PREDICTABILITY, SURPRISE, ATTENTION, AND CONDITIONING

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The experiments to be described here have no special relevance to the problem of punishment. The studies to be reported do employ the CER procedure (Estes and Skinner, 1941). This procedure, within which an aversive US follows a warning signal regardless of the animal's behavior, has been contrasted to the arrangements employed in response-contingent punishment (Hunt and Brady, 1955). This type of comparison, however, is not germane to the present research. The kinds of results considered in this chapter derive from rats in a CER procedure, with shock as the 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 these studies is a concern with phenomena often referred to as examples of "selective attention". To the degree that punishment contingencies may be brought under stimulus control, the present work might be related to other contributions in this volume.

The present work arose from an interest in the possible role of "attention" in Pavlovian conditioning. The usual statement of the conditions sufficient for a Pavlovian CR asserts simply that a neutral, to-be-conditioned CS must be presented in contiguity with a US. What happens, however, when 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? Does the animal attend, and thus condition, more to some elements than to others? What kinds of experimental manipulations might direct the animal's attention to one or another element?

The first experimental approach to these questions was, in overview, as follows. First, condition an animal to respond to a simple CS, consisting of Element A. Then, condition 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 primitive notion was that, because of the prior conditioning 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 conditioning to Element A was responsible for a failure to respond to Element B we must, of course, show that animals conditioned to the compound without prior conditioning to A do respond when tested with B. To control for amount of experience with the US, and variables correlated with it, we ought also to show that if compound conditioning is followed by conditioning to A alone, the animal will respond when tested with B.

This relatively simple design has since expanded in a number of unexpected directions, and our original primitive notions about attention have been forcibly revised -- if not refined. To date, we have utilized over 1,200 rats as subjects, in more than 110 experimental groups. There has been an earlier report of the first stages of this work (Kamin, 1968); in the present chapter, we shall review the basic preliminary findings, then focus on some of the more recent developments.

The basic CER procedure utilized in all these studies employs naive hooded rats as subjects, reduced to 75 percent of ad lib. 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 conditioning is then begun. During CER conditioning, 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 .5 sec. 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 CER conditioning to various CS's, in different sequences. The precise sequences of CS's are detailed in the body of this report. Typically, following the CER conditioning, 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 conditioning procedure is depicted in Figure 1, which presents median suppression ratios, as a function of acquisition trial, for three representative groups of subjects. The groups have been conditioned with either noise, light, or the compound as a CS. The major point to note at present is that after a very few trials 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 conditioning 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 conditioning trials. This is very significantly different from the result for Group B, within which the same compound conditioning trials have been preceded by prior conditioning to the noise element. Thus, our speculation that prior conditioning to an element might "block" conditioning to a new, superimposed element receives support. When we next 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 conditioning trial, but in a different sequence. Group B, for whom the noise conditioning preceded compound conditioning, is less suppressed on the test trial than is Group A, for whom the noise conditioning followed compound conditioning. This again supports the notion that prior conditioning to A blocks conditioning to the B member of the compound. The further fact that Group A is not as suppressed as Group G is <u>not</u> to be regarded as produced by interpolation of noise conditioning after compound conditioning. 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 no 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.

The blocking effect demonstrated by the experimental treatments described above is not specific to the particular sequence of stimuli employed. When four new groups of rats were trained, reversing the roles of the light and noise stimuli, a total block of conditioning to the noise member of a compound was produced by prior conditioning to the light element (Kamin, 1968). Further, it should be pointed out that we have tested many rats, after de novo conditioning to the light-noise compound, to <u>each</u> element separately. We have never observed a rat which did not display some suppression to each element. Thus, granted the present intensity levels of light and noise, the blocking effect depends upon prior conditioning to one of the elements; when conditioned from the outset to the compound, no animal "ignores" completely one of the elements.

