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ORIGINAL PAPER

Similarity of locomotor personality trait within parents improves their reproduction in the common vole (*Microtus arvalis*) under laboratory conditions

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Abstract

In the last decade, the personality traits of the common vole (*Microtus arvalis*) have been well described. However, to date, the mechanisms by which they are maintained in vole populations have received only marginal attention. Inspired by a study of mound-building mice, the present study focused on the possible role of assortative mating based on similar personality traits within the breeding pairs. Under laboratory conditions, seven behavioural parameters were evaluated in 63 individuals (34 males, 29 females) during three successive open field (OF) tests: total distance moved, ratio between the inner area distance/total distance moved, grooming, jumping, locomotion, scanning, and latency to the first movement. Five observed behavioural parameters based on duration were reduced to two synthetic parameters using principal component analysis (PCA). Using GLMM, we calculated for each individual the intercepts (considered personality trait) and slopes of random effects in the total distance, ratio of distances, and the scores of two PCA ordination axes. The effect of within-pair differences in intercepts (personality traits similarity) for each tested variable on the number of offspring was then tested using the function for zero-inflated models. A significant negative correlation was obtained only for the personality trait similarity of the total distance moved. This means that the smaller the personality trait difference (higher similarity) of overcoming a distance (locomotor ability) between the parents led to an increased number of offspring. The results are discussed in terms of the parents' fitness strategies under different population densities.

Keywords Common vole · Behavioural personality trait · Assortative mating · Offspring production

Introduction

In the last decade, behavioural personality traits and their plasticity have been often studied in the common vole (*Microtus arvalis*, Lantová et al. 2011; Eccard and Herde 2013; Herde and Eccard 2013; Gracceva et al. 2014; Urbánková et al. 2020). One of the reasons why the common vole became a model species was the aim to look for potential proximal mechanisms that might drive the cyclic changes in population density (Esther et al. 2014; Pinot et al. 2014, 2016). Studying vole population and environmental interactions is important not only for fundamental science but also for applied science such as pest management and conservation (Jacob et al. 2014, 2020; Heroldová et al. 2021). This raised the question if behavioural personality traits may also contribute to reproduction. Indeed, Rangassamy et al. (2015) first described a possible role of personality traits in mammal reproduction outside of humans. Personality traits in parents were found to improve reproduction in the mound-building mouse (*Mus spicilegus*). Inspired by this study, we assessed the situation in the common vole.

The preference for similar traits or phenotypes during reproduction is known as assortative mating, which can be divided into positive or negative (disassortative). Positive assortative mating means that there is a tendency to

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prefer individuals with similar phenotypes, while negative assortative mating is a preference for different individuals (Jiang et al. 2013). Thiessen et al. (1997) argued that positive assortative mating may be a successful strategy since couples sharing a similarity are likely to put more than 50% of their genetic information into their offspring. However, inbreeding depression can deteriorate the viability of the future offspring reproductive line. Therefore, there is also an opposite tendency to maintain high diversity of the main histocompatibility complex (MHC) genes and prefer different partners (Leclaire et al. 2017; Santos et al. 2016). Positive assortative pairing is usually done according to body size, shape or colour (Harris, and Siefferman 2014; Hase and Shimada 2014). Similar behavioural traits should be probably common, especially in species with biparental offspring care at least during the breeding season.

There are several reasons for choosing a partner according to a personality trait, one of which is that some personality characteristics may indicate the quality of parental care (Dirienzo and Hedrick 2014). Some females can predict the male's ability to protect offspring based on its behaviour (Teyssier et al. 2014). The importance of the similarity in personality traits of partners for the success of reproduction has been documented several times in fish and birds (see e. g. Ihle et al. 2015; Laubu et al. 2016). The combination of certain personality traits may lead to a better physical state of the offspring, or to a larger number of offspring (see meta-analyses of Smith and Blumstein 2008; Jiang et al. 2013). For example, the influence of a personality trait was determined by exploration in the Great tit *Parus major* (Dingemanse et al. 2004). Great tits were more reproducibly successful (their young were in better condition) if both individuals in the pair were identified as "slow". If both individuals were considered "fast", they were more successful in defending their territory (Both et al. 2005).

