Title
Effects of Physical Environement and Social Experience on Stimulus Seeking Behaviour and Emotionality in Rats (Rattus norvegius)

Journal
International Journal of Comparative Psychology, 5(3)

ISSN
0889-3675

Authors
Pisula, W
Ostaszewski, P M
Matysiak, J

Publication Date
1992

DOI
10.46867/C4NC7V

International Journal of Comparative Psychology, Vol. 5, No. 3, 1992

EFFECTS OF PHYSICAL ENVIRONMENT AND SOCIAL EXPERIENCE ON STIMULUS SEEKING BEHAVIOR AND EMOTIONALITY IN RATS (*Rattus norvegicus*)

W. Pisula
P. M. Ostaszewski
J. Matysiak
University of Warsaw

ABSTRACT: The influences of the physical and social aspects of the environment on temperament in rats are reported in two experiments. In Experiment One changes in animal behavior due to social isolation and enrichment of the physical environment were studied in rats subjected to experimental conditions when they were 25–30 days old. Enrichment of the physical environment led to decreased need for light stimulation and increased exploratory behavior. Social isolation led to an increase in emotional reactivity. Experiment Two was analogous to Experiment One, differing only in that 60–70 day-old animals were given the experimental conditions. In this case enriched physical environment and social isolation led to decreased exploratory behavior. Need for light stimulation was affected by the interaction of experimental variables. Need for kinesthetic and tactile stimulation were affected by the social environment. Enrichment of the physical environment also led to a decrease in emotional reactivity in the rats. Our experiments indicate that environmental effects were age-contingent. It is proposed that there is probably a relationship between categories of environment and temperament. Further, our findings draw attention to the possibility of a related evolution of sensory systems and temperamental traits.

Such temperamental features of humans and animals as need for sensory stimulation or emotional reactivity have been considered to be strongly determined by genetic factors (Strelau, 1983). However, several theoretical approaches have postulated that temperamental features can respond to environmental influence (Denenberg, 1964; Strelau, 1983; Matysiak, 1985). Active self-exposure by animals to sensory stimulation in specially constructed chambers (Wong, 1976; Matysiak, 1985) as well as running in a running wheel can be assumed to indicate need for sensory

Address correspondence to W. Pisula, Faculty of Psychology, University of Warsaw, ul. Stawki 5/7, 00-183 Warsaw, Poland.

stimulation (Matysiak, 1985). Archer (1973) and Walsh and Cummins (1976), in turn, have shown that behavior in open field tests is a valid (with some limitations) indicator of widely-conceptualized emotionality and exploration in animals. Brush et al. (1985) have shown speed of acquisition of defensive responses to be a valid measure of emotional reactivity in animals.

Manipulating the so-called social environment of animals is frequently used in studies of the effects of environmental factors on temperament. Koch and Arnold (1972) found increased emotional reactivity in rats, as measured by heart rate and open field defecation and urination, in response to limitation of the animal's contact with the mother in early stages of development. Socially deprived rats also revealed less exploratory behavior than control animals.

The most marked effects of social isolation on exploratory behavior in rats have been found when isolation was introduced between the twenty-fourth and forty-fifth day of life. Rats isolated from their peers at that age revealed increased exploration of an object but were more reluctant to explore a new cage (Einon & Morgan, 1976). Baenninger (1967) found that the period between 16–20 and 35–40 days of life is a time of intensive peer play in rats. Marked changes in animal behavior due to social isolation during this period suggest that it is a critical period for social behavior and emotionality (Einon & Morgan, 1976).

Isolation at a later age also affects exploratory behavior in rats (Renner & Rosenzweig, 1986) and the observed changes in behavior are of mainly qualitative, not quantitative, nature. Renner (1987) found that socially isolated rats had a scantier repertoire of exploratory behavior and such behavior was of a generally lower level as compared with animals maintained in an enriched environment.

Studies by Parker and Morinan (1986) support the view that isolated rats are more anxious than rats maintained in a group. Isolated animals showed a lower level of exploratory behavior and higher emotional reactivity.

A frequent manipulation of the physical environment in rat studies consists of enriching the environment. However, Renner (1987) and Renner and Rosenzweig (1986) found that the effects of enrichment can be observed throughout the life of the rat. Forgays and Michelson-Read (1962) showed that the most important period for acquisition of experience in an enriched environment is the period between the twenty-second and forty-third day of life.