We should also note that animals conditioned to noise alone after previous conditioning to light alone acquire at the same rate as do naive animals conditioned to noise alone. Prior conditioning to noise alone also does not affect subsequent conditioning 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 indicate that, granted prior conditioning 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" or perceive 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 conditioning 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, <u>even before</u> 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 <u>do notice</u> 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). Clearly, the light element had been perceived by Group Y. 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 compound which was non-reinforced; the noise element *per se* 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 was confirmed by examining all of our data. We had at last count conditioned 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. (When the transitional trial was reinforced, the median ratio on the second compound trial was again .02). 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 conditioned 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 is activated at that point such that the new element is not perceived on subsequent compound trials. Thus, it is at least conceivable that perceptual gating (deficient attention) provides the mechanism through which redundant stimuli are made non-conditionable. This view can be contrasted to the notion that redundant stimuli, though perceived in an intact manner, are simply not conditioned. We shall return to this problem a little later, after reviewing briefly some of the parameters of the blocking effect.

The data gathered to date, much of which has been more fully described elsewhere (Kamin, 1968), indicates such facts as the following. The blocking effect, granted prior conditioning to Element A, remains total even if the number of compound conditioning trials is very substantially increased; on the other hand, if conditioning to Element A is terminated before suppression has become asymptotic, a <u>partial</u> block of conditioning to the B member of the compound occurs. The amount of blocking is very smoothly related to the amount of prior conditioning to Element A. The block can be eliminated by extinguishing suppression to A prior to beginning compound conditioning; if suppression to A is extinguished following compound conditioning (A having been conditioned prior to the compound), the block remains. When blocking experiments were conducted with new groups of animals, holding constant the intensity value of Element B, while varying for different groups the intensity of Element A, the amount of blocking was a clear function of the relative intensities of the two elements. That is, more blocking of conditioning to B occurs if A is physically intense than if A is physically weak. This, however, is confounded with the fact that the level of suppression achieved by conclusion of the conditioning trials to A varies with the intensity of A; and we have already indicated that blocking varies with the level of suppression conditioned to A.

We have, as well, examined the blocking effect under a large number of procedural variations which have had no effect whatever on the basic phenomenon. Thus, e.g., 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 <u>turning off</u> of a background 80 db noise, rather than the <u>turning on</u> of an 80 db noise. To put matters simply, the blocking phenomenon is robust, and easily reproducible.

We turn now to consideration of a classical phenomenon to which the blocking effect seems clearly related; we shall later return to a more detailed analysis of blocking itself. The blocking effect demonstrated in these studies seems in many ways reminiscent of the "overshadowing" of a "weak" element by a "strong" element in a compound CS. The basic observation reported by Pavlov (1927, pp. 141 ff.) was that if a compound CS was formed of two stimulus elements differing greatly in intensity or "strength," the weaker element, when presented on test trials, failed to elicit any CR, despite repeated prior reinforcement of the compound. This was true although the weaker element was known to be independently conditionable. The major distinctions between the Pavlovian finding and the present blocking effect are, first, that overshadowing was said to occur without prior conditioning of the stronger element, and second, that overshadowing was reported to depend fundamentally on a substantial difference between the relative intensities of the two elements. The available summaries of Russian protocols from Pavlov's laboratory, however, indicate that at least in some of the overshadowing studies the dog had in fact, at an earlier time in its lengthy experimental history, been conditioned to the stronger stimulus. Thus it seemed possible to us that overshadowing might not be obtained if naive animals were, from the outset of an experiment, conditioned to a compound consisting of strong and weak elements.

The data already reported make it clear that complete overshadowing is not obtained when naive rats are conditioned to a compound of 80-db noise plus light. Following sixteen such reinforced compound trials, animals tested either to noise or to light each display clear conditioning; the ratios are .05 to light and .25 to noise. We wished now to see whether overshadowing might be observed if the relative intensities of the light and noise elements were radically changed. To test this, new groups were conditioned (this time for eight trials) to a compound consisting of our standard light plus 50-db. noise. The group then tested to light displayed a ratio of .03, while the group tested to noise had a ratio of .42. The weak noise was thus almost completely overshadowed by light. Further, animals conditioned to 50-db noise alone, following conditioning to the compound, did not acquire significantly more rapidly than did naive rats conditioned from the outset to 50-db noise! These results are entirely corroborative of the Bavlovian reports. There remains the problem of relating overshadowing, which is not dependent on prior conditioning to one of the elements, to blocking, which is so dependent.

There is at least one obvious way of incorporating both phenomena within the same framework. We could assume that, during the early trials of conditioning to a compound, independent and parallel associations are being formed between each element and the US. With the further assumption that the association to the stronger element is formed more rapidly than that to the weaker, the overshadowing experiment becomes a case in which, implicitly, precisely the same sequence of events takes place which is explicitly produced in the blocking experiment. That is, in the overshadowing case an association to one element (the stronger) is substantially formed before conditioning to a second element takes place. Thus, conditioning of the second element is blocked!

