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Replicating Roaches: A Preregistered Direct Replication of Zajonc, Heingartner, and Herman's (1969) Social-Facilitation Study

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Abstract

Fifty years ago, Zajonc, Heingartner, and Herman (1969) conducted a famous experiment on social enhancement and inhibition of performance in cockroaches. A moderating effect of task difficulty on the effect of the presence of an audience, as revealed by impaired performance in complex tasks and enhanced performance in simple tasks, was presented as the major conclusion of this research. However, the researchers did not test this interaction statistically. We conducted a preregistered direct replication using a 2 (audience: present vs. absent) × 2 (task difficulty: runway vs. maze) between-subjects design. Results revealed main effects for task difficulty, with faster running times in the runway than the maze, and for audience, with slower running times when the audience was present than when it was absent. There was no interaction between the presence of an audience and task difficulty. Although we replicated the social-inhibition effect, there was no evidence for a social-facilitation effect.

Keywords

social facilitation, social inhibition, Zajonc, replication, cockroach, open data, open materials, preregistered

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Social facilitation could be regarded as one of the oldest topics in academic social psychology; Norman Triplett (1898) was the first to systematically test this phenomenon. Today, social-facilitation and social-inhibition effects are well-established phenomena in social psychology (for reviews, see Bond & Titus, 1983; Geen & Gange, 1977; Guerin, 1993; Seitchik, Brown, & Harkins, 2017). Allport (1924) defined social facilitation as the enhancement of individual performance depending on the presence of other individuals, and this effect has been found in animals (e.g., Allee, 1938) as well as in humans (e.g., Dashiell, 1930; Travis, 1925). However, seemingly conflicting evidence of social inhibition in humans (e.g., Husband, 1931; Pessin, 1933; Pessin & Husband, 1933) as well as in different animal species (e.g., Gates & Allee, 1933; Klopfer, 1958), led Robert Zajonc (1965) to the conclusion that the effect of the presence of other individuals on performance critically depends on an interaction with specific task characteristics. This moderation effect was specified in Zajonc's drive theory (see also Baron, 1986), which built on and extended Hull's (1943) theory of learning and the Hull-Spence drive theory (Hull, 1943; Spence, 1956).

Zajonc's (1965) drive theory emphasizes that behavior is a multiplicative function of habit strength and drive, $E = f(H \times D)$, where E represents the excitatory potential toward a behavior (i.e., performance), H represents habit strength, and D represents generalized drive. Zajonc's theory indicates that the effect of the presence of other individuals should increase drive. The effect of drive on performance, however, should critically depend on the nature of the task—that is, whether the response has already been acquired (e.g., a simple running response) or still needs to be learned (e.g., a choice response). According to Zajonc's theory, increased drive resulting from the presence of conspecifics should facilitate the already learned response,

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thereby improving performance in simple tasks, but should interfere with the acquisition of a to-be-learned task, thereby impairing performance in complex tasks. Zajonc reviewed evidence from studies on performance that were consistent with this theory. Also, a meta-analysis of 241 studies (Bond & Titus, 1983) found a small facilitation effect in simple tasks ($d = 0.32$) and a small inhibition effect in complex tasks ($d = -0.20$), supporting the proposed moderating effect in humans. The presence of other individuals explained between 0.3% and 3% of the variance in performance. Drive is not the only mechanism that has been proposed to underlie social facilitation and inhibition. Alternatively, distraction-conflict theory (Sanders & Baron, 1975), self-awareness (Duval & Wicklund, 1972), or learned drive (Cottrell, 1972) have been suggested as potential mechanisms.

Fifty years ago, Zajonc, Heingartner, and Herman (1969) conducted a famous experiment on social enhancement and inhibition of performance in cockroaches. Theirs was the first study to test the postulated interaction between task difficulty and audience presence using experimental manipulations of both factors. This study is now a classic in experimental psychology and has been highly cited in textbooks, major reviews, influential articles, and online encyclopedias in diverse fields of psychology (e.g., Amabile, 1983; Aronson, Wilson, Akert, & Sommers 2018; Baron & Kerr, 2003; Baumeister, 1982; Blascovich, Mendes, Hunter, & Salomon, 1999; Haslam, 2004; Kassin, Fein, & Markus, 2014; Myers & DeWall, 2015; Petri & Govern, 2012). The major conclusion presented by Zajonc et al. was that, as they predicted, task difficulty moderated the effect of an audience, that is, it led to social facilitation in simple tasks and led to social inhibition in complex tasks.

