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Non-linear effects in the retention of an avoidance task induced by anabolic steroids

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Abstract

The results of the study reported in Brain Research in 1995 by Isaacson et al. [Isaacson, R.L., Varner, J.A., Baars, J.-M., de Wied, D., 1995. The effects of pregnenolone sulfate and ethylestrenol on retention of a passive avoidance task. Brain Res. 689, 79–84] have been re-examined with special emphasis placed on the distributions of latencies found in the passive avoidance task using rats. This study used two retention tests, one 24 h after training the other at 48 h after training. In the first experiment in that study a range of doses of two anabolic steroids, pregnenolone sulfate and ethylestrenol, were given s.c. just after the footshock training trial. In experiment 2 a similar range of doses of both steroids was given to the rats 1 h before the first retention test. Placing emphasis on the distributions rather than measures of central tendencies revealed that, in contrast to the vehicle treated animals, the anabolic steroid treated animals exhibited bimodal distributions of response latencies. These differences between control and hormone treated animals were observed in both experiments. The new information was interpreted in terms of non-linear dynamics including some aspects of Chaos theory.

Keywords: Anabolic steroid; Pregnenolone sulfate; Ethylestrenol; Passive avoidance behavior; Memory; Non-linear dynamics; Chaos theory; Attractor

1. Introduction

On this celebration of David de Wied's 75th year of life, I will discuss the implications of some data from a project on which he and I, and some others, collaborated a few years ago (Isaacson et al., 1995). The experimental paradigm was that of simple passive avoidance. Our data were reported using traditional statistical summarizations and analyses for "significance". However, traditional methods suffer from the use of measures of central tendencies and the assumption that the nature of the distributions found is similar for all groups. The traditional methods often do not describe the real effects of the experimental manipulations.

As I recall, I gave a short presentation of a re-analysis of this data a year or two ago at this institution. I remember receiving a letter from Dr. de Wied afterwards asking me about some of the methods I used in analyzing the data. The fact that he asked these questions indicated he had listened intently to what I had to say. His questions were certainly appropriate. The lesson is that scientists should put as much effort into listening as talking. Furthermore, if Dr. de Wied had not used as many dose levels of the two hormones as he did or undertake the second experiment in which the hormones were given before retention testing then there would not have been sufficient data for an in depth analysis. However, these are the things we expect from a great scientist.

1.1. What to expect

In this paper I am returning to the data in the 1995 report and will offer a modified, new interpretation of the results from this experiment that would not die — at least from my memory and from my thoughts. The data from these experiments require the use of non-traditional ways of analysis and understanding. Examinations of the data do not justify the use of standard assumptions made in parametric methodologies; in particular, there are no linear or monotonic progressions or appropriate distributions.

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2. The 1995 experiment

The experiment under consideration was one published by Isaacson et al. in *Brain Research* in 1995. The experiment was a classic one-trial passive avoidance task. The animals were first given experience with the apparatus on one day, which was followed by a day in which they were allowed to move from an illuminated platform to a smaller dark compartment for three trials. On the fourth trial the animals received a 2-s footshock when they moved into the dark compartment. Separate groups of animals received high or low footshock. Retention trials were given 24 and 48 h later. On all retention tests the animals were allowed a maximum of 300 s to enter the dark enclosure. In Experiment 1 the rats were given vehicle injections or anabolic steroid injections after their punished response on the fourth trial of the second day. In the second experiment injections of the hormones were given 1 h before the 24-h retention test. A second day of retention testing was given 48 h after training.

It should be emphasized that any effects found must be due to effects on recall/retention mechanisms and not to effects on the learning experience per se, since the animals were not under any treatment at the time of the informative shock trial. From the published report, it might seem likely that the effects of the treatments represent effects on memory consolidation. However, considering the results from Experiment 2, this is not a likely explanation for observed effects.

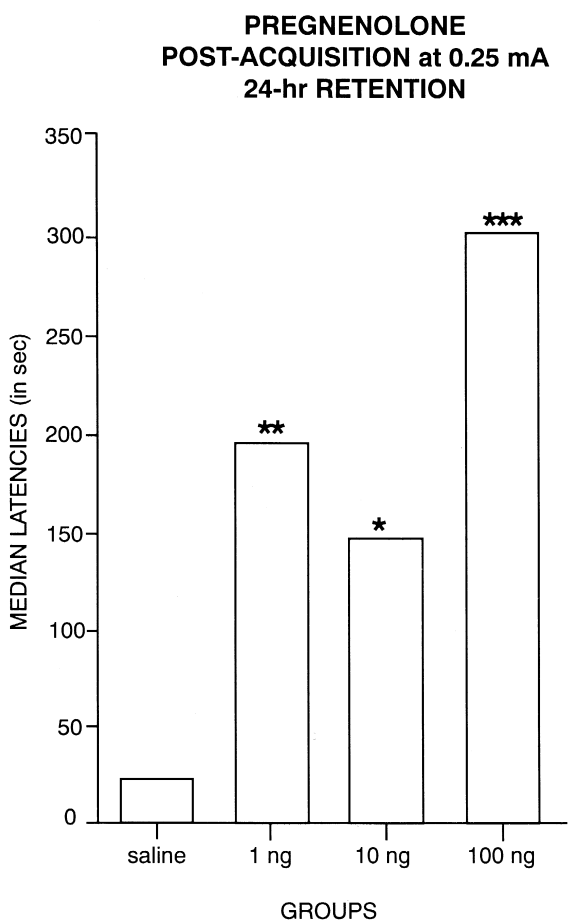

Fig. 1. Median latencies of vehicle and pregnenolone treated rats on the 24-h retention test. Low footshock used in training. Data shown in all tables from Isaacson et al. (1995).