These assumptions might be made more plausible if we examined the rates at which independent groups of animals acquire the CER when conditioned to either light, noise, or the compound. The relevant acquisition curves for the first eight trials of conditioning are presented in Figure 3. The upper left-hand panel of Figure 3 presents curves for groups trained with light, 50 db-noise, and the compound light-plus-50db, respectively. The group conditioned to light is asymptotically suppressed by Trial 5, before really substantial suppression is observed in the group conditioned to 50-db. The upper right-hand panel of Figure 3 indicates that there is relatively little difference in the rates of conditioning to light and to 80-db noise. Thus, assuming the same rates of conditioning to each element within a compound as those observed when the elements are separately conditioned in independent groups, the overshadowing effect would be expected for the 50-db compound, but not for the 80-db compound.

There are further between-group comparisons possible within Figure 3, which seem to support the argument. Within the upper right-hand panel, it can be observed that the compound group acquires significantly more rapidly than does <u>either</u> the light group or the 80-db group. That is, a clear "summation" of the two stimuli can be detected when conditioning to the compound. However, in the upper left-hand panel, there is clearly no summation; the compound group conditions at the same rate as the group trained to the stronger element, light. The 50-db element cannot be seen to affect in any way conditioning in the relevant compound group. Thus the presence of absence or overshadowing, measurable only after conditioning to a compound, is correlated with the presence or absence of a summation effect, detectable by comparing a compound group to other groups conditioned to single elements. This correlation of summation with overshadowing, it might be noted, seems relevant to Hull's early interpretation (1943, Ch. 13) of Pavlovian overshadowing. Basically, Hull regarded overshadowing as an extreme example of generalization decrement; the weaker member of the compound was assumed to be so dissimilar to the compound that it elicited no response. This view, which regards overshadowing as entirely dependent upon a post-conditioning within-subject testing procedure, does not account for the association of overshadowing with the failure to observe summation in between-group comparisons made <u>during</u> conditioning. The very weak element in a compound CS really seems in some sense to be "blotted out".

The weaker element in a compound, as has been noted, is one which, at least in independent groups, conditions less rapidly than the stronger element. The question thus arises whether overshadowing is a direct consequence of the relative intensities of the two elements, or whether the effect is mediated by the different rates of conditioning controlled by the separate elements. The finding that the effect depended directly upon relative intensities would be suggestive of perceptual and "attention-like" notions: e.g., the weaker stimulus might not be "noticed" when compounded with a very strong stimulus. To fit overshadowing into the same framework as blocking, however, it would be convenient if the effect depended upon differential rates of conditioning. We have already reported that at least partial blocking of conditioning to a strong stimulus is obtained when the weak stimulus is conditioned prior to its compounding with the strong stimulus.

To decide between the two alternatives, we employed exactly the same pairs of CS elements utilized in the preceding studies, but manipulated the differential rates of conditioning controlled by the elements. This is quite easily done. When an intense US is employed in a CER procedure, differences in the rates of conditioning produced by CS's of different intensities are substantially reduced; all CS's are conditioned very rapidly (Kamin, 1965). We thus assumed that, by repeating the overshadowing studies already reported, but now employing a 4 ma., rather than the standard 1 ma., US, the differences in rates of acquisition produced by light, by 50 db, and by 80 db would be reduced, with all groups tending to condition substantially in a very few trials. This in turn should mean that overshadowing -- if it is dependent on the formation of a strong association to one element before substantial conditioning has occurred to the other -- should be greatly reduced, if not eliminated.

