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THE NEED FOR POWER, BRAIN NOREPINEPHRINE TURNOVER AND LEARNING

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This experiment was designed to explore whether brain norepinephrine (NE) serves as a specific reward system for the power drive. Previous research has indicated that 3-methoxy-4-hydroxyphenyl glycol (MHPG), a urinary metabolite reflecting central NE turnover, is positively correlated with features of assertiveness which one might expect of a person high in the need for power (*n* power) or in a state of aroused power motivation. Twenty-seven male undergraduates, 13 of whom were high and 14 of whom were low in *n* power as assessed by a TAT measure, were recruited as subjects. Before and after the laboratory session, subjects voided all urine and concentrations of epinephrine, norepinephrine and MHPG were obtained from samples. The laboratory task consisted of 20 picture–word pairs in which the subject had to learn to anticipate the word associated with each picture before the word was presented. Five pairs of stimuli in each of the following picture–word combinations were presented 12 times: neutral–neutral, neutral–power, power–neutral and power–power. The results revealed that, as predicted, subjects high in *n* power learn most power-related material faster than subjects low in *n* power. The need for achievement is unrelated to the learning of any picture–word pairs. The neurochemical data indicated that subjects maintaining a relatively high MHPG excretion rate during the experiment who were also high in *n* power showed the greatest mastery of power related compared with neutral picture–word pairs. These findings are consistent with the hypothesis that brain NE turnover is specifically related to the learning of power-related responses in subjects high in *n* power.

1. Introduction

Aroused motivational states like hunger generally facilitate the learning of responses connected with satisfying the motive. Thus when McClelland et al. (1953) set out to measure individual differences in motive strength, they argued that a key method of determining whether they had succeeded in doing so was to see if those individuals who scored higher on the measure actually learned responses faster that were relevant to satisfying that motive. They began by arousing the achievement motive, determining its effects on fantasy or spontaneous thought patterns in

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written stories to pictures, and then arguing that the presence of more of these fantasy effects in some individuals, under non-aroused conditions, indicated greater strength of the achievement motive (*n* achievement) in those individuals. They validated this hypothesis by demonstrating that individuals scoring higher in *n* achievement learned moderately difficult materials faster. That is, they and others since (see Atkinson, 1958) have shown that the incentive for this motive is 'doing better' which can be most easily satisfied by learning faster when the probability of successful achievement is moderate. If the task is very easy or very difficult, working harder is unlikely to enable the person to 'do better'.

A similar approach has been followed to obtain and validate a measure of the need for power (*n* power) (See Veroff, 1957; Winter, 1973). The thought patterns in stories written after this motive is aroused involve 'having impact', usually on other people, by aggression, persuasion, or creating emotions in them. Individuals who write stories containing a lot of such thoughts under normal conditions are considered to be high in *n* power. As compared with individuals low in *n* power, young men high in *n* power get into arguments more often, collect more symbols of prestige, play more competitive sports, seek sexual conquests more often, join more organizations to enhance their power, etc. (Winter, 1973; McClelland, 1975).

However, it has never been entirely clear just how motives facilitate learning. A possible mechanism for *n* power may involve catecholamine functioning. Steele (1973) showed that arousal of power motivation through the use of taped stirring speeches increased power imagery in stories written afterwards and also increased the excretion of epinephrine (E) and norepinephrine (NE) in urine. Furthermore the amount of power imagery after power arousal correlated 0.71 and 0.66 with size of increase in excretion rates for E and NE respectively ($N = 16, p < 0.01$). He found no relationship between levels of *n* achievement in stories following achievement arousal and catecholamine excretion rates.

Animal studies have shown that brain NE may serve as a substrate for a reward system (Olds, 1977; Stein, 1975). For example rats will press a bar to receive small amounts of NE injected into the lateral ventricle (Wise et al., 1973). It seems unlikely that brain NE is the only neurotransmitter with these rewarding characteristics (Olds, 1977; Routtenberg, 1978) but brain NE may be the neurotransmitter substance which serves specifically as the substrate for *n* power. No convincing evidence for such a hypothesis exists but it is suggested by the fact that aggression (or power arousal) is associated with greater catecholamine excretion.