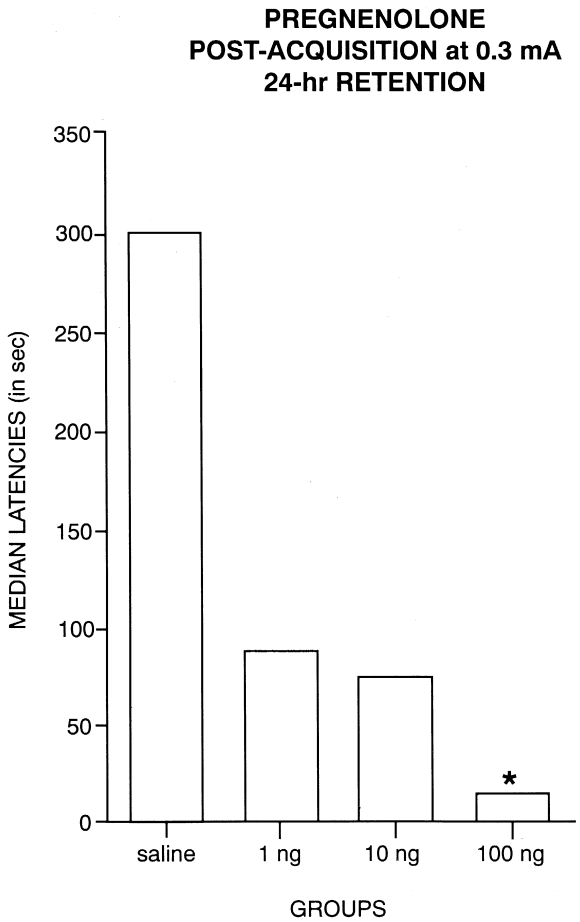

Fig. 2. Median latencies of vehicle and pregnenolone treated rats on the 24-h retention test. High footshock used in training.

3. The effects of hormone administration

3.1. The steroids used

Two steroids were used: pregnenolone sulfate and ethylestrenol (α-pregn-*n*-4-en-17-ol). In the first experiment each group received one of three doses (1, 10, or 100 ng) of the hormones. In the second experiment five doses of pregnenolone were used (0.1, 1, 10, 100, 1000 ng) and either six doses (in the low footshock group) or five doses (high footshock group) of ethylestrenol. Sixteen groups of animals were tested with the size of the groups ranging from 9 to14 animals in Experiment 1 and from 12–18 animals in Experiment 2. There were large ranges of

latency data found in all groups except the high shock, vehicle treated group. The large variance in response latencies was an important reason for re-examining the results. All the animals in both experiments received the same "informative" shock trial. It is important to remember all treatments were after this trial. All of the animals received the same information. Judging from the saline control animals in the low footshock condition, it might be concluded that the animals in the low foot shock condition learned very little. At least they evidenced little learning in the 24- or 48-h tests. The results from traditional methods of analyzing the data from the vehicle and pregnenolone treated animals in the 24-h retention tests is shown in Figs. 1 and 2 for the low and high footshock conditions, respectively. The data from the ethylestrenol and the ethylestrenol-vehicle groups are very similar to those presented in these figures and are not presented here.

3.2. Consideration of the distribution of response latencies

Essentially the vehicle treated animals exhibited unimodal distributions in both the low and high footshock conditions — although response times were at different ends of the time period. However, quite a different distribution was found in the animals given any dose of pregnenolone. To illustrate these differences Figs. 3 and 4 show the percentages of animals in the vehicle groups and from each of the two anabolic steroid groups. Animals from all the dose groups have been combined in these figures. In both high and low footshock conditions a bimodality of response latencies can be seen.

Our original conclusion from the 24-h retention test was that the administration of either of the anabolic steroids to the low shock level animals, at all doses, produced enhancement of retention relative to the vehicle injected controls. On the second retention test the distributions of all of the groups were very similar to those observed at 24 h. There was a tendency, however, for a greater number of intermediate latencies in the 10 and 100 ng dose animals in the 48 h test than in the 24 h test.

3.3. The analysis of latencies in blocks of 100 s

To analyze this further, all the data were blocked into three 100-s periods (0–100, 101–200, and 201–300 s).