The results were clear-cut. The groups conditioned with a 4 ma. US to the compound light-plus-80db, when tested with, respectively, light or 80 db, displayed virtually total suppression. The same result was obtained when groups conditioned with a 4 ma. US. to the compound light-plus-50 db were tested with either light or 50 db. These CS elements, of course, are identical to those employed in the preceding overshadowing studies. The fact that light does not overshadow 50 db when an intense US is employed makes it clear that overshadowing is not a simple, direct consequence of the relative intensities of conditioned stimulus elements, and seems to eliminate a single "attentional" interpretation of overshadowing. The alternative interpretation seems quite well supported by examination of the lower two panels of Figure 3. These panels present CER acquisition curves for new independent groups, analogous to the curves in the upper panels, but with US intensity now set at 4 ma. The new groups acquire more rapidly than do corresponding groups conditioned to 1 ma; more important, all new groups acquire rapidly, and none of the single element groups appears to have conditioned "substantially" before conditioning in another such group was well under way. We do not have enough data to make any precise guess about how much conditioning must occur to one element, in how many trials, before how much conditioning to another element, in order for overshadowing to occur in animals for whom the two elements are compounded. The results do indicate clearly, however, that overshadowing is not the result of a simple interaction of sensory events. They suggest as well that the occurrence of overshadowing can be predicted from examination of the rates of acquisition of independent groups conditioned to the separate elements. We might note, finally, that in each of the lower two panels of Figure 3 clear summation effects are detectable, once again associated with the failure to observe overshadowing.

We return now to some further experimental analyses of the basic blocking effect. Within the work previously reported, substantial prior conditioning 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 conditioning, 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> conditioning trials to light at the end of the experiment. The focus of interest is on rate of acquisition during this conditioning 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 conditioning 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 conditioned 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 conditioning 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 conditioned similarly to Group 2-A, the animals did notice the superimposed light at least on the first, 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 Groups2-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 conditioning 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 contemporaneous or the subsequent behavior of the animal. These results are obviously consistent with a perceptual gating concept, so long as the gating mechanism is not activated until after the transitional trial.

Where then do we stand now? The fact that the superimposed element proves to be redundant -- that the US is already perfectly predicted by Element A -- seems to be central to any interpretation of the blocking effect. Presumably, then, blocking would not occur if the superimposed element were made "informative". We have earlier demonstrated that, if the compound is non-reinforced, the animal utilizes the information provided by Element B very efficiently. The strategy at this point was to perform a study within the blocking paradigm, reinforcing the compound trials, but at the same time making Element B informative. This was accomplished by radically increasing US intensity during the compound trials above the level employed during the prior conditioning to Element A, as with Group 2-M in the set of experimental treatments 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. Here at last is a simple procedure which can virtually 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 throughout 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 conditioning which seems responsible for eliminating the block. These results provide clear support for the assumption that blocking occurs because of the redundancy of the superimposed element. The question remains, how does redundancy prevent the formation of an association between a CS-element and a US with which it is contiguously presented?

The most recent conception at which we have arrived seems capable of integrating all the data already presented. The notion is this: perhaps, for an increment in an associative connection to occur, it is necessary that the US instigate some "mental work" on the part of the animal. This mental work will occur only if the US is unpredicted -- if it in some sense "surprises" the animal. Thus, in the early trials of a normal conditioning experiment, the US is an unpredicted, surprising event of motivational significance, and the CS-US association is formed. Within the blocking experiment, the occurrence of the US on the first compound trial is to some degree surprising. This can be deduced, circularly, from the empirical observation that, on the transitional trial only, suppression is moderately attenuated; and some little learning about Element B can be demonstrated to have occurred on the transitional trial, but on no other compound trial. Finally, if in the blocking experiment US intensity is radically increased when compound training is begun, the new US is obviously surprising, and no block is observed.

Precisely what mental work is instigated by a surprising US? The language in which these notions have been couched can be made more respectable, as well as more specific. Thus, as a first try, suppose that, for an increment in an associative connection to occur, it is necessary that the US provoke the animal into a "backward scanning" of its memory store of recent stimulus input; only as a result of such a scan can an association between CS and US be formed, and the scan is prompted only by an unpredicted US, the occurrence of which is "surprising."

This sort of speculation, it can be noted, leaves perception of the superimposed CS-element intact. The CS-element fails to become conditioned not because its input has been impeded, but because the US fails to function as a reinforcing stimulus. We have clearly moved some distance from the notion of attention to the CS -- perhaps to enter the realm of "retrospective contemplation" of the CS!