As mentioned above, the importance of similarity in personality traits for reproductive success was also documented in the monogamous mound-building mouse. This mating system is not common in mammals, but even there, parental compatibility appears to be useful. Couples with similar levels of anxiety started reproduction earlier than dissimilar ones (Rangassamy et al. 2015). In the common vole, the promiscuous mating system is quite different. Moreover, there are two very distinct phases of high and low population density where mating has a different character. The first (also called the peak phase) is characterized by increased migratory activity, especially in males, with random pairing and thus increasing genetic diversity. The phase of low density (population collapse) is characterized rather by isolated individuals and a reduction of genetic diversity (Gauffre et al. 2014). Thus, mating between partners with similar personality traits (genes) within relatively isolated inhabited islets can improve reproduction due to increased cooperation of parents with similar behaviour and produce more vital offspring due to reduced fluctuating asymmetry. At the same time, it can help to maintain these similar personality traits in the vole population, thereby improving reproduction (for review see Jiang et al. 2013).

Based on the abovementioned data about the positive effect of behavioural similarity on reproduction, the aim of this study was to determine whether similarity in partner behaviour will affect reproduction in a solitary-living rodent, the common vole. The working hypothesis of our study was that pair similarity in personality behavioural traits enhances the total offspring number.

Material and methods

Vole individuals

Wild common voles were caught on agriculturally managed meadows during March and April (2015) using Sherman live traps for small mammals. The parental pairs came from two distant localities (about 20 km apart) to prevent inbreeding (locality 1: České Budějovice, 48.977821 N, 14.441390 E, locality 2: Lužnice, 49.080373 N, 14.755786 E). No weight (Mann–Whitney U tests; males: $n = 16/18$, $Z = -1.12$, $P = 0.262$; females: $n = 10/19$, $Z = -1.24$, $P = 0.179$) or reproduction (Mann–Whitney U test; $n = 19/36$, $Z = 1.03$, $P = 0.305$) differences were found between individuals from the two populations. These captured animals were adults after the winter that gave birth to young under the spring light regime (L:D 12:12) in our breeding colony. This procedure was chosen because pups born into the spring regime grow intensively and soon reach sexual maturity (Niethammer and Krapp 1982). For the experiment, we used individuals from the F1 generation. In our breeding colony, we tested 63 adult individuals (34 males and 29 females) at the age of 3 months. To ensure that the animals were adults, sexual maturity was checked in males according to the scrotal position of the testes and in females according to the presence of standard stages of the oestrous cycle based on a vaginal smear (Cora et al. 2015; Nubbemeyer 1999). Due to the laboratory environment, the selected animals were controlled for almost identical age/weight.

Voles were kept individually in polycarbonate breeding boxes 58 × 36 × 20 cm (VELAZ Prague) with wood shavings, hay, and a plastic tube as a shelter ($l = 15$ cm, $d = 4$ cm). Commercial pellets for rats and mice, as well as pellets for guinea pigs and rabbits (VELAZ Prague), fresh carrots, and water were available ad libitum. All individuals were individually marked on the breeding boxes. The laboratory conditions were stable, with room temperature of 21–23 °C under a L:D 12:12 photoperiod, similar as for their parents. Body weights showed some sexual dimorphism (males

22–28 g, females 18–22 g). The voles were tested between 9 a.m. and 4 p.m. in a random order, because voles are animals with a polyphasic circadian activity with alternating 2–3 h of moving and rest (Gerkema et al. 1993).

The voles were bred and tested in accordance with the principles of animal welfare and guidelines of the Departmental Commission for Animal Protection of the Ministry of Education, Youth and Sports (permit number 7945/2010–30) and the animal treatment also conformed to the journal's ethic guidelines. After the experiments, the voles were kept in the laboratory and were used for further breeding and behavioural tests.

Experimental design

The personality traits were determined during three open field (OF) tests with 2-week intervals (OF test 1, 2, and 3), which in the models was designated as the independent variable "OF-test". Each test session was recorded on a digital camera (Panasonic Color CCTV Camera WV-CP500/G) placed 150 cm above the testing arena. The video sequence was analysed using EthoVision 8.0 TX (Noldus). Individuals were tested in the OF test in a random order to avoid biases caused by daily activity patterns. During 7 test-hours, from 9 a.m. to 4 p.m., we tested 21 individuals in each of 3 days, in total 63 animals. In the next OF tests, we randomized the order of individuals for each of 3 days ($1-21$) separately. The day-time was not significant (Supplementary material, Table S1). After the third OF test, to ensure the females were sexually active, vaginal smears were evaluated again (see above), and the voles were mated. In total, the proestrus-like stage was observed in 40 females, oestrus in 15, and metestrus in two females. The males were then placed into the female breeding boxes. A total of 57 pairs of voles were involved in the experiment, with 33 pairs created during the first round and 24 new ones during the second round. If the males tried to escape from the female breeding box, they were removed after 15 min ($n=3$ males). If the males did not try to escape, they were left in the female breeding box for a maximum of four days. The relationships between the number of offspring and the behavioural personality trait differences of the parents were calculated based on male– female absolute differences (|M–F|) after Rangassamy et al. (2015).

