ple phosphorylation to oxidation. The requirement for a phospholipid for this activity may represent an intermediate step between reactions mediated by soluble enzymes and those mediated by, and dependent on, highly organized structures like the mitochondrion. Further study with the "soluble system" may provide an understanding of the mechanism of oxidative phosphorylation and of the broader question of enzyme interaction in complex structures.

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Social Facilitation

A solution is suggested for an old unresolved social psychological problem.

Robert B. Zajonc

Most textbook definitions of social psychology involve considerations about the influence of man upon man, or, more generally, of individual upon individual. And most of them, explicitly or implicity, commit the main efforts of social psychology to the problem of how and why the *behavior* of one individual affects the behavior of another. The influences of individuals on each others' behavior which are of interest to social psychologists today take on very complex forms. Often they involve vast networks of interindividual effects, such as one finds in studying the process of group decision-making, competition, or conformity to a group norm. But the fundamental forms of interindividual influence are represented by the oldest experimental paradigm of social psychology: social facilitation. This paradigm, dating back to Triplett's original experiments on pacing and competition, carried out in 1897 (1), examines the consequences upon behavior which derive from the sheer presence of other individuals.

Until the late 1930's, interest in social facilitation was quite active, but with the outbreak of World War II it suddenly died. And it is truly regrettable that it died, because the basic questions about social facilitation—its dynamics and its causes—which are in effect the basic questions of social psychology, were never solved. It is with these questions that this article is concerned. I first examine past results in this nearly completely abandoned area of research and then suggest a general hypothesis which might explain them.

Research in the area of social facilitation may be classified in terms of two experimental paradigms: audience effects and co-action effects. The first experimental paradigm involves the observation of behavior when it occurs in the presence of passive spectators. The second examines behavior when it occurs in the presence of other individuals also engaged in the same activity. We shall consider past literature in these two areas separately.

Audience Effects

Simple motor responses are particularly sensitive to social facilitation effects. In 1925 Travis (2) obtained such effects in a study in which he used the pursuit-rotor task. In this task the subject is required to follow a small revolving target by means of a stylus which he holds in his hand. If the stylus is even momentarily off target during a revolution, the revolution counts as an error. First each subject was trained for several consecutive days until his performance reached a stable level. One day after the conclusion of the training the subject was called to the laboratory, given five trials alone, and then ten trials in the presence of from four to eight upperclassmen and graduate students. They had been asked by the experimenter to watch the subject quietly and attentively. Travis found a clear improvement in performance when his subjects were confronted with an audience. Their accuracy on the ten trials before an au-

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dience was greater than on any ten previous trials, including those on which they had scored highest.

A considerably greater improvement in performance was recently obtained in a somewhat different setting and on a different task (*3*). Each subject (all were National Guard trainees) was placed in a separate booth. He was seated in front of a panel outfitted with 20 red lamps in a circle. The lamps on this panel light in a clockwise sequence at 12 revolutions per minute. At random intervals one or another light fails to go on in its proper sequence. On the average there are 24 such failures per hour. The subject's task is to signal whenever a light fails to go on. After 20 minutes of intensive training, followed by a short rest, the National Guard trainees monitored the light panels for 135 minutes. Subjects in one group performed their task alone. Subjects in another group were told that from time to time a lieutenant colonel or a master sergeant would visit them in the booth to observe their performance. These visits actually took place about four times during the experimental session. There was no doubt about the results. The accuracy of the supervised subjects was on the average 34 percent higher than the accuracy of the trainees working in isolation, and toward the end of the experimental session the accuracy of the supervised subjects was more than twice as high as that of the subjects working in isolation. Those expecting to be visited by a superior missed, during the last experimental period, 20 percent of the light failures, while those expecting no such visits missed 64 percent of the failures.