Sackett (1967) found that sensory experience in the early stages of life in rats affects preference for specific modalities of stimulation. Sensorially deprived rats preferred less complex and less novel stimuli. Greatest exploratory behavior, on the other hand, was found in animals maintained in standard conditions as regards degree of stimulation.

Smith (1972) analyzed open field behavior (exploration) in rats maintained in an enriched as opposed to a deprived environment. A second variable controlled in their study was richness of environment prior to or after weaning. Exploration in the open field was affected by environmental richness irrespective of the developmental stage of animals exposed to experimental treatment. Animals maintained in deprived conditions explored more than animals maintained in enriched conditions.

Manosevitz (1970) compared the behavior of mice maintained in standard and enriched environments using the open field test, activity wheel, and competition for food as dependent variables. Mice maintained in the enriched environment were more active in the open field and in the activity wheel than mice maintained in the standard conditions. The former were also less reactive emotionally and were quicker to learn to acquire food when it was scarce.

Hennessy, Hershberger, Bell, and Zachman (1976) and Tees, Midgley, and Bruinsma (1980) found that rats reared early in life in an environment enriched in sensory stimulation select environments that are more stimulating.

Changes in behavior due to experience in an enriched environment seem to be most conspicuous when the rat explores an object (Renner & Rosenzweig, 1986; Renner, 1987). These authors suggest that the elementary forms of exploration, i.e., emotional reactivity and general motor activity, are much less affected by environmental manipulations than complex activities.

The work reviewed above leads to the hypothesis that social and physical environmental factors are important determinants of behavior aimed at securing sensory stimulation.

Matysiak and Toeplitz (1990) studied the effect of genetic and environmental factors on the need for stimulation and found that rats maintained in an enriched environment show reduced need for light stimulation. Need for kinesthetic and tactile stimulation was not affected by environmental factors. However, this finding was not confirmed by the next work by Matysiak, Ostaszweski, Pisula, and Watras (1992). It was argued that the lack of corroboration could be due to insufficient control of the age of the studied animals in the Matysiak et al. (1992) study.

The following experiments were undertaken to test the effects of environmental factors on need for stimulation and emotional reactivity, and the relevance of age at the time of treatment. Since in many of the studies reported in the literature (Renner & Rosenzweig, 1986; Renner, 1987; Matysiak et al., 1992) environmental (in the sense of physical) and social factors are confounded, social isolation and enrichment of the physical environment were treated as two independent experimental variables in the present study. The main purpose of this study was to estimate the relative role of physical and social influences on temperamental characteristics in rats.

Four tests were used in both experiments:

1) a chamber for self-exposure to light stimuli, to measure the level of need for light stimulation,

2) a modified dual activity wheel to measure the need for kinesthetic and tactile stimulation and to measure preference for mobile activity supplying poor (kinesthetic and tactile) or rich (kinesthetic, tactile, and light) stimulation,

3) an open field test to investigate emotionality and exploratory behavior,

4) a standard shuttle-box to measure emotional reactivity during avoidance-response training.

All animals used in both experiments came from the same colony at the same time.

EXPERIMENT ONE

In this experiment a 2 × 2 factorial design was adopted with maintenance in an enriched versus a standard condition as one factor and in a group versus in isolation as the second factor. The rats were 25–30 days old at the start of the experiment.

Animals

Forty-eight outbred male Wistar rats were observed. The animals came from an animal dealer's colony about 40 kilometers from our laboratory. They were weaned when about 25 days old. Once weaned the rats were transported to our laboratory.

Apparatus

Two types of maintenance cages were used: a standard wire cage, 40 × 30 × 20 cm, and an "enriched" wire cage twice as large (40 × 60 × 20 cm) and equipped with a swing (15.5 cm from top, 8.5 cm in width), a see-saw (20 × 5 cm, 7 cm high in the middle point), a ladder (21 × 11 cm, 0.7 cm between rungs), and two table-tennis balls. All equipment (but balls) were made of metal.