Open field (OF) test

Our OF test was carried out in a square Perspex arena (75 L × 75 W × 50 H cm) with non-transparent walls. The area was divided virtually into 5 × 5 squares (15 × 15 cm), in which the outer zone along the walls accounted for 64% of the area and the inner zone 36%. In the test room, light intensity was maintained at about 100 lx to ensure equal illumination. All experimental animals were carried from their breeding boxes to the experimental arena in their plastic shelter tubes and were subsequently gently placed to the outer zone of the arena on the same side maintaining the same direction of the animal's body (i.e. forced OF test). The arena was divided virtually into 5 × 5 squares (15 × 15 cm), in which the outer zone along the walls (16 squares) accounted for 64% of the area and the inner zone (9 squares) 36%. Each session lasted 5 min since prolonged tests cause habituation of voles, i.e. less frequent and less pronounced exploration as observed in previous studies (Lantová et al. 2011; Urbánková et al. 2020). The arena was cleaned with watered-down ethanol after each experiment. The behavioural parameters were assessed as follows: (1) distance moved in the inner zone (36%) of the arena (m), (2) total distance moved during the test (m), (3) grooming—behaviour focused on own body surface/fur (s), (4) jumping—jumping up the walls often quickly repeated (s), (5) locomotion—forward movement often interrupted by other behaviours (s), (6) scanning—staying on place and turning head (s), and (7) latency of the first movement (s).

Statistical analyses

We first performed a principal component analysis (PCA) for parameters that were obtained for each individual ($n=63$ individuals) in three consecutive OF tests (1–3) using Canoco 5 (Ter Braak and Šmilauer 2018). The analysis was performed in order to reduce the number of behavioural parameters based on duration (duration of locomotion, scanning, jumping, grooming, and latency to movement) into two synthetic behavioural variables, i.e. two ordination axes. The percentage data were arcsine transformed and we used test round (1–3) as a covariate. Two variables based on the moved distance (the total distance moved, ratio of the distance moved in the inner area to the total distance moved) were further tested separately since they were not suggested to be arcsine transformed and represent different variables that were independent on percentages of each behaviour. We used scores from the first and second ordination axis, and the original values of the distance variables using the lmer function in R 4.0.2 (R Core Team 2020) using lme4 package. These analyses were performed to gather the intercepts and slopes of random effects of the analysed behavioural parameters for each individual. Previous tests showed that sex and weight did not significantly affect the behavioural variables (P at least 0.436). Therefore, we used the round of each OF test (1–3) as an independent variable, in addition as a slope of random effect id to assess the temporal reaction norm of the individual variation. In doing so, we estimated the intercept, slope, and covariances between them and assessed the consistency repeatability (R_C) after Biro and Stamps (2015). We used updated version of rptR package (Stoffel et al. 2017) enabling us to compute repeatability according to the distribution of each dependent variable. Thus, we used rptGaussian function for variables, which distribution did not significantly differ from Gaussian distribution (total distance moved, scores from the first and second ordination axes; Kolmogorov–Smirnov tests, for all variables $P > 0.100$). The distribution of ratio of the distance moved in the inner area to the total distance moved significantly differed from Gaussian distribution (K-S test, $P < 0.050$). Therefore, we used rptProportion function comparing the two variables (distance within the inner and outer part of arena) using cbind function (Stoffel et al. 2017). We also performed likelihood ratio tests to assess the fixed effects using the lrtest and the lmerTest package to assess the effect of random factors (Supplementary material, Table S3). For each breeding pair and behavioural trait (distance moved total, ratio inner/total distance moved and scores from the first and second ordination axes), we calculated the differences in the random intercepts between male and female (|M–F|), meaning the parent personality trait similarity for consequent BLUP analyses (Houslay and Wilson 2017).

Furthermore, we tested the effect of the differences in the random intercepts between male and female (the parent personality trait similarity) on the number of offspring. We used id of male and female as random factors and function glmmTMB function for zero-inflated models in R since the data included a high proportion of zeros. We used first and second order of independent variables due to expectation of non-linear relationships. Consequently, the relationship between the number of young (dependent variable) and the similarity in personality trait total distance moved was visualised using non-linear estimation in Statistica 13 (TIBCO Software Inc. 2017). For all tests, we considered the cut-off for statistical significance as $P < 0.05$.