Dashiell, who, in the early 1930's, carried out an extensive program of research on social facilitation, also found considerable improvement in performance due to audience effects on such tasks as simple multiplication or word association (*4*). But, as is the case in many other areas, negative audience effects were also found. In 1933 Pessin asked college students to learn lists of nonsense syllables under two conditions, alone and in the presence of several spectators (*5*). When confronted with an audience, his subjects required an average of 11.27 trials to learn a seven-item list. When working alone they needed only 9.85 trials. The average number of errors made in the "audience" condition was considerably higher than the number in the "alone" condition. In 1931 Husband found that the presence of spectators interferes with the learning of a finger maze (*6*), and in 1933 Pessin and Husband (*7*) confirmed Husband's results. The number of trials which the isolated subjects required for learning the finger maze was 17.1. Subjects confronted with spectators, however, required 19.1 trials. The average number of errors for the isolated subjects was 33.7; the number for those working in the presence of an audience was 40.5.

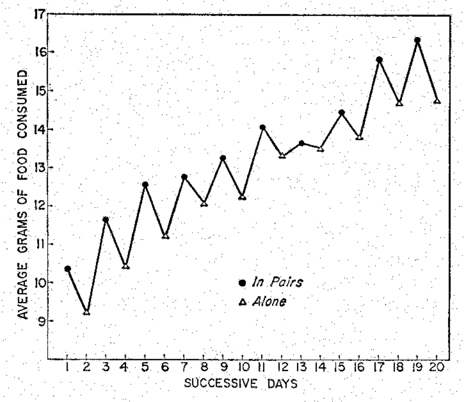

Fig. 1. Data on feeding of isolated and paired rats. [Harlow (*11*)]

The results thus far reviewed seem to contradict one another. On a pursuit-rotor task Travis found that the presence of an audience improves performance. The learning of nonsense syllables and maze learning, however, seem to be inhibited by the presence of an audience, as shown by Pessin's experiment. The picture is further complicated by the fact that when Pessin's subjects were asked, several days later, to recall the nonsense syllables they had learned, a reversal was found. The subjects who tried to recall the lists in the presence of spectators did considerably better than those who tried to recall them alone. Why are the learning of nonsense syllables and maze learning inhibited by the presence of spectators? And why, on the other hand, does performance on a pursuit-rotor, word-association, multiplication, or a vigilance task improve in the presence of others?

There is just one, rather subtle, consistency in the above results. It would appear that the emission of well-learned responses is facilitated by the presence of spectators, while the acquisition of new responses is impaired. To put the statement in conventional psychological language, performance is facilitated and learning is impaired by the presence of spectators.

This tentative generalization can be reformulated so that different features of the problem are placed into focus. During the early stages of learning, especially of the type involved in social facilitation studies, the subject's responses are mostly the wrong ones. A person learning a finger maze, or a person learning a list of nonsense syllables, emits more wrong responses than right ones in the early stages of training. Most learning experiments continue until he ceases to make mistakes—until his performance is perfect. It may be said, therefore, that during training it is primarily the wrong responses which are dominant and strong; they are the ones which have the highest probability of occurrence. But after the individual has mastered the task, correct responses necessarily gain ascendency in his task-relevant behavioral repertoire. Now they are the ones which are more probable—in other words, dominant. Our tentative generalization may now be simplified: audience enhances the emission of dominant responses. If the dominant responses are the correct ones, as is the case upon achieving mastery, the presence of an audience will be of benefit to the individual. But if they are mostly wrong, as is the case in the early stages of learning, then these wrong responses will be enhanced in the presence of an audience, and the emission of correct responses will be postponed or prevented.

There is a class of psychological processes which are known to enhance the emission of dominant responses. They are subsumed under the concepts of drive, arousal, and activation (*8*). If we could show that the presence of an audience has arousal consequences for the subject, we would be a step further along in trying to arrange the results of social-facilitation experiments into a neater package. But let us first consider another set of experimental findings.

