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by

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"Attention-like" Processes in Classical Conditioning[1]

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The experiments to be described have, I am afraid, only a marginal relevance to the focus of this symposium. The studies do involve the use of aversive stimulation, and it is this largely fortuitous fact which has resulted in my presence here today. The intent of the studies, however, has been to examine the role of "attention-like" processes in conditioning. With this aim in mind, the procedure employed throughout has been the conditioned emotional response (CER), first described by Estes and Skinner (1941). Previously, (Kamin, 1965), we have attempted to indicate how the CER provides an extremely sensitive and efficient procedure for the analysis of variables affecting Pavlovian conditioning in general. Thus, the results to be described today, and the theoretical consequences which flow from them, are not, I am convinced, limited to the aversive case. The present results derive from rats in a CER procedure, with an electric shock US; but very similar results have been obtained in the McMaster laboratory by H. M. Jenkins, using pigeons in a food-reinforced operant discrimination. What appears to be involved in all of these studies is a concern with some of the phenomena, easily observable in conditioning experiments, which are usually referred to as examples of "selective attention".

The present work on "attention-like" processes arose from the use of compound CS's in a Pavlovian conditioning paradigm. The usual statement of the conditions sufficient for establishment of a Pavlovian conditioned response asserts simply that a neutral, to-be-conditioned CS must be presented in contiguity with an unconditioned stimulus (US). When, however, a compound CS, consisting of elements known to be independently conditionable, is presented in contiguity with a US, are all elements of the CS effectively conditioned? If not, what factors determine which elements of the CS <u>are</u> conditioned?

The experimental approach in overview was as follows. Train an animal to respond to a simple CS, consisting of Element A. Then, train the animal to respond to a compound, consisting of Element A plus a superimposed Element B. Finally, test the animal with Element B alone. Will it respond to Element B? Put very naively, our first notion was that, because of the prior training to Element A, that element might so "engage the animal's attention" during presentation of the compound that it would not "notice" the added Element B. The failure to notice the superimposed element might preclude any conditioning to it. To conclude that the prior training to Element A was responsible for a failure to respond to Element B we must, of course, show that animals trained to the compound without prior training to A <u>do</u> respond when tested with B. To control for amount of experience with the US, we ought also to show that if compound training is <u>followed</u> by training to A alone, the animal will respond when tested with B.

The first approach to "attention" involved this relatively simple design. The work has developed in several directions, however, and to date has utilized more than 1,000 rats as subjects, in more than 100 experimental groups. I should like today to summarize some selected aspects of this work.

The basic CER procedure utilized in all studies employs naive hooded rats as subjects, reduced to 75 percent of <u>ad lib.</u> body weight and maintained on a 24-hr. feeding rhythm. The rats are first trained to press a bar for a food reward in a standard, automatically programmed operant conditioning chamber. The daily sessions are two hours in length, with food pellets being delivered according to a 2.5-min. variable interval reinforcement schedule. The first five sessions (10 hrs.) produce stable bar-pressing rates in individual rats, and CER training is then begun. During CER training, the food reinforcement schedule remains in effect throughout the daily 2.hr. session, but four CS-US sequences are now programmed independently of the animal's behavior. The CS, typically, has a duration of three minutes, and is followed immediately by a half-second US, typically a 1 ma. shock. For each CER trial (four trials daily), a "suppression ratio" is calculated. The ratio is B/ A+B, where B represents the number of bar presses during the 3-min. CS, and A the number of bar presses during the 3-min. period immediately preceding the CS. Thus, if the CS has no effect on the animal's bar pressing, the ratio is .50; but as the CS, with repeated trials, begins to suppress bar pressing, the ratio drops toward an asymptote very close to .00. We regard the learned suppression produced by the CS as an index of an association between CS and US, much as conditioned salivation to a metronome may be regarded as such an index.

The CS, in the experiments to be described, was either a white noise (typically 80 db), the turning on of an overhead house light (7.5 w. bulb diffused through milky plastic ceiling), or a compound of noise-plus-light presented simultaneously. The normal condition of the chamber is complete darkness. The various experimental groups received reinforced CER training with various CS's in different sequences. The precise sequences of CS's are detailed in the body of this report. Typically, following the CER training, the animal was given a single test day, during which a non-reinforced CS was presented four times within the bar-pressing session. The data to be presented are suppression ratios for the first test trial. While no conclusions would be altered by including the data for all four test trials, the fact that the test CS is not reinforced means that test trials following the first contribute relatively little to differences between experimental groups.

The characteristic outcome of our basic training procedure is depicted in Figure I, which presents median suppression ratios, as a function of acquisition trial, for three representative groups of subjects. The groups have been trained with either noise, light, or the compound as a CS. The major point to note at present is that after a very few trials of training all groups approach asymptotic suppression. It can also be observed that light has a slightly suppressing effect on the very first trial, so that the light group tends to acquire slightly more rapidly than the noise group. Finally, the compound group acquires significantly more rapidly than either of the others.

The first experimental approach to attention is illustrated in the design outlined below. The code-letter for an experimental group is indicated at the left of the paradigm. Then, the CS employed with that group during consecutive phases of CER training is noted; "L", "N", and "LN" refer, respectively, to a light, a noise, or a compound CS. The number of reinforced trials with each type of CS is indicated in parentheses immediately following the CS notation; four reinforced trials are given daily. Finally, the CS employed during the test trial is indicated, together with the median suppression ratio for the group on the test trial. The number of animals per experimental group varies, in the studies to be reported, between 8 and 20.

Group A:	LN (8)	N (16)	Test L	.25
Group B:	N (16)	LN (8)	Test L	.45
Group G:	———	LN (8)	Test L	.05
Group 2-B:	———	N (24)	Test L	.44

There are a number of relevant comparisons which can be made within the above set of four experimental treatments. The basic comparison is that between Groups G and B. The test result for Group G indicates, as a kind of baseline, the amount of control normally acquired by the light as a result of eight reinforced compound training trials. This is very significantly different from the result for Group B, within which the same compound training trials have been preceded by prior training to the noise element. Thus, our speculation that prior training to an element might "block" conditioning to a new, superimposed element receives support. When however, we compare Groups A and B, we again observe a significant difference. These two groups have each received the same number of each type of CER training trial, but in a different sequence. Group B, for whom the noise training preceded compound training, is less suppressed on the test trial than is Group A, for whom the noise training followed compound training. The fact that Group A is less suppressed than Group G is <u>not</u> to be interpreted as a kind of "retroactive interference" effect produced by interpolation of noise training after compound training. It must be remembered that four days elapse, for Group A, between the last compound trial and the test; appropriate control groups have established that Group A's poor performance on the test, relative to Group G's, can be attributed to the passage of time. This "recency effect", of course, works counter to the direction of the significant difference we have observed between Groups A and B. The failure of Group B to suppress to light as much as does Group A, even with a strong recency effect working to Group B's advantage, suggests a fundamental failure of conditioning to the light in Group B. This is confirmed when we compare the test results of Groups B and 2-B. These groups each experience noise followed by shock 24 times, but for Group B light is superimposed during the final eight trials. The fact that the test trial to light yields equivalent results for B and 2-B indicates that the superimpositions have produced literally <u>no</u> conditioning to the light. The test ratios for both these groups are slightly below .50, indicating again that independent of previous conditioning, an initial presentation of light has a mildly disruptive effect on on-going bar-pressing behavior.