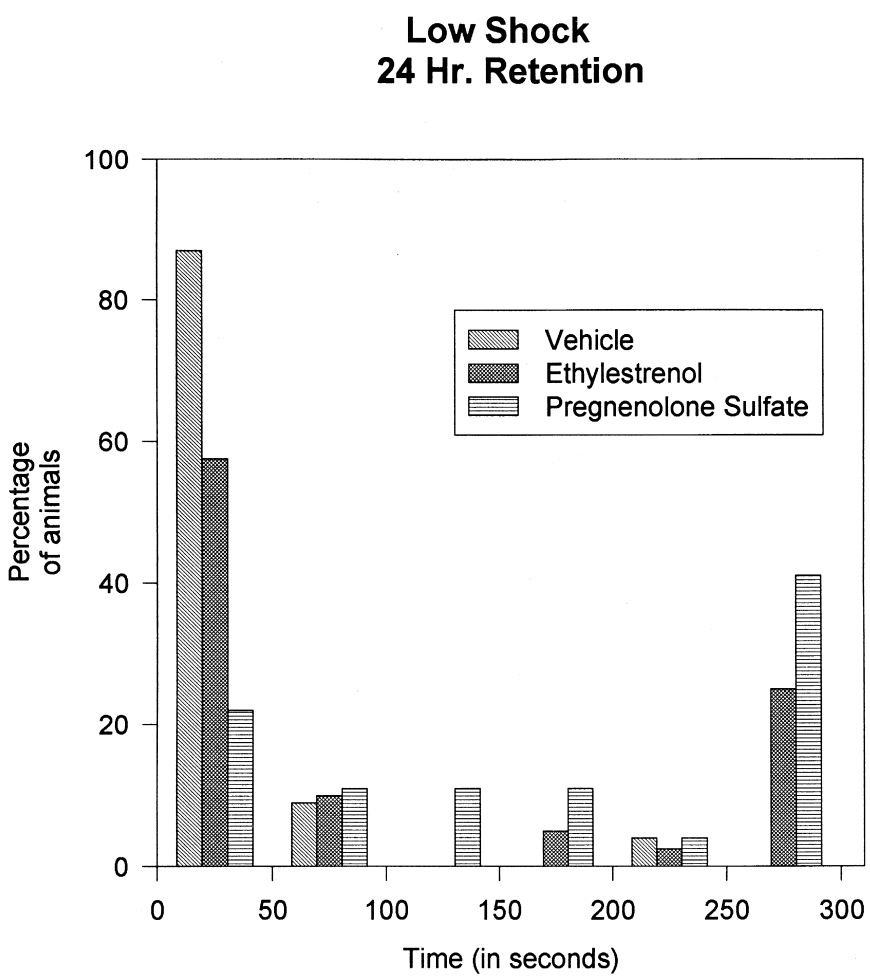

Fig. 3. Percentage of animals in vehicle, ethylestrenol, and pregnenolone groups (all doses combined) that fall into 50-s time periods of the 300 s allowed in the retention period. Low footshock used in training.

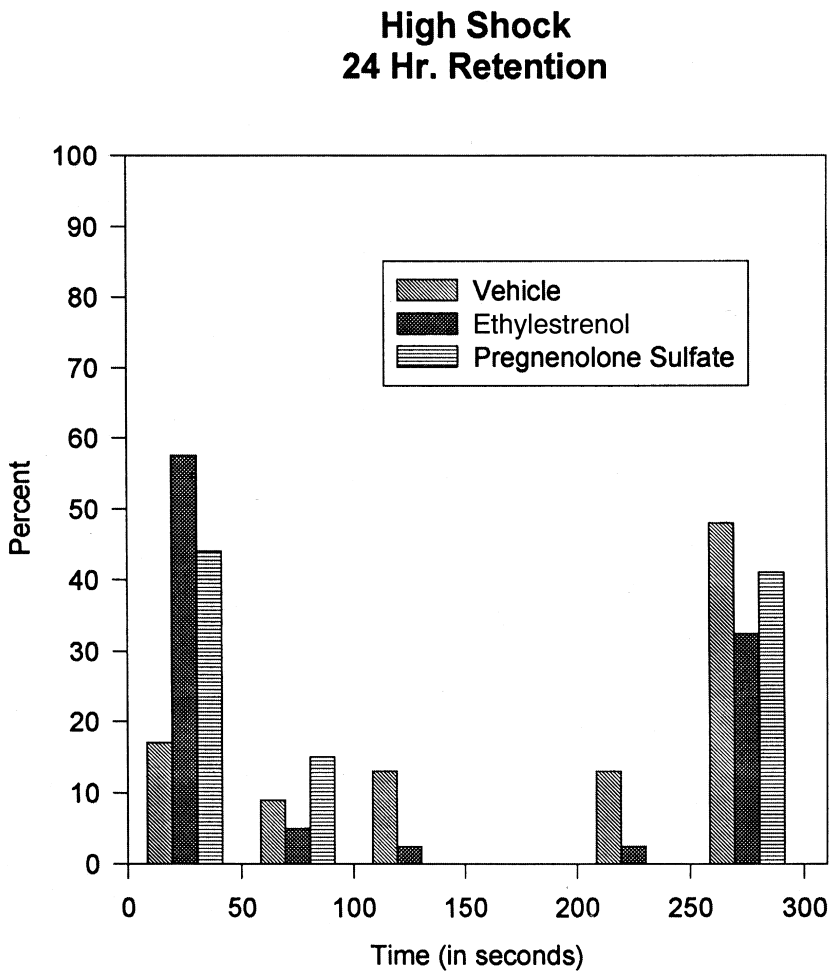

Fig. 4. The same presentation of data as described in Fig. 3 except that high footshock was used in training.