Since motives facilitate relevant learning, it is predicted that subjects high in *n* power will acquire power-related responses more quickly than subjects low in *n* power or high in another motive such as *n* achievement. Furthermore over the course of their acquiring power-related responses subjects high in *n* power are expected to evidence greater brain NE turnover. This hypothesized neurochemical process might provide a mechanism to explain the faster learning of power-releated responses by these subjects since brain NE might serve a rewarding or attention focussing function.

The possibility of testing such a hypothesis in humans exists because it has been demonstrated that 3-methoxy-4-hydroxyphenyl glycol (MHPG) is a urinary catecholamine metabolite that reflects central NE turnover (Schanberg, Bresse, Schildkraut et al., 1968; Rubin, Miller, Clark, Poland and Arthur, 1970; Mass, Hattox, Greene and Landis, 1979). Furthermore MHPG in urine has been linked to certain aspects of assertiveness which are similar to characteristics that one would expect from aperson high in *n* power or in a state of aroused power motivation. MHPG is lower in bipolar depressed patients who are not assertive and it is relatively higher in hypomanics who are more assertive (Schildkraut, Keeler, Papousek and Hartman, 1973). MHPG in urine also increases with the challenges to assertive control provided by having to land aircraft at night on carriers (Rubin et al., 1970). These data are consistent with findings in rats that acting assertively to avoid shock increases brain NE (Weiss, Stone and Harrell, 1970). Thus it seems possible that individuals high in *n* power will when acquiring power related responses show a higher urinary excretion of MHPG, indicating greater brain NE turnover. The present experiment was designed to test this hypothesis. Measures of urinary epinephrine and norepinephrine were also included to determine whether any relationships obtained were general to catecholamine functioning.

2. Procedure

Subjects were 27 male undergraduates whose motive scores were obtained a year previously as part of a general testing program. They had written 5-min stories to each of four pictures (ship captain, man and woman in a nightclub, two women scientists in a laboratory, man and woman in a trapeze act) which were scored for *n* power (Winter, 1973) and *n* achievement (McClelland et al., 1953) by coders whose agreement with expert scores was in the 85–90% range. Subjects were recruited for a psychophysiological experiment so that approximately half had a *T*-score of 50 or more ($N = 13$) on *n* power corrected by regression for story length, and somewhat more than half (17 out of 27) a high Activity Inhibition score (two or more instances of the word 'not' in all stories) to test a hypothesis which was part of another experiment (McClelland, Alexander, Davidson, Floor and Saron, 1979). On the first day they reported to the laboratory in order to habituate them to the situation. They filled out some questionnaires on stress as part of another experiment, were introduced to the EEG recording apparatus, and provided a urine sample to help adapt them to a procedure which tends to elevate catecholamine output on its first application (Frankenhaeuser, 1975). They then made an appointment for the actual testing session within the next 48 hours. Since it is known that certain substances influence catecholamine outputs they were given instructions not to ingest chocolate, vanilla, bananas, citrus fruits, cheese or alcohol for two days prior to the testing session. They were also instructed during the two hours before the experiment, to urinate completely, noting the time, and not to eat, smoke, exercise or drink anything except water. Subjects who forgot any of these instructions were rescheduled. All subjects were run between the hours of 4–9 p.m. in order to minimize known diurnal variations in catecholamine output (Frankenhaeuser, 1975). On arrival the subjects first voided all urine and drank a large glass of water so that urine could be collected again at the end of the $2\frac{1}{2}$ hour session. The volume of urine was measured and a sample was frozen and sent to a commercial laboratory for assay of the concentrations of epinephrine (E) and norepinephrine (NE) by the trihydroxyindole method (Euler and Lishajko, 1961).

In order to determine urine excretion rate the volume of urine excreted was divided by the minutes since the last urination. The concentration of E and NE was multiplied by the urine excretion rate to get their excretion rates. 3-methoxy-4-hydroxyphenyl-glynol (MHPG) concentrations were determined in the Neuropsychopharmacology Laboratory, Harvard Medical School, Department of Psychiatry of the Massachusetts Mental Health Center using an electron-capture gas–liquid chromatographic technique. * Urine was again collected at the end of the session and samples assayed for these same variables using the same procedure. The subjects then filled out several questionnaires and were prepared for EEG recordings as part of another study.