While these results tended to encourage the speculation with which we began, there was of course the possibility that they were specific to the particular sequence of stimuli which we employed. Perhaps prior training to noise blocks conditioning to light during compound training; but would prior conditioning to light block conditioning to noise? The following groups were examined in order to answer this question.

Group E:	LN (8)	L (16)	Test N	.36
Group F:	L (16)	LN (8)	Test N	.50
Group H:	———	LN (8)	Test N	.25
Group 2-F:	———	L (24)	Test N	.49

These four experimental paradigms are entirely analagous to those outlined previously. The sole difference is that the roles of light and noise have been interchanged, so that we are now attempting to block conditioning to noise by previous training to light. Happily, the pattern of results and significant differences in this set of four groups is identical to that observed earlier. There is literally no evidence for conditioning to the noise element of a compound if the animal has been previously conditioned to light alone. Thus, the blocking effect has some generality, and is not dependent on which particular stimulus is conditioned first. When we compare the present results of the noise test to those earlier reported for the light test, it is obvious that, the blocking effect aside, light tends to be the more potent member of the light-noise compound. This is consonant with our earlier observation that rats trained to suppress to light alone condition somewhat more rapidly than do rats trained to noise alone. We should stress, however, that (although we do not here present the data) we have tested many rats, after *de novo* training to the light-noise compound, to <u>each</u> element separately. We have never observed a rat which did not display some suppression to <u>each</u> element. Thus, granted the present intensity levels of light and noise, the blocking effect depends upon prior training to one of the elements; when trained from the outset to the compound, no animal "ignores" completely one of the elements.

We should also note that animals trained to noise alone after previous training to light alone acquire at the same rate as do naive animals trained to noise alone. Prior training to noise alone also does not affect subsequent training to light alone. It seems very probable that this lack of transfer between the two stimuli, as well as some degree of equivalence between the independent efficacies of the stimuli, are necessary preconditions for the kind of symmetrical blocking effect which we have demonstrated.

The results so far presented suggest that, granted prior training to an element, no conditioning occurs to a new element which is now superimposed on the old. This might mean, as we first loosely suggested, that the animal does not "notice" the superimposed element - the kind of peripheral gating mechanism popularized by Hernandez-Peon (1956) is an obvious candidate for theoretical service here. To speak loosely again, however, we might suppose that the animal <u>does</u> notice the superimposed stimulus, but does not condition to it because the stimulus is "redundant". The motivationally significant event, shock, is already perfectly predicted by the old element. The possible importance of "redundancy" and "informativeness" of stimuli in conditioning experiments has been provocatively indicated by Egger and Miller (1962). We thus decided to examine whether, in the case when the superimposed stimulus predicted something new (specifically, non-reinforcement), it could be demonstrated that the animal noticed the new stimulus. The following two groups were examined.

Group Y:	N (16)	LN, non-reinforced (8)	N, non-reinforced (4)
Group Z:	N (16)	N, non-reinforced (12)	

The results for both groups during non-reinforced trials are presented in Figure 2.

Through the first 16 CER training trials these groups are treated identically, and on the sixteenth trial the median ratio to noise was .02 for each group. When Group Y was presented with the compound on its next trial, its ratio increased to .18; on the equivalent trial Group Z, presented with the familiar noise, had a ratio of .01. The difference between groups on this trial fell short of significance, but is certainly suggestive. The animals in Group Y seem to notice the superimposed light, even before the compound is followed by non-reinforcement. It must be remembered that, until the moment of non-reinforcement on Trial 17, Group Y is treated identically to the "blocked" Group B in the original experiment. Thus, if this result can be replicated, we have evidence that animals do notice the superimposed element, at least on the first trial of its introduction. The evidence is in the form of an attenuation of the suppression which would have occurred had not the new element been superimposed.

To return to the comparison between Groups Y and Z, on the second non-reinforced trial Group Y's ratio was .31, Group Z's was .02. This difference was significant. Thus, a single non-reinforced presentation of the compound was sufficient for Group Y to discriminate between noise (always reinforced) and the compound (non-reinforced). The very rapid extinction in Group Y cannot be attributed to the mere failure to reinforce the noise element, as Group Z's performance makes perfectly clear. The nature of the discrimination formed by Group Y is further illustrated by comparing performance of the two groups throughout the extinction phase of the experiment. By the eighth non-reinforced trial, the ratios were .41 for Group Y and .33 for Group Z. Then, on the next trial, the stimulus for Group Y was changed to noise alone. The Group Y ratio on this trial was .17, the Group Z ratio was again .33. This was a significantly lower ratio for Group Y than had been observed on the preceding trial. Thus, to some degree, animals in Group Y had learned that it was the <u>compound</u> which was non-reinforced; the noise element <u>per se</u> had been "protected" from extinction.

We now see that, if the superimposed element provides new information, the animal not only notices the element but can utilize the information which it provides with truly impressive efficiency. Further, the attenuated suppression noted on the "transitional trial", when the new element is first superimposed on the old, suggested that, even in the earlier experiments in which the new element was redundant, the animals may have noticed it. This suggestion is confirmed by examining all of our data. We have thus far trained 153 animals with 16 trials of noise alone, followed by at least one trial of the compound. The median ratio of these animals on the sixteenth noise trial was .02; on the transitional trial (before reinforcement or non-reinforcement of the compound can exert any differential effect) the median ratio was .15. There were 106 subjects which displayed higher ratios on the transitional trial than on the sixteenth noise trial; 17 which displayed lower ratios on the transitional trial; and 30 which had equal ratios on the two trials. This is a highly significant effect. There is thus no doubt that, <u>at least on the first, transitional trial</u>, an animal previously trained to a single element notices the superimposition of a new element. This observation is clearly fatal to our original theoretical notions. There remains the possibility, however, that in the case when the transitional trial proves the superimposed stimulus to be redundant, some gating mechanism comes into play at that point such that the new element is not perceived on subsequent trials.

We shall return to this implausible notion a little later.

The fact that the superimposition of a new element produces an attenuation of the suppression previously learned to the old element suggests the possibility of regarding the new element as a Pavlovian external inhibitor. (When one remembers that our measure is failure to press the bar, it is obvious that the effect under discussion cannot be attributed to anything so simple as the new stimulus eliciting investigatory behavior incompatible with bar pressing). This might encourage such questions as whether a stimulus which, at the moment of reinforcement, is acting as an inhibitor, can acquire an increment in associative strength. There are, however, several considerations which seem to militate against considering the added stimulus as an inhibitor. We have examined various types of transitional trials. When an animal has first been trained to a compound, and is then presented with a single element of that compound, suppression on the transitional trial is attenuated to approximately the same degree as in the reverse case. That is, the suppression is attenuated equally whether we add an element to the old CS, or subtract an element from it. The change in the old CS seems to be the controlling variable.