The chambers for self-exposure to light stimuli (40 × 30 × 20 cm) have been described elsewhere (Matysiak, 1985). As the base for constructing them, we used the maintenance cages. Inside, on the two opposite longer walls, 10 cm above the base, were symmetrical bars. Pressing on one bar (experimental) switched on a light of 1.6 lux for the duration of the bar press whereas nothing happened when the other bar (control) was pressed. The source of light was nine small (10 Watts) bulbs mounted at the cover of the chamber behind frosted glass. The number of bar presses and their duration were registered using the MS IMPOL computer system.

The activity wheels were in similar cages as the chambers for self-exposure of light. The base of the chamber was the maintenance cage. On two opposite, shorter walls were doors leading to the activity wheels. These doors remained open all the time. Both wheels were identical and consisted of a wire running track 15 cm wide and 30 cm in diameter. Both wheels had identical inertia (the same weight, construction and the same time and number of free rotations during the testing trials). They differed as to effects of movement. Movement sufficient to rotate the experimental wheel 10° switched on a light in the whole chamber for the duration of the movement plus three seconds. The 3 sec delay in switching off the light was introduced in order to counteract any flickers due to slight, uncontrolled movements of the wheel (e.g., directly after the animal had left it). Moving the control wheel had no additional effects. The number of revolutions of the experimental and control wheels were recorded. In this test, as in the previous one, water and food were available ad libitum.

The circular open field, 160 cm in diameter, was surrounded by a white, metal wall 35 cm high. The floor was made of white plastic tiles size 20 × 20 cm. In the center, 120 cm above the floor, a 200 W bulb was suspended.

The shuttle box for training the avoidance response was 48 × 22 × 23 cm large and was built on a base of metal rungs 3 mm thick and placed 14 mm apart. The walls of the chambers were made of Plexiglas tiles of which three were coated in light-absorbent material while one was uncoated and permitted observation of the animal. The conditioned stimulus, a light of 5 lux, was supplied by bulbs secured in the lid of the chamber behind frosted glass. The unconditioned stimulus was an electric shock issued through the floor bars.

Procedure

One day after arrival at the laboratory the rats were transferred to their home cages. Twelve rats were placed, 6 each, in two standard cages and twelve were placed one each in 12 standard cages, 12 additional animals were placed six each in two enriched cages and the final 12 were placed one each in 12 enriched cages. A temperature of 23 °C and a 12 h light/dark cycle (beginning at 0800 h) were used in the maintenance room.

When the rats were about 90 days old the experiment proper began. All animals were first tested in the self-exposure to light chamber and in the activity wheels (23.5 h tests). The order of testing of each animal and the order of tests were randomized. Each animal took the two tests on two consecutive days. Each test started at 1230 h.

Previous research (Matysiak, 1985; Matysiak & Toeplitz, 1990) has shown that when animals are tested in the light self-exposure chamber most information is gained when the indices of two basic variables are analyzed: need for stimulation and general motor activity.

1) Need for stimulation was measured using the following formula:

$$NS = Ne/(Ne + Nc) \times Te/(Te + Tc)$$

where

Ne = Number of presses on experimental bar
Nc = Number of presses on control bar
Te = Total duration of experimental bar depression
Tc = Total duration of control bar depression

2) General motor activity was measured by computing the total number of presses on both bars.

General motor activity index and the number of wheel rotations were analyzed for the initial 90-min phase of measurement.

Both the above indices and NS coefficient were analyzed for a 22-hour phase following the initial phase.

Two days after all rats completed the tests they were observed in the 3 min open field test. The number of defecations, urinations, crossed squares and rearings were recorded.

The last test was the conditioning of the defensive responses. Within two days each animal went through twenty trials in two sessions, ten trials per session. The strength of the shock was adjusted individually and ranged from 1.5 to 2.5 mA. The conditioned stimulus lasted 4 sec after which the shock was introduced. The electric current and the light were switched off when the rat responded correctly, i.e., crossed a 3 cm barrier running across the middle of the cage. The following indices were measured: duration of escape, i.e., the time that elapsed from the moment the electric current was switched on until the animal switched it off; the duration of avoidance, i.e., the time that elapsed from the moment the light was switched on till the animal crossed to the opposite side of the cage before the electric shock was turned on, and the number of correct avoidance responses.

RESULTS

Two-factor ANOVA with physical environment and social environment as factors was carried out. In the occurrence of interaction, simple effects were tested with Fisher's procedure.

