Pharmacology Biochemistry and Behavior, Vol. 2, pp. 55–62. ANKHO International Inc., 1974. Printed in the U.S.A.

Brain Amine Levels and Competitive Behavior Between Rats in a Straight Runway

JANDIRA MASUR[1], SILVIA CZERESNIA, HILDA SKITNEVSKY AND E. A. CARLINI[2]

Departamento de Psicobiologia, Escola Paulista de Medicina, Rua Botucatu, 862 04023 São Paulo, Brazil

(Received 24 May 1973)

MASUR, J., S. CZERESNIA, H. SKITNEVSKY AND E. A. CARLINI. *Brain amine levels and competitive behavior between rats in a straight runway.* PHARMAC. BIOCHEM. BEHAV. 2(1) 55–62, 1974. – Competitive behavior was studied in pairs of rats, under conditions where the whole brain amine levels of one of these rats was manipulated pharmacologically. The test situation employed was a narrow runway in which one rat had to push its partner in order to be rewarded with food. Competition between pairs was not affected by administration of 300 and 600 mg/kg of *para*-chlorophenylalanine, although these doses caused a 90 percent decrease in brain serotonin levels. A 100 mg/kg dose of tryptophan, which increased brain serotonin level by 36 percent did not alter competition either; doses of 300 and 500 mg/kg of tryptophan induced marked alteration in the behavior of rats, to such an extent that competition did not occur. Fifty, 100 and 200 mg/kg of dihydroxyphenylalanine, administered 50 min before test situation, induced significant increases in winning behavior, either in naive rats or in previously "loser" rats. Forty-eight hr later the winning behavior frequency of these animals returned to values near the chance level of 50 percent. The increase in winning behavior coincided with a significant increase in brain dopamine measured 50 min after the treatment; norepinephrine was not altered. Forty-eight hr later, when the winning frequency was back to normal, brain dopamine levels returned to control values. Twenty-five mg/kg bis (4-methyl-l-homopiperazinyl-thiocarbonyl) disulphide (FLA–63), did not change dopamine level in brain but markedly reduced that of norepinephrine. This dose of FLA–63 induced an increase of winning behavior. α-Methyl-*para*-tyrosine (150 mg/kg) and 3,α-dimethyltyrosine (100 mg/kg) decreased brain levels of dopamine and norepinephrine but did not alter the competitive behavior of rats. The possibility that dopamine may be involved in this behavioral situation is discussed.

Competition Social behavior Brain amines PCPA DOPA Tryptophan FLA–63 α-MT

MANIPULATIONS of brain amine levels of animals have been shown to influence their social interaction. Rats treated with *para*-chlorophenylalanine (PCPA), an inhibitor of serotonin synthesis showed an increase of rolling over and social grooming (28). Treatment with α-methyl-*p*-tyrosine, an inhibitor of catecholamine synthesis, decreased social interactions of *Macaca speciosa*, whereas PCPA was without effect [25]. These data led us to investigate whether competitive behavior between rats could be also influenced by alteration of brain amines, as to our knowledge there are no reports concerning this point. To measure competition we utilized the straight runway test which has been used to observe drug effects [18, 19, 35] and was shown to detect strain differences in mice [15].

MATERIAL AND METHODS

Animals

Male Wistar rats from our own colony, 90 days old at the beginning of the experiment were used. The animals were weaned at 25 days of age and kept in groups of 6 in wooden cages measuring 48 x 28 x 20 cm. When 75 days old they were housed by pairs, according to their weights, in wire cages measuring 32 x 16 x 29 cm. During all the time the animals were maintained on a 12 hr day–night cycle at room temperature of 23±1°C. Daily handling consisted of cleaning the cages and providing food and water. For the biochemical studies other rats of same sex, age and strain were used.

Drugs

Depletion of 5-hydroxytryptamine (5–HT) was induced through the administration of dl-*para*-chlorophenylalanine (PCPA; Sigma Chemical Corporation) prepared in Tween-80 and saline. PCPA was reported to reduce brain concentration of 5–HT to 90 percent, whereas catecholamines are reduced by only 15 percent [13]. dl-Tryptophan (Sigma Chemical Corporation) prepared in saline, was used to increase serotonin brain levels, as the serotonin formed from it may have a better possibility to be incorporated in the serotonin stores than the serotonin derived from 5-hydro-

[1] With a fellowship from Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP)
[2] Pesquisador conferencista – bolsista do Conselho Nacional de Pesquisas (CNPq)

xytryptophan [1,20]. Solutions in saline of dl α-methyl-*para*-tyrosine-methylester hydrochloride (AMT; Sigma Chemical Corporation) and 3,α-dimethyltyrosine-methylester hydrochloride (DMT; Kistner Labjänst AB), inhibitors of tyrosine hydroxylase [11,21], were employed to decrease brain levels of dopamine (DA) and norepinephrine (NE). Inhibition of dopamine β-hydroxylase was achieved with the use of bis (4-methyl-l-homopiperazinyl-thiocarbonyl) disulphide (FLA–63; AB Biotec) prepared in distilled water acidified with 1N HCl and with the pH brought later to 6.0 using 1N NaOH. dl-Dihydroxyphenylalanine (DOPA; Mann Research Laboratories) solutions were prepared in distilled water with help of 1N HCl and pH brought to 5.8 to 6.2. Proper control solutions were prepared with the solvents with pH identical to that of the drug solutions. The amounts injected, calculated in terms of the bases, are mentioned in the results. All injections were given i.p. in a volume corresponding to 0.2–0.5 ml/100 g of body weight.