Results

Behavioural parameters

Using multivariate PCA analysis, we found that the percentages of latency and grooming times were positively correlated. Simultaneously, latency (correlation coefficient − 0.93), and grooming (− 0.63) were negatively correlated with the first ordination axis. The percentages of time jumping were positively correlated with the second ordination axis (0.86), while locomotion was negatively correlated with the second ordination axis (− 0.43), but positively correlated with the first ordination axis (0.46). The percentages of time for scanning were rather independent of the abovementioned relationships but were slightly positively correlated with the second ordination axis (0.24, Supplementary material, Table S2). Therefore, we probably found a shy-bold gradient along the first ordination axis and a high-low exploration pattern along the second ordination axis (Fig. 1). These two gradients were used for further analyses. The variables based on distance moved were tested separately. The total distance moved was considered a proxy for locomotor ability and the ratio of the distance moved in the inner zone to the total distance moved was another proxy for shy-bold trait.

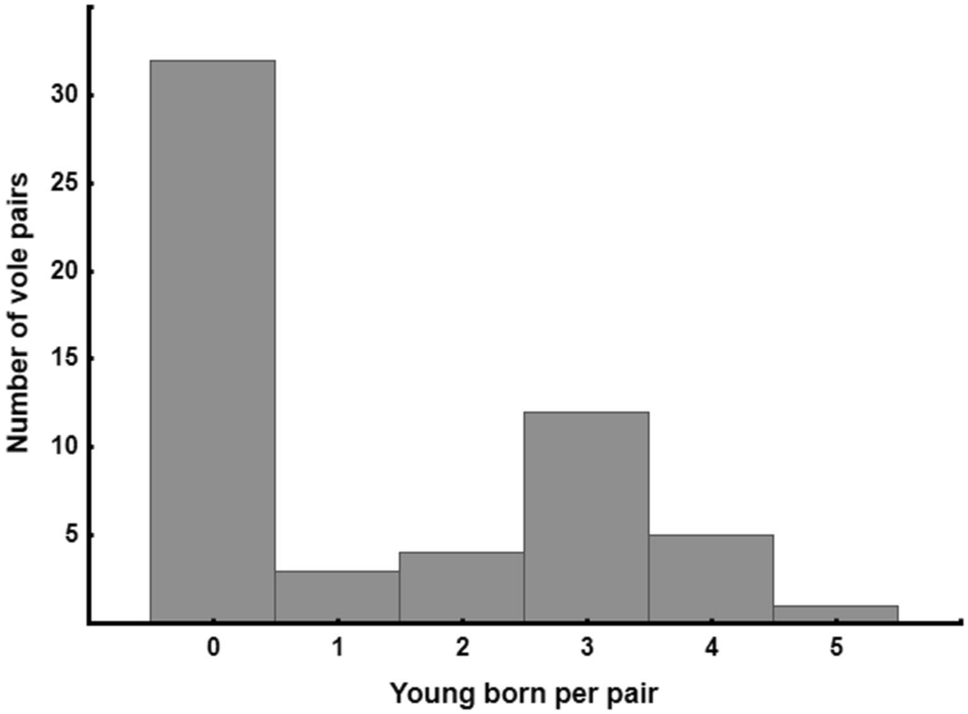

Fig. 1 Histogram of the number of young born in the experimental pairs

Consistency repeatability was significant ($P < 0.001$) in all behavioural evaluated parameters (Table 1). The total distance moved reached high value ($R_C = 0.642$), while the ratio inner/total distance covered had the lowest value ($R_C = 0.065$). The values for the first and second PCA ordination axis were also high ($R_C = 0.799$ and 0.672 respectively).

We found a statistically significant fixed effect of the repeated OF tests on three of four behavioural parameters that entered the analyses (total distance moved, score from the first and the second ordination axes of the PCA analysis). Random effects were statistically significant for all four dependent variables (Table 2, Supplementary material, Table S3).

Reproduction and personality trait differences

In both rounds of mating (57 parent pairs), 72 offspring were obtained, with 33 offspring produced during the first round and 39 during the second one. The number of offspring among pairs was rather unbalanced (Fig. 2). More than half of the pairs ($n = 32$) produced no offspring. The final production was (mean ± SD) 1.3 ± 1.6 offspring per all pairs, or 2.9 ± 1.0 offspring per fertile pairs.

The difference between male and female random intercepts for the total distance moved was the only statistically significant independent variable (glmmTMB analysis, $df = 5$, 9.3% of explained variability, Chi = 14.53, $P < 0.001$), other variables (M–F inner area/total distance moved, M–F score from first and second ordination axis) did not have significant effect (P at least 0.628). The number of offspring decreased with increasing differences in the random intercepts of distance moved between male and female (Fig. 3). Thus, the more the pairs were similar, the more offspring they produced.