We now turn to an examination of some of the parameters controlling the blocking effect demonstrated in the first experiment. The fixed points from which we begin are the performances of Groups G and B. Group G, which received 8 compound trials with no previous conditioning, displayed a ratio of .05 when tested to light; Group B, with 16 noise training trials preceding the 8 compound trials, displayed a ratio of .45, representing a complete block of conditioning to light. What would happen if, following the 16 prior training trials to noise, a larger number of compound training trials were given? Would conditioning to the light eventually occur? This was tested in Group M, which received 24 compound training trials, rather than the 8 which had been given Group B. The Group M ratio, when tested to light, was .45 - identical to Group B. Thus it appears that the block is not overcome by extended training to the compound. Further, during the extended block of compound training trials, the Group M animals seemed to display the asymptotic ratio characteristic of animals trained to noise alone, rather than the slightly lower asymptote characteristic of animals trained, from the outset, to the compound. Thus, the only observable effect of the light on the behavior of Group M animals was the moderate attenuation of suppression noted on the transitional trial. It is as if the animals notice the light on the transitional trial but, once the light proves to be redundant, do not notice it on subsequent trials.

What would happen if we preceded the standard 8 compound trials by a smaller number of prior noise training trials than the 16 which produced a complete block in Group B? Group N received only 4 prior noise training trials, sufficient to produce considerable, but much less than asymptotic, suppression to the noise. The ratio for Group N, tested to light following the standard compound training, was .26. This ratio is significantly higher than that for Group G, and significantly lower than that for Group B. Thus, a moderate amount of prior training to noise produces a partial block; as the number of prior training trials to noise is increased from 0 to 4 to 16, the extent of the block increases smoothly. We have since learned that eight prior training trials to noise, by which time suppression to noise is asymptotic, is sufficient to produce a complete block, and in more recent studies have adopted 8 trials of prior training as our standard procedure.

We have, as well, examined the blocking effect under a number of procedural variations which have had no effect whatever on the basic phenomenon. Thus, if the standard experiment is repeated employing a 1-min., rather than a 3-min., CS, a complete block is obtained. The same outcome is observed if the experiment is performed employing a 3-ma., rather than a 1-ma., US throughout. And again, complete blocking is obtained if the first CS, on which light onset is superimposed as a new element, is the turning off of a background 80 db noise, rather than the turning on of an 80 db noise. To put matters simply, the blocking phenomenon is robust, and easily reproducible.

When prior training to the noise element establishes the conditions necessary for demonstrating the block, can we eliminate the block by extinguishing the animal's suppression to the noise before giving it compound training? To answer this, Group O was first given 4 noise training trials; from Group N's performance, we know that, were we to institute compound training immediately, the final test ratio to light would be about .26. With Group O, however, the noise stimulus was at this point presented 12 times without shock, before the compound training. This was sufficient virtually to eliminate suppression to the noise before the beginning of compound training. Though suppression to the compound was learned very quickly, when tested to light alone Group O's ratio was .10 - not significantly different from the baseline Group G, and significantly lower than Group N's .26. The blocking effect can thus be eliminated by teaching the animal not to respond to the previously conditioned element before inaugurating compound training. This training must take place <u>before</u> the compound training; Group S received 4 noise training trials, 8 compound trials, and <u>then</u> 12 noise extinction trials before the test to light. They showed no conditioning to the light. Thus it is not merely previous conditioning to an element which produces the block; the animal must retain its CR at the onset of compound training.

To this point in the analysis, substantial prior training to an element has invariably given rise to <u>no</u> evidence of conditioning to the superimposed element. Thus the block has appeared to be a dramatically all-or-none affair.

We now ask whether the total block which we observed in our basic Group B was in part an artifact of the relatively blunt measure of conditioning which we employed. The test trial to light, following compound training, measures transfer from the compound to the element. The savings method is known to be extremely sensitive in demonstrating transfer; much more so than is the "recall" method represented by our test. We now repeated the basic experiment, but the test was no longer a single test trial to light; instead, all animals were given four <u>reinforced</u> training trials to light at the end of the experiment. The focus of interest is on rate of acquisition during this training to light. The two basic groups are outlined below.

Group 2-A:	N (16)	LN (8)	L (4)
Group 2-B:	------	N (24)	L (4)

While Groups 2-A and 2-B have each experienced noise followed by shock 24 times before the training to light alone, the difference is of course that Group 2-A has on the last eight trials experienced the light superimposed on the noise. Will Group 2-A therefore show any savings, relative to Group 2-B, when trained to the light alone? Or have the eight superimpositions of light literally left no effect on the animal?

There was, as our earlier results would have suggested, no significant suppression to the light by either group on the first training trial to light. However, Group 2-A displayed significantly more suppression on each of trials 2, 3, and 4 than did Group 2-B. Thus, it is clear that the eight light superimpositions did indeed leave some trace, which was manifested in a significant savings effect. However, we are reminded that our earlier data already demonstrated that, in groups trained similarly to Group 2-A, the animals did notice the superimposed light at least on the <u>first</u>, transitional trial. Can it be the case that the significant savings exhibited by Group 2-A is entirely attributable to the first trial on which light is superimposed? Or, do the compound trials following the first also contribute to the savings effect?

To answer this question, Group 2-N was examined. The procedure is sketched below, and should be compared to those diagrammed in the immediately preceding paradigm.

Group 2-N:	N (16)	LN (1)	N (7)	L (4)

Group 2-N differs from Group 2-B only on the transitional trial; though the total number of reinforced experiences of noise is equated across Groups 2-A, 2-B, and 2-N, Group 2-N receives seven fewer light superimpositions than does Group 2-A. Nevertheless, the acquisition curves to light alone in the final phase of the experiment are virtually identical for Group 2-N and 2-A; like Group 2-A, Group 2-N is significantly more suppressed than Group 2-B on each of Trials 2, 3, and 4. If we compute median suppression ratios over the four trials of light training for each group, they are .28 for each of Groups 2-A and 2-N, but .38 for Group 2-B. Thus it is clear that the savings which we have demonstrated can be entirely attributed to the first, transitional trial. We had in any event independent evidence that the animal noticed the light on that trial, and it is now clear that the reinforcement at the termination of that trial does produce an increment in the associative connection between light and shock. There still, however, is nothing in the data which can allow us to conclude that the animal notices a redundant, superimposed element on any trial <u>after</u> the transitional trial; or at least, we have no indication that reinforced presentations of the superimposed element after the transitional trial in any way affect either the contemperaneous or the subsequent behavior of the animal. The attention notions which prompted these studies seemed routed by the brute empirical fact of the transitional trial; but, with the aid of a redundancy concept, a strategic retreat seems to have been effected, involving the surrender of only a single trial!

We turn now to a set of groups aimed at elucidating some of the temporal parameters of the blocking effect. These data, however, reflect as well on the plausibility of regarding presentation of a previously trained element as equivalent to "blotting out" or "blocking" the simultaneous presentation of an untrained element. Previous work on acquisition of the CER (Kamin, 1965) has indicated that a critically sensitive point is the moment in time when CS and US are literally contiguous.. The introduction of a very brief gap between termination of a CS and presentation of the US adversely affects conditioning. What would be the effect of "blocking" the CS during the moment of its contiguity with the US? The paradigms aimed at this question are sketched below, with a slightly modified notation to be explained in the following paragraph.