Co-action Effects

The experimental paradigm of co-action is somewhat more complex than the paradigm involved in the study of audience effects. Here we observe individuals all simultaneously engaged in the same activity and in full view of each other. One of the clearest effects of such simultaneous action, or co-action, is found in eating behavior. It is well known that animals simply eat

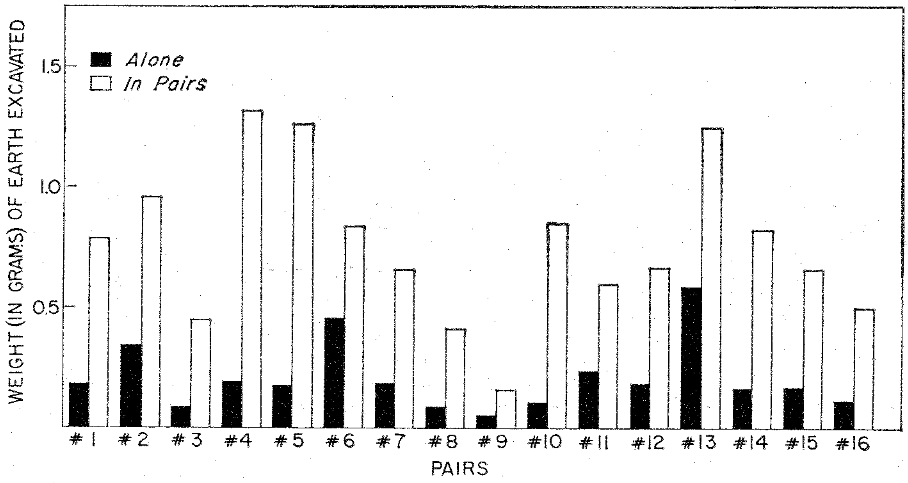

Fig. 2. Data on nest-building behavior of isolated and paired ants. [Chen (*13*)]

more in the presence of others. For instance, Bayer had chickens eat from a pile of wheat to their full satisfaction (*9*). He waited some time to be absolutely sure that his subject would eat no more, and then brought in a companion chicken who had not eaten for 24 hours. Upon the introduction of the hungry co-actor, the apparently sated chicken ate two-thirds again as much grain as it had already eaten. Recent work by Tolman and Wilson fully substantiates these results (*10*). In an extensive study of social-facilitation effects among albino rats, Harlow found dramatic increases in eating (*11*). In one of his experiments, for instance, the rats, shortly after weaning, were matched in pairs for weight. They were then fed alone and in pairs on alternate days. Figure 1 shows his results. It is clear that considerably more food was consumed by the animals when they were in pairs than when they were fed alone. James (*12*), too, found very clear evidence of increased eating among puppies fed in groups.

Perhaps the most dramatic effect of co-action is reported by Chen (*13*). Chen observed groups of ants working alone, in groups of two, and in groups of three. Each ant was observed under various conditions. In the first experimental session each ant was placed in a bottle half filled with sandy soil. The ant was observed for 6 hours. The time at which nest-building began was noted, and the earth excavated by the insect was carefully weighed. Two days afterward the same ants were placed in freshly filled bottles in pairs, and the same observations were made. A few days later the ants were placed in the bottles in groups of three, again for 6 hours. Finally, a few days after the test in groups of three, nest-building of the ants in isolation was observed. Figure 2 shows some of Chen's data.

There is absolutely no question that the amount of work an ant accomplishes increases markedly in the presence of another ant. In all pairs except one, the presence of a companion increased output by a factor of at least 2. The effect of co-action on the latency of the nest-building behavior was equally dramatic. The solitary ants of session 1 and the final session began working on the nest in 192 minutes, on the average. The latency period for ants in groups of two was only 28 minutes. The effects observed by Chen were limited to the immediate situation and seemed to have no lasting consequences for the ants. There were no differences in the results of session 1, during which the ants worked in isolation, and of the last experimental session, where they again worked in solitude.

If one assumes that under the conditions of Chen's experiment nest-building *is* the dominant response, then there is no reason why his findings could not be embraced by the generalization just proposed. Nest-building is a response which Chen's ants have fully mastered. Certainly, it is something that a mature ant need not learn. And this is simply an instance where the generalization that the presence of others enhances the emission of dominant and well-developed responses holds.