Biochemical assays. Animals were decapitated, the brains rapidly removed, washed with cool 0.9% saline and immediately homogenized in 0.4 N $HClO_4$ (for catecholamine assays) or in 0.1N HCl (for 5–HT assay). DA and NE were measured according to Anton and Sayre [2,3]; for DA assays 5N HCl was added for the reduction of DOPA fluorescence [3]. 5–HT was measured as recommended by Bogdanski *et al.* [5]. Decapitations were performed at 24, 72 and 144 hr after 300 and 600 mg/kg of PCPA, 12 hr after the first dose of 50 mg/kg of AMT (4 hr after the total dosage of 150 mg/kg), 4 hr after 100 mg/kg of DMT, 50 min after 25, 50, 100 and 200 mg/kg of DOPA and 80 min after 25 mg/kg of FLA–63. For each drug treatment 6 to 8 rats were used, 2 of them being controls.

Apparatus

The same as described in detail elsewhere [19]. Briefly, it consisted of a straight wood runway 100 cm long, connected at the extremities with two identical open-topped chambers measuring 20 × 20 × 20 cm; a guillotine door bisected the runway.

Procedure

Individual training for the behavioral competitive sessions. The animals, deprived of food for 20–22 hr were individually trained to traverse the runway. Experimental sessions of 3 runs each were performed at every 48 hr. The runs consisted of introducing the animals alternately in each end-box and recording the latency time to reach the opposite end-box where they were rewarded with peanuts delivered in a cup for 20 sec. The interval between runs was 3–5 min. Four such sessions were given at the end of which all animals were performing in less than 10 sec.

Competitive sessions. After the individual training, one rat of each pair received the drug under study and its partner was injected with the proper control solution. The pairs were formed by cage-mates of similar weight. The competitive sessions occurred at several time intervals after the injections, according to the drug under study. The rat under drug action was placed in one of the goal boxes while the control-injected rat was placed in the remaining box. The guillotine door, at the middle of the runway, was opened when both animals reached it. As they were unable to pass each other, they started to push; the rat which pushed the partner to the opposite chamber was classified as the winner and received the peanut reward, while the loser was returned to its homecage. Each experimental session consisted of 5 such competitive trials for each pair; after each trial, the loser rat was sumittted to an individual run in order to assure that it would not extinguish its conditioned behavior.

Experiments with PCPA. Thirty-three pairs of rats were used. One rat from each of 18 pairs received 300 mg/kg of PCPA and for the other 15 pairs one rat from each pair was injected with 600 mg/kg. All the 33 partners were injected with control solution. The competitive sessions (consisting of 5 competitive trials for each pair) took place 24, 72 and 144 hr after the injections. Brain assays of serotonin were performed with other rats injected with the same amount of drugs and decapitated 24, 72 and 144 hr later.

Experiments with tryptophan. Thirty-three pairs of rats were used. Fifteen such pairs were new animals, that is they were never injected before. One rat from each of these 15 pairs received 100 mg/kg of tryptophan, and control solution was given to their partners. The other 18 pairs of rats had received PCPA or saline 16 days earlier (experiment with PCPA). One rat each from 9 of these pairs received 300 mg/kg of tryptophan, and one rat from each of the other remaining 9 pairs were injected with 500 mg/kg of tryptophan. All their 18 partners received control solution. The competitive sessions (5 competitive trials for each pair) were performed 2 hr after drug administration. Brain serotonin determinations were carried out with other rats injected with the same amount of drugs and sacrificed 2 hr after the injections.

Experiments with DOPA. (a) Four new groups of rats consisting of 14–16 pairs each, were used. One rat from each pair of the 4 groups received, respectively, 25, 50, 100 and 200 mg/kg of DOPA. The partners received control solution. The competitive sessions occurred 50 min and 48 hr after drug administration.

Brain DA and NE assays were carried out with other rats injected with the same amount of drugs and decapitated 50 min after injections. Dopamine was also assayed 48 hr after the 200 mg/kg dosage.

(b) Nineteen new pairs of rats were first submitted to two competitive sessions, 48 hr apart, without receiving drugs. Rats which lost at least 7 of the 10 competitive trials were classified as losers and received 48 and 96 hr later 200 mg/kg of DOPA. Their winner partners were injected with control solution. Fifty min after injections, competitive sessions were again carried out.

Experiments with AMT and DMT. Eleven pairs of new rats were used. One rat of each pair was injected with 100 mg/kg of DMT while the partners received control solution. Four hr later a competitive session was carried out. For the experiment with AMT, 18 pairs of new animals were used. At 4 hr intervals [24], one rat from each pair received 3 injections of 50 mg/kg of drug (total 150 mg/kg). The partners were similarly injected with control solution. The competitive session occurred 4 hr after the last injection. Assays of brain DA and/or NE were performed in other rats similarly treated with 100 mg/kg of DMT or 150 mg/kg of AMT.

Experiments with FLA–63. One rat from each of 18 new pairs was injected with 25 mg/kg of FLA–63 and its partner with control solution. The competitive sessions were performed 80 min and 48 hr later. Brain measurements of DA or NE were performed with other rats injected with the same amount of drug and killed 80 min after injections.

Experiments with FLA–63 plus DOPA. Ten rats, one

from each of 10 new pairs received 25 mg/kg of FLA–63 and 30 min later 100 mg/kg of DOPA. Their partners were injected twice with the control solutions. Fifty min after the second injection the rats were submitted to the competitive session.

Statistics

Behavioral studies. Based on the fact that each rat of a pair had 50 percent chance level to win and since nothing in their previous experience differentiated them, the Binomial test was used. The number of pairs employed in each experiment was such that the possibility of obtaining by chance a large difference from the expected 50 percent level was very low [29].

In addition, the Wilcoxon matched pairs test [29] was employed to analyse the results of DOPA effects on rats which were previously losers.