These notions, whatever their vices, do suggest experimental manipulations. With the "backward scan" concept in mind, an experiment was performed which employed the blocking paradigm, but with an effort to "surprise" the animal very shortly after each presentation of the compound. Thus, animals were first conditioned, in the normal way, to suppress to the noise CS, with the usual 1 ma., .5-sec. US. Then, during the compound trials, the animal received reinforced presentations of the light-noise compound, again with a 1 ma., .5-sec. US. However, on each compound trial, five seconds following delivery of the US, an <u>extra</u> (surprising) shock (again 1 ma., .5-sec.) was delivered. When, after compound training, these subjects were tested with the light CS, they displayed a median ratio of .08! That is, the blocking effect was entirely eliminated by the delivery of an unpredicted shock shortly following reinforced presentation of the compound.

We have emphasized the close temporal relation between the unpredicted extra shock and the preceding compound CS. This emphasis is, of course, consistent with the "backward scanning" notion. There are, however, several alternative interpretations of the efficacy of the unpredicted shock in eliminating the blocking effect. There is the obvious possibility that the extra shock "combines" with the shortly preceding normal US to form, in effect, a US more intense than that employed during the prior conditioning to the noise element. We have already indicated that a radical increase of US intensity during the compound trials will eliminate the blocking effect. There is in the data, however, a strong indication that the extra shock functions in a manner quite different from that of an intense US. It is true that, if US intensity is increased from 1 ma. to 4 ma. during the compound trials, the blocking effect is eliminated; but it is also true that, if independent groups of naive rats are conditioned, with either a light, noise, or compound CS, paired with a 4 ma. US, they acquire the CER significantly more rapidly than do equivalent groups conditioned with a 1 ma. US. That is, acquisition of the CER is a clear positive function of US intensity. We have conditioned naive groups of animals, with either light or noise CS's, delivering the "extra" shock, 5 sec. after the normal US, <u>from the outset of conditioning</u>. In each case, the acquisition curve of rats conditioned with the extra shock was virtually superimposed on that of rats conditioned with the normal US. Thus, the extra shock does <u>not</u> appear to increase effective US intensity.

We have stressed the notion that the second, extra shock might cause the animal to scan the preceding sensory input, and that conditioning to the superimposed CS element occurs as a consequence of this scanning. There remains, however, the plausible alternative that the effect of the unpredicted, extra shock is to "alert" the animal in such a way that it is more "attentive" or sensitive to <u>subsequent</u> events - i.e., to the following compound trials. Thus, in this latest view, the extra shock does not increase the amount of conditioning taking place to the superimposed CS element on the first compound trial, but it <u>does</u>

increase the amount of such conditioning taking place on all subsequent compound trials. Within the experiment already performed, unfortunately, there is no way of deciding whether the extra shock facilitates conditioning to the CS which precedes it, or to the CS which follows it. We do know, from appropriate control groups, that the extra shock does not cause the animal to suppress to extraneous exteroceptive stimuli which are subsequently presented.

There should be no great experimental difficulty in "localizing" the effect of the extra shock. We can, for example, deliver the extra shock at varying temporal intervals following the compound trials to different groups. Presumably, backward scanning should be less effective in forming an association when the extra shock is remote in time from the preceding trial. This approach, however, has the disadvantage that moving the extra shock away from the preceding trial moves it toward the subsequent trial. This problem in turn might be overcome by presenting only one compound trial a day. The sensitivity of the procedure seems to be such that, employing a savings technique, we might demonstrate the facilitating effect of a single extra shock, delivered on a single compound trial, with no subsequent compound conditioning. This effect in turn might be related to the temporal interval between the compound trial and the extra shock. There is no dearth of potential experiments to be performed, and not much sense in attempting to anticipate their outcomes.

To sum up, the blocking experiment demonstrates very clearly that the mere contiguous presentation of a CS element and a US is not a sufficient condition for the establishment of a CR. The question, very simply is: what has gone wrong in the blocking experiment? What is deficient? The experiment was conceived with a primitive hunch that "attention" to the to-be-conditioned stimulus element was a necessary precondition, and many of the results to date are consistent with the notion that the deficiency is "perceptual", having to do with impeded input of the CS element. This blocked input was at first conceived as a consequence of a kind of "competition for attention" between the previously conditioned element and the new element. The results to date, however, make it clear that, if such an attentional deficit is involved, the redundancy of the new element is critical for producing it. The extra shock experiment, most recently, has suggested an alternative conception. The input of the new CS element can be regarded as intact, but the predictability of the US might strip the US of a function it normally subserves in conditioning experiments -- that of instigating some "processing" of the memory store of recent stimulus input, which results in the formation of an association. There is also the possibility, of course, that the predictability of the US, by the time compound training is begun in the blocking experiment, strips the US of the function of "alerting" the animal to <u>subsequent</u> stimulus input.