Group D:	N (16)	L (8)
Group 2-Q:	N (16)	L, + N last 5 sec. (8)
Group 2-Z:	N (16)	L, + N first 5 sec. (8)
Group 2-Y:	N (16)	L, only 175 sec. (8)
Group 3-J:	———	L, + N last 5 sec. (8)

The first training phase outlined in the above paradigms involves no new considerations; all groups but 3-J receive the standard 16 prior training trials to noise. Group D then receives eight training trials with light. Groups 2-Q and 2-Z also receive eight training trials with light, but the noise stimulus is superimposed on the light during either the last or the first 5 seconds of its (the light's) 180-second action. Group 2-Y, following the prior noise training, receives training trials with the light under a trace-conditioning procedure. That is, the light acts for only 175 seconds, with the shock coming, as always, 180 seconds after light-onset. Finally, Group 3-J receives the same training as Group 2-Q in the second phase, but 3-J has not had prior training to the noise. The focus of interest in this experiment is on performance during the second phase, when all groups are receiving reinforced training to the light. The light has a duration of 180 seconds for all groups but one, 2-Y, for which the light lasts 175 seconds. The acquisition data during the second phase are presented for all groups in Figure 3.

The first comparison to be made is between Groups D and 2-Q. The acquisition of suppression to the light is significantly less rapid in Group 2-Q. Thus, the short burst of noise during the final 5-second action of the light does have a blocking effect. Whether a 5-second noise burst will have such a blocking effect, however, depends upon its temporal relation to the light stimulus, and to shock. Thus, Group 2-Z acquires at the same rate as Group D, significantly more rapidly than does Group 2-Q. It is only when the noise "blots out" the light at the time when light and shock are about to occur in contiguity that the blocking effect is obtained. This temporally specific blocking effect of a brief noise burst is clearly dependent on the noise's having previously been established as a CS. When, as in Group 3-J, a 5-second noise burst is superimposed over the final 5 seconds of light action from the outset of training, no blocking occurs. The rate of acquisition for 3-J is the same as that for D and 2-Z.

While Group 2-Q does exhibit a temporally specific blocking effect, it must be noted that this group <u>does</u> acquire suppression to the light; it is only that this suppression is acquired at a relatively slow rate. This, however, does not necessarily mean that the 5-second noise burst fails to "blot out" the light completely during its (the noise's) action. To assess this, we require Group 2-Y. This group, following the standard initial training to noise, receives the light for only 175 seconds; the light is literally turned off during the 5 seconds preceding shock. This trace conditioning procedure produces acquisition of suppression to the light, but at a relatively slow rate; in fact, the rate is virtually identical to that observed in Group 2-Q; and is significantly slower than that in Groups Y, 2-Z, and 3-J. Thus, exactly the same behavioral effect is produced either by turning the light off literally, or by "blotting it out" with a superimposed noise. To put it very simply, it is indeed as if the animal does not see the light when a previously trained noise is acting.

The blocking effect can be shown to occur even during a training regimen which makes the superimposed stimulus logically the only correct predictor of shock. Thus, Group 3-E first received 16 training trials during which reinforced presentations of the compound alternated with non-reinforced presentations of noise alone. This bank of 16 discrimination training trials was sufficient to produce excellent discrimination between the compound and the noise element. When Group 3-E was now tested to light alone, its ratio was .13, a very considerable suppression. The performance of Group 3-E is portrayed in Figure 4. This can be contrasted to the performance of Group 3-F, which first received 16 reinforced trials to noise alone, and then 16 discrimination training trials during which reinforced compound presentations alternated with non-reinforced presentations of the noise alone. The Group 3-F animals as indicated in Figure 5, showed no sign whatever of discriminating between the compound and the noise element during these 16 trials. Their continued suppression during these trials is similar to what one might expect from the performance of a group which, after first being trained to noise alone on a continuous reinforcement schedule, is now shifted to a 50 percent partial reinforcement schedule with noise alone. Again, it is as if Group 3-F, which enters the discrimination training phase with a strongly established suppression to the noise, fails to see the light; and concludes simply that the noise is now being partially reinforced. This occurs despite the fact that during discrimination training, the light is the only cue which differentiates reinforced from non-reinforced trials. This cue was readily learned by the Group 3-E animals; however, when tested to the light alone, the Group 3-F animals showed no suppression.

To this point, our speculations about the blocking phenomenon have centered on the possibility that what is involved is, essentially, a deficit in reception of the superimposed element. The CS input is, so to speak, degraded. Perhaps, then, the block can be overcome by increasing the likelihood that the superimposed element will be attended to; e.g., by making it physically intense with respect to the prior trained element.

The next set of experiments involved first the training of different groups of animals with different noise intensities. Then each group was given compound training, with a constant light stimulus superimposed over each group's noise intensity. The question is whether the degree to which light is "blotted out" will vary with the intensity of the competing noise stimulus. The primitive notion here is that, if the block is perceptual in nature, it might be easier for a constant light stimulus to "win the animal's attention" if it is pitted against a physically weak stimulus than if it is pitted against a physically strong stimulus. The experimental paradigms are outlined below.

Group T-1:	N-50 db (16)	LN-50 db (8)	Test L	.21
Group T-2:	N-60 db (16)	LN-60 db (8)	Test L	.34
Group T-3:	N-80 db (16)	LN-80 db (8)	Test L	.42
Group T-4:	LN-50 db (8)	N-50 db (16)	Test L	.06
Group T-5:	LN-60 db (8)	N-60 db (16)	Test L	.00
Group T-6:	LN-80 db (8)	N-80 db (16)	Test L	.32

These paradigms can be viewed as a replication of the very first experiment described (demonstrating the block with Groups A and B), plus an extension of this experiment to the cases where the noise stimulus is of 50 and 60 decibels. The block produced in the present study by prior noise training at the 80 db level (Group T-3 vs. Group T-6) is significant, and comparable in magnitude to that demonstrated with Groups A and B. With the same type of comparison, we can demonstrate significant blocks at both the 50 and 60 db levels. But of more immediate interest, the amount of suppression during the light test is indeed a clear function of the competing noise intensity. Groups T-1, T-2, and T-3 all differ significantly from each other; the stronger the noise, the less conditioning occurs to light.

There is, however, a serious flaw in the present experiments, which negates the otherwise obvious interpretation; and which at the same time suggests a fundamentally different interpretation. To begin with, the amount of suppression to noise after 16 training trials was itself a function of noise intensity. We had rather expected that Groups T-1 through T-3 would converge to a common asymptote of virtually complete suppression by the sixteenth trial of noise training, but this was not the case. The 50 db group in particular was significantly less suppressed than the others. Thus, the relatively successful conditioning to light in Group T-1 might be attributable to the relatively ineffective prior noise conditioning, rather than to the contrasting physical intensities of noises and light. We had already demonstrated that, with an 80 db noise, a partial blocking effect is produced if the prior noise training is continued for only 4 trials. This procedure has in common with Group T-1 the fact that, at the time when the light is first superimposed, suppression to the noise is not complete. This confounding of degree of suppression produced with physical intensity of the noise makes it foolhardy for us to view the present data as supporting a perceptual interpretation of the block.