Biochemical Studies. The Student's *t* test was used.

RESULTS

Experiments with PCPA

As expected, 300 and 600 mg/kg of PCPA pretreatment markedly reduced brain 5–HT levels; brain serotonin level's decreased significantly from that of control values at 24, 72 and 144 hr after pretreatment with PCPA (Fig. 1). The decrease was greater at 72 hr. However, these decreases did not affect the behavior of rats in the competitive situation. Treated rats won from 39 to 56 percent of the competitive trials when tested at 24, 72 or 144 hr after injections, showing no difference from the 50 percent chance level (Fig. 1). The overall behavior of PCPA-treated rats showed no gross alteration.

Experiments with tryptophan

Brain serotonin levels were significantly increased 2 hr after the 3 doses of tryptophan (Table 1). Rats injected

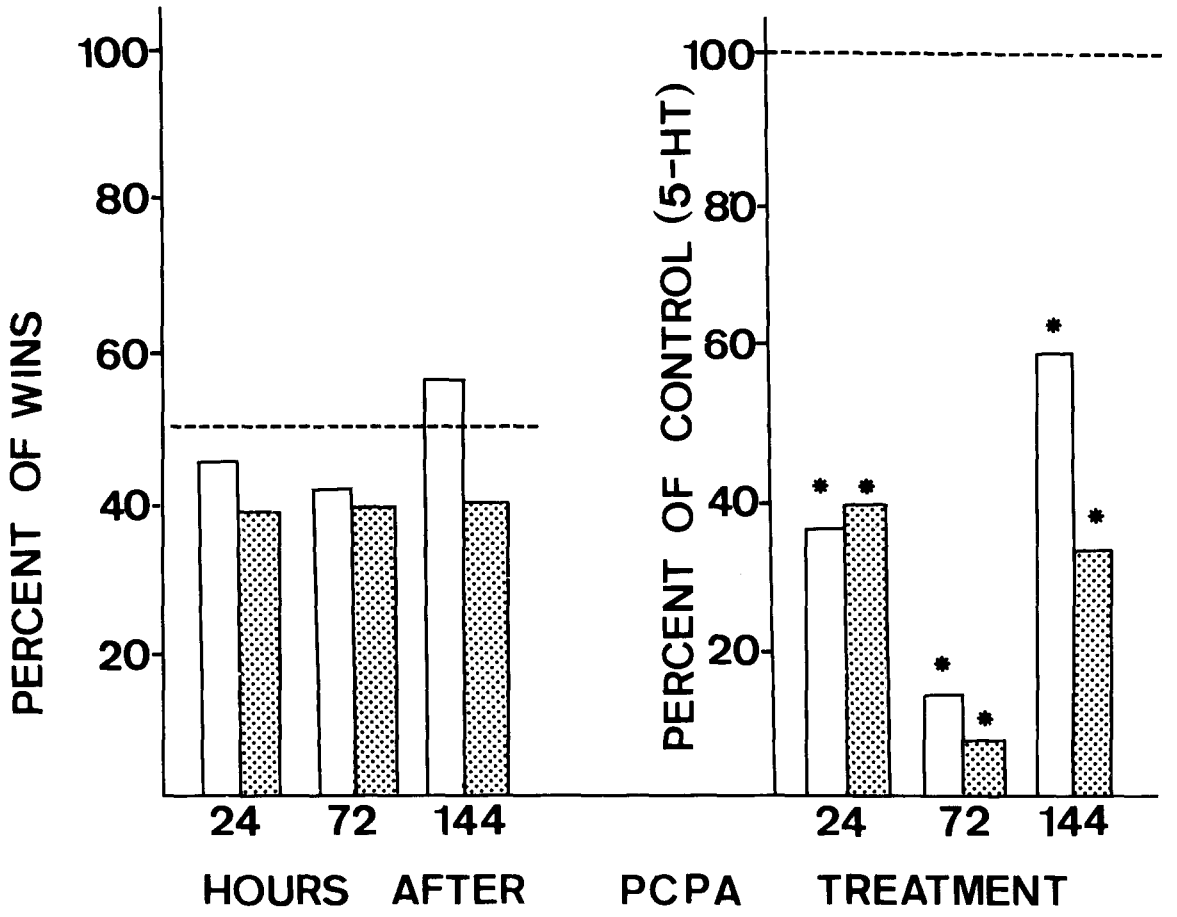

FIG. 1. Percentage of winning behavior (left part of the figure), and brain serotonin levels (right part) of rats pretreated with 300 mg/kg (open columns) and 600 mg/kg (dotted columns) of PCPA. Behavioral measures and chemical assays were performed 24, 72, and 144 hr after drug treatments. Note that in spite of the drastic reduction of brain 5–HT (72 hr) the animals performed within chance level. The control level of 5–HT (average of determinations performed at 24, 72 and 144 hr) was 0.728±0.12 μg/g (100 percent). The asterisks indicate significant differences at a level of at least 5% (Student's *t* test).

TABLE 1

BRAIN LEVELS OF 5-HT AFTER TREATMENT WITH TRYPTOPHAN

Treatment	Dose mg/kg	Time After Treatment (hr)	% of 5-HT Compared to Controls*
Tryptophan	100	2	135.7†
	300	2	139.1†
	300	48	96.3
	500	2	144.6†
	500	48	95.8

*Serotonin levels in control animals 0.717 ± 0.09 μg/g (100 percent)

†Statistical significant differences (p at least 0.05; Student t test).

with 100 mg/kg scored 59 percent of wins, which is within the chance level of 50 percent. All these rats, although slightly affected in motor behavior, were able to perform adequately in the runway. The animals injected with the larger doses (300 and 500 mg/kg) showed, however, a peculiar behavior when introduced into the apparatus. In most trials their latencies were similar to that of controls (2 or 3 sec), but once entering the runway they stopped motionless. Upon opening guillotine door its partner tried and failed to push it back, since tryptophan treated animals did not move. Under this situation, which lasted sometimes for as long as 15 to 20 min, it was not possible to analyse the effects of 300 and 500 mg/kg of tryptophan on the competitive behavior studied.