Zajonc et al. (1969; Experiment 1) analyzed the effects of 72 cockroaches running alone, in coaction, or in the presence of an audience through either a simple runway or a more complex maze. Zajonc et al. reported a significant interaction between conditions and task ($p < .01$), seemingly in line with the prediction derived from drive theory. Yet coaction and audience conditions were pooled together into a social condition and contrasted against the alone condition. Surprisingly, no statistical tests of the often-cited interaction between the mere presence of an audience and task difficulty were reported—and cannot be calculated from the reported data. Looking at the descriptive statistics, one can see that the running times are in line with the predictions (alone–simple: average $Mdn = 62.65$ s, audience–simple: average $Mdn = 39.30$ s, alone–complex: average $Mdn = 221.35$ s, audience–complex: average $Mdn = 296.64$ s), but we cannot know whether the proposed Audience × Task Difficulty interaction did reach statistical significance. Moreover, the study is very likely to have been underpowered (with $N = 40$ for the critical 2 × 2 between-subjects interaction).

Zajonc's impact on social-facilitation research is undeniable, and his famous cockroach study is part of the collective memory of psychologists worldwide and has inspired subsequent social-facilitation research. Given the enormous impact of this seminal study, we were puzzled to see that the central conclusion, which has fueled large amounts of subsequent empirical work, was not backed by statistical evidence. Therefore, we conducted a preregistered, well-powered direct replication to finally provide a test of the critical Audience × Task Difficulty interaction.

Method

A detailed description of the procedure, as well as the exact construction plan of the apparatus, can be found in the original article by Zajonc et al. (1969, Experiment 1). We precisely rebuilt the apparatus and followed the original procedure as closely as possible. All deviations from original procedures will be mentioned in the following. We adjusted the width of the runways and boxes (but not the length of the acrylic glass cube) because the cockroaches we used (*Blaberus craniifer*) are slightly larger than the ones in the original study (*Blatta orientalis*). As are most cockroaches, including *Blatta orientalis, Blaberus craniifer* are active at night and are sensitive to light exposure and pheromonal communication (Bell, Roth, & Nalepa, 2007; Wobus, 1966). This is important because the experimental procedure depends on light exposure, and the social-facilitation and social-inhibition effects might depend on pheromonal communication. Photophobia was crucial because the starting box was illuminated with a floodlight to make the cockroach start running. Pheromonal communication might have been important condition for the social-facilitation and social-inhibition effects to emerge, as the runway and maze were connected to the audience boxes with little air holes. We selected *Blaberus craniifer* because this type of cockroach shows these critical behavioral tendencies.

The use of a different type of cockroach could be considered a limitation of our study. Nonetheless, we decided to use *Blaberus craniifer* because the *Blatta orientalis* tested by Zajonc et al. (1969) are no longer used in research in Germany (where the study was conducted). The phenomenon of social facilitation and inhibition has been observed in diverse species (e.g., Allee, 1938; Hosey, Wood, Thompson, & Druck, 1985; Klopfer, 1958), including humans (see Bond & Titus, 1983), and thus generalizes across species, so we were confident that it would also generalize within the same species. Also note that social effects on performance in cockroaches have been observed in different types of cockroaches (e.g., *Periplaneta americana*; Gates & Allee, 1933). The preregistration for this study, construction plans for and photos of the apparatus, and videos showing the experimental procedure can be found on the Open Science Framework (preregistration: https://osf.io/h8mxu; data and materials: https://osf.io/c7t6k).