The selection of 100-s latency blocks was arbitrary but was a reasonable approach given the unusual distributions. In the present case these divisions resulted in groups of numbers that are numerically close to each other, in an absolute sense, and in relative close proximity in the obtained distributions. Names were given to the three blocks of latencies: Excellent memory (E) for the footshock (latencies > 201 s), intermediate (I) quality of retention (101–200 s), and poor (P) retention (< 100 s). Table 1A presents the percent of animals in each group that fall into these categories in the 24-h test and Table 1B presents the data from the same groups of animals in the 48-h test.

Under the low footshock condition the vehicle administration group had a unimodal distribution with short latencies. Normally this would indicate little or no learning of the avoidance task. It could be that the aversive effects of the low intensity footshock were so low as to fail to induce learning in the rats. In an alternate view an association between the dark location and footshock may have been learned but the aversiveness of the anticipated shock was so low that the aggravation of being in the light outweighed the penalty of movement into the dark. Rats receiving the low dose of the anabolic steroid after training with the low footshock exhibited an unexpected bimodal distribution. About 40% of the animals exhibited short latency response but another 40% exhibited long latency

Table 1
Percent of animals in vehicle (V), 1, 10, and 100 ng pregnenolone dose groups given just after the training trial. The animals received the low footshock. They were tested 24 h (see A) and 48 h (see B) after footshock. Retention categories: E = Excellent (201–300 s), I = Intermediate (101–200 s), P = Poor (< 100 s)

	E	I	P
(A)			
V	11	0	89
1 ng	44.5	11	44.5
10 ng	33	22	45
100 ng	55	34	11
(B)			
V	22	0	78
1 ng	33	0	67
10 ng	44	22	34
100 ng	55	22	22

responses, the indicator of learning and retention of the dark-pain association. Twenty percent of the animals had latencies in between short and long latencies. These results might be expected if, in the vehicle treated animals, behavior was organized around a behavioral goal, a single theme, a single attractor, it is apparent that the point P (a type of behavior?) moves about one of two cores and makes abrupt changes between the cores.

4. A note on "attractors"

Over the past 20 years or so, the use of the terms "attractor" and "strange attractor" have come into ever-greater use because of the increasing interest in Chaos theory. The term "attractor" is used to represent the state of a system over a reasonably long period of time (excluding transients). The system portrayed may be in a steady state. If so it can be represented by a single point in an *n*-dimensional space. More formally, an attractor is the set on which the point P, the system of interest, is moving (or not) over a rather long period of time (Ruelle, 1991). An attractor representing a system with periodic oscillations can be described by a complex loop. The usual mammalian circadian rhythms would be an example of such an oscillating system. Attractors are used to describe systems that are not dependent on the initial state from whence the system begins. Such are common and are not at all strange.

"Strange attractors" differ from common attractors in that smooth lines, curves, or surfaces cannot represent them. They are more "fractal". They are also sensitive to the initial states from which they start.

One of the most famous strange attractors is that illustrated in Fig. 5. It was created by Ed Lorenz to display the convection patterns of air currents arising and returning to earth as it warms and cools. While considering the beautiful pathways followed by point P in the Lorenz attractor, it will be useful to perform an imaginary experiment. Imagine that the image has a fine grid placed over it. Think of the vertical lines of the grid intersecting the curves of the attractor and count each contact made by every vertical line. Starting at the left side of the attractor the first line to touch the attractor will be small, probably a 1 or 2, depending on whether it touches the extreme edge of the outer curve or is a little to the right of the edge. However, as the vertical lines are counted left to right the number of contacts will quickly increase for each vertical line as the core of the left attractor is reached. Then, the count will decline until it reaches an internal minimum where the pathways occur between the two sets of curves. Progressing further to the right, the count per line will increase again approaching the right core. Passing the core the counts will decline until the edge is reach. Putting the counts for the vertical lines into a graph would produce a bimodal distribution. Each mode would be similar to the common bell-shaped curve. This may be important since the anabolic steroids induced so many bimodal distributions. The creation of attractors like those of Lorenz could account for these results.