Experiments with DOPA

(a) Brain dopamine levels were significantly increased to 50 min after 50, 100 and 200 mg/kg of DOPA; 25 mg/kg had no effect (Fig. 2). On the other hand, brain norepinephrine remained within normal values, regardless of the amount of DOPA injected (Fig. 2). Rats treated with 50, 100 and 200 mg/kg of DOPA showed piloerection 50 min after the injections; when submitted to the competitive

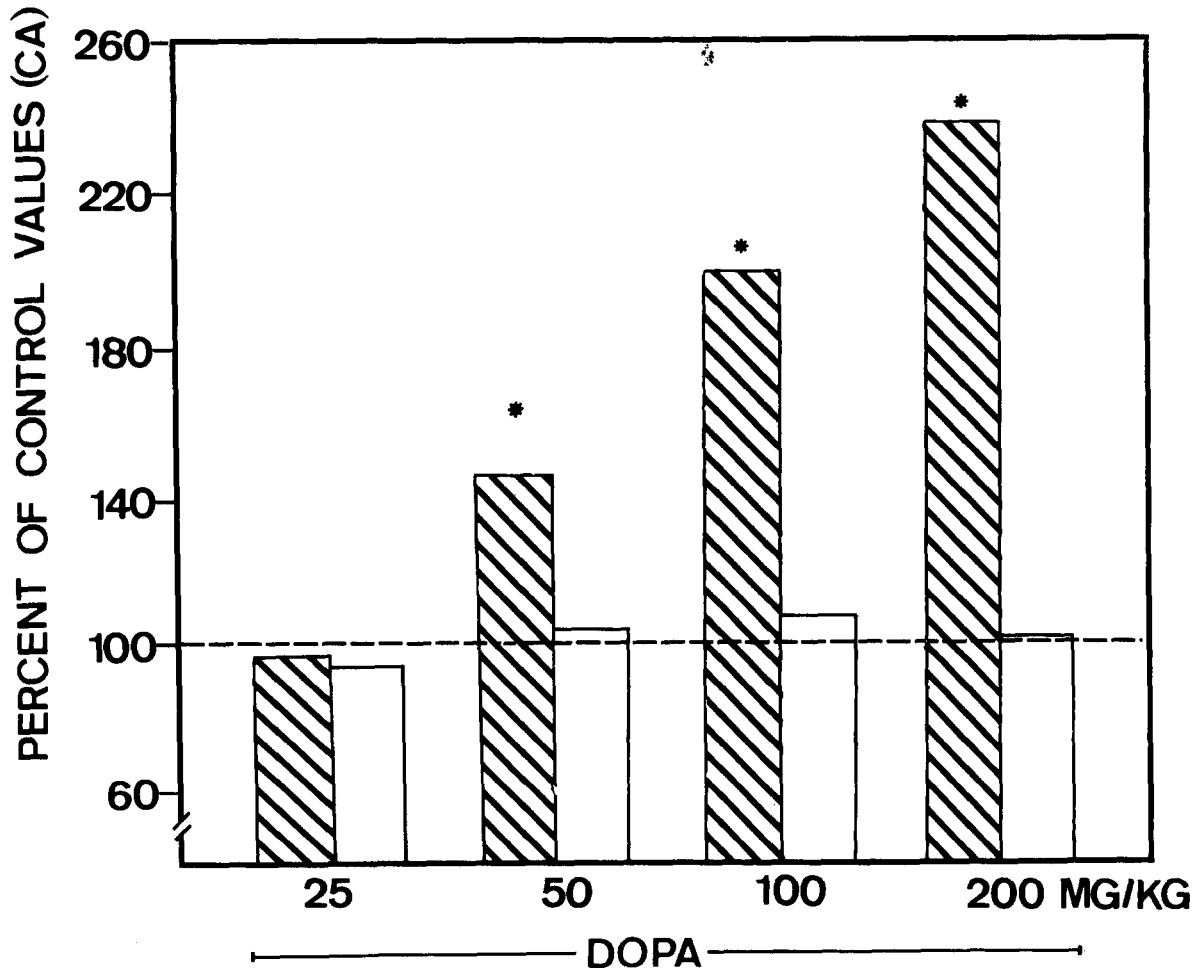

FIG. 2. Brain dopamine (hatched columns) and norepinephrine (open columns) levels, 50 min after treatment with several doses of DOPA. DA and NE levels in control animals were, respectively, 0.812±0.11 and 0.403±0.03 μg/g (100 percent). The asterisks indicate significant differences at a level of at least 5% (Student's t test).