Animal Behavior in Self-exposure Chamber and Activity Wheels during the First 90 Min Phase of Measurement. During the initial 90-min phase of measurement, the only behavior that differentiated the animals from the different groups was activity in the light wheel, $F(1,43) = 4.569$, $p = .039$ (Figure 1a). This was the main effect of the physical environment. Rats maintained in the enriched environment ran in this wheel more than rats maintained in the standard environment.

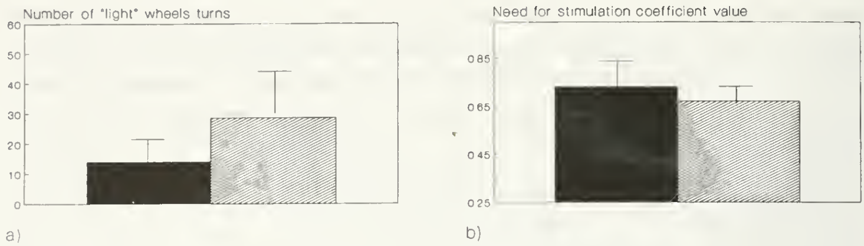

FIGURE 1. Means and standard deviations of: a) number of light wheels turns during first 90 min of measurement, ■ standard, ▨ enriched; b) need for stimulation coefficient [NS = Ne/(Ne + Nc)] computed on the base of results of the second 22 h of measurement, ■ standard, ▨ enriched.

There were no differences for the control wheel.

Animal Behavior in Self-exposure Chamber and Activity Wheels during the 22 H Test Period. The index computed according to the complete formula showed no differences but the analysis of variance of the partial index of need for stimulation [NS = Ne/(Ne + Nc)] revealed a higher need for light stimulation in the animals maintained in a standard environment as compared with the animals maintained in the enriched conditions, $F(1,32) = 6.232$, $p = .018$ (Figure 1b).

No differences among groups were found for all behavior measures in the activity wheels.

Open Field Behavior. The animals differed in the number of rearings. An interaction of physical and social factors was found, $F(1,43) = 4.42$, $p = .042$ (Figure 2a). Socially isolated rats maintained in the enriched environment reared more than socially isolated rats maintained in standard conditions.

Socially isolated animals urinated more than animals maintained in groups, $F(1,35) = 6.784$, $p = .014$ (Figure 2b).

Acquisition of Defensive Response. Rats maintained in isolation made less correct avoidance responses than group maintained rats, $F(1,33) = 13.829$, $p = .001$ (Figure 3a) and these responses were also slower, $F(1,33) = 14.575$, $p = .001$ (Figure 3b). Rats maintained in enriched conditions were slower to avoid shock than those in standard cages, $F(1,33) = 6.722$, $p = .015$ (Figure 3b).

DISCUSSION

Our experiment has shown that rats maintained in an enriched environment need less stimulation (lower NS coefficient) than rats maintained in a standard environment. This finding supports the data of Matysiak and Toeplitz (1990). Earlier research (Sackett, 1967; Hennessy et al., 1976; Tees et al., 1980) revealed an opposite effect. This may be due to the fact that earlier researchers did not sufficiently distinguish

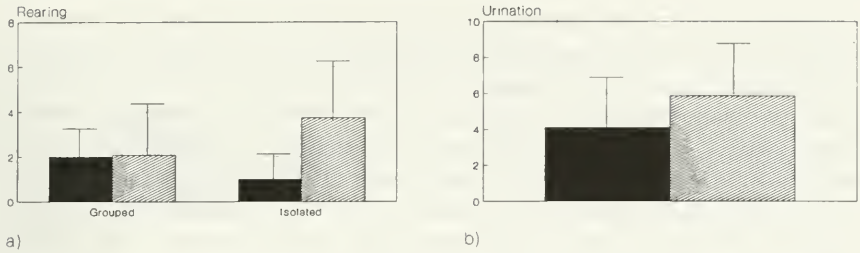

FIGURE 2. Means and standard deviations of: a) rearing, ■ standard, ▨ enriched; b) urinations in the open field, ■ grouped, ▨ isolated.

between exploratory behavior and general motor activity; the same indicators may show different kinds of activity. For example, bar pressing may be an indicator of exploration during the first 30 min of the test but cannot play such a role in an unchanged situation after 20 hours on the one hand. Behavior aimed at supplying the organism with sensory stimulation may play a role on the other hand. Our finding for the initial, 90-min period of testing rat activity in the activity wheels and in the open field (rearing) corroborate earlier findings. We believe that exploration is the most important kind of activity during this phase of wheel running. Rats maintained in the enriched environment ran more than control rats in the "light" wheel and seemed to explore more intensively in the open field, although this was not an interaction effect of physical and social enrichment. These results are in general accordance with Manosevitz (1970), Renner and Rosenzweig (1986) and Renner (1987).