If the process involved in audience effects is also involved in co-action effects, then learning should be inhibited in the presence of other learners. Let us examine some literature in this field. Klopfer (*14*) observed greenfinches—in isolation and in heterosexual pairs—which were learning to discriminate between sources of palatable and of unpalatable food. And, as one would by now expect, his birds learned this discrimination task considerably more efficiently when working alone. I hasten to add that the subjects' sexual interests cannot be held responsible for the inhibition of learning in the paired birds. Allee and Masure, using Australian parakeets, obtained the same result for homosexual pairs as well (*15*). The speed of learning was considerably greater for the isolated birds than for the paired birds, regardless of whether the birds were of the same sex or of the opposite sex.

Similar results are found with cockroaches. Gates and Allee (*16*) compared data for cockroaches learning a maze in isolation, in groups of two, and in groups of three. They used an E-shaped maze. Its three runways, made of galvanized sheet metal, were suspended in a pan of water. At the end of the center runway was a dark bottle into which the photophobic cockroaches could escape from the noxious light. The results, in terms of time required to reach the bottle, are shown in Fig. 3. It is clear from the data that the solitary cockroaches required considerably less time to learn the maze than the grouped animals. Gates and Allee believe that the group situation produced inhibition. They add, however (*16*, p. 357): "The nature of these inhibiting forces is speculative, but the fact of some sort of group interference is obvious. The presence of other roaches did not operate to change greatly the movements to different parts of the maze, but did result in increased time per trial. The roaches tended to go to the corner or end of the runway and remain there a longer time when another roach was present than when alone; the other roach was a distracting stimulus."

The experiments on social facilitation performed by Floyd Allport in 1920 and continued by Dashiell in 1930 (*4*, *17*), both of whom used human subjects, are the ones best known. Allport's subjects worked either in separate cubicles or sitting around a common table. When working in isolation they did the various tasks at the same time and were monitored by common time signals. Allport did everything possible to reduce the tendency to compete. The subjects were told that the results of their tests would not be compared and would not be shown to other staff members, and that they themselves should refrain from making any such comparisons.

Among the tasks used were the following: chain word association, vowel cancellation, reversible perspective, multiplication, problem solving, and judgments of odors and weights. The results of Allport's experiments are well known: in all but the problem-solving and judgments test, performance was better in groups than in the "alone" condition. How do these results fit our generalization? Word association, multiplication, the cancellation of vowels, and the reversal of the perceived orientation of an ambiguous figure all involve responses which are well established. They are responses which are either very well learned or under a very strong influence of the stimulus, as in the word-association task or the reversible-perspective test. The problem-solving test consists of disproving arguments of ancient philosophers. In contrast to the other tests, it does not involve well-learned responses. On the contrary, the probability of wrong (that is, logically incorrect) responses on tasks of this sort is rather high; in other words, wrong responses are dominant. Of interest, however, is the finding that while intellectual work suffered in the group situation, sheer output of words was increased. When working together, Allport's subjects tended consistently to write more. Therefore, the generalization proposed in the previous section can again be applied: if the presence of others raises the probability of dominant responses, and if strong (and many) incorrect response tendencies prevail, then the presence of others can only be detrimental to performance. The results of the judgment tests have little bearing on the present argument, since Allport gives no accuracy figures for evaluating performance. The data reported only show that the presence of others was associated with the avoidance of extreme judgments.

In 1928 Travis (*18*), whose work on the pursuit rotor I have already noted, repeated Allport's chain-word-association experiment. In contrast to Allport's results, Travis found that the presence of others decreased performance. The number of associations given by his subjects was greater when they worked in isolation. It is very significant, however, that Travis used stutterers as his subjects. In a way, stuttering is a manifestation of a struggle between conflicting response tendencies, all of which are strong and all of which compete for expression. The stutterer, momentarily hung up in the middle of a sentence, waits for the correct response to reach full ascendancy. He stammers because other competing tendencies are dominant at that moment. It is reasonable to assume that, to the extent that the verbal habits of a stutterer are characterized by conflicting response tendencies, the presence of others, by enhancing each of these response tendencies, simply heightens his conflict. Performance is thus impaired.

Avoidance Learning

In two experiments on the learning of avoidance responses the performances of solitary and grouped subjects were compared. In one, rats were used; in the other, humans.