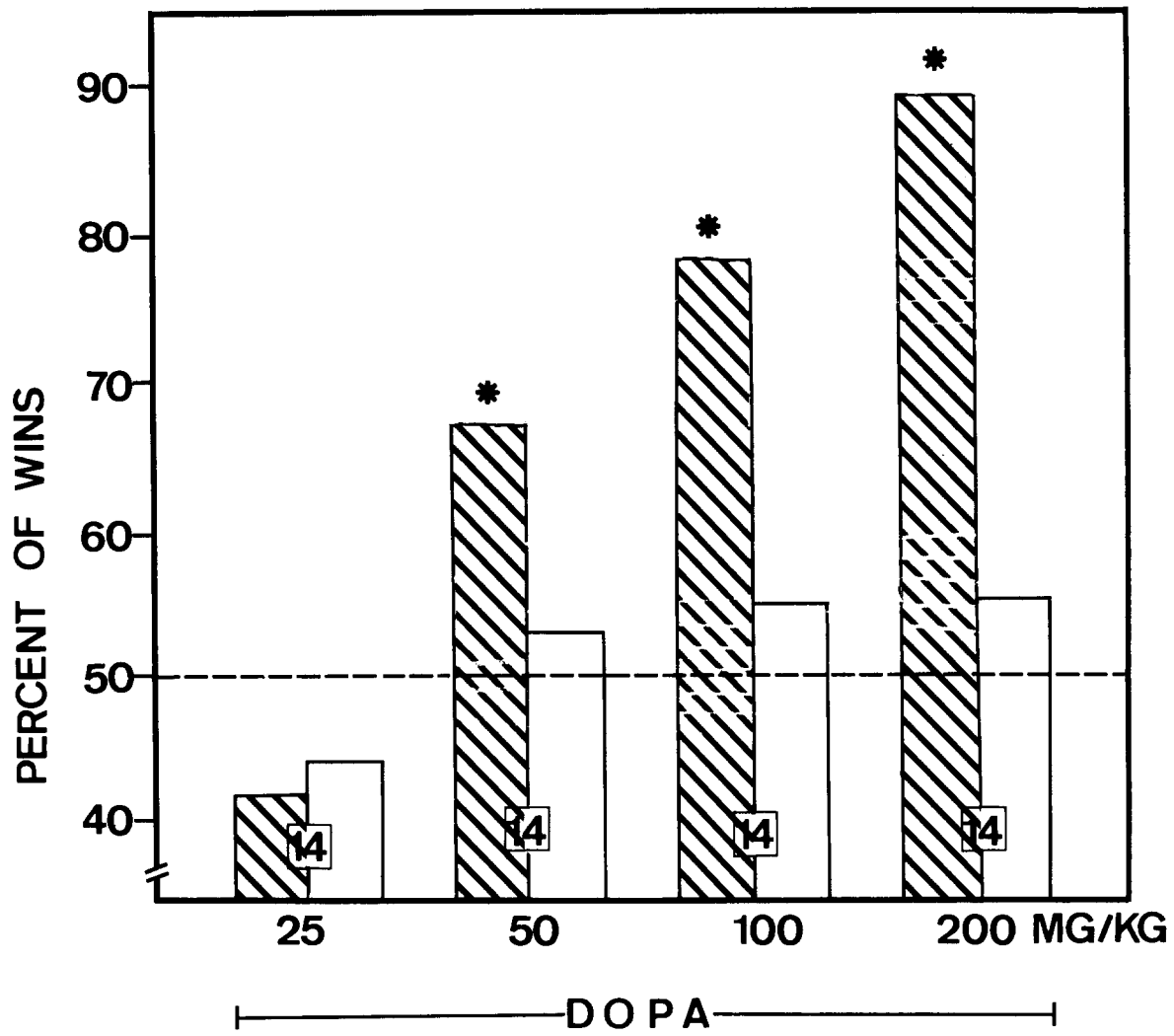

FIG. 3. Percent of winning behavior of rats, 50 min (hatched columns) and 48 hr (open columns) after the injection of several doses of DOPA. The asterisks indicate p at least 0.05 (Binominal test). Figures within columns indicate number of pairs tested. Noted that the increase of winning behavior after DOPA coincided with the increase of brain dopamine (see Fig. 2).

trials they won respectively, 68, 78 and 89 percent of the contests (Fig. 3). These values differ significantly from the expected chance level of 50 percent. The behavior of DOPA-treated rats in the apparatus was apparently normal although some animals showed an increase in latency to enter the runway. However, 2 rats treated with 100 mg/kg and one with 200 mg/kg did not compete since they did not leave the starting box. Forty-eight hr later, on the second competitive session, the winning frequency of trained rats came down to values near 50 percent (Fig. 3). Brain dopamine levels (after 48 hr of DOPA treatment) also returned to control values.

(b) DOPA treatment (200 mg/kg) on rats classified previously as losers increased their winning behavior (Fig. 4). In the 2 competitive sessions before drug administration they scored respectively 29 and 16 percent of wins (average 22.5 percent). However, after 2 administrations of DOPA they won respectively 43 and 51 percent of competitive trials. These values differ from the last session without drug (Wilcoxon test for matched pairs; $p \leqslant 0.01$).

Experiments with AMT and DMT

The animals treated with 150 mg/kg of AMT did not show gross behavioral alterations. In the competitive session carried out 4 hr after the last injection, they won 53 percent of the competitive trials, which is within chance level (Fig. 5). On the other hand, the amounts of brain dopamine and norepinephrine were respectively 14.1 and 30.8 percent of the control values (Fig. 5).

The rats treated with DMT showed depression and loss of muscular tonus. Brain dopamine levels were 38 percent below control levels (Fig. 5). They won 33 percent of the contests (Fig. 5), a value which is not significant and probably depends on the toxic effects of the drug.