The detailed examination of these data indicates another confounding, which may be of considerable theoretical significance. We have already indicated that the level of suppression at the outset of compound training was a function of noise intensity. Further, the degree of attenuation of suppression produced by the new element on the transitional trial varied with noise intensity (and, of course, with level of suppression at the outset of compound training). Thus, the 80 db group required only one compound training trial before its suppression ratio returned to the level achieved on the last noise training trial, the 60 db group required two compound training trials, and the 50 db group seven such trials, before achieving suppression ratios as low as those obtained on the last noise training trial. These results directly parallel the amount of conditioning subsequently displayed to the light element; if suppression is minimal during the early compound trials, relatively little blocking occurs. This effect is shown quite clearly within the 50 db group, for whom a significant rank order correlation of minus .58 exists between suppression on the early compound trials and the test ratio later displayed to light. The magnitude of this correlation seems more impressive when one considers the numerous factors which might lead one to expect a positive correlation between these two measures of conditioning.

This latest observation suggests a rather different way of thinking about the blocking phenomenon. The data make it perfectly clear that, for a stimulus to be conditioned, mere temporal contiguity with the US is not sufficient. Perhaps the necessary precondition is that the stimulus be contiguous with the US during a series of trials during which the to-be-conditioned response is less than asymptotic, and thus can be conditioned. There appears to be nothing in our data which contradicts this statement. This notion implies that the degree to which the superimposed stimulus attenuates performance on the transitional trial, and on the immediately subsequent trials, is critical. The factors which determine the degree of this attenuation (external inhibition, generalization decrement, or what-have-you) may profoundly influence the degree of blocking. This line of speculation seems to be moving rather far from the naive perceptual and "attention-like" notions with which we began. If asymptotic suppression on early compound trials is a sufficient condition for the blocking effect, there is no necessity to assume that reception of the superimposed element is in any way impeded. This in turn suggests an alternative interpretation of blocking, to which we shall return after examining a final aspect of the most recently described experiment. This final analysis involves a comparison of the original acquisition to the compound, or to the noise, of groups T-1 through T-6.

When Groups T-1 through T-3 are compared, rate of acquisition varies significantly with noise intensity; the more intense the noise CS, the more rapid is acquisition. When Groups T-4 through T-6 are compared, rate of acquisition is similarly monotonically related to the intensity of the noise element in the compound. This is not particularly surprising, but a further comparison involving the 50 db compound group is not so routine. While Group T-6 acquires significantly more rapidly than do independent groups trained to either light alone or to 80 db noise alone, and while Group T-5 acquires significantly more rapidly than do independent groups trained to either light or to 60 db noise, Group T-4 acquires at the <u>same</u> rate as does a group trained to light alone. Thus, although a between-group summation effect is observed by combining light with either 80 or 60 db noise in a compound, no such effect is obtained by combining light with 50 db. It is as if, even without any prior training, light completely "blots out" a weak, 50 db noise. This occurs despite the fact that 50 db is, by itself, an eminently conditionable CS. The lack of summation between 50 db and light is strikingly manifested by the behavior of Group T-4 in the second phase of the experiment. When these animals are switched from the compound to 50 db noise alone, they exhibit (unlike the 60 and 80 db groups) virtually <u>no</u> suppression. They must acquire to the noise element <u>de novo</u>. This result is clearly reminiscent of the "overshadowing" of a "weak" element by a "strong" element in a compound, as reported many times by Pavlov (1927, pp. 141 ff.) The question now arises whether this type of "overshadowing", which is not dependent upon prior training to one of the elements, is a basically different phenomenon from the blocking effect.

There is at least one obvious way of incorporating both phenomena in the same framework. We need only assume that, during the early training trials to a compound, independent associations are being formed between each element and the US. We know from groups trained independently with light and with 50 db noise, that the suppression to light is already asymptotic on the fifth trial, before any substantial suppression is observed in a group trained with 50 db noise. Thus, we can regard the compound group as one in which a prior training to the light element <u>has in fact occurred</u> before the noise element can be conditioned; the usual blocking effect then ensues. There remains, of course, the fact that all this is dependent upon the relative intensities of the noise and light elements; but the effects of various stimulus intensities may be mediated by the differential conditioning rates with which they are correlated. There thus appears to be no need to postulate different mechanisms for Pavlovian "overshadowing" and for our own blocking effect. The use of explicit prior conditioning to produce a block seems to be only another way of setting up the same chain of events which, in Pavlov's case, was set up by training from the outset to a compound consisting of "strong" and "weak" elements.

We return, in conclusion, to our most recent conception of the blocking effect, one which is no longer dependent upon the notion of a degraded CS input. To illustrate the present notion, a final experiment will be described, with the paradigms outlined below.

Group B:	N-1 ma (16)	LN-1 ma (8)	Test L .45
Group 2-M:	N-1 ma (16)	LN-4 ma (8)	Test L .14
Group 3-U:	N-4 ma (8)	LN-4 ma (8)	Test L .36

The comparison between Groups B and 2-M is instructive, for here at last is a simple procedure which can eliminate the blocking effect. Within Group 2-M, shock intensity is radically increased during the compound trials. The effect of this operation is to allow the formation of a clear association between the superimposed element and the US; Group 2-M, on the test trial, is significantly more suppressed than the standard Group B. This effect is <u>not</u> a simple consequence of employing an intense US during the compound trials. With Group 3-U, the same intense US is employed <u>throughout</u> the experiment, and a clear blocking effect is manifested: the test ratio of 3-U does not differ significantly from that of B, but does from that of 2-M. Thus, it is the <u>change</u> of shock intensity during the compound trials from that employed during prior training which seems responsible for eliminating the block.

We can attempt to integrate the present result with our previous observation that conditioning occurred only on those compound trials when suppression was not asymptotic, in the following way. Let us suppose that, in order for an association between a CS and a US to be strengthened, it is necessary that the US "surprise" the animal. That the sudden introduction of a 4 ma. US should be "surprising" to Group 2-M is clear enough. We can also assume, in a completely circular fashion, that whenever suppression on a compound trial is not asymptotic, the animal does not "confidently expect" the US; delivery of the US on such a trial is thus to some degree "surprising", and the result is some increment in the association between the US and whatever CS is present during the trial. That is, surprise (and thus conditioning) can occur either because the animal does not confidently expect any US at all, or because the US which in fact occurs is different in some way from that which the animal does confidently expect. This latter form of surprise is presumably operative for Group 2-M. Within the standard blocking procedure, we can assume that the attenuation of suppression observed on the transitional trial reflects the fact that superimposition of the new element has, on that trial, made the animal less than certain that the US will follow. Thus some conditioning does occur on that trial. This <u>post facto</u> reasoning seems capable of accommodating all of our previous data.

This final conception is very different from the "attention-like" notions with which we began. Perception of the CS can now be regarded as entirely intact; it is the US which is now regarded as, in a sense, "degraded". Unless the US is surprising, the "mental work" necessary for the formation of an association between CS and US will not be provoked. This notion that a redundant, non-informative CS will not be conditioned is clearly related to the Egger and Miller view.