5. Results and relationships to attractors

In the vehicle group every animal's latency can be considered to be a sample from a single distribution, an

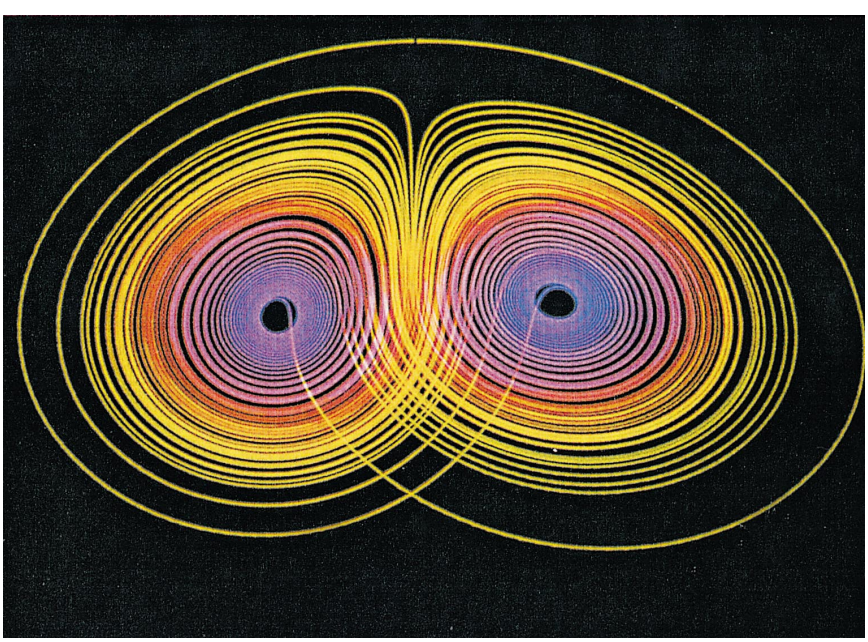

Fig. 5. A colorful representation of a Lorenz strange attractor (adapted from Gleick, 1987).

Table 2
Percent of animals in vehicle (V), 1, 10, and 100 ng pregnenolone dose groups given just after the training trial. The animals received the high footshock. They were tested 24 h (see A) and 48 h (see B) after footshock. Retention categories are described in Table 1

	E	I	P
(A)			
V	89	11	0
1 ng	44	0	55
10 ng	44	0	55
100 ng	33	0	66
(B)			
V	78	22	0
1 ng	44	0	55
10 ng	55	22	22
100 ng	33	0	67

attractor, centered near the short latency times. In the 1-ng dose group two widely separated distributions are prominent. On a population basis the probability is about 0.5 that an animal would respond from one of the two distributions. From Table 1 it appears that with the 10 and 100 ng doses intermediate response times can be observed. This could be thought of as indicating a chaotic, non-systematic, random distribution. It might suggest that other attractors are being accessed. From the summary presented in Table 1 it is apparent that similar patterns of latencies are found on both testing days. These distributions cannot be due to the chance selection of an unusual set of subjects since the same distribution changes are found in the animals treated with the same large range of ethylestrenol doses (not shown). In addition the presence of the hormone in the blood of the animals is not essential to the effects observed. By 48 h after injection, the hormone must have cleared the body and the effects observed must be due to some persistent alteration in the animals. It would be of great interest to know just how persistent the effects of the different doses of these steroids would be.

Considering the effects of the hormones on animals trained under high footshock conditions, the vehicle treated animals again show a unimodal distribution in the 24 h and 48 h tests (an attractor). *All* of the pregnenolone treated animals had clear bimodal distributions as shown in Table 2 (a strange attractor). The data in Table 2A show that the same pattern as Table 2B, the 48-h retention test.

Figs. 6 and 7 present the individual data of all pregnenolone animals in the 24-h retention tests as well as indicating the median values by the superimposed small

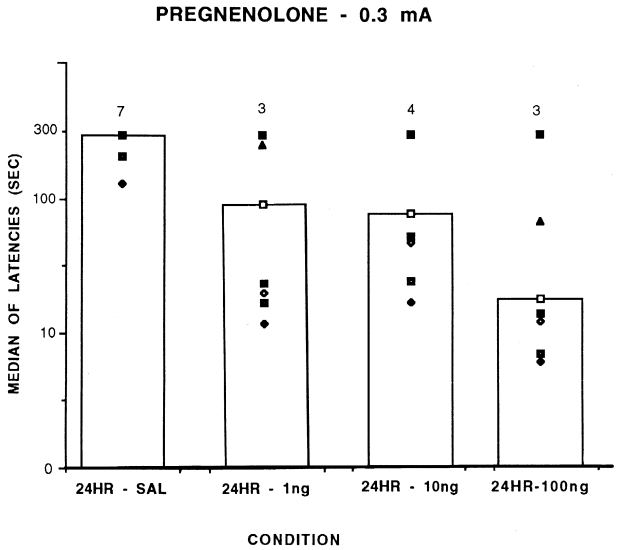

Fig. 7. Median latencies indicated by the tops of histograms for the saline and pregnenolone groups tested 24 h after training with high footshock. Individual rats indicated by small icons. Note *Y*-axis is logarithmic.