We believe our results confirm the view that different mechanisms are responsible for exploratory behavior and behavior contingent on the need for sensory stimulation. The term used to explain the individual level of need for stimulation is the coefficient of transformation of stimulus strength suggested by Matysiak (1985). This hypothetical (physiological) mechanism causes individual differences in stimulation processing. The same stimuli may be stronger or not for different individuals. Drops in need for sensory stimulation can be interpreted as manifestations of

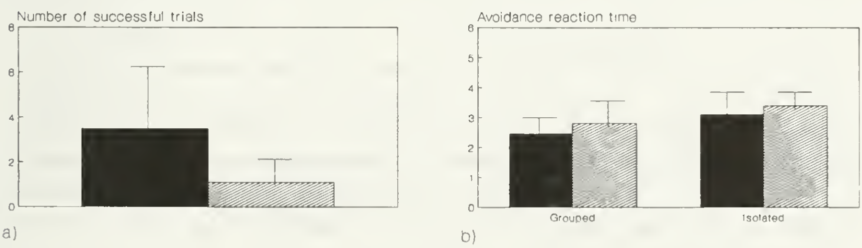

FIGURE 3. Means and standard deviations of: a) number of correctly performed avoidance responses during two sessions (twenty trials), ■ grouped, ▨ isolated; b) avoidance reaction time, ■ standard, ▨ enriched.

increases in individual reactivity. This reactivity is defined in terms of the value of the coefficient of transformation of the stimulus strength.

We finally found an increase in emotional reactivity (urination and defensive responses) in our socially isolated rats and a decrease of emotional reactivity in rats maintained in enriched conditions. This is in accordance with the theory of Denenberg (1964) and later findings of Baenninger (1967), Koch and Arnold (1972), Parker and Morinan (1986), and gives added support to the view that the social environment is decisive for the development of the emotional sphere.

EXPERIMENT TWO

Experiment Two was similar to Experiment One, the difference being that 60–70 day-old rats were studied in the experimental treatments.

Animals

Forty-eight outbred male Wistar rats were tested.

Procedure

All experimental manipulations were as in Experiment One. The rats were 60–70 days old when the experiment started. Until the experimental treatment started, the rats were maintained in standard (see Experiment One) cages in groups of six.

RESULTS

Behavior during 90 Min of Measurement in Self-exposure Chamber and Activity Wheels. Analysis of activity in the self-exposure chamber revealed that animals maintained in standard conditions were much more active than rats maintained in the enriched environment, $F(1,37) = 13.765$, $p = .001$ (Figure 4a).

Significantly greater activity was found in the activity wheels in animals maintained in groups as compared with socially isolated animals. This was found both in the light wheel, $F(1,40) = 8.904$, $p = .005$ (Figure 4b), and in the control wheel, $F(1,40) = 9.313$, $p = .004$ (Figure 4c).

Rat Behavior during 22 H Test Period in Self-exposure Chamber and Activity Wheels. Analysis of the variance of the need for light stimulation (NS-coefficient computed according to complete formula) revealed a significant interaction of the experimental variables, $F(1,34) = 5.901$, $p = .021$ (Figure 5a). Isolated rats, maintained in standard conditions, revealed a larger need for light stimulation than isolated rats maintained in an enriched environment.

As concerns activity in the activity wheels, rats maintained in groups were significantly more active than rats maintained in social isolation.