There seems little doubt that, as experimentation continues, still other conceptions will be suggested. The experimental procedures are at least capable of discarding some conceptions, and of reinforcing others. The progress to date might encourage the belief that ultimately these studies could make a real contribution toward answering the fundamental question toward which they are addressed: what are the necessary and sufficient conditions for the establishment of an association between CS and US within a Pavlovian paradigm?

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Footnote

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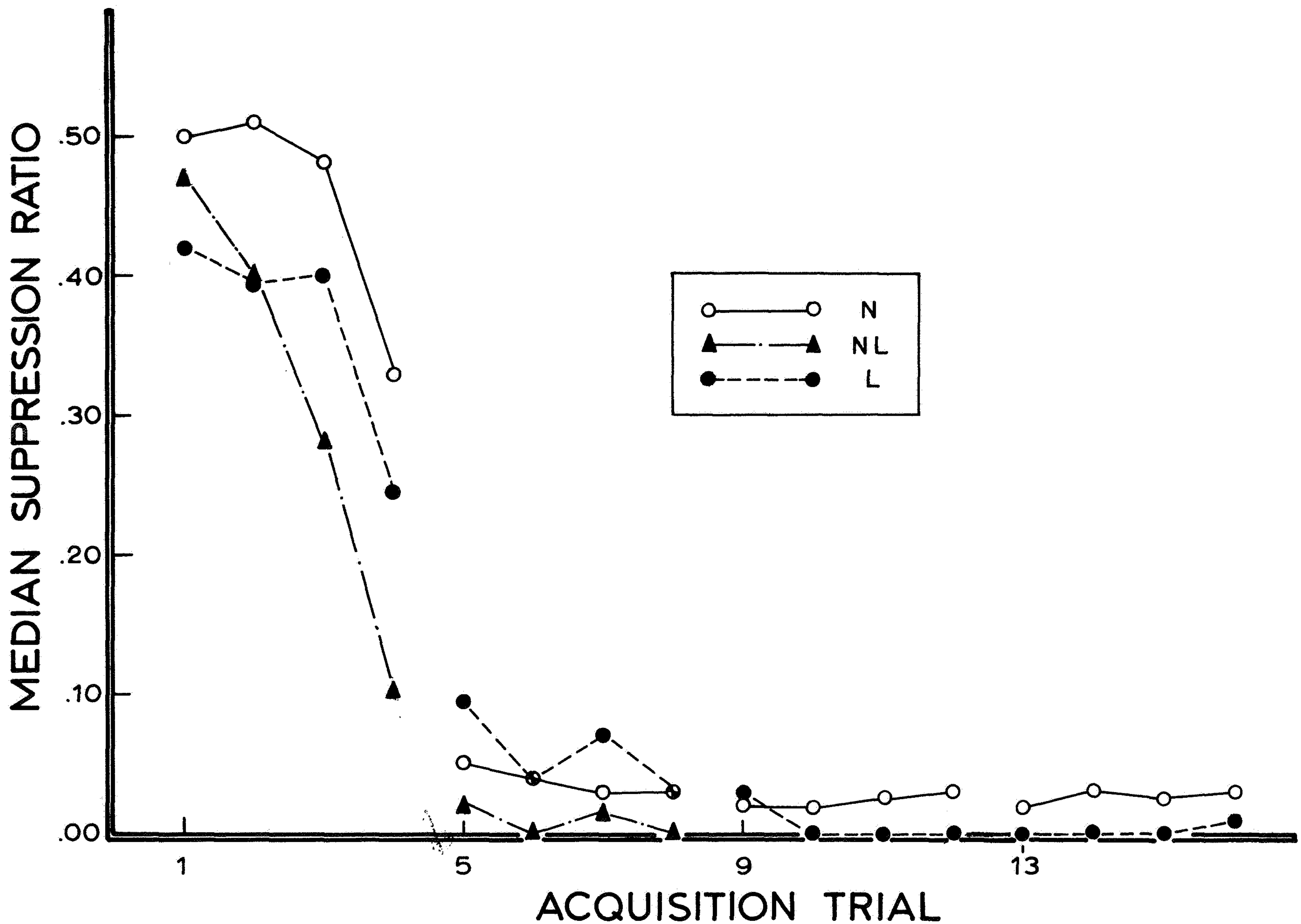
Figure Captions

Figure 1. Acquisition of CER, by trial, for three groups of rats, trained with either light, noise, or compound CS.