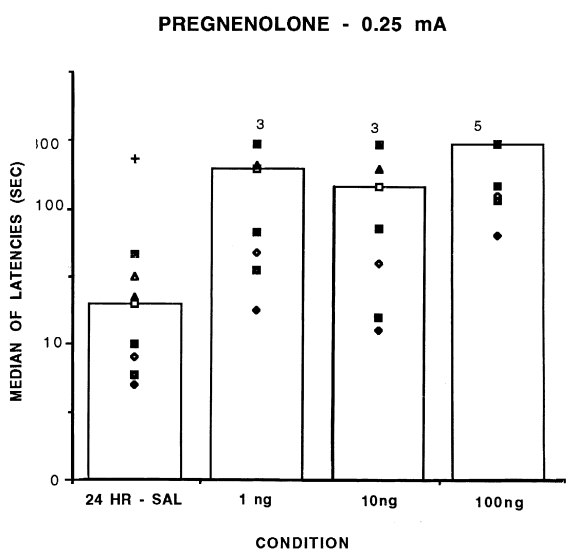

Fig. 6. Median latencies indicated by the tops of histograms for the saline and pregnenolone groups tested 24 h after training with low footshock. Individual rats indicated by small icons. Note *Y*-axis is logarithmic.

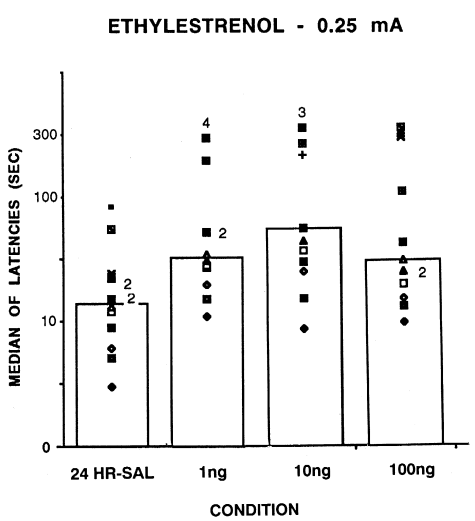

Fig. 8. Median latencies of groups of animal treated with saline or ethylestrenol 24 h after training using low footshock. Data as presented in Fig. 6.

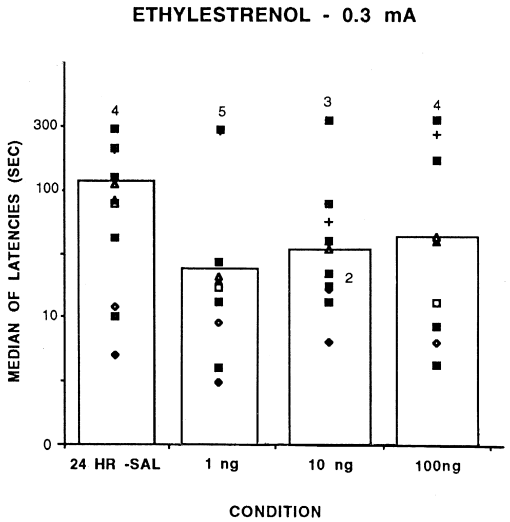

Fig. 9. Median latencies of groups of animals treated with saline or ethylestrenol 24 h after training using high footshock. Data as presented in Fig. 7.

Table 3
Percent of animals in vehicle (V), 0.1, 1, 10, 100, and 1000 ng pregnenolone dose groups administered 1 h before the 24 h retention tests. The animals received the low footshock. Data is reported for the 24-h retention test (see A) and the 48-h retention test (see B). Retention categories are described in Table 1

	E	I	P
(A)			
V	8	8	84
0.1 ng	40	0	60
1 ng	8	8	84
10 ng	56	0	44
100 ng	24	16	60
1000 ng	24	8	68
(B)			
V	8	8	89
0.1 ng	40	8	52
1 ng	8	0	92
10 ng	32	16	52
100 ng	16	8	76
1000 ng	24	0	76

icons. A similar presentation of the ethylestrenol treated rats is presented in Figs. 8 and 9. The logarithmic *Y*-axis scale should be noted. Using a un-transformed scale would have made the bipolar distributions far more dramatic.

What can be said about the effect of the administration of the small amounts of anabolic steroids given to the animals? It is certainly not fair to say that retention is enhanced by post-learning administration of the hormones even in the low footshock condition. Nor is it correct to say that memory is impaired by the hormone-treatment in the high footshock condition. What is the meaning of bimodal or multimodal distributions?

6. The effects of steroids given just before retention testing

The data obtained in the second experiment of the 1995 report were also re-analyzed in the hope of finding further information about the behavioral changes noted in the post-learning steroid administration. In experiment 2 the hormones were given 1 h before the 24-h retention test. A second retention test was given 24 h later — 48 h after the training trial.

Under the low shock training procedures, animals given the vehicle before the retention test produced unimodal distributions. Most of these animals rapidly entered the dark compartment (Table 3). Rats receiving either pregnenolone or ethylestrenol exhibited bimodal distributions although they gave more "poor" than "excellent" performances. The pregnenolone treated rats, however, tended to have more intermediate latencies. Since extra handling and the stress of injection occurred 1 h before the 1st retention test, the 24-h test was imposed on animals in a different physiological state than animals in the first experiment. This may account for the lack of a clear unimodal distribution in the vehicle treated animals given high footshocks in training (Table 4). This was the case for the separate vehicle treated groups used in both the pregnenolone and the ethylestrenol experiments. The combination of high footshock in training and the steroids could have produced "transients" in behavior.