The present conceptions of "surprise" and "confident expectation" seem something less than fully operational, but no real difficulty seems to be involved. The fact that mere contiguity of a CS and US will not produce conditioning is overwhelmingly clear, and must be dealt with theoretically. We can regard the normal conditioning experiment as a situation in which an unpredicted US causes the animal to scan the recent stimulus input; if, and only if, this scanning occurs, an association is formed between the US and a contiguous CS. The final assumption is simply that the scanning will not occur if the US is preceded by an informative CS. Whether such a view can survive a sustained experimental attack seems highly doubtful. However, our most recent experiments, involving new, independent forms of "surprise", have so far failed to dislodge it. Hopefully, with further experimentation, the concepts of surprise and informativeness can be made more operational, and less circular.

References

Egger, M. D., & Miller, N. E. Secondary reinforcement in rats as a function of information value and reliability of the stimulus. J. exp. Psychol., 1962, 64, 97-104.

Estes, W. K., & Skinner, B. F. Some quantitative properties of anxiety. J. exp. Psychol., 1941, 29, 390-400.

Hernandez-Peon, R., Scherrer, H., & Jouvet, M. Modification of electrical activity in cochlear nucleus during "attention" in unanesthetized cats. Science, 1956, 123, 331-332.

Kamin, L. J. Temporal and intensity characteristics of the conditioned stimulus. In W. F. Prokasy (Ed.), Classical conditioning: a symposium New York: Appleton-Century-Crofts, 1965, Ch. 7.

Pavlov, I. P. Conditioned reflexes. London: Oxford Univer. Pr., 1927.

Footnotes

1. This paper was prepared for delivery at the Symposium on Aversive Motivation, University of Miami, April, 1967. The work was supported by a research grant from the Associate Committee on Experimental Psychology, National Research Council of Canada.

Figure Captions

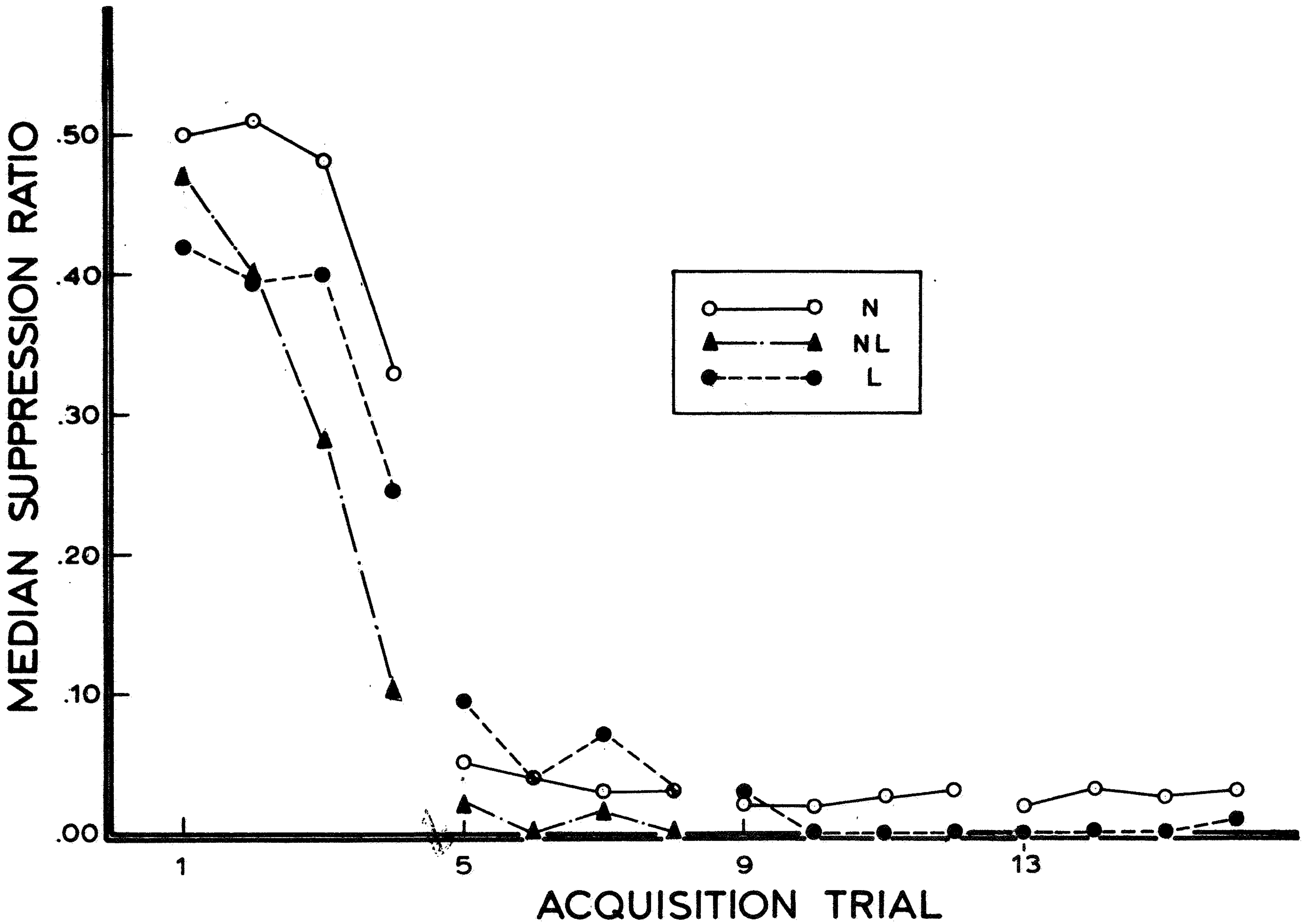
Figure 1. Acquisition of CER by three independent groups of rats.

Figure 2. Extinction of CER after acquisition to noise alone. Arrow in abscissa indicates point at which group extinguished with light-noise compound is switched to noise alone.

Figure 3. Acquisition of CER to light by five independent groups of rats. Note that "control" is Group 3-J, "Normal" is Group D, "5" N, "Onset" is Group 2-Z, "5" N, End" is Group 2-Q, and "Trace" is Group 2-Y.

Figure 4. Acquisition of a discriminated CER in a single group of rats. Compound trials were reinforced, noise alone trials were non-reinforced. Finally, four test trials were given to light alone.

