 2007). The introduction of the novel object to the arena changed the conditions of the environment. The novel object was likely perceived as a threat by the female Mozambique thicket rats, while the male Mozambique thicket rats found it to be interesting (Mettke-Hofmann *et al*. 2006). This could indicate that when facing potential threats male Mozambique thicket rats are more likely to respond by actively exploring the novel object, while female Mozambique thicket rats are more likely to respond by avoiding the novel object.

Pooled together, these results (Figure 13 and 14; Table 10) show that in comparison, males Mozambique thicket rats are bolder and confront novel stimuli, while female Mozambique thicket rats are shyer, anxious, and stressed in front of novel stimuli as boldness is associated with being less aversive to novelty and a greater willingness to explore; while shyness is associated with being aversive towards novelty, being timid, avoidant and relatively less

aggressive (Koolhaas *et al*. 1999; Mortez *et al*. 2004; Sih *et al*. 2004; Koolhaas *et al*. 2008; Rupia *et al*. 2016; Yuen *et al*. 2017).

### *Differences between male and female woodland dormice in an Open-Field Test*

Male and female woodland dormice showed similar behavioural responses in the open-field test (Figure 15 and 16; Table 11). However, the behaviours were not expressed at the same frequency (Figure 15). Male woodland dormice performed exploratory behaviours i.e., jumping and sniffing, more frequently than the female woodland dormice did (Figure 15). Interestingly, they also groomed more than the female woodland dormice did (Figure 15). In the open-field test, grooming is indicative of stress (Komorowska and Pisula 2003; Díaz-Morán *et al*. 2014), while jumping is usually associated with vertical exploration and attempting to escape (Martin and Réale 2006). The correlation between jumping and grooming (Figure 15) could suggest that male woodland dormice respond to novelty-induced stress by attempting to escape from the arena. On the contrary, the correlation between sitting (in the corner of the arena) and sniffing (Table 11) could suggest that male woodland dormice respond to novelty by initially being avoidant and not exploring. Both male and female woodland dormice showed a preference for running and walking, as well as sitting (Table 11). This appears to be contradictory; however, novelty is known to elicit both avoidance and exploration in rodents (Wilson *et al*. 1994; Mettke-Hoffman *et al*. 2006). These similarities between male and female woodland dormice possibly highlight species-specific behavioural strategies used when exposed to novel environments, which would be, to initially be avoidant in order to gain information about the novel environment, followed by exploration once it has been ascertained that there are no threats in the novel environment. This is a plausible explanation as, although exploring a novel environment can offer benefits such as new resources, discovery of new territory and new information about the environment (Brown and Braithwaite 2004; Mettke-Hofmann *et al*. 2006), avoidance can also serve as a valuable tool for avoiding predators (Wilson 1975) and parasites in the environment (Wilson *et al*. 1993). Thus, woodland dormice are cautious when they are exposed to a novel environment, as any potential benefits from the environment may come with energetic costs, as well as the risk of being predated on (Mettke-Hofmann *et al*. 2006). Their preference for shy behaviours could also be due to that, woodland dormice inhabit dense forests which offer ample cover, unlike the test arena which had no place for them to hide (Madikiza 2010).

Pooled together, these results (Figure 15 and 16; Table 11) show that both male and female woodland dormice initially react to novel environments by being avoidant, however they eventually explore the novel environment after establishing that there are no threats.

### *Differences between male and female woodland dormice in a Novel Object Test*

Male and female woodland dormice showed similar behavioural responses in the novel object test (Figure 17 and 18; Table 12). However, the behaviours were not expressed at the same frequency (Figure 17). Female woodland dormice performed behaviours associated with active exploration (running, rearing) and aggression (biting) more frequently than male woodland dormice did (Figure 17). The aggression shown towards the novel object could suggest that the novel object was perceived as a threat. This aggressive behaviour could also be linked to high levels of blood oestrogen, as the sampling period coincided with the woodland dormouse's mating season (Madikiza 2010). High concentration levels of oestrogen are linked to increased olfactory threshold in female rodents (Archer 1975; Gioiosa *et al*. 2007). Thus, it is likely that smell of the lavender oil droplet on the ball were irritating, hence they responded aggressively. On the contrary, the correlation between sitting (in the corner of the arena) and sniffing (Figure 11 and Table 12) observed in the male woodland dormice, could indicate that they responded to the novel object by avoiding it and studying it at a distance. Overall, both male and female woodland dormice show a preference for performing behaviours associated with shyness, avoidance, and exploration (Figure 17; Table 12). This appears to be contradictory, however a plausible explanation could be that both male and female woodland dormice, show an initial aversion to novelty by sitting and sniffing at the novel object at a distance. This would allow for the rodent to gain information about the novel object without necessarily interacting with it (Mettke-Hoffman *et al*. 2006). These results (Figure 17) are also supported by studies on laboratory rats, which showed that in comparison to male rats, female rats had a greater tendency to explore and rear in novel environments and in front of novel stimuli more than males (Hughes 1968; Gray 1971). Pooled together, these results (Figure 17 and 18; Table 12) show that both male and female woodland dormice initially react to novel environments by being avoidant, however they eventually explore the novel environment after establishing that there are no risks.

# Conclusion

The aim of this study was to assess the personality of the Namaqua rock mouse, Mozambique thicket mouse, and the woodland dormouse to understand how personality varies in rodent assemblages, i.e., to highlight species-specific and inter-sexual differences in personality. The open-field test and the novel object test were used to gain insight into the behavioural responses shown by these three species in novel environments and in the presence of novel objects. This study showed that novelty elicits both shy and exploratory behaviours in these rodent species. However, there are slight differences in personality among the three species due to inherent traits. In comparison, the Mozambique thicket rat is the boldest species in novel, open environments, followed by the Namaqua rock mouse, and lastly the woodland dormouse. And the Mozambique thicket rat is the boldest species when facing a novel object, followed by the woodland dormouse, and lastly the Namaqua rock mouse. Males and females were compared within each species to determine if there were any sex-specific differences within each species. The comparison revealed that, when exposed to novel environments, male and female Namaqua rock mice behave similarly, however the introduction of a novel object causes male Namaqua rock mice to be more exploratory. Similarly, male Mozambique thicket rats are bolder than female Mozambique thicket rats in novel, open environments and in the presence of novel objects. Thus, male Mozambique thicket rats are more likely to confront novel objects; while female Mozambique thicket rats are shyer, anxious, and stressed in the presence of novel objects. Male and female woodland dormice both show an initial aversion towards novelty, prior to ascertaining that there are no threats in the environment. This is then followed by exploration of the novel environment and novel object; however, females are more likely to interact with the novel object. Overall, this study showed that novelty elicits both shy and exploratory behaviours in these three rodent species, which highlights two strategies utilised by rodents to survive, i.e., exploring novel environments for potential benefits; and being cautious to stay safe in unfamiliar environments. In consideration of this, it would be beneficial to preserve pristine forests to protect keystone structures that are crucial for preserving diversity in species and personality types. However, more studies on long-term trapping and correlation with personality tests could reveal more information on personality profiles and their subsequent consequences.

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