Surprisingly, for animals receiving high levels of footshock during training in Experiment 2, almost every group evidenced a bimodal distribution with no great differences between the vehicle treated and the hormone treated animals (compare Tables 5 and 6). An exception to this

Table 4
Percent of animals in vehicle (V), 0.1, 1, 10, 100, and 1000 ng pregnenolone dose groups administered 1 h before the 24 h retention test. The animals received the high footshock. Data is reported for the 24-h retention test (see A) and the 48-h retention test (see B). Retention categories are described in Table 1

	E	I	P
(A)			
V	50	16	34
0.1 ng	50	8	42
1 ng	50	0	50
10 ng	24	8	68
100 ng	40	16	44
1000 ng	67	0	33
(B)			
V	32	16	52
0.1 ng	48	16	32
1 ng	24	8	68
10 ng	40	8	52
100 ng	40	16	40
1000 ng	50	0	50

Table 5
Percent of animals in vehicle (V), 1, 10, and 100 ng ethylestrenol dose groups administered 1 h before the 24 h retention test. The animals received the low footshock. Data reported for the 24-h retention test (see A) and the 48-h retention test (see B). Retention categories are described in Table 1

	E	I	P
(A)			
V	0	0	100
1 ng	21	7	63
10 ng	24	16	64
100 ng	8	16	76
(B)			
V	0	7	93
1 ng	35	0	65
10 ng	40	0	60
100 ng	16	16	68

Table 7
From Experiment 1: The percentages of animals in all group subjects, regardless of footshock level during training, with response latencies greater than 201 sec (excellent retention). PREG = pregnenolone treated groups; ETHYL-E = ethylestrenol treated groups. Latencies of the vehicle treated animals (V) given low (left) or high (right) on the line beneath hormone designation

	PREG	ETHYL-E
Percent of vehicle treatment groups in E range		
Low Shock	11	0
High Shock	89	42
Percent of all hormone treated groups in E range		
	55	46
	45	46
	44	38
	44	36
	33	35
	33	30

occurred in the rats given the highest dose of pregnenolone. These animals had a clear bimodal distribution.

7. General considerations and assumptions

7.1. The benefits of using attractor concepts

While the point might be argued, I will assume that all animals acquired the same information on the training trial. Second, I would propose that every animal has within it propensities to run into the dark chamber and to stay on the lighted platform. These "propensities" can be thought of as "attractors" as was mentioned previously. The use of "attractor" is useful because it carries little linguistic "extra baggage" and can be used to include both mental and behavioral organization toward a particular end. However, when the steroids are given the data seem to indicate that the choice of which attractor demonstrated by a particular animal does *not* reflect an optimal choice or perhaps a choice at all. Under the high shock conditions of experiment 1, the steroid animals' bimodality of latency distributions is not the wisest solution to the problem.

Table 6
Percent of animals in vehicle (V), 1 ng, 10 ng, and 100 ng ethylestrenol dose groups administered 1 h before the 24 h retention test. The animals received the high footshock. Data reported for the 24 h retention test (see A) and the 48 h retention test (see B). Retention categories are described in Table 1

	E	I	P
A			
V	42	14	42
1 ng	42	0	58
10 ng	21	0	79
100 ng	40	16	44
B			
V	56	7	35
1 ng	21	21	58
10 ng	8	16	76
100 ng	56	0	44

7.2. A curious result

Table 7 shows the percent of "excellent" retention scores (>201 s) of animals given either pregnenolone or ethylestrenol and given high and low footshock levels in Experiment 1. The percent of vehicle treated groups in the E category is shown in the subheading for each steroid group. These percentages are quite similar and there are no distinctions between the high and low footshock treatments. The number of steroid treated rats with long (or short) latencies remains the same regardless of the level of footshock received. Considering the similarity of the percent of E scores the high and low footshock groups, it appears that the strength of the footshock is immaterial to the latency of response during retention testing.

7.3. Persistence of performance

Examination of 24-h and 48-h retention test scores indicates that over 80% of the animals in the high and low footshock groups given saline or a steroid were in the same latency categories on both tests. The changes that most frequently occurred were those from a longer latency category to a shorter one.

8. More about attractors

The ways in which attractors are expressed depends on the nature of the machine, system, or organism involved. It is also the case that some systems, biological or not, cannot exhibit non-linear behaviors. Thus, the nature of

attractors depends on both the structure of the system and on the opportunities offered by the environment.