Let us first consider the results of the rat experiment, by Rasmussen (*19*). A number of albino rats, all litter mates, were deprived of water for 48 hours. The apparatus consisted of a box containing a dish of drinking water. The floor of the box was made of a metal grille wired to one pole of an electric circuit. A wire inserted in the water in the dish was connected to the other pole of the circuit. Thirsty rats were placed in the box alone and in groups of three. They were allowed to drink for 5 seconds with the circuit open. Following this period the shock circuit remained closed, and each time the rat touched the water he received a painful shock. Observations were made on the number of times the rats approached the water dish. The results of this experiment showed that the solitary rats learned to avoid the dish considerably sooner than the grouped animals did. The rats that were in groups of three attempted to drink twice as often as the solitary rats did, and suffered considerably more shock than the solitary subjects.

Let us examine Rasmussen's results somewhat more closely. For purposes of analysis let us assume that there are just two critical responses involved: drinking, and avoidance of contact with the water. They are clearly incompatible. But drinking, we may further assume, is the dominant response, and, like eating or any other dominant response, it is enhanced by the presence of others. The animal is therefore prevented, by the facilitation of drinking which derives from the presence of others, from acquiring the appropriate avoidance response.

The second of the two studies is quite recent and was carried out by Ader and Tatum (*20*). They devised the following situation with which they confronted their subjects, all medical students. Each subject is told on arrival that he will be taken to another room and seated in a chair, and that electrodes will be attached to his leg. He is instructed not to get up from the chair and not to touch the electrodes. He is also told not to smoke or vocalize, and is told that the experimenter will be in the next room. That is all he is told. The subjects are observed either alone or in pairs. In the former case the subject is brought to the room and seated at a table equipped with a red button which is connected to an electric circuit. Electrodes, by means of which electric shock can be administered, are attached to the calf of one leg. After the electrodes are attached, the experimenter leaves the room. From now on the subject will receive ½ second of electric shock every 10 seconds unless he presses the red button. Each press of the button delays the shock by 10 seconds. Thus, if he is to avoid shock, he must press the button at least once every 10 seconds. It should be noted that no information was given him about the function of the button, or about the purpose of the experiment. No essential differences are introduced when subjects are brought to the room in pairs. Both are seated at the table and both become part of the shock circuit. The response of either subject delays the shock for both.

The avoidance response is considered to have been acquired when the subject (or pair of subjects) receives less than six shocks in a period of 5 minutes. Ader and Tatum report that the isolated students required, on the average, 11 minutes, 35 seconds to reach this criterion of learning. Of the 12 pairs which participated in the experiment, only two reached this criterion. One of them required 46 minutes, 40 seconds; the other, 68 minutes, 40 seconds! Ader and Tatum offer no explanation for their curious results. But there is no reason why we should not treat them in terms of the generalization proposed above. We are dealing here with a learning task, and the fact that the subjects are learning to avoid shock by pressing a red button does not introduce particular problems. They are confronted with an ambiguous task, and told nothing about the button. Pressing the button is simply not the dominant response in this situation. However, escaping is. Ader and Tatum report that eight of the 36 subjects walked out in the middle of the experiment.

One aspect of Ader and Tatum's results is especially worth noting. Once having learned the appropriate avoidance response, the individual subjects responded at considerably lower rates than the paired subjects. When we consider only those subjects who achieved the learning criterion and only those responses which occurred *after* criterion had been reached, we find that the response rates of the individual subjects were in all but one case lower than the response rates of the grouped subjects. This result further confirms the generalization that, while learning is impaired by the presence of others, the performance of learned responses is enhanced.

There are experiments which show that learning is enhanced by the presence of other learners (*21*), but in all these experiments, as far as I can tell, it was possible for the subject to *observe* the critical responses of other subjects, and to determine when he was correct and when incorrect. In none, therefore, has the co-action paradigm been employed in its pure form. That paradigm involves the presence of others, and nothing else. It requires that these others not be able to provide the subject with cues or information as to appropriate behavior. If other learners can supply the critical individual with such cues, we are dealing not with the problem of co-action but with the problem of imitation or vicarious learning.