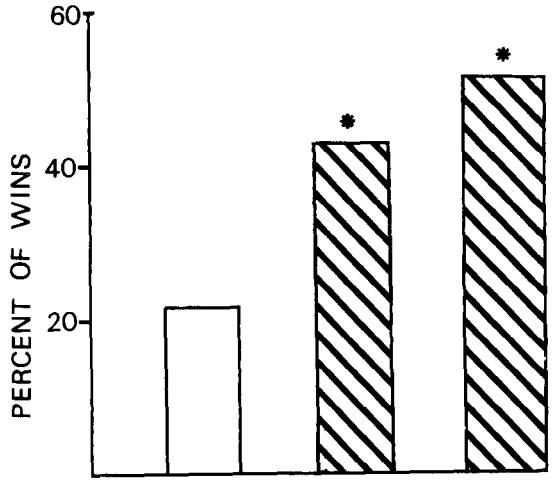

FIG. 4. Percentage of winning behavior of rats classified as losers, before and after the administration of 200 mg/kg of DOPA. Open column indicates the average percentage of wins achieved by the loser rats in 2 sessions without drug administration. Hatched columns show the percentage of wins of same rats 50 min after 2 individual doses of 200 mg/kg of DOPA. Asterisks indicate significant differences when compared to their performance when untreated ($p \leq 0.01$; Wilcoxon matched pairs test).

Experiments with FLA−63

A few minutes after the injection of 25 mg/kg of FLA−63 the rats began to lay down in the cages; however, they assumed normal posture when stimulated. Thirty to 60 min after injections they behaved in an apparently normal way, although they showed piloerection. When submitted to the competitive session 80 min after drug administration, 5 of the treated rats did not enter the runway. The remaining 13 rats competed normally, pushed vigorously their partners and won 90 percent of the contests (Fig. 5). Brain dopamine levels of FLA−63-treated rats were comparable to that of control rats; NE was decreased by 85 percent (Fig. 5).

Experiments with FLA−63 plus DOPA

The behavior of all rats injected with FLA−63 was strongly affected after the injection of 100 mg/kg of DOPA. They showed pronounced decrease of motor activity and piloerection. When introduced into the apparatus they did not move from the starting box, making competition impossible.

DISCUSSION

The present results show that 300 and 600 mg/kg of PCPA, which reduced brain 5−HT levels to less than 10 percent of control values, did not influence the competitive

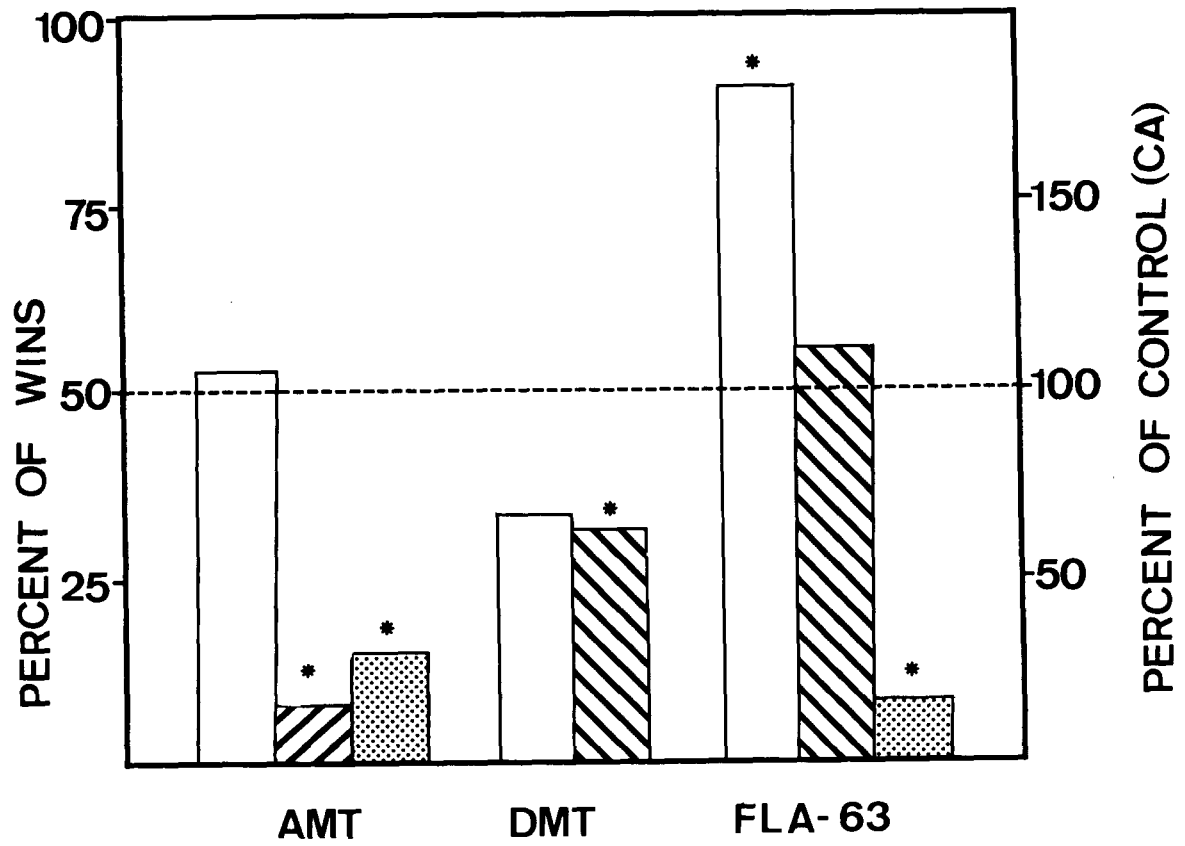

FIG. 5. Percentage of wins (open columns), brain levels of DA (hatched columns) and NE (dotted columns) of rats treated with 150 mg/kg of AMT, 100 mg/kg of DMT and 25 mg/kg of FLA−63. Asterisks indicate significant differences at a level of at least 5% (Binomial test for behavioral measurements; Student's t test for chemical determinations). The control levels of DA and NE were, respectively, 0.832±0.13 and 0.421±0.12 μg/g (100 percent).

behavior of rats as measured by the straight runway test (Fig. 1). A 35.7 percent increase in brain serotonin, induced by 100 mg/kg of tryptophan, did not alter the competitive behavior of the rats either. Therefore, it appears that the competitive behavior studied is not related to 5–HT content in brain.