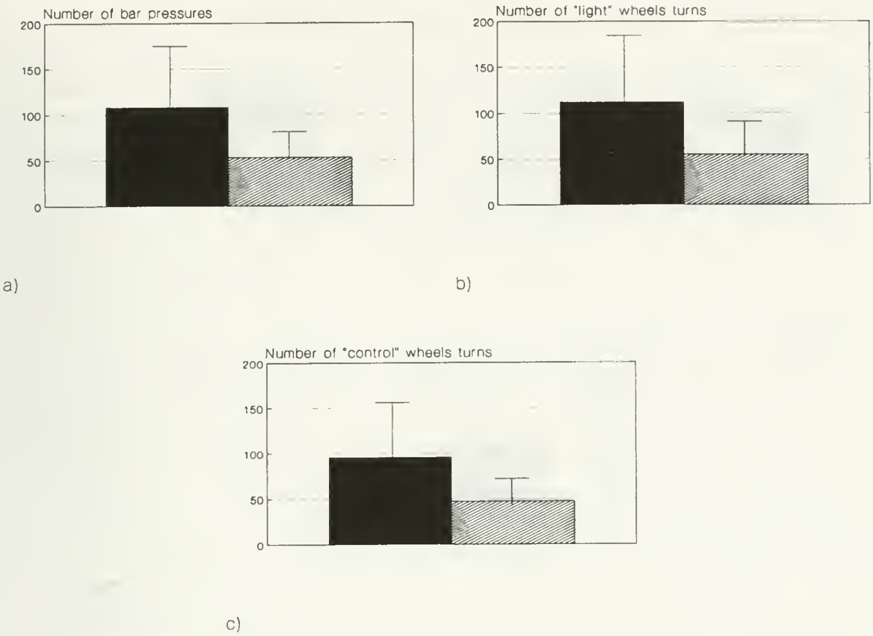

FIGURE 4. Means and standard deviations of: a) number of pressures on both bars during first 90 min of measurement in self-exposure chamber, ■ standard, ▨ enriched; b) number of light wheels turns during first 90 min of measurement, ■ grouped, ▨ isolated; c) number of control wheels turns during first 90 min of measurement, ■ grouped, ▨ isolated.

This relationship holds both for the light wheel, $F(1{,}40) = 18.806$, $p = .001$ (Figure 5b) and the control wheel, $F(1{,}40) = 12.192$, $p = .001$ (Figure 5c).

Behavior in the Open Field. Analysis of behavior in the open field showed that rats maintained in the standard environment reared more than rats maintained in the enriched environment, $F(1{,}43) = 4.551$, $p = .039$ (Figure 6).

Acquisition of Defensive Response. No differences were found in defensive responses.

DISCUSSION

An important finding from Experiment Two is the different relationship between environmental factors and need for light stimulation than in Experiment One. We may thus conclude that the strength and direction of changes in behavior due to environmental experience are contingent to a significant extent upon the developmental phase in which the environmental experience took place.

There is an important limitation of such a conclusion. The animals

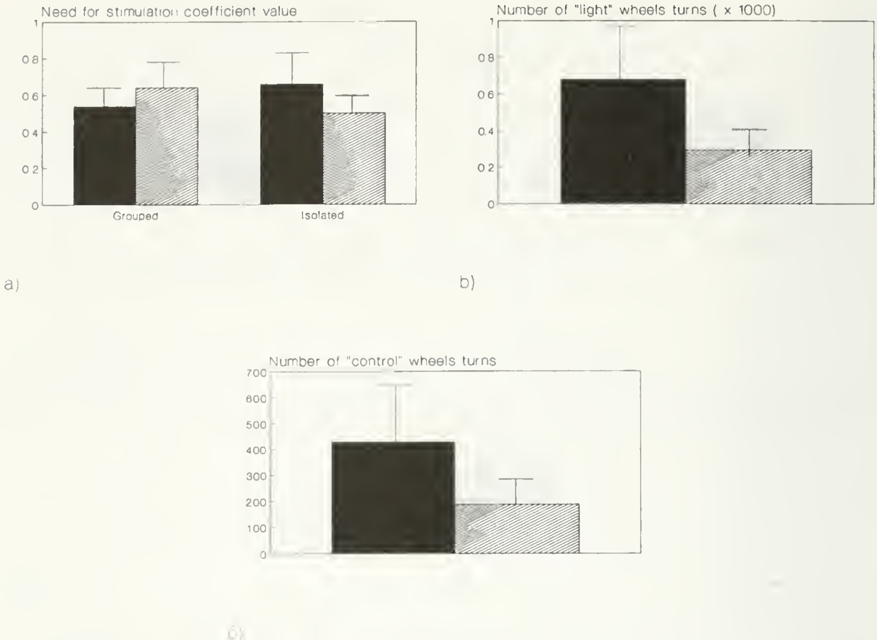

FIGURE 5. Means and standard deviations of: a) need for stimulation coefficient NS = [Ne/(Ne + Nc)]•[Te/(Te + Tc)] computed on the base of second, 22 h phase of measurement in the self-exposure chamber, ■ standard, ▨ enriched; b) number of wheels turns during second, 22 h phase of measurement, ■ grouped, ▨ isolated; c) number of control wheels turns during second, 22 h phase of measurement, ■ grouped, ▨ isolated.

spent different amounts of time in the experimental conditions in Experiment One and Experiment Two. Thus, the differences in results of those two experiments may be due, to some extent, to experience before observation, such as the duration of housing. We believe such an interpretation would probably be true if the obtained differences were only quantitative. However, as we obtained different directions of change in the dependent variables in these experiments, we infer that these differences were related to the different developmental phase of the animals

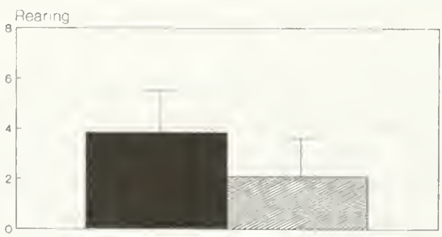

FIGURE 6. Means and standard deviations of rearings in the open field, ■ standard, ▨ enriched.

when given the experimental treatment in Experiment One and in Experiment Two.

Attention must also be drawn to the finding that social environment affects need for kinesthetic and tactile stimulation (22 h test in activity wheels). Rats are "contact" animals (Marler & Hamilton, 1966), i.e., they seek physical contact with their partners. The tactile sense is crucial in this context. Hence when tactile stimulation is restricted, this could have a marked effect on those behaviors which reflect need for tactile and kinesthetic stimulation.

Different kinds of exploratory behaviors were affected by both social and physical environments as shown in the results from the first 90 min in activity wheels, self-exposure chamber and open-field. It is noteworthy that enriching the environment in Experiment Two, as opposed to Experiment One, led rather to a decrease in intensity of exploration. A significant role of the social environment also emerged in regulation of such behavior. Rats maintained in groups were more exploratory than rats maintained in social isolation. This finding corroborates that of Parker and Morinan (1986). The lack of interaction of experimental factors is also noteworthy.

As compared with Experiment One, changes in emotional reactivity due to social isolation were weaker. This is in accordance with the conclusion of Denenberg (1964) and Einon and Morgan (1976) who wrote that the critical period for social isolation in rats is the early phase of development.

GENERAL DISCUSSION

The general purpose of the conducted studies was the examination of the effects of environmental influences on temperamental traits in rats. According to the traditional point of view (Strelau, 1983), temperamental traits are strongly determined by genetic factors, the environmental effects recognized as rather secondary or additional. This way of thinking was especially strong with respect to so called "lower mammals." Our studies have shown a significant role of environmental experience in the development of temperament in rats. We draw attention to the fact that different environmental effects were found depending on the age of rats at which experimental treatment started.

Strelau (1983) claims that the social environment affects temperament via formal features, i.e., excessive or insufficient stimulation. Our studies have shown that specific types of stimulation differentially affect specific temperamental features. In general, we agree with Strelau, but we must underscore that various modalities of stimulation specifically affect different features of temperament. This specificity changes as animals grow older. Thus, the qualitative aspect of sensory stimulation is also important for temperament development. The role of qualitative properties of sensory stimulation have been pointed out, so far, for the development of intelligence and abilities.

Our findings do not permit any unequivocal conclusions as to the categories of environmental factors which affect temperament. We may put forward the opinion, however, that emotional reactivity in rats and their need for tactile stimulation are more affected by social experience of the individual rats whereas need for light stimulation is more affected by the physical environment. It draws our attention to the possible, common evolution of the sensory systems and temperamental traits.

ACKNOWLEDGEMENT

This work was financed by the research program of Polish Ministry of Education No. III.25/VII.

REFERENCES

Archer, J. (1973). Test for emotionality in rats and mice: a review. *Animal Behaviour, 21,* 205–235.

Baenninger, L. P. (1967). Comparison of behavioral development in socially isolated and grouped rats. *Animal Behaviour, 15,* 321–323.

Brush, F. R., Baron, S., Froehlich, J. C., Ison, J. R., Pellegrino, L. J., Phillips, D. S., Sakellaris, P. C., & Williams, V. N. (1985). Genetic differences in avoidance learning by *Rattus norvegicus*: Escape/avoidance responding, sensitivity to electric shock, discrimination learning, and open field behavior. *Journal of Comparative Psychology, 99,* 60–73.

Denenberg, V. H. (1964). Critical periods, stimulus input, and emotional reactivity: A theory of infantile stimulation. *Psychological Review, 71,* 335–351.

Einon, D. F., & Morgan, M. J. (1976). A critical period for social isolation in the rat. *Developmental Psychobiology, 10,* 123–132.

Forgays, G. D., & Michelson-Read, J. (1962). Crucial periods for free-environmental experience in the rat. *Journal of Comparative and Physiological Psychology, 55,* 816–818.

Hennessy, M. B., Hershberger, W. A., Bell, R. W., & Zachman, T. A. (1976). The influence of early auditory experience on later auditory and tactual variation seeking in the rat. *Developmental Psychobiology, 9,* 255–260.

Koch, M. D., & Arnold, W. J. (1972). Effects of early social deprivation on emotionality in rats. *Journal of Comparative and Physiological Psychology, 78,* 391–399.

Manosevitz, M. (1970). Early environmental enrichment and mouse behavior. *Journal of Comparative and Physiological Psychology, 71,* 459–466.

Marler, P., & Hamilton, W. J. III. (1966). *Mechanisms of animal behavior.* New York: John Wiley & Sons, Inc.

Matysiak, J. (1985). Need for sensory stimulation: Effects on activity. In J. Strelau (Ed.), *Temperamental bases of behavior: Warsaw studies on individual differences.* Netherlands, Lisse: Swets & Zeitlinger.

Matysiak, J., & Toeplitz, Z. (1990). Influence of genetic and environmental factors on self-exposure to sensory stimuli in rats. *Ricerche di Psichologia, 2,* 20–28.

Matysiak, J., Ostaszewski, P. M., Pisula, W., & Watras, S. (1992). Genetic and environmental effects on the need for sensory stimulation and emotional reactivity in rats. In D. G. Forgays, T. Sosnowski, & K. Wrzesniewski (Eds.), *Anxiety: Recent developments in cognitive, psychophysiological, and health research* (pp. 167–177). Washington, Philadelphia, London: Hemisphere Publishing Corporation.

Parker, V., & Morinan, A. (1986). The socially-isolated rat as a model for anxiety. *Neuropharmacology, 25,* 663–664.

Renner, M. (1987). Experience-dependent changes in exploratory behavior in adult rat (*Rattus norvegicus*): Overall activity level and interactions with objects. *Journal of Comparative Psychology, 101,* 94–100.

Renner, M. J., & Rosenzweig, M. R. (1986). Object interactions in juvenile rats (*Rattus norvegicus*): Effects of different experimental histories. *Journal of Comparative Psychology, 100,* 229–236.

Sackett, G. P. (1967). Response to stimulus novelty and complexity as a function of rats' early rearing experiences. *Journal of Comparative and Physiological Psychology, 63,* 369–375.

Smith, H. V. (1972). Effects of environmental enrichment on open-field activity and Hebb-Williams problem solving in rats. *Journal of Comparative and Physiological Psychology, 80,* 163–168.

Strelau, J. (1983). *Temperament, personality, activity.* London: Academic Press.

Tees, R. C., Midgley, G., & Bruinsma, Y. (1980). Effects of controlled rearing on the development of stimulus seeking behavior in rats. *Journal of Comparative and Physiological Psychology, 94,* 1003–1018.

Walsh, R. N., & Cummins, R. A. (1976). The open-field test: A critical review. *Psychological Bulletin, 83,* 482–504.

Wong, R. (1976). *Motivation, a biobehavioral analysis of consummatory activities.* New York: Macmillan Publishing Co.