Unfortunately, we were not able to estimate effect sizes for power calculations given the data presented by Zajonc et al. (1969; they did not report effect sizes, *SD*s, *SE*s, *F* values for the critical interaction, or post hoc contrasts, but they did report means). Zajonc et al. used 10 cockroaches in each of the four conditions of the critical 2 (audience: present vs. absent) × 2 (task difficulty: runway vs. maze) between-subjects design, with each cockroach running 10 trials (in order to reduce outliers in the data).

We decided to triple the sample size of the original study (resulting in a total sample of 120), allowing us to detect medium-sized effects (f = .25), with an α of .05 and a power of .8. Subjects were selected from one discrete colony of death's head cockroaches. All roaches were reared in a contained zoological research facility with constant professional care and conditions, where all experimental procedures also took place. They were maintained in a room with constant light (12-hr light/dark cycle) and temperature (23° C). As in the original study, only female adult cockroaches were selected as subjects, and they were chosen by trained zookeepers. At least 1 week prior to the testing (average = 11 days), all test subjects were housed in individual opaque boxes in the same room. During individual housing, the cockroaches were exclusively fed a diet of peeled apples. The cockroaches were randomly assigned to the conditions of a 2 (audience: present vs. absent) × 2 (task difficulty: runway vs. maze) between-subject design. Additionally, a group of 40 cockroaches served as an audience. All roaches had to complete a task by running from a starting box through a straight runway (simple task) or a maze (complex task) into a goal box. The maze was a runway with a junction (see https://osf.io/c7t6k for plans of the maze). Subjects performed the tasks either in the presence of 40 cockroaches, equally separated into four boxes, or alone. The boxes were placed inside an acrylic glass cube with sides directly contiguous with the walls of the runways and aligning air holes allowing the transmission of olfactory cues.

Because it was impossible to make the experimenters blind to the conditions, we asked them to follow a detailed behavioral and measurement protocol to avoid the unlikely possibility of experimenter or demand effects. At the beginning of each trial, a roach was put into the starting box, and an opaque cover was placed over the box. A floodlight (150 W) was located behind the starting box, and the experimental room was dark. Each trial began with an experimenter removing the cover, turning on the floodlight that was in line with the runway or the maze, and opening the door separating the starting box from the runway or maze. Black pasteboard covered the entire wall that held the goal box—as well as the box itself—to ensure that the roach was attracted to the goal box. The running time ended when the roach entered the goal box. The gate closed behind the roach, and all acrylic glass parts were swabbed with a water-based cleaning agent to remove olfactory cues. The roach was then given a 2-min break between trials within the darkened goal box.

As our dependent variable, we measured the running times each subject needed to finish the task. Measurement started when the roach left the starting box and ended when the roach entered the goal box completely. We also measured the starting latency, which is the time the roach needed to leave the starting box after the door separating the starting box from the runway or maze was opened. If a subject did not leave the starting box within 5 min, the trial was aborted and restarted. We analyzed running times only from subjects that completed at least two trials successfully. We had to abandon the preregistered goal of eight successful trials (see https://osf.io/h8mxu) because of a substantial level of poor performance. A total of 17 roaches had to be excluded because they failed to meet the minimum inclusion criteria of two successful trials. There is no information in Zajonc et al.'s (1969) original article regarding how many trials were completed and how many cockroaches were excluded from the analyses.

Results

Data collection continued until the target sample size of 120 subjects with at least two successful trials was obtained. The median running time for each cockroach over all successful trials served as the dependent variable. Plots of the descriptive statistics can be found in Figure 1. Both main effects—task difficulty and the presence of an audience—were significant, and Bayes factors comparing the null and alternative hypotheses (BF_{10}s) indicated strong evidence in favor of rejecting the null hypothesis (Ly et al., 2019).

In line with the descriptive data provided by Zajonc et al. (1969), our data showed that cockroaches needed more time to complete the maze (M = 137.48 s, SD = 121.88), compared with the easier runway (M = 77.00 s, SD = 76.16), $F(1, 116) = 15.45$, $p < .001$, $\eta_p^2 = .12$, BF_{10} = 20.79. Moreover, in the audience-present condition,