Figure 2. Extinction of CER, by trial, following conditioning to noise. The groups were extinguished either to noise alone, or to the compound. The arrow in the abscissa indicates point at which group extinguished to compound is switched to noise alone.

Figure 3. Acquisition of CER, by trial, for independent groups of rats trained with either 50-db noise, 80-db noise, light, or compound CS. Two upper panels are for groups trained with 1 ma. US, two lower panels for groups trained with 4 ma. US.



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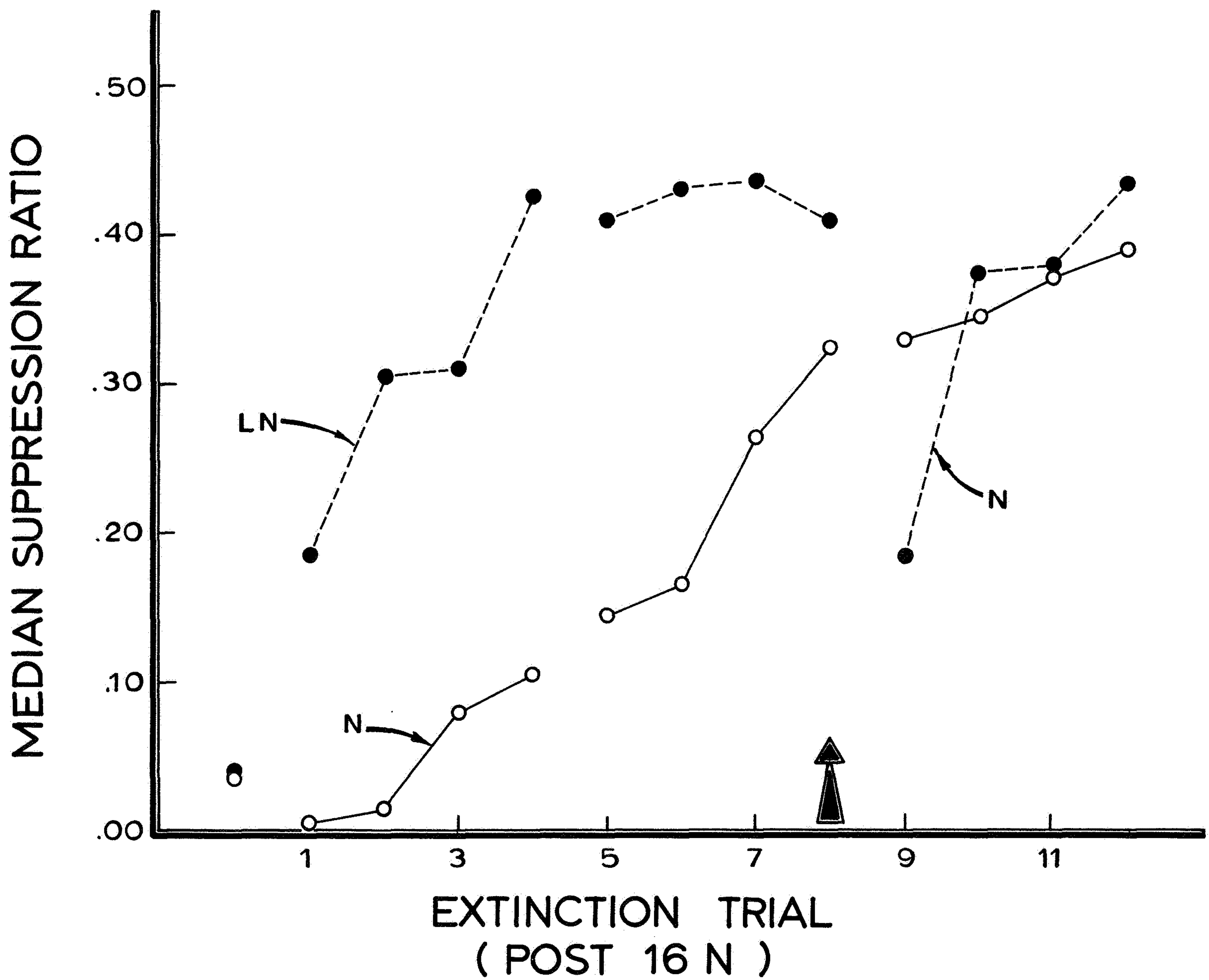
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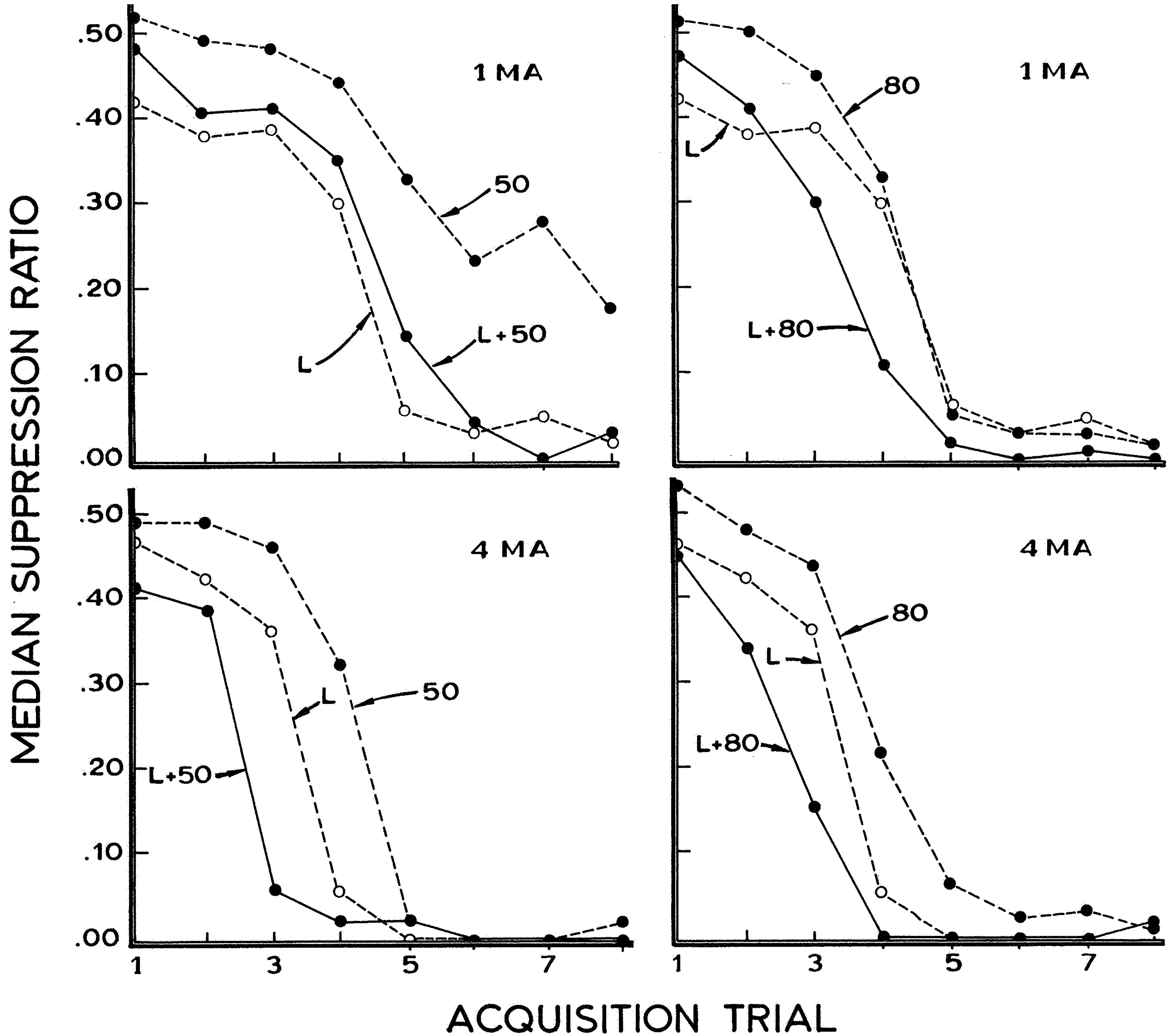
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