Pretreatment with 50–200 mg/kg of DOPA clearly increased the capacity of rats to win. The frequency of wins was dependent on the doses previously given (Fig. 3). This effect of DOPA was also observed in previously experienced losers (Fig. 4). As seen in Fig. 2 this effect of DOPA coincided with the increase of brain dopamine induced by the amino acid; on the other hand, no changes in the levels of NE were observed. It has been reported before that about 50 min after administration of DOPA only dopamine is increased in brain [7,10]. Furthermore, 25 mg/kg of DOPA induced neither an increase of wins nor alterations in brain DA and NE (Figs. 2 and 3). Therefore, if catecholamines are playing a role in this effect of DOPA, dopamine seems to be a more likely candidate. A decrease in brain 5–HT concentrations follows the administration of l–DOPA [7]. This decrease alone could not account for our results as the behavior of PCPA-treated rats was not altered in our test situation (Fig. 1). It can not be ruled out, however, that both a decrease of 5–HT and an increase of dopamine, could interfere with the competitive behavior of the rats. In this respect, it has been described that aggressiveness appeared in mice simultaneously treated with PCPA and DOPA [17]. DOPA induces several behavioral alterations, such as catatonic-like state [34], fighting and vocalization classified as rage [23,34], bizarre social behavior [14] and changes in avoidance response [7,27]. Although it is difficult to correlate these effects with our results, it is open to discussion whether the described DOPA induced rage could not be a determinant of winning behavior. However, we did not observe rage in our rats, supporting previous reports [23] that for a clear manifestation of rage it is required a MAO inhibitor treatment plus DOPA. It could be that, although not apparent, treated animals were more "likely to fight" than their partners, and that this "disposition" was disclosed in the competition situation. In this respect it was recently shown that although 40 mg/kg of DOPA failed to elicit aggressive behavior, it was able to potentiate the aggressiveness induced by marihuana in starved rats [22].

The hypothesis of an eventual involvement of dopamine in the observed increase of winning behavior of rats competing in the straight runway, is strengthened by our previous results [31], showing that apomorphine and amphetamine greatly increased the frequency of victories. Thus, doses of 0.75 and 1.0 mg/kg of apomorphine and 1.0 to 2.0 mg/kg of amphetamine induced winning in near 90 percent of the animals. As it is known, these drugs act through stimulation of DA receptors and release of DA and NE from storage sites, respectively [9, 12, 26]. The results obtained with FLA–63 (Fig. 5) are difficult to understand. This compound did not affect DA concentration in brain and depressed NE levels to 15 percent of control values. On the other hand, FLA–63-treated rats won near 90 percent of the competitive trials. This increase in winning could tentatively be explained on the basis of the findings of Svensson and Waldeck [30]. These authors have found that 1 hr after FLA–63 treatment there was a 100 percent enhancement in the formation of ^{3}H-DA from ^{3}H-Tyrosine.

However, the results obtained with AMT and DMT pretreated animals are not in agreement with our previous data. For example, animals treated with 150 mg/kg of AMT won the competitive trials within chance level (53 percent) in spite of the marked decrease in the DA and NE contents in brain (Fig. 5). The runway competitive situation is not the only experimental behavioral model unaccessible to modifications by treatment with AMT. Thus, the drug did not alter shock-induced fighting between rats, an effect clearly obtained with 6-hydroxydopamine [32]. It is also pertinent in this respect that animals with brain catecholamines extensively depleted several days after treatment with 6-hydroxydopamine are not easily distinguishable from normal ones if left undisturbed [4,8], have locomotor activity comparable to that of control rats [6,33], and maintain normal rates of self-stimulation [16]. This could indicate that although DA and/or NE may be important in mediating some types of behavior, its role is more easily observable through an increase of its brain concentration rather than a decrease, which could explain our failure to alter the competitive behavior with AMT.

In conclusion, our results suggest that brain dopamine but not serotonin is involved in the competitive behavior of rats, as measured by the runway method.

REFERENCES

1. Aghajanian, G. K. and I. M. Asher. Histochemical fluorescence of raphe neurons: selective enhancement by tryptophan. *Science* **172:** 1159–1161, 1971.
2. Anton, A. H. and D. F. Sayre. A study of the factors affecting the aluminum oxide trihydroxyindole procedure for the analysis of catecholamines. *J. Pharmac. exp. Ther.* **138:** 360–375, 1962.
3. Anton, A. H. and D. F. Sayre. The distribution of dopamine and DOPA in various animals and a method for their determination in diverse biological material. *J. Pharmac. exp. Ther.* **145:** 326–336, 1964.
4. Barnes, L., F. Cann, A. G. Karczmar, G. Kindel and V. C. Longo. Effects of l-dopa on behavior and on brain amines in mice treated with 6-hydroxydopamine. *Pharmac. Biochem. Behav.* **1:** 35–40, 1973.
5. Bogdanski, D. F., A. Pletscher, B. B. Brodie and S. Udenfriend. Identification and assay of serotonin in brain. *J. Pharmac. exp. Ther.* **117:** 82–88, 1956.
6. Burkard, W. P., M. Jalfre and J. Blum. Effects of 6-hydroxydopamine on behaviour and cerebral amine content in rats. *Experientia* **25:** 1295–1296, 1969.
7. Butcher, L. L. and J. Engel. Behavioral and biochemical effects of l-DOPA after peripheral decarboxylase inhibition. *Brain Res.* **15:** 233–242, 1969.
8. Coscina, D. V., J. Seggie, D. D. Godse and H. C. Stancer. Induction of rage in rats by central injection of 6-hydroxydopamine. *Pharmac. Biochem. Behav.* **1:** 1–6, 1973.
9. Ernst, A. M. Mode of action of apormorphine and dexamphetamine on gnawing compulsion in rat. *Psychopharmacologia (Berl.)* **10:** 316–323, 1967.
10. Everett, G. M. and J. W. Borcherding. l–Dopa: effect on concentrations of dopamine, norepinephrine, and serotonin in brains of mice. *Science* **168:** 849–850, 1970.
11. Hanson, L. C. F. Biochemical and behavioural effects of tyrosine hydroxylase inhibition. *Psychopharmacologia (Berl.)* **11:** 8–17, 1967.