The learning task consisted of 20 picture–word pairs in which the subject had to learn to anticipate the word associated with each picture before it was presented. The pictures were exposed automatically by a slide projector for 250 ms followed after 2 s by a word also projected for 250 ms. Pictures and words alternated with an interstimulus interval of 2 s. On the second run through the pairs, the subject tried to say the word before it appeared which was associated with each picture. The experimenter recorded whether he succeeded or not. There were 20 pairs in the list which were exposed to the subject 12 times in random order, although most of the subjects were anticipating all the paired words correctly by the eighth trial. Pictures and words were considered power-related (P) or neutral (N) based on the proportion of subjects who in previous research had written strongly power-related stories to them (score of +3 or more in *n* power, see Winter, 1973). For the 10 pictures classified as power-related, the median per cent of stories elicited in previous research with a score of +3 or more in *n* power was 37% (range 29%–74%); for the 10 pictures classified as neutral the comparable median was 15.5% (range 8%–20%). Words were classified as power-related in terms of the ratings given them by an independent group of 24 judges who rated each word as shown in connection with its picture as to the degree to which it signified forcefulness to them on a scale of 1–7. The average forceculness rating of the 10 power-related words was 4.8 contrasted with 2.4 for the neutral words. There was a slight overlap in range: two of the power-related words were rated slightly less forceful than the two neutral words rated most forceful.

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There were five pairs representing each of the four possible combinations of types of pictures and words. A typical PP pair showed a picture of two racing cars to which the word 'break' had to be associated. An NP pair showed a young man and woman walking in the snow to which the word 'fight' had to be associated. An NN pair showed a young man and woman seated on a bench by a river to which the word 'form' had to be associated. The words were all the same length (4 or 5 letters) and very familiar (i.e. minimum frequency per million words of running text = 244; median = 1277, Carroll, Davies and Richman, 1971).

The measure chosen to reflect speed of learning was the number of correct anticipations on trials three and four combined because at this stage learning was incomplete and individual differences in speed of learning should be most apparent. Of particular interest was whether subjects high in *n* power showed greater mastery of power related picture–word pairs at this stage than subjects low in *n* power.

3. Results

Table 1 shows the mean number of correct word anticipations on trials 3 and 4 for subjects high and low in *n* power. As expected those high in *n* power tended to learn the power-related pairs faster. The difference was significant for pairs in which either the stimulus or response was power-related. The difference was not significant for the PP pairs, possibly because these were the easiest pairs for the subjects to learn, especially for those low in *n* power.

The measure of *n* achievement also obtained for the picture story test showed no relationship to speed of learning all the pairs or any combination of them.

Fig. 1 illustrates the superiority of the subjects high in *n* power over those low in *n* power at learning NP pairs, a superiority which showed up on the third learning trial, where the difference in mean number of correct anticipations was significant at $p < 0.05$, and continued through the sixth trial, where the difference in mean number of correct anticipations was still significant at $p < 0.05$.

Fig. 1 also shows, as does table 1, that there is a nonsignificant tendency for the subjects high in *n* power to learn to anticipate neutral words to neutral pictures faster than subjects low in *n* power. Thus overall the high *n* power subjects tended to learn all the responses to pictures faster than the low *n* power subjects. In order to test the brain NE turnover hypothesis more precisely, it seems desireable to subtract out any general learning advantage that the subjects high in *n* power have and obtain a purified measure of the advantage they show in learning power related pairs specifically.