8.1. A mechanical example

A "water wheel" is often used to demonstrate the development of non-linear behavior (e.g., Gleick, 1987). In this paradigm, water is sprayed on the blades or paddles of a vertically mounted wheel. The waterwheel turns in a clock-wise direction when water flows slowly onto the wheel but as the flow increases it will at some time slow down and start turning in the opposite direction. This will occur when the blades of the water wheel have buckets attached to them that hold water until, on the down cycle of the wheel the buckets dump out their contents. The reversal of direction occurs when the speed is so great that the buckets cannot empty themselves on the down cycle and carry some of their contents up the up side of the route. If the speed is so great that a great deal is retained in the buckets, the spin of the wheel goes in a backward direction. Thus, by adjusting the rate of flow of water, two directions of turning can produced in the wheel. This is a non-linear, non-monotonic result from a linear increase in water flow. It is obvious that in order to have this kind of result the paddles of the water wheel must have buckets — just plain paddles do not work. The general point is that systems must have the components that allow for the non-linear effects to express themselves.

8.2. Biological examples

Perhaps a more pertinent example of non-linear results as a consequence of increasing a biological parameter is that of the administration of progesterone to males (Witt et al., 1994, 1995). In this case low doses of progesterone *enhance* male sexual behavior while very large doses of the hormone result in the suppression of this behavior. The facilitation of male sexual behavior can be observed even in castrated male mammals. The effects of administration of large doses of progesterone to human males are still uncertain but given the variability found in human testosterone levels, it seems to be a dubious method of controlling the behavior of sexual deviants.

As an example of a non-linear effect over time, consider the effects of amphetamine on behavior. In rats and mice general locomotor behavior increases in a monotonic manner with increasing doses of D-amphetamine — up to a point. After a certain dose is reached, activity decreases in favor of immobility and the repeated occurrence of stereotyped responses of the head and upper body. The attractor of locomotion has been changed to the attractor of stereotypy. In people it is my understanding that larger doses of amphetamine can produce alterations in the previously dominant themes of mental activity as well as stereotypy.

About 30 years ago Lanier and Isaacson (1977) found that before puberty in the rat all doses of amphetamine, however large, only produced increases in locomotion. After puberty, low doses produce increases in activity but the high doses produce stereotypy. At the time of puberty, the drug seemed to be totally without effect (unless the animals had previously suffered hippocampal damage). At the time of puberty a dramatic change occurs in the ability to express stereotyped responding. This is undoubtedly related to the massive hormonal changes that occur during this time period. It is likely that the motor systems that produce both locomotor activity and the motor actions expressed in stereotyped behavior exist well before puberty. What must develop in the transition into adulthood is the ability to elicit or form attractors of certain kinds.

9. Other factors influencing non-linear responding

9.1. Response restrictions

Both the nature of the behavior of attractors and the sensitivity of a system that induces them are determined by the nature of the systems involved and by the opportunities for their expression. In the simple behavioral paradigms used in the 1995 experiment by de Wied, me, and others the animals had only two options: to run to the dark or to stay on the lighted platform. The administration of the anabolic steroids produced the strange attractor situation, the bimodal distributions. At least for the inter-retention test interval used, the animals tended to stay with the same attractor on both tests.

9.2. Experimental conditions

The conditions of testing and training may induce behavior representative of strange attractors. For example, consider the effects of high footshock given before the retention test in Experiment 2. This procedure produced non-linear results in the vehicle treated animals. Compare Table 3 with Table 4 and Table 5 with Table 6. The pretest injections likely produced a state conducive to the expression of the bimodality of the data but only when high footshock was given during training.

9.3. Stress, pain and frustration

The possibility that conditions of stress, pain, frustration, and hormonal disturbances can induce non-linear behaviors and the creations of strange attractors reflected in behavior may be important in understanding many aspects of human behavior. Almost everyday the media present us with instances of people exhibiting unpredictable behaviors. The ones that come to public attention are usually those most tragic if not atrocious. These can be individual acts or the acts of a number of people who seem bound to unusual belief based organizations that call for

violent attacks on others or themselves. Do such cases, conditions represent the creation of strange attractors common to a number of people? Are the strange attractors in the mathematical theories of Chaos and strange in the usual sense of the word? It may be of great importance that a large number of individuals exhibiting the unanticipated behaviors are in the prepubertal and pubertal periods that lead to adulthood.

10. Puberty and adolescence

It is possible, if not likely, that this pre-adulthood period is one of the most important for the creation of "strange attractor" based behaviors. Once a strange attractor is established it will exert its influence for an extended period of time. Since the pubertal and adolescent periods are prime times for the creation of attractors, they may affect the developmental orientation of the individual and, thereby affect the person for the rest of his or her life. Given the intensity of the changes going on in this period of life, especially those of a hormonal nature, this would not be unlikely. Coupled with anatomic alterations in pre-frontal and limbic regions of the brain during these developmental periods much of an individual's residual behaviors, thoughts, abilities and talents are produced (see Spear, 2000).

To return to the data at hand, no matter how the data are considered or the terms used, the post-training exposure to anabolic steroids induces non-linear dynamics that radically affect retention performance. These changes are not suited to traditional analyses or to easy explanation. The ideas developed about strange attractors by may be helpful in describing and perhaps even understanding some of the data collected in a variety of experiments. They may also be useful in thinking about some aspects of human behaviors that now seem beyond current explanatory powers. Many of the currently "inexplicable behaviors" of mankind threaten the very existence of life on this planet and deserve our utmost attention.

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