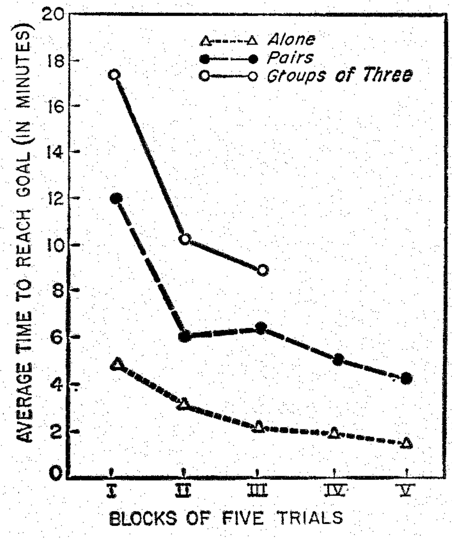

Fig. 3. Data on maze learning in isolated and grouped cockroaches. [Gates and Allee (*16*)]

The Presence of Others as a Source of Arousal

The results I have discussed thus far lead to one generalization and to one hypothesis. The generalization which organizes these results is that the presence of others, as spectators or as coactors, enhances the emission of dominant responses. We also know from extensive research literature that arousal, activation, or drive all have as a consequence the enhancement of dominant responses (*22*). We now need to examine the hypothesis that the presence of others increases the individual's general arousal or drive level.

The evidence which bears on the relationship between the presence of others and arousal is, unfortunately, only indirect. But there is some very suggestive evidence in one area of research. One of the more reliable indicators of arousal and drive is the activity of the endocrine systems in general, and of the adrenal cortex in particular. Adrenocortical functions are extremely sensitive to changes in emotional arousal, and it has been known for some time that organisms subjected to prolonged stress are likely to manifest substantial adrenocortical hypertrophy (*23*). Recent work (*24*) has shown that the main biochemical component of the adrenocortical output is hydrocortisone (17-hydroxycorticosterone). Psychiatric patients characterized by anxiety states, for instance, show elevated plasma levels of hydrocortisone (*25*). Mason, Brady, and Sidman (*26*) have recently trained monkeys to press a lever for food and have given these animals unavoidable electric shocks, all preceded by warning signals. This procedure led to elevated hydrocortisone levels; the levels returned to normal within 1 hour after the end of the experimental session. This "anxiety" reaction can apparently be attenuated if the animal is given repeated doses of reserpine 1 day before the experimental session (*27*). Sidman's conditioned avoidance schedule also results in raising the hydrocortisone levels by a factor of 2 to 4 (*26*). In this schedule the animal receives an electric shock every 20 seconds without warning, unless he presses a lever. Each press delays the shock for 20 seconds.

Table 1. Basal plasma concentrations of 17-hydroxycorticosterone in monkeys housed alone (cages in separate rooms), then in a room with other monkeys (cages in same room). [Leiderman and Shapiro (*35*, p. 7)]

Subject	Time	Conc. of 17-hydroxycorticosterone in caged monkeys (μg per 100 ml of plasma)	
		In separate rooms	In same room
M-1	9 a.m.	23	34
M-1	3 p.m.	16	27
M-2	9 a.m.	28	34
M-2	3 p.m.	19	23
M-3	9 a.m.	32	38
M-3	3 p.m.	23	31
Mean	9 a.m.	28	35
Mean	3 p.m.	19	27

While there is a fair amount of evidence that adrenocortical activity is a reliable symptom of arousal, similar endocrine manifestations were found to be associated with increased population density (*28*). Crowded mice, for instance, show increased amphetamine toxicity—that is, susceptibility to the excitatory effects of amphetamine—against which they can be protected by the administration of phenobarbital, chlorpromazine, or reserpine (*29*). Mason and Brady (*30*) have recently reported that monkeys caged together had considerably higher plasma levels of hydrocortisone than monkeys housed in individual cages. Thiessen (*31*) found increases in adrenal weights in mice housed in groups of 10 and 20 as compared with mice housed alone. The mere presence of other animals in the same room, but in separate cages, was also found to produce elevated levels of hydrocortisone. Table 1, taken from a report by Mason and Brady (*30*), shows plasma levels of hydrocortisone for three animals which lived at one time in cages that afforded them the possibility of visual and tactile contact and, at another time, in separate rooms.