This was done, as table 1 shows, by obtaining the average number of correct responses on trials 3 and 4 for the partially power-related pairs (PN + NP/2), since it was these pairs those high in *n* power learned significantly faster, and subtracting the number of correct responses to the neutral (NN) pairs. This measure (labelled power pair learning advantage or PPLA) is not very significantly larger for the high

Table 1
Mean number of correct anticipations on trials 3 and 4 for different types of picture–word pairs for subjects high and low in *n* power

Type of picture–word pairs		High *n* power * $N = 13$	Low *n* power $N = 14$	Difference	*p* difference
5 neutral picture, power word (NP),	mean	7.85	5.71	2.14	<0.05
	s.d.	1.96	2.99		
5 power picture, neutral word (PN),	mean	7.77	5.57	2.20	0.02
	s.d.	1.80	2.53		
5 power picture, power word (PP),	mean	7.69	6.79	0.90	n.s.
	s.d.	1.90	2.48		
5 neutral picture, neutral word (NN),	mean	7.77	6.50	1.27	n.s.
	s.d.	2.33	2.41		
All pairs	mean	31.08	24.57	6.51	0.06
	s.d.	7.18	9.05		
NP + PN/2 – NN	mean	0.04	0.86	0.90	0.17
	s.d.	1.43	1.70		

* *T*-Score *n* power corrected for correlation with protocol length $\geqslant 50$.

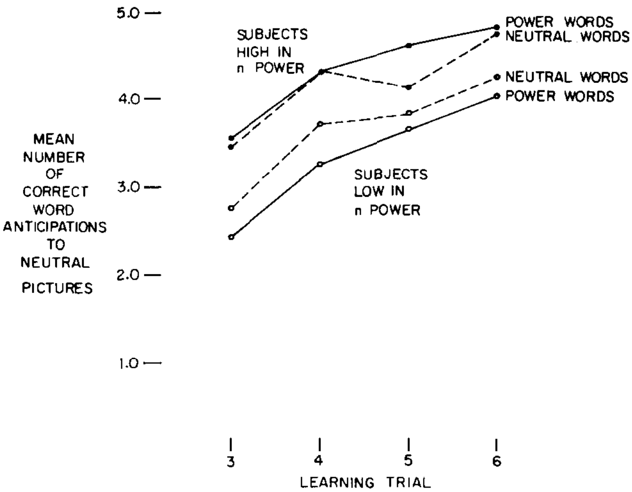

Fig. 1. Average number of correct power word anticipations to neutral pictures on successive learning trials.

over the low *n* power subjects, but if the main hypothesis is correct, it should show the most sensitive relationship to brain NE turnover.

Since the hypothesis is that brain NE turnover during the learning task should relate to power pair learning advantage in those high in *n* power, the most appropriate neurochemical measure would appear to be the level of MHPG during the experiment, as determined by subtracting the rate of MHPG excretion afterwards from the rates of MHPG excretion before. This would correct for individual differences in MHPG excretion rates having nothing to do with what happens during the experiment. In general we would expect that those showing a higher MHPG excretion rate during the experiment would show a greater power pair learning advantage, especially if they were also high in *n* power. Overall the mean MHPG excretion rate dropped from 2.10 μg/min before to 1.75 μg/min after the experiment, a decrease of –0.35 μg/min which is highly significant ($t = 2.98$, $p < 0.01$), and which may be due to the fact that the subjects were immobilized in a chair during the $2\frac{1}{2}$ hours of the experiment as contrasted with walking around for a similar time period before the experiment. A median split shows that nine subjects actually gained in MHPG excretion rate from before to after the experiment, and another five showed a drop of less than 0.50 μg/min. These were classified as showing relatively high MHPG levels during the experiment. The remaining 13 subjects who showed a drop in MHPG of more than –0.50 μg/min (median drop = –0.81 μg/min) were classified as showing low MHPG levels during the experiment.

Table 2 tests the main hypothesis and shows that it is confirmed. In the analysis of variance neither the *n* power nor MHPG change variables by themselves are sig-

Table 2
Power pair learning advantage (PPLA) * as a function of n power and MHPG excretion rate **

MHPG excretion rate change (after–before) ***	High n power $N = 13$	Low n power $N = 14$
High *** N	7	6
mean PPLA *	+0.50	−0.50
SD	1.41	1.26
Low *** N	7	7
mean PPLA *	−0.86	−0.93
SD	2.34	0.62
Analysis of variance	F	p
High vs. low n power	1.78	<0.20
High vs. low MHPG change	0.61	n.s.
Interaction	0.61	n.s.

* Average number of correct word anticipations in learning trials 3 + 4 for partially power-related pairs (PN + NP/2) minus number of correct anticipations on trials 3 + 4 for neutral pairs (NN).

** t test, high n power + high MHPG change vs. low n power + low MHPG change = 2.27, $p < 0.05$.

*** Mean MHPG excretion rate before = 2.10 μg/min; after = 1.75 μg/min; t difference = 2.98, $p < 0.01$. High after–before change = dropped less than −0.50 μg/min; low = dropped more than −0.50 μg/min.

‡ T-score n power corrected for correlation with protocol length ≥50.

nificantly related to the power pair learning advantage score, but in combination they are. Subjects high in n power who maintained relatively high MHPG levels during the experiment show a significantly greater power pair learning advantage than subjects low in both variables. In fact five out of seven of those high on both variables learned the power pairs (PN + NP) as fast as or faster than the NN pairs, as compared with only one out of seven of those low on both variables ($p < 0.05$ by Fisher's exact test).

Similar analyses were made for the other two catecholamine measures. That is, subjects were classified as high and low in NE and E excretion rates during the experiment by subtracting the excretion rates after from those before the experiment. When these rates were cross-classified with high vs. low n power as in Table 2, no significant differences appeared between those high or low on both variables. In other words, as expected, it is only the index of central catecholamine function, MHPG, that proved to be related to relatively faster learning of power-related pairs among subjects high in n power. Nor did subjects with high n achievement and high MHPG change scores show a greater power pair learning advantage or any kind of learning advantages as compared to subjects low on both variables.

4. Discussion

Subjects high in *n* power learn partially power-related materials significantly faster than subjects low in *n* power. This confirms the hypothesis that *n* power is in fact an index of individual differences in motive level. The fact that *n* achievement is unrelated to speed of learning of any groups of picture–word pairs supports the theoretical expectation that motives specifically facilitate the learning only of responses related to their satisfaction. For both theory and research findings support the hypothesis that *n* achievement promotes faster learning of responses only when its incentive of moderate risk is involved (see Atkinson, 1958).

It was also found that MHPG excretion rate during the experiment was related to faster learning of partially power-related over neutral paired associates. While *n* power is not significantly related to MHPG excretion rate, the two variables combine to give a good prediction of who will learn the partially power-related pairs faster than the neutral pairs. One way this can be understood is to assume that a motive or drive by itself does not produce a higher secretion rate of a neurotransmitter. Theoretically a motive might be considered to have to interact with relevant stimuli to release a transmitter substance. If this were so, subjects high in *n* power would have to be exposed to power stimuli according to the theory to release more brain NE to facilitate learning. To make the point clear by analogy, the hunger drive by itself might not produce an increase in a neurotransmitter but only if the organism encountered some food (relevant stimuli) which would serve to release a neurotransmitter which would facilitate responses leading to getting the food. Thus one might suppose that brain NE is a substrate for the reward system for *n* power which combines only with it (and not with *n* achievement for example) to produce faster learning of power-related pairs and not faster learning in general.

An alternative explanation for the results might be that MHPG is an index of general alertness rather than a specific index of arousal of a power reward system. For various reasons some people are more alert, as indexed by a higher MHPG excretion rate during the learning and if they happen also to be high in *n* power they will learn power-related responses faster than people who are neither as alert nor as high in *n* power. Possible objections to this explanation are: (1) increased altertness does not facilitate learning all pairs in combination with *n* power but only the power-related pairs relative to the neutral pairs; and (2) other possible signs of alertness, or arousal, such as E and NE excretion rates do not interact with *n* power to promote faster learning of any type of picture–word pairs.

Thus is appears that brain NE turnover is somehow specifically related to facilitating the learning of power-related materials for subjects high in *n* power. The most logical explanation for this facilitating effect would appear to be to draw on the finding that brain NE can serve as a reward in animals and to infer that it may be the specific reward system for the power drive. But obviously much further study is needed to confirm this interesting possibility. For the number of cases is small, and the critical comparison, while seemingly the most reasonable, was only one of several that were made which showed lesser levels of significance.

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