Figure 5. Failure to acquire a discriminated CER in a single group of rats when discrimination training is given following prior acquisition to noise alone.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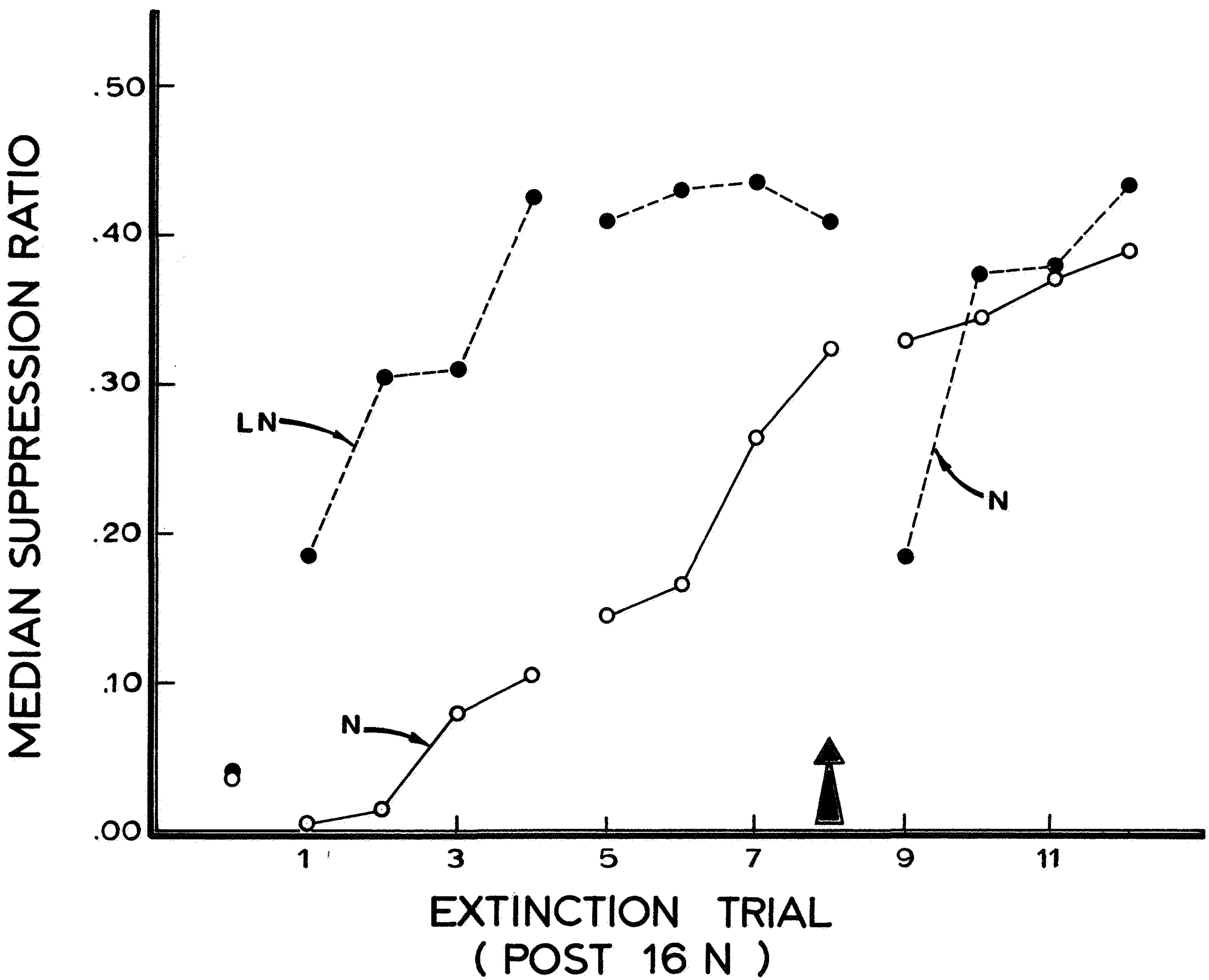

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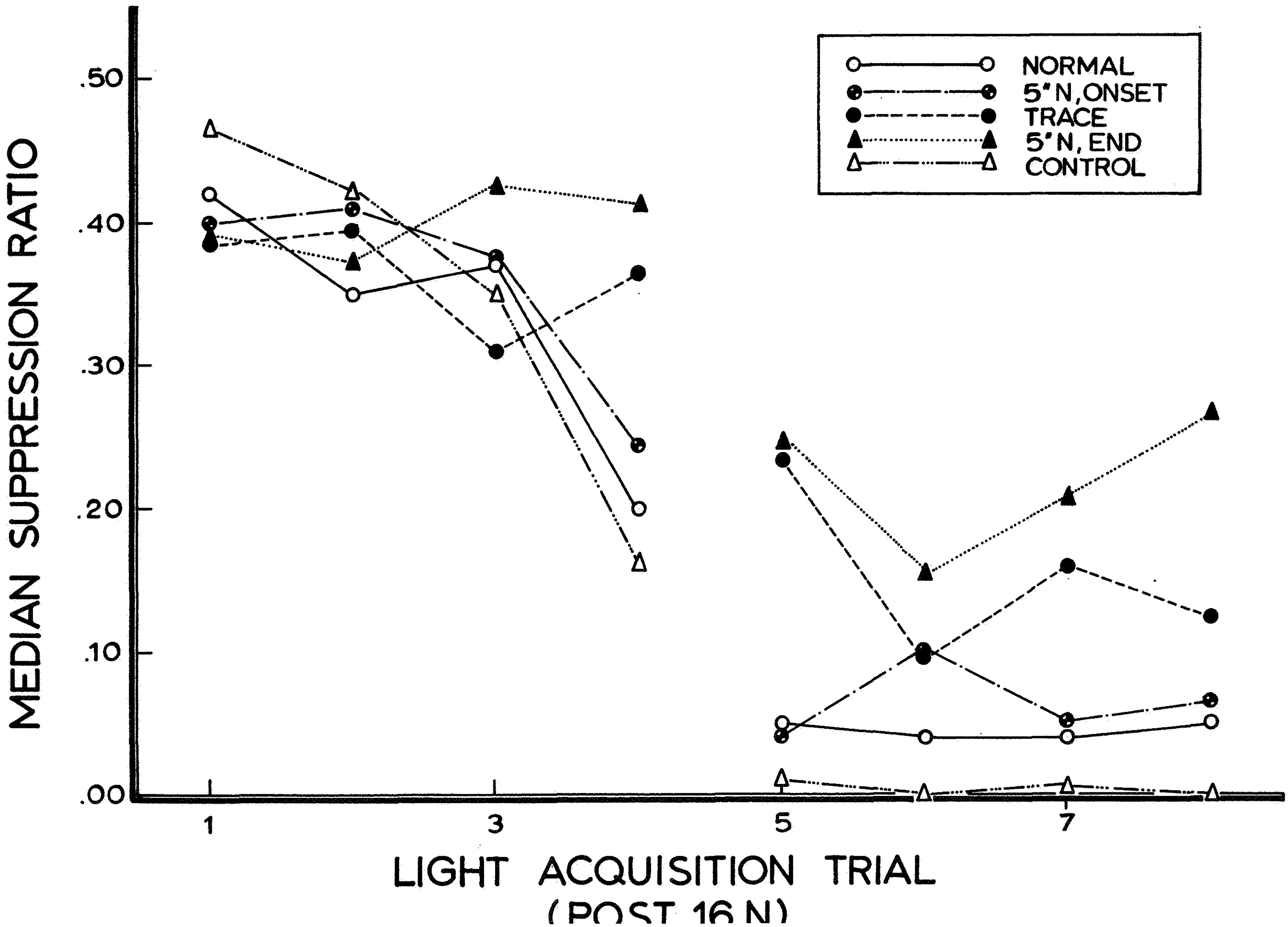
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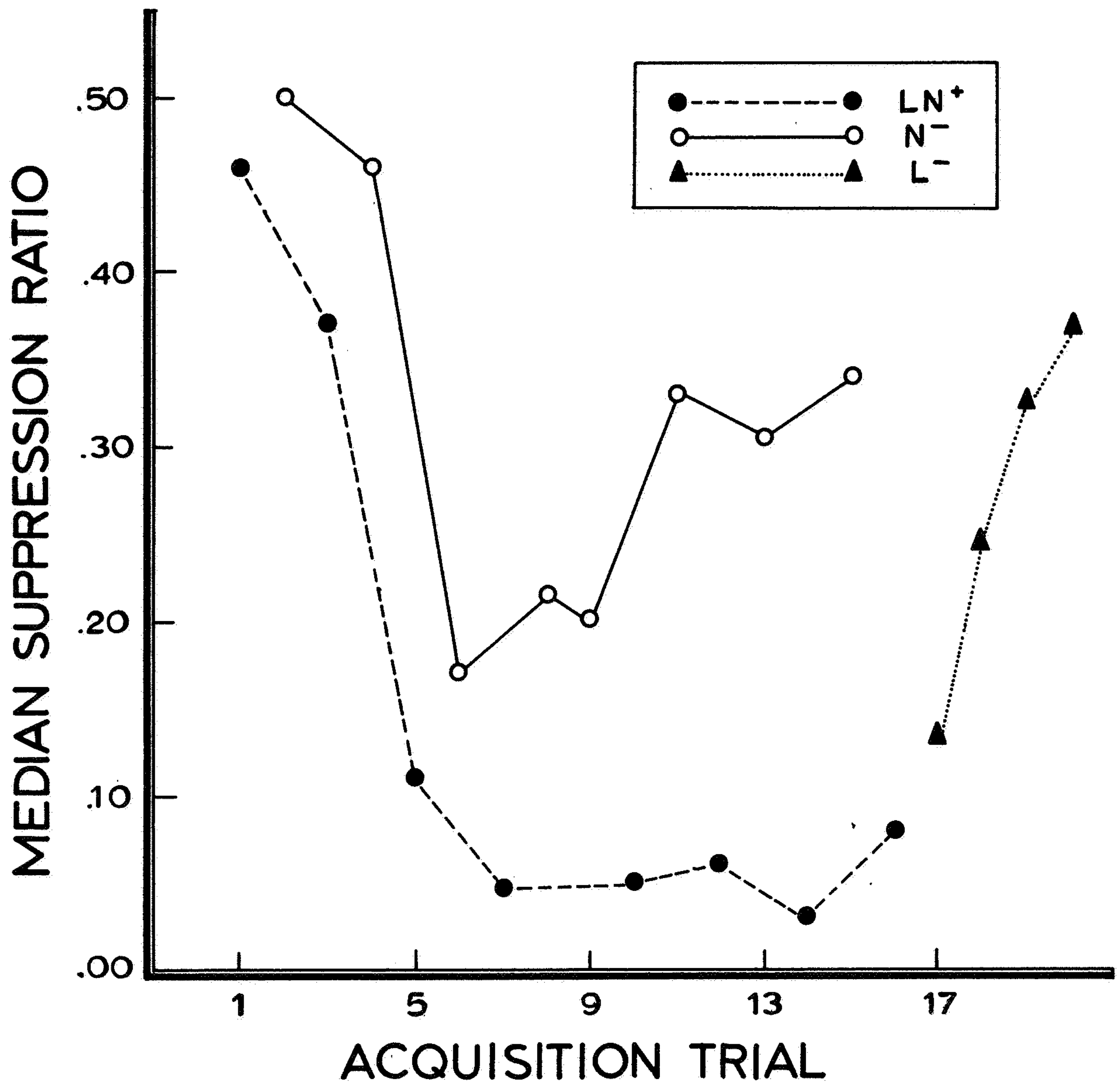