Discussion

Vole behaviour in the OF test

Our set of three OF tests showed that the behaviour of animals corresponds with previous results gathered by our laboratory (Lantová et al. 2011; Urbánková et al. 2020) as well as by other common vole study groups (Eccard and Herde 2013; Gracceva et al. 2014; Herde and Eccard 2013). Similar to the results of the previous cited studies, our voles were able to cover more or less similar distances (2–8 m/min) including more or less the same behavioural elements: duration of locomotion, scanning, jumping. Probably due to short OF test, a low number of individuals manifested grooming behaviour, which is considered as an anxiety indication. After more time probably, all the animals would be able to discover that it is not possible to escape from the area and under such situation, the animals could begin to

Table 1 Repeatability of behavioural parameters (for all parameters $P < 0.001$) and estimates of random effects based on GLMM analyses. Estimates include variances in intercepts, slopes (OF-tests), residuals within individuals, and the correlation between random intercepts and slopes with 95% confidence interval. σ^2, variance

Parameters	Consistency repeatability $R_C \pm SE$	Confidence interval CI 95%	Intercept σ^2	Slope σ^2	Residual	Intercept-slope correlation and CI	Intercept σ^2	Slope σ^2
Distance total	0.642 ± 0.042	0.599–0.675	188.0 ± 13.7	17.4 ± 3.14	9.35 ± 3.06	− 0.89 (− 0.93, − 0.81)	188.0 ± 13.7	17.4 ± 3.14
Inner/total ratio	0.065 ± 0.021	0.029–0.067	< 0.01 ± 0.02	0.01 ± 0.13	0.02 ± 0.13	− 0.35 (− 0.58, − 0.15)	< 0.01 ± 0.02	0.01 ± 0.13
PCA axis 1	0.779 ± 0.025	0.677–0.722	0.93 ± 0.96	0.03 ± 0.18	0.12 ± 0.34	− 0.73 (− 0.84, − 0.39)	0.93 ± 0.96	0.03 ± 0.18
PCA axis 2	0.672 ± 0.065	0.641–0.749	0.64 ± 0.81	0.05 ± 0.24	0.10 ± 0.32	− 0.69 (− 0.79, − 0.36)	0.64 ± 0.81	0.05 ± 0.24

Table 2 Estimated parameters of the GLMM models for four behavioural dependent variables with repeated OF-tests as an independent variable with fixed effect. Estimates of the fixed effects include intercepts with SE, slopes (OF-test 1–3) with *SE*. Results of regressions between intercepts and slopes (beta) and statistical significance (*P*)

Dependent variable	Intercept ± *SE*	Slope ± *SE*	Beta (*P*)	*P*
Distance moved	17.93 ± 1.82	1.17 ± 0.65	− 0.90	< 0.001
Inner area/total distance moved	0.04 ± 0.03	0.03 ± 0.01	− 0.45	0.026
PCA axis 1	< 0.01 ± 0.10	< 0.01 ± 0.03	− 0.81	< 0.001
PCA axis 2	1.62 ± 1.21	− 0.03 ± 0.04	− 0.63	< 0.001

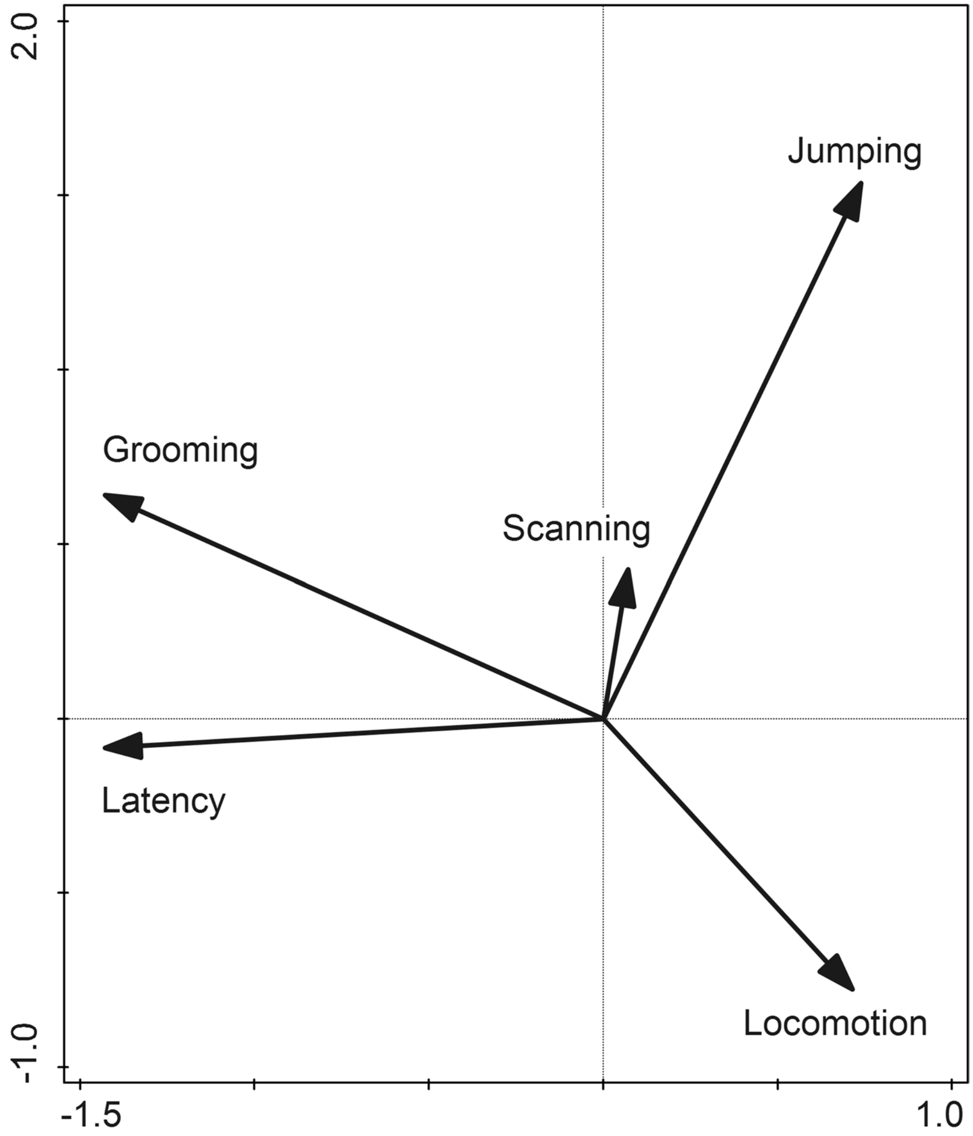

Fig. 2 Projection scores for percentages of time of behavioural traits in three OF tests. PCA analysis, ordination axis I and II together explained 75.5% of the variation

solve this conflict situation by displacement activities, most often by the self-grooming. From the observed behavioural parameters, PCA extracted a shy-bold gradient along the first axis and an exploration gradient along the second ordination axis. This personality configuration almost completely corresponds to the findings of the abovementioned studies, with sometimes only the order of the ordination axes changed.

The values of repeatability determined in our study were generally high, ranging between $R_C = 0.779$ in scores from first ordination axis and $R_C = 0.642$ in total distance moved. Higher repeatability could be an indication of stability, which is for behavioural tests important. Both well-kept animals and stable laboratory conditions can contribute to this stability. Locomotor activity is of considerable interest when phenotyping mice. This is reflected by the numerous studies using locomotor activity as a proxy of overall behavioural activity (e.g. Tang et al. 2002; van Gaalen and Steckler 2000; Uchiumi et al. 2008; Kostrzewa and Kas 2014). On the contrary, the lowest repeatability $R_C = 0.065$ was found for the ratio inner area/total distance moved. This shy-bold parameter is to great extent linked to the current state of the animal and can vary greatly among experiments (Eilam 2010).

Wilson (2018) emphasized that the repeatability index R should be used in a defined context and with clear intention. In our study, repeatability was calculated according to Biro and Stamps (2015) as a consistency repeatability (R_C) for the three tests. This type of repeatability respects individual trajectory, which is especially useful in the case of behavioural plasticity of personality traits. Among other factors, repeatability depends mainly on the intervals between tests (Bolivar et al. 2000; Bouton 2007), which was relatively short (two weeks) in our case. Based on an extensive literature review, Bell et al. (2009) calculated the mean agreement repeatability of behavioural parameters ($R_A = 0.37$) using

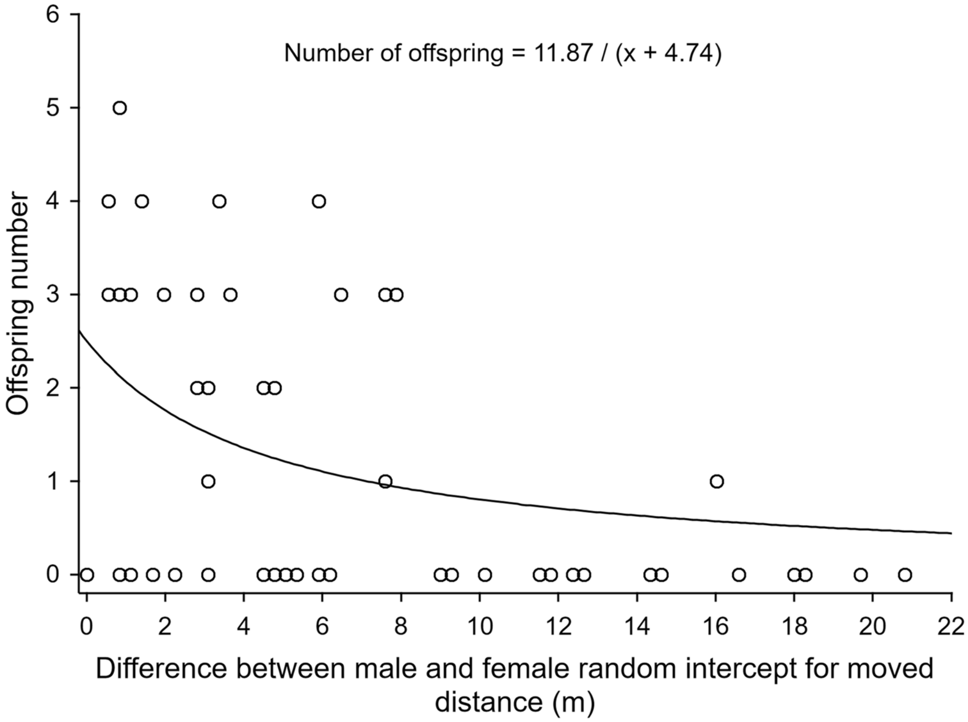

Fig. 3 The effect of the difference between male and female glmmTMB random intercepts of the moved distance on the number of offspring ($n=57$ pairs) using non-linear estimation

the method of Lessells and Boag (1987). However, this is a slightly different index, which is decreased by parallel behavioural shifts by the animals during the repeated tests.

Comparably higher values were found at the upper value of ranges for agreement repeatability (R_A) in voles (0.25–0.63, Herde and Eccard 2013; Lantová et al. 2011) and for consistency repeatability (R_C) in the black rat (0.22–0.81, Žampachová et al. 2017). It should be emphasized that these comparisons between species must be treated cautiously knowing that the same repeatability can be achieved in samples with completely different population structures (Dochtermann and Royauté 2019).

Reproduction

Female voles in central Europe produce about four litters with 1–13 young for one year, with an average of 5.5 young (Reichstein 1957; 1960 ex Niethammer and Krapp 1982). On average, the litter is 4.2 young under laboratory conditions. The decreased number of young is explained by less suitable breeding conditions and embryonic mortality (Reichstein 1964 ex Niethammer and Krapp 1982). These authors calculated the mean value based on the number of young in litters of fertile females only. In our case, the mean value shifted to 1.3 offspring in all pairs ($n=57$), or 2.9 offspring only for fertile females ($n=25$). One of the reasons for recording such a large proportion of couples without offspring (56.1%) may be the completely random combination of individuals, without any possibility of spontaneous partner preferences. Second, the status of sexual activity could be important. An extensive study of free-living voles from the Czech Republic (Pelikán 1959) showed that, within the 18–22 g category of adult females, only 49 to 85% are sexually active. In adult males (22–28 g), these percentages ranged from 47 to 91%. Under laboratory condition, the slow achievement of sexual maturity could possibly be caused by a higher concentration of female pheromones (Lee-Boot effect) due to the separation of females from males (Heise and Rozenfeld 1999; Kelliher and Wersinger 2009). The mentioned shift could be also caused the light regime (L:D 12:12), which was maybe perceived by the animals as late summer time. However, this light regime was set as the spring time, when the vole reproduction increases (Niethammer and Krapp 1982).

Although voles are short-lived organisms, this does not mean that the circannual rhythm of reproduction has completely disappeared, and activity is controlled by circadian rhythm and seasonal light–dark synchronization only (Lincoln 2019). Despite a stable laboratory environment, this circannual rhythm may modulate activity in some way. It is known for voles that there are spring, summer, and autumn cohorts, which differ qualitatively in different life strategies (Gliwicz 1996; Lambin and Yoccoz 2001). We captured the parent individuals during March and April. After the birth of the F1 generation, we waited 3 months to make sure that all individuals had achieved sexual activity, which may have been too long. In August, some individuals might have been in the phase of decreased sexual activity, which could cause a lower proportion of fertile couples. However, this should not have affected our main results, as infertile couples were evenly distributed between small and large behavioural differences within the pairs. It should be noted that no dead new-born was found to indicate a mother's stress.

Locomotor personality trait differences versus reproduction

Statistical analysis of the relationship between personality trait similarity in parents and the number of offspring showed that the more the pairs were similar the more offspring they produced. Assuming that the ultimate goal of reproduction is to transfer one's own genes to the next generation, it is well understood that females will prefer similar males who also have a similar genome with many of the same genes (Thiessen et al. 1997). However, it is argued that more isolated populations can lead to inbreeding if there is no preference for diversity, mainly represented by different MHC (Zufall et al. 2005; Boehm and Zufall 2006). In the case of voles, however, there is no such isolation effect, due both to the widespread zoogeographic distribution and continuity of the primary and secondary habitats in the agricultural landscape, and significant cycles of abundance followed by emigration to new environments (Gauffre et al. 2014).

Locomotor personality trait can play a significant role rather in the mating and copulation of solitary species i.e. in a different context than in species living in pairs e. g. in songbirds. For them, the similarity of shy-bold or exploration personality traits is more important for their offspring successful rearing (Jiang et al. 2013). The importance of similarity in locomotor activity traits of partners for the success of reproduction has been documented several times in some fish and bird species (e. g. Ihle et al. 2015; Laubu et al. 2016, 2017). Attention has been often focused on the influence of a personality trait closely associated with exploration, as was found in the great tit (Dingemanse et al. 2004). Great tits were more successful in reproduction (their offspring were in better condition) if both individuals in the parent pairs were marked as "slow". If both individuals were considered as “fast”, they were more successful in defending their territory and food resources (Both et al. 2005). The similarity of behavioural traits also supported reproduction in mammals, such as the mound-building mouse (Rangassamy et al. 2015). This species lives in monogamous couples, where the father helps with the upbringing of the offspring. In such a social system, it is quite understandable that similarity in behavioural manifestations is useful. In this species, parental care is also connected with huge mound building (Poteaux et al. 2008; Tognetti et al. 2017). Therefore, it is no wonder that similarity in behavioural traits could be important for this building activity. Similar behavioural compatibility and increased reproductive success have also been previously found in the monogamous California mouse *Peromyscus californicus* (Gleason et al. 2012).

In the common vole, males and females live under completely different social conditions. Promiscuous individuals are exposed to changing population densities between seasons and even years. Personality trait similarity in a pair could be greater probably during high population densities (e.g. Andreassen et al. 2013), when females can easily choose and achieve an increased number of pups with a preferred male, and conversely, can afford to reject an unpreferred male. In this case, it could be a strategy for the foreseeable future with enough males (Stamps and Krishnan 2014) and corresponds with laboratory preference tests, where females prefer known males over unknown ones (Říčánková et al. 2007). It is also possible that a male's odours and behavioural manifestations which are more similar to those of a female will be more likely accepted by that female than distinct ones (Jiang et al. 2013). Females are even able to show aggression against dissimilar individuals (Říčánková et al. 2007). A more similar acceptable male can induce the oestrus phase and ovulation in the female due to the time spent together (Sawrey and Dewsbury 1985). Induced ovulation is very useful with accidental contact of partners at low population densities (Katandukila and Bennett 2016). Clulow and Mallory (1970) suggested that induced ovulation may be a general feature of the genus *Microtus*. These mating contacts can be supported by the pairs having a very similar locomotor activity (Perkins and Fitzgerald 1994; Larivière and Ferguson 2003; Jiang et al. 2013). Therefore, mating of partners with similar personality traits (genes) could be successful during the whole population cycle.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s13364-022-00649-z.

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Author contribution Gabriela Urbánková: conceptualization, methodology, writing—original draft preparation. Jan Riegert: methodology, formal analysis, editing. Nella Mladěnková: methodology, investigation. Tereza Dikošová: investigation, resources. Lenka Janochová: investigation, resources. František Sedláček: supervising, conceptualization, validation, writing—review and editing.

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval The voles were bred and tested in accordance with the principles of animal welfare and guidelines of the Departmental Commission for Animal Protection of the Ministry of Education, Youth and Sports (permit number 7945/2010–30) and the animal treatment also conformed to the journal's ethic guidelines. After the experiments, the voles were kept in the laboratory and were used for further breeding and behavioural tests.

Consent to participate All authors agreed with the participation on the study of influence of behavioural traits on reproduction.

Consent for publication All authors agreed with the content and gave explicit consent to submit this paper.

Competing interests The authors declare no competing interests.

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