Mason and Brady also report urinary levels of hydrocortisone, by days

Table 2. Variations in urinary concentration of hydrocortisone over a 9-day period for five laboratory monkeys and one human hospital patient. [Leiderman and Shapiro (*35*, p. 8)]

Subjects	Amounts excreted (mg/24 hr)								
	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.	Mon.	Tues.
Monkeys	1.88	1.71	1.60	1.52	1.70	1.16	1.17	1.88	
Patient		5.9	6.5	4.5	5.7	3.3	3.9	6.0	5.2

of the week, for five monkeys from their laboratory and for one human hospital patient. These very suggestive figures are reproduced in Table 2 (*30*). In the monkeys, the low weekend traffic and activity in the laboratory seem to be associated with a clear decrease in hydrocortisone. As for the hospital patient, Mason and Brady report (*30*, p. 8), "he was confined to a thoracic surgery ward that bustled with activity during the weekdays when surgery and admissions occurred. On the weekends the patient retired to the nearby Red Cross building, with its quieter and more pleasant environment."

Admittedly, the evidence that the mere presence of others raises the arousal level is indirect and scanty. And, as a matter of fact, some work seems to suggest that there are conditions, such as stress, under which the presence of others may lower the animal's arousal level. Bovard (*32*), for instance, hypothesized that the presence of another member of the same species may protect the individual under stress by inhibiting the activity of the posterior hypothalamic centers which trigger the pituitary adrenal cortical and sympathetico-adrenal medullary responses to stress. Evidence for Bovard's hypothesis, however, is as indirect as evidence for the one which predicts arousal as a consequence of the presence of others, and even more scanty.

Summary and Conclusion

If one were to draw one practical suggestion from the review of the social-facilitation effects which are summarized in this article he would advise the student to study all alone, preferably in an isolated cubicle, and to arrange to take his examinations in the company of many other students, on stage, and in the presence of a large audience. The results of his examination would be beyond his wildest expectations, provided, of course, he had learned his material quite thoroughly.

I have tried in this article to pull together the early, almost forgotten work on social facilitation, and to explain the seemingly conflicting results. This explanation is, of course, tentative, and it has never been put to a direct experimental test. It is, moreover, not far removed from the one originally proposed by Allport. He theorized (*33*, p. 261) that "the sights and sounds of others doing the same thing" augment ongoing responses. Allport, however, proposed this effect only for *overt* motor responses, assuming (*33*, p. 274) that "*intellectual* or *implicit responses* of thought are hampered rather than facilitated" by the presence of others. This latter conclusion was probably suggested to him by the negative results he observed in his research on the effects of co-action on problem solving.

Needless to say, the presence of others may have effects considerably more complex than that of increasing the individual's arousal level. The presence of others may provide cues as to appropriate or inappropriate responses, as in the case of imitation or vicarious learning. Or it may supply the individual with cues as to the measure of danger in an ambiguous or stressful situation. Davitz and Mason (*34*), for instance, have shown that the presence of an unafraid rat reduces the fear of another rat in stress. Bovard (*32*) believes that the calming of the rat in stress which is in the presence of an unafraid companion is mediated by inhibition of activity of the posterior hypothalamus. But in their experimental situations (that is, the open field test) the possibility that cues for appropriate escape or avoidance responses are provided by the co-actor is not ruled out. We might therefore be dealing not with the effects of the mere presence of others but with the considerably more complex case of imitation. The animal may not be calming *because* of his companion's presence. He may be calming *after* having copied his companion's attempted escape responses. The paradigm which I have examined in this article pertains only to the effects of the mere presence of others, and to the consequences for the arousal level. The exact parameters involved in social facilitation still must be specified.

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