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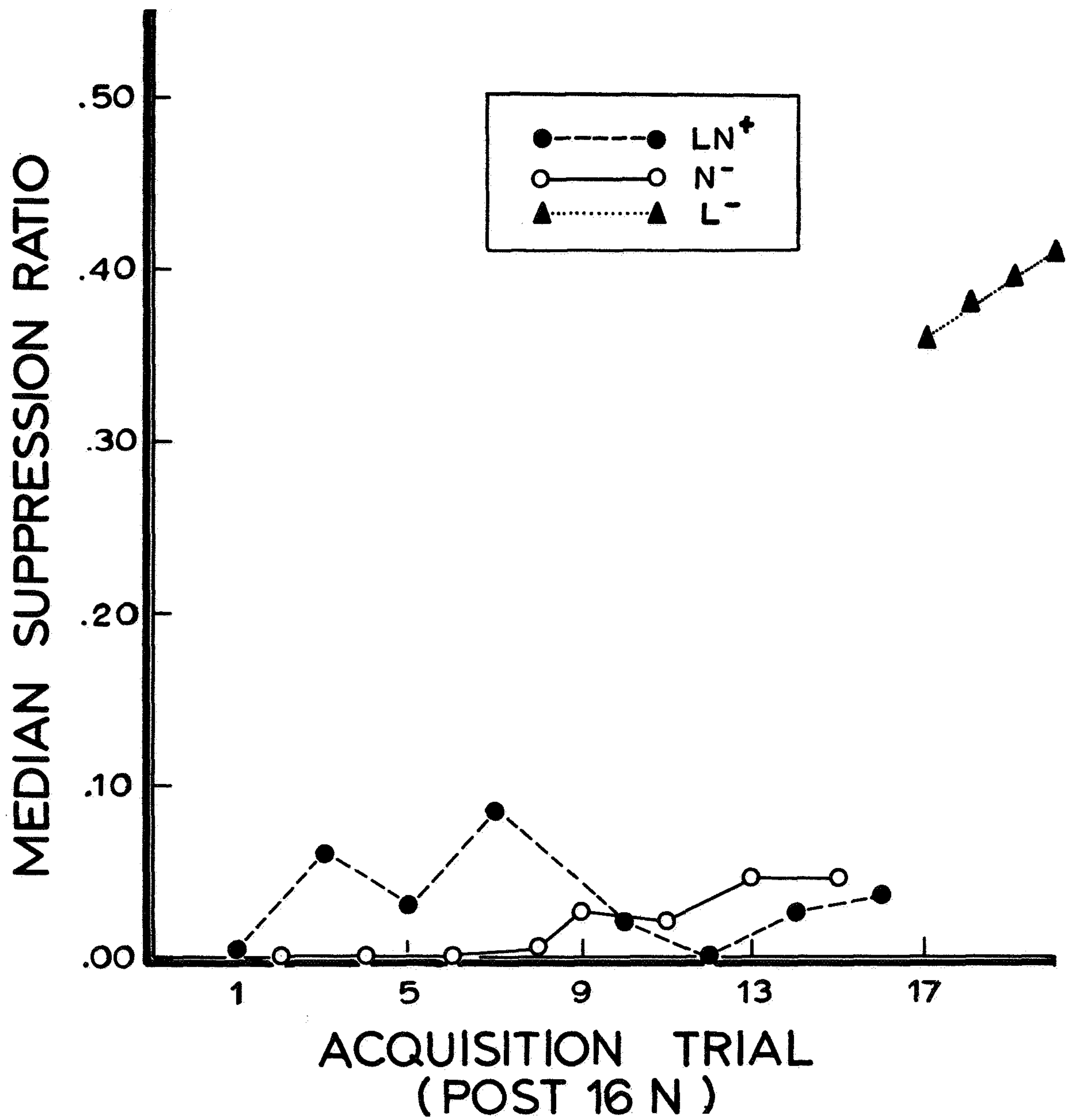
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