12. Hanson, L. C. F. Evidence that the central action of (+)-amphetamine is mediated via catecholamines. *Psychopharmacologia (Berl.)* **10:** 289–297, 1967.
13. Koe, B. K. and A. Weissman. p-chlorophenylalanine: A specific depletor of brain serotonin. *J. Pharmac. exp. Ther.* **154:** 499–516, 1966.
14. Lammers, A. J. J. C. and J. M. Van Rossum. Bizzare social behaviour in rats induced by a combination of a peripheral decarboxylase inhibitor and dopa. *Eur. J. Pharmac.* **5:** 103–106, 1968.
15. Lindzey, G., H. Winston and M. Manosevitz. Social dominance in inbred mouse strains. *Nature* **191:** 474–476, 1961.
16. Lippa, A. S., S. M. Antelman, A. E. Fisher and D. R. Canfield. Neurochemical mediation of reward: a significant role for dopamine? *Pharmac. Biochem. Behav.* **1:** 23–28, 1973.
17. Lycke, E., K. Modigh and B. E. Roos. Aggression in mice associated with changes in the monoamine metabolism of the brain. *Experientia* **25:** 951–953, 1969.
18. Masur, J., I. G. Karniol and J. Palermo. *Cannabis sativa* induces winning behaviour in previous loser rats. *J. Pharm. Pharmac.* **24:** 262, 1972.
19. Masur, J., R. M. W. Martz, D. Bieniek and F. Korte. Influence of (–) Δ^9-*trans*-tetrahydrocannabinol and mescaline on the behavior of rats submitted to food competition situations. *Psychopharmacologia (Berl.)* **22:** 187–194, 1971.
20. Moir, A. T. B. and D. Eccleston. The effects of precursor loading in the cerebral metabolism of 5-hydroxyindoles. *J. Neurochem.* **15:** 1093–1108, 1968.
21. Nagatsu, T., M. Levitt and S. Udenfriend. Tyrosine hydroxilase - The initial step in norepinephrine biosynthesis. *J. biol. Chem.* **239:** 2910–2917, 1964.
22. Palermo, J. and E. A. Carlini. Aggressive behaviour elicited in rats by *Cannabis sativa*: effects of p-chlorophenylalanine and DOPA. *Eur. J. Pharmacol.* **17:** 215–220, 1972.
23. Randrup, A. and I. Munkvad. Dopa and other naturally occuring substances as causes of stereotypy and rage in rats. *Acta psychiat. neurol. scand.* **42:** 193–199, 1966.
24. Rech, R. H., H. K. Borys, and K. E. Moore. Alteration in behavior and brain catecholamine levels in rats treated with α-methyl-tyrosine. *J. Pharmac. exp. Ther.* **153:** 412–419, 1966.
25. Redmond, Jr. D. E., J. W. A. A. Kling and C. V. G. H. Dekirmenjian. Social behavior of monkeys selectively depleted of monoamines. *Science* **174:** 428–430, 1971.
26. Scheel-Krüger, J. Some aspects of the mechanism of action of various stimulant amphetamine analogues. *Psychiat. Neurol. Neurochir. (Amst.)* **75:** 179–192, 1972.
27. Seiden, L. S. and T. W. Martin. Potentiation of effects of l-dopa on conditioned avoidance behavior by inhibition of extracerebral dopa decarboxylase. *Physiol. Behav.* **6:** 453–458, 1971.
28. Shillito, E. E. The effect of *para*-chlorophenylalanine on social interaction of male rats. *Br. J. Pharmac.* **38:** 305–315, 1970.
29. Siegel, S. *Nonparametric statistics for the behavioral sciences.* New York: McGraw-Hill, 1956.
30. Svenson, T. H. and B. Waldeck. On the significance of central noradrenaline for motor activity: experiments with a new dopamine β-hydroxylase inhibitor. *Eur. J. Pharmac.* **7:** 278–282, 1969.
31. Terada, C. W. and J. Masur. Amphetamine and apomorphine alter the behavior of rats submitted to a competitive situation in a straight runway. *Eur. J. Pharmac.* (in press).
32. Thoa, N. B., B. Eichelman and K. Y. NG Larry. Shock-induced aggression: effects of 6-hydroxydopamine and other pharmacological agents. *Brain Res.* **43:** 467–475, 1971.
33. Uretsky, N. J. and R. I. Schoenfeld. Effect of l-Dopa on the locomotor activity of rats pretreated with 6-hydroxydopamine. *Nature New Biology* **234:** 157–159, 1971.
34. Wende, C. V. and M. T. Spoerlein. Psychotic symptoms induced in mice by the intravenous administration of solutions of 3,4-dihydroxyphenylalanine (Dopa). *Arch. Int. Pharmacodyn.* **137:** 145–154, 1962.
35. Work, M. S., N. Grossen and H. Rogers. Role of habit and androgen level in food-seeking dominance among rats. *J. comp. physiol. Psychol.* **69:** 601–607, 1969.