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INDIVIDUAL DIFFERENCES IN THE BEHAVIOR OF ALBINO AND WILD HOUSE MICE *(MUS MUSCULUS)*

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ABSTRACT: Adult male and female albino (AA) and wild (WW) housemice were individually evaluated in the laboratory for their performance in exploration (EX), insect predation (PD), burrowing (BW) and food hoarding (HD) activities. The results showed that (a) in both AA and WW adult mice there are individual differences (IDs), tending to be stable at least for periods of 60 days; (b) WW tended to show higher frequencies of the activities (WW males in EX and WW females in EX, PD, and HD); (c) significant sex differences occurred both in AA (with females scoring higher in EX and BW, and males in HD) and in WW (with higher female frequencies of burrowing); (d) individual animals had distinct combinations of performance in the four behavioral activities, suggesting independence among the motivational systems responsible for the regulation of these activities.

RESUMO: Camundongos albinos (AA) e selvagens (SS) adultos - machos e fêmeas - foram testados individualmente em laboratório quanto a seus desempenhos na atividade exploratória (EX), predação de insetos (PR), escavação de subterrâneo (ES) e armazenamento de alimento (AR). Os resultados mostraram que (a) em camundongos adultos, albinos e selvagens, existem diferenças individuais (DIs), estáveis pelo menos para períodos de 60 dias; (b) os SS apresentaram tendência a um maio desempenho (machos SS em EX e fêmeas SS em EX, PR e AR); existem diferenças intersexuais, estatísticamente significantes, tanto entre os AA (tendo a fêmeas apresentado maior desempenho em EX e ES, e os machos em AR) quanto nos SS (as fêmeas com maior desempenho em ES): (d) os animais têm combinações distintas de desempenhos nas quatro atividades avaliadas, o que sugere uma independência entre sistemas motivacionais responsáveis pela regulação destas atividades.

The importance of individual differences in behavioral

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performance is being increasingly acknowledged not only from a methodological (Martin & Kraemer, 1987), adaptive and evolutionary standpoint (Hirsh & McGuire, 1982) but also from a physiopathological standpoint (Koolhaas & Oortmerssen, 1988).

Individual differences (IDs) have been described in several mammalian and nonmammalian species (see Negrão & Schmidek, 1987 for references). In most of these studies only a single behavior is analysed. In a previous paper (Negrão & Schmidek, 1987) our laboratory has shown marked and stable IDs in four biologically relevant behavioral activities in rats namely burrowing, food hoarding, exploration and insect predation. The simultaneous analysis of several behavioral activities proved to be important. Individual performance in each of these activities was independent, suggesting that the process of individualization involves a specific modulation of independent motivational systems, as has already been suggested by Tryon (1934) and others more recently.

In the present experiment, individual performance in the same four behaviors was measured in adult male and female, albino and wild housemice. The following assumptions were made: (a) individual animals would show markedly different performances in each of these behaviors; (b) individual performances in different behaviors would be independent and thus not a mere consequence of more general phenomena such as level of activity; (c) males and females as separate groups would show different performances; (d) albino and wild mice as separate groups would show different performances.

METHODS

Subjects

Albino and wild mice of both sexes were used in the experiment. Albinos (20 males and 20 females aged 90 days at the beginning of the experiment) were from different litters of a heterogeneous breeding stock kept in the animal facilities of our campus. Wild housemice (6 adult males and 6 adult females) had been trapped in a rice storage area 3 or more weeks prior to the first test series. The animals were individually housed in wooden cages (20 x 30 x 15 cm), with wood wool (replaced weekly), and *ad libitum* water and food (loose Purina rat chow and supplements) in the cage. The light cycle was 12:12 h (lights on at 6:30 a.m.); the temperature varied from 20°

to 26°C.

Apparatus

Four different types of equipment were used to evaluate the performance of individual animals in the four behavioral activities relevant for the species under study: exploration, insect predation, burrowing and food hoarding. This methodology is similar to that previously used with rats (Negrão & Schmidek, 1987), but now adapted to mice.

Exploration was evaluated in a multichamber system (Fig 1) in which one cage (a 15 x 25 x 10-cm wooden box with a translucent glass lid) acted as a den compartment. This cage was connected to a complex environment by means of a tunnel comprising a rigid plastic tube, 10 cm long and 7.6 cm in diameter. The den and environment were discriminable by both odors and brightness. The den contained only self-produced odors (Hughes, 1991) and was darkened by a translucid lid. The complex environment consisted of 12 intercommunicating compartments (20 x 20 x 25 cm each). The first of these (1A) was also connected to the den. Six of these compartments (1A-6A) were connected in series through 7.6 cm diameter tubes to corresponding compartments (1B-6B) of the same size. Each pair of corresponding A and B compartments was separated by a water tank (20 x 20 cm in surface area and 10 cm deep). This tank could be crossed by swimming, jumping or, as almost always happened, by means of runways of different widths, ranging from 1.8 to 0.2 cm.

Insect predation was tested with the animal in a 50 x 25 x 8-cm wooden cage with a transparent glass front wall and cover. Five intact immature (approximately 2 cm long) cockroaches *(Periplaneta americana)* raised in our laboratory were used as prey. Before the test, the five insects were placed in a 20-cm long, 5.1-cm wide tube obstructed at the proximal end with a sliding lid and at the other end with a piston. At the beginning of the test this tube was attached to an opening on the side wall of the arena, the sliding lid was removed, and the cockroaches were pushed into the arena with the piston.

Burrowing tests were performed in a 120 x 25 x 25-cm terrarium containing 10 cm of loosely packed dampened soil that was replaced before each session by the following procedure: after each test the top layer was scraped away and discarded; the remaining soil was transferred to a large container and thoroughly mixed with soil of controlled humidity (between 200 and 260g water per 1000g of dry

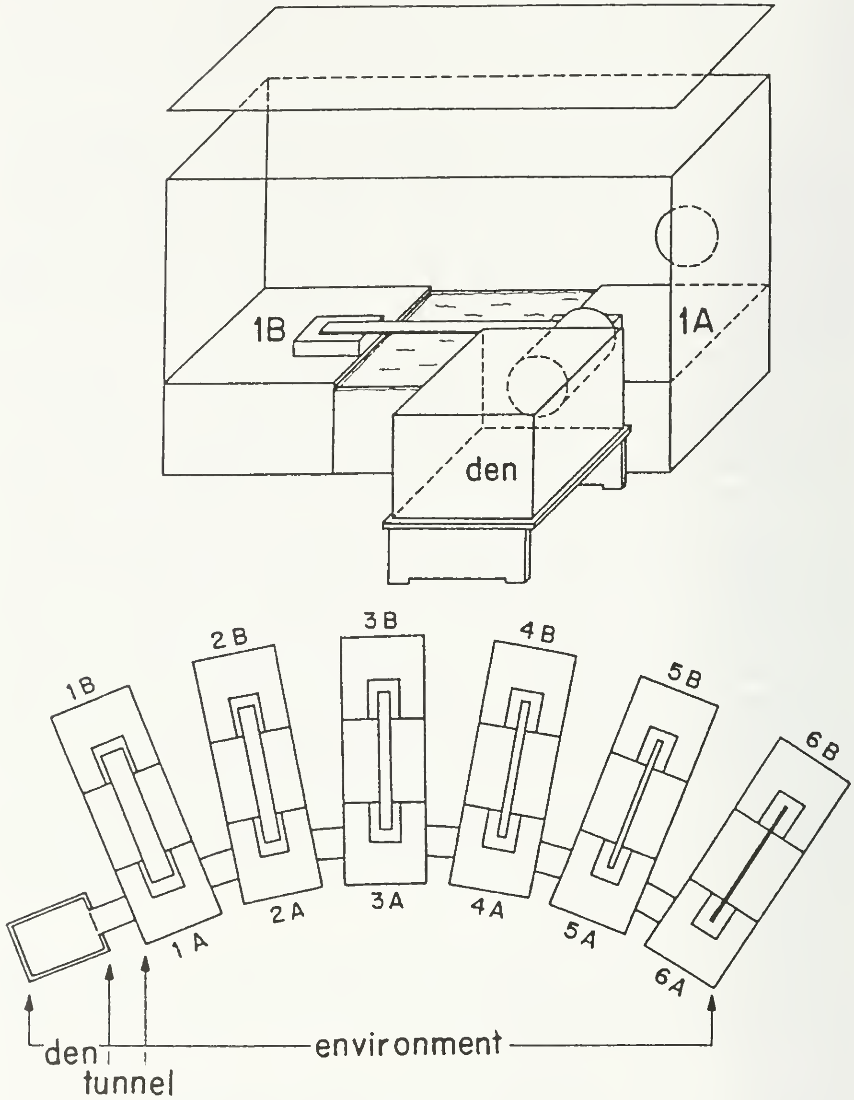

Figure 1. Schematic illustration of the multichamber exploration set. The upper figure shows a lateral view of the den and the first pair of A and B environmental compartments separated by a water tank. The lower figure shows a top view of the whole system.

soil); the terrarium was then filled again with soil from this container. An opaque platform (85 x 25 cm in surface area and 1 cm in thickness) was placed on the surface. Excavations were usually performed under the platform starting at its edge. This platform prevented cave-ins, and permitted an adequate evaluation of the burrowing activity.

Hoarding tests were carried out in a set of two interconnected cages. One, designed to work as a den compartment, was a 25 x 25 x 10-cm plywood box, closed, except for a rigid plastic tube, 25 cm long and 3.6 cm in diameter, that enabled access to a 50 x 35 x 35 cm glass-walled and wire mesh-covered cage. A reticulum of lines, forming 5 x 5-cm squares was drawn on the ground of both cages. Hoarding materials were offered in the environment cage at the beginning of the test. These materials consisted of 33 food pellets placed in a checkerboard pattern (one pellet in each alternate square of the reticulum) interspersed with nesting materials (20 small twigs, 15 round gravel-stones) and two handsfull of wood shavings.

Procedure

Each mouse was given the test battery three times each being separated by 30 days. Each battery began at 10 a.m. on the first day (Test I), when the animal was identified, weighed, and housed in the den compartment of the exploration set. We started this test 1 h later by opening the tunnel and by recording the whereabouts and behavioral patterns of the animal during a 15-min period with the use of an event recorder specially designed for this purpose (Schmidek et al, 1983). At 6 p.m. on the same day, the animal was transferred to the predation cage in which the insect predation test was to be performed 24 h later. During this period of adaptation to the cage, the animal had no other food except for a live immature cockroach and *ad libitum* water. The predation test on 6 p.m. of the second test day started immediately after the delivery of the five cockroaches into the cage and lasted 15 min, during which time the mouse's behavioral activities were recorded with the event recorder. At 9 a.m. on the third day, the mouse was transferred to the terrarium for the burrowing test. This test ended on the fourth day at 9 a.m. when a topographical map of the surface and underground of the terrarium was drawn. At 10 a.m. on this fourth day, the mouse was transferred to the hoarding cages and at 4 p.m. on the same day, food and nesting materials were offered as described. At 10 a.m. on the fifth day we ended the hoarding test by recording the new arrangement of materials in both compartments. At the end of each test, the cages were washed and dried and the soil in the terrarium was replaced as described above. The second and third series of tests (Test II and III) were begun 30 and 60 days later respectively.

RESULTS

Performance by males and females, and between both strains were compared via the Mann-Whitney *U* test and χ^2 test. Agreement among individual performances in the first, second and third series of tests was calculated via the Kendall *W* concordance analysis (Siegel, 1956).

Range and medians in both experimental groups are shown in Table 1. It was apparent that different animals exhibited widely different performances. Although some showed low performance in the exploration (EX) test (e.g., albino male AM33 with 1.1, 2.4 and 2.0 minutes of active exploration in tests I to III, or albino female AF44 with 3.7, 3.9 and 4.4 minutes in these tests), most of them showed intense exploratory activity (e.g., albino male AM09 with 5.8, 6.5 and 6.3 min. and albino female AF22 with 6.5, 7.3 and 7.4 min, respectively). In the insect predation test (PD) there were some animals that did not kill any cockroach (AM11, AM15, AM35, AM37, AM45, AF14, and AF46) whereas others killed three or more in each test (albino mice AM23, AM29 and AF38 and wild mice WM11, WF01 and WF06). In the burrowing test (BW) there were some mice, especially albino males that did not burrow in any of the three series of tests (AM13, AM17, AM29, AM39, AM45, and AF38). However, most animals, even in the first test series, excavated burrows - some of them quite large (e.g., AM09 with 775, 1400 and 1400 cm^2, AF30 with 900, 1475 and 1500 cm^2, WM13 with 500, 775 and 1300 cm^2, WF02 with 1100, 1000 and 1625 cm^2). Also in the hoarding test (HD), individual performances were widely contrasting. Some mice carried most of the food pellets to the den compartment (e.g., AM19 that carried 54.8, 97.0 and 81.3% of the pellets to the den compartment, AM47 with respectively 78.8, 69.7 and 69.7%, WF08 with 69.7, 100.00, 51.5% or WF10 with 66.7, 81.8 and 63.6%) whereas others showed no hoarding behavior at all (AM39, AM43, AF12, and AF34).

Individual performance in the three test series tended to be stable in albino animals with a statistically significant concordance in each of the four behaviors. Values of Kendall concordance coefficient *W* in albino male mice were .726 for EX, .814 for PD, .790 for BW and .699 for HD. In Albino females these values were .776, .567, .769 and .758 respectively for EX, PD, BW and HD. All these values are statistically significant for $p <.05$. Despite the reduced numbers of wild mice, significant concordance was detected in BW males ($W = .699$) and in EX and HD females ($W = .840$ and .936, respectively).

TABLE I

Range and median values of behavioral performance in both experimental groups

	DURATION ACTIVE EXPLORATION (Min)			NUMBER OF COCKROACHES KILLED			UNDERGROUND BURROWING AREA (Area=cm^2)			PELLETS IN DEN (%)		
SERIES	I	II	III	I	II	III	I	II	III	I	II	III
	ALBINO MICE - Males (N=20)											
Range Median	1.1-7.2 3.4	1.4-7.3 4.7	2.0-6.3 4.7	0.0-5.0 0.0	0.0-5.0 1.0	0.0-5.0 2.0	0-1050 463	0-1400 550	0-1400 425	0.0-78.8 18.0	0.0-97.0 32.8	0.0-81.3 27.8
	ALBINO MICE - Females (N=20)											
Range Median	1.5-6.5 4.7	3.9-7.3 5.7	3.7-7.4 5.7	0.0-4.0 0.0	0.0-5.0 1.0	0.0-5.0 2.0	0-1075 650	0-1475 725	0-1500 800	0.0-53.1 12.1	0.0-65.6 17.2	0.0-71.9 12.3
	WILD MICE - Males (N=6)											
Range Median	4.8-8.0 6.5	4.6-6.1 5.8	4.0-6.3 4.8	0.0-5.0 1.0	1.0-5.0 2.5	3.0-5.0 4.0	250-575 450	300-775 600	375-1300 613	3.0-100.0 37.9	0.0-34.4 18.2	3.0-60.6 9.3
	WILD MICE - Females (N=6)											
Range Median	4.3-6.6 6.0	4.6-7.0 5.9	4.0-5.4 5.3	0.0-5.0 2.5	2.0-5.0 3.5	0.0-5.0 5.0	350-1400 675	100-1200 650	100-1625 875	0.0-69.7 48.5	12.1-100.0 31.8	6.1-63.6 18.2

In spite of the stability of individual performance in each behavior, there were no significant concordances among the individual performances in the four tests of each series (values of *W* in test series I to III were .249, .304, and .394 for albino males; .195, .341, and .348 for albino females; .140, .058, and .360 for wild males; .080, .197 and .167 for wild females). No animals presented a systematically high or low performance in all tests and several mice presented even quite contrasting performances in two or more behavioral activities. For example albino male AM09 had average performances in EX (3.0, 4.9 and 2.9 min of active exploration) and HD (9.4, 18.8 and 56.3% of pellets in the den), but very high PD (all cockroaches killed in the three tests) and nil BW performances. In contrast, albino female AF22 had very high EX scores (6.5, 7.3 and 7.4 min as active exploration), low PD (only one cockroach killed in test III) average BW (675, 1100 and 700 cm^2 of underground burrowing), and low HD (3.1, 3.1 and 9.4% of pellets in the den).

Sex differences occurred mainly in the albino strain. In the three series of EX tests females as a separate group showed a higher performance than males (values of Mann-Whitney *U* were respectively, 107.5, 99.0 and 108.0, all with $p < .05$). Albino females also presented significantly higher BW performances in the second and third test series ($U = 130.5$ and 131.0, respectively). On the other hand, albino males presented significantly higher values in the second HD test ($U = 124.5$). Among wild mice sex differences occurred only in the first BW test ($U = 7.0$) in which females excavated larger burrows.

Significant differences between both stocks occurred mainly in the first test series with the wild animals scoring higher than albinos. In males significant differences occurred only in the first two EX tests ($U = 12.0$ and 25.0). In females there were differences in EX, PD and HD with wild females having significantly higher performances in the first test series ($U = 25.0$, 23.0 and 28.0). Wild females had also higher performances in the second PD and HD tests ($U = 24.0$ and 27.0). In contrast albino females had higher EX scores in the third test ($U = 30.0$). It was also observed that, in the burrowing activity, no differences between stocks occurred and that, even in the first series of tests most animals (14 out of 20 albino males, 17 out of 20 albino females and all the wild mice) dug underground burrows, some rather extensive (e.g., AM43, AF16, AF18, AF34, WF02, WF03 had burrows with areas = 1000 cm^2). An evident difference between both stocks is the broader range of individual performance in albino mice, especially the occurrence of low performance. Among albinos, 21 out of 40 animals had nil performances in two or all of the three tests of any behavior; among wild mice this occurred only with one out of 12 animals. This difference was statistically significant ($\chi^2 = 5.68$; $p <.02$).

Besides these quantitative evaluations our behavioral tests showed some characteristics that deserve description. In opposition to the high inter-individual variability of behavioral performance, there was greater homogeneity in the motor patterns observed in the diverse animals. In the exploration tests the mice typically showed hesitant locomotion during the first exits from the den compartment. The animals remained for longer periods of time in the tunnel with repeated to-and-fro movements. During the first exploration of the environment the animal almost crouched on the floor. In the predation test there were characteristics common to all animals that showed marked predatory motivation, namely, the insects were pursued, grabbed with the forepaws and bitten, usually in the head. In the burrowing test a rather fixed sequence of motor patterns occurred involving excavating with the forepaws, pulling the loosened soil beneath the body, followed by kicking the soil with the hindpaws. These patterns were observed even in albino mice in the first test series (i.e. during the first contact of the animal with the soil). The excavated burrow contained one or two large chambers which communicated with the environment through one long and narrow tunnel. The burrowing pattern in both stocks was either all (if a burrow was started a rather large excavation resulted) or none (the animal did not make an underground excavation). Animals removed volumes of soil which corresponded to many times their body volume. In wild animals, due to their smaller size and higher performance, this proportion was even more marked. For example, female WF02 weighing 14 grams removed about 4500 cc of soil, corresponding roughly to 300 times its body volume. In the hoarding tests there were also some typical motor patterns, namely, exploratory activity in the environment associated with hoarding of materials occurred in bouts. Often only one kind of material (food or nesting material) was transported during a bout. Individual animals differed not only in the total amount of transported material but also in their preference for food or non-food items. Hoarded materials were taken in the mouth and transported one-by-one to the den where they were left without any distinct arrangement.

DISCUSSION

Our present results show that behavioral performance in mice is distributed over a wide range. Individual differences do not seem to be a consequence of casual variability since individual performance in a given behavioral activity tended to remain stable along the experimental period (60 days), as shown by the significant concordance coefficient among the three test series. Nor are these differences a consequence of some general factor such as the animal's level of activity since individual performance in different behaviors (measured in the same test series), showed no significant concordance.

There are references to IDs in mice and other rodents in the literature. In *exploratory behavior* marked differences among individuals have been described, both in mice (Wolfe, 1969) and rats (Tryon, 1934; Negrão & Schmidek, 1987; Hooks, et al., 1991). In *predatory behavior* of rodents marked individual variations are also described. Butler (1973) found a great variability in the cricket-killing behavior of mice. Polsky (1975) described great inter-individual differences in the locust-killing activity of the golden hamster. IDs were also reported in mouse-killing (Paul, Miley & Baenninger, 1971), frog-killing (Johnson, De Sisto & Koening, 1972) and cockroach-killing (Negrão & Schmidek, 1987) behavior of rats. In *burrowing behavior* of mice, Dudek et al. (1983) described high inter-individual variability, even in some inbred strains. Also in wild house mice high variability in this behavior has been demonstrated (Bouchard & Lynch, 1989). Finally there are clear descriptions of IDs in *hoarding behavior* in rats (Negrão & Schmidek, 1987), golden hamsters (Polsky, 1975) and mice (Smith & Ross, 1953a) in which subgroups of "hoarders" and "non-hoarders" were described. IDs in nest building activity of mice have also been described (Lisk, Pretlow & Friedman, 1969). Several types of nest ("half-nest", "bird-nest", "pocket-pallet nest", "semi-circle nest" and "maternal-nest") differing greatly in size and complexity, have also been catalogued by these authors. Contrasting with the great variability in performance we found a remarkable homogeneity in the motor patterns of each behavior as already documented for exploration (Birke, D'Udine & Albonetti, 1985; Connor, 1975; Oortmerssen, 1971), and burrowing (Adams & Boice, 1981).

Our identification of sex differences in exploratory behavior is in accordance with the results of D'Amato (1986) who described higher frequencies of exploration in females. The role of the estrous cycle in this phenomenon is still uncertain. An increase of locomotor activity in the early morning of the cycle has been described but more complex behavioral patterns such as "peeking" have not revealed such a relation (Guttman, Lieblich & Gross, 1975).

We have also detected sex differences in burrowing behavior with females tending to burrow more than males. Similar differences have also been described in rats (Boice, 1977; Negrão & Schmidek, 1987). Notice, however, that in both species the range of IDs produces wide overlapping in male and female performance.

In spite of the reduced number of wild mice in our experiment, some interesting contrasts to albinos appeared. The first important difference is the broader range of individual performance in albino mice, especially with respect to low performance. As described, 21 albinos out of 40 had nil scores in two or all of the three tests of any behavior whereas among wild mice this occurred only with 1 out of 12 animals. This picture conflicts with the considerations of Wolfe (1969). According to this author, due to their greater heterozygous characteristics, wild mice should present a greater inter-individual variability. Our data suggest that selective pressures in the wild life may actually reduce variability in behavioral performance (especially in the range of low performance).

The wild environment may be responsible for the higher exploration of wild mice in the first test series. In fact Henderson (1970) showed that mice reared in an enriched environment (a breeding cage containing several objects) show more exploration than control-groups of animals raised in conventional cages ("restricted environment"). In our test it is possible that this influence determines the initial differences between both groups as well as accounting for the gradual attenuation of these differences once both groups are kept in conventional individual cages. The greater exploration of wild mice may also be influenced by them having pigmented eyes. Dixon and DeFries (1968) showed that albino mice on average are less active than pigmented animals in an open field test. Obviously this possibility cannot be the only determining factor in our experiment since wild animals had explored more only in the first exploration test.

Both stocks also differed in predation performance which was higher in wild mice. It is probable that the previous experience of this group in insect predation have determined the difference. Notice in this respect, that the average predation performance of albino animals increased from test to test. Training influences on insect predation performance have been described in mice (Thomas, 1969) and in other rodents such as rats (Negrão & Schmidek, 1987), golden hamsters (Polsky, 1977) and grasshopper mice (Baxter, 1979).

Albino and wild animals also differed in hoarding behavior. Wild females hoarded more in the first two test series. Environmental factors acting upon a genetic predisposition may have caused this difference. According to Bindra (1948), the amount of material that is hoarded by a rodent reflects the animal's previous experience concerning availability of the material and safety of the den in relation to the environment. If the environment is safe and food is abundant the food is consumed directly in the environment. Conversely the more the environment is dangerous and/or the food is scarce the greater will be the hoarding performance. Both these factors may have been acting on wild animals determining their increased transport of food pellets to the den in the first test series. Also, the richness of the original environment of wild animals may have influenced their hoarding activity (Manosevitz, Campenot & Swencionis, 1968).

If we compare individual performance in several types of behavior some interesting facts appear. Our animals showed a significant tendency to keep a similar performance in each one of the four behaviors along the three test series (in a period of three months for each animal). Contrasting with this stability there was no evident correlation between the performances in different behaviors in the same test series. Actually, some animals showed quite contrasting performances in different behaviors (tested on successive days). Thus it seems that in a given animal the motivational processes regulating performance in different behavioral activities tend to be independent of each other. The degree of specificity and fine tuning of these regulating processes may be illustrated by hoarding activity. Motivation for hoarding different materials seems to be specific and rather independent. From our observations, individual performance in food and non-food material-hoarding sometimes indicated many discrepancies, and different non-food materials were hoarded with different intensities. A similar differentiation among materials has already been described in mice (Smith & Ross, 1953b) and rats (Herberg, Pye & Blundell, 1972) for hoarding of food versus cotton balls, and in rats (Wallace, 1978) for the hoarding of different non-food materials. The process of independent regulation of different motivational systems turning each animal into an individual with a conspicuous response pattern to the environment may be adaptive. As already discussed for other species (Barash, 1976; Hirsh & McGuire, 1982; MacDonald, 1983), IDs increase variability with obvious selective advantages and may lead, in a social species such as the mouse, to a spontaneous division of activities. As a hypothesis one might speculate that, based on their specific motivations, individual animals tend to assume specific roles in the group.

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REFERENCES

Adams, N., & Boice, R. (1981). Mouse *(Mus)* burrows: Effects of age, strain, and domestication. *Animal Learning and Behavior, 9,* 140-144.

Barash, D. P. (1976). Social behaviour and individual differences in free-living alpine marmots *(Marmota marmota). Animal Behaviour, 24,* 27-35.

Baxter, C. (1979). Cricket predation by the Northern Grasshopper Mouse. *Behavioral and Neural Biology, 27,* 210-213.

Bindra, D. (1948). What makes rats hoard? *Journal of Comparative and Physiological Psychology, 41,* 397-402.

Birke, L. I. A., D'Udine, B., & Albonetti, M. E. (1985). Exploratory behavior of two species of Murid rodents, *Acomys cahirinus* and *Mus musculus*: a comparative study. *Behavioral and Neural Biology, 43,* 143-161.

Boice, R. (1977). Burrows of wild and albino rats: effects of domestication, outdoor raising, age, experience, and maternal state. *Journal of Comparative and Physiological Psychology, 91,* 649-661.

Bouchard, P. R., & Lynch, C. B. (1989). Burrowing behavior in wild house mice: Variation within and between populations. *Behavioral Genetics, 19,* 447-456.

Butler, K. (1973). Predatory behavior in laboratory mice: strain and sex comparisons. *Journal of Comparative and Physiological Psychology, 85,* 243-249.

Connor, J. L. (1975). Genetic mechanisms controlling the domestication of a wild house mouse population *(Mus musculus* L.) *Journal of Comparative and Physiological Psychology, 89,* 118-130.

D'Amato, F. R. (1986). Time budgets and behavioural synchronization in aggregated and isolated male and female mice. *Behavioural Processes, 13,* 385-397.

Dixon, L. K., & DeFries, J. C. (1968). Effects of illumination on open-field behavior in mice. *Journal of Comparative and Physiological Psychology, 66,* 803-805.

Dudek, B. C., Adams, N., Boice, R., & Abbott, M. E. (1983). Genetic influences on digging behaviors in mice *(Mus musculus)* in laboratory and seminatural settings.

Journal of Comparative Psychology, 97, 249-259.

Guttman, R., Lieblich, I., & Gross, R. (1975). Behavioral correlates of estrous cycle stages in laboratory mice. *Behavioral Biology, 13,* 127-132.

Henderson, N. D. (1970). Genetic influences on the behavior of mice can be obscured by laboratory rearing. *Journal of Comparative and Physiological Psychology, 72,* 505-511.

Herberg, L. J., Pye, J. G., & Blundell, J. E. (1972). Sex differences in the hypothalamic regulation of food hoarding: hormones versus calories. *Animal Behaviour, 20,* 186-191.

Hirsh, J., & McGuire, T. R. (Eds.) (1982). *Behavior-genetic analysis* (Benchmark Papers in Behavior, Vol. 16). Stroudsburg, PA: Hutchinson Ross Publication Co.

Hooks, M. S.; Jones, G. H.; Smith, A. D.; Neill, D. B. & Justice, J. B. Jr. (1991). Individual differences in locomotor activity and sensitization. *Pharmacology Biochemistry and Behavior, 38,* 467-470.

Hughes, R. N. (1991). The role of self-produced and other-animal-produced odors in rats' preferences for novelty in an exploration box. *Psychobiology, 19,* 168-174.

Johnson, R. N., De Sisto, M. J., Jr., & Koening, A. B. (1972). Social and developmental experience and interspecific aggression in rats. *Journal of Comparative and Physiological Psychology, 79,* 237-242.

Koolhaas, J. M., & Oortmerssen, G. A. van, (1988). Individual differences in disease susceptibility as a possible factor in the population dynamics of rats and mice. *Netherlands Journal of Zoology, 38,* 111-122.

Lisk, R.D., Pretlow, R. A., 3rd, & Friedman, S. M., (1969). Hormonal stimulation necessary for elicitation of maternal nest-building in the mouse *(Mus musculus). Animal Behaviour, 17,* 730-737.

MacDonald, K. (1983). Stability of individual differences in behavior in a litter of wolf cubs *(Canis lupus). Journal of Comparative Psychology, 97,* 99-106.

Manosevitz, M., Campenot, R. B., & Swencionis, C. F. (1968). Effects of enriched environment upon hoarding. *Journal of Comparative and Physiological Psychology, 66,* 319-324.

Martin, P., & Kraemer, H. C. (1987) Individual differences in behaviour and their statistical consequences. *Animal Behavior, 35,* 1366-1375.

Negrão, N., & Schmidek, W.R. (1987). Individual differences in the behavior of rats *(Rattus norvegicus). Journal of Comparative Psychology, 101,* 107-111.

Oortmerssen, G. A. van (1971). Biological significance, genetics and evolutionary origin of variability in behaviour within and between inbred strains of mice *(Mus musculus)* - a behaviour genetic study. *Behaviour, 38,* 1-92.

Paul, L., Miley, W. M., & Baenninger, R. (1971). Mouse killing by rats: roles of hunger and thirst in its initiation and maintenance. *Journal of Comparative and Physiological Psychology, 76,* 242-249.

Polsky, R. H. (1975). Hunger, prey feeding, and predatory aggression. *Behavioral Biology, 13,* 81-93.

Polsky, R. H. (1977). The ontogeny of predatory behaviour in the golden hamster. *(Mesocritetus a. auratus).* II. The nature of the experience. *Behaviour, 61,* 58-81.

Schmidek, W.R., Negrão, N., Nishida, S. M., & Vieira, R. (1983). An inexpensive event recorder for continuous behavioral recording. *Brazilian Journal of Medical and Biological Research, 16,* 161-164.

Siegel, S. (1956). *Nonparametric statistics for the behavioral sciences,* New York: McGraw Hill.

Smith, W., & Ross, S. (1953a). The hoarding behavior of the mouse: I. The role of previous feeding experience. *Journal of Genetic Psychology, 82,* 279-297.

Smith, W., & Ross, S. (1953b). The hoarding behavior of the mouse: III. The storing of "non-relevant" material. *Journal of Genetic Psychology, 82,* 309-316.

Thomas, K. (1969). Predatory behavior in two strains of laboratory mice. *Psychonomic Science, 15,* 13-14.

Tryon, R. C. (1934). Individual differences. In F. A. Moss (Ed.), *Comparative psychology.* Englewood Cliffs, NJ: Prentice-Hall.

Wallace, R. J. (1978). Hoarding of inedible objects by albino rats. *Behavioral Biology, 23,* 409-414.

Wolfe, J. L. (1969). Exploratory activity and new object response of wild and laboratory house mouse. *Communications in Behavioral Biology, 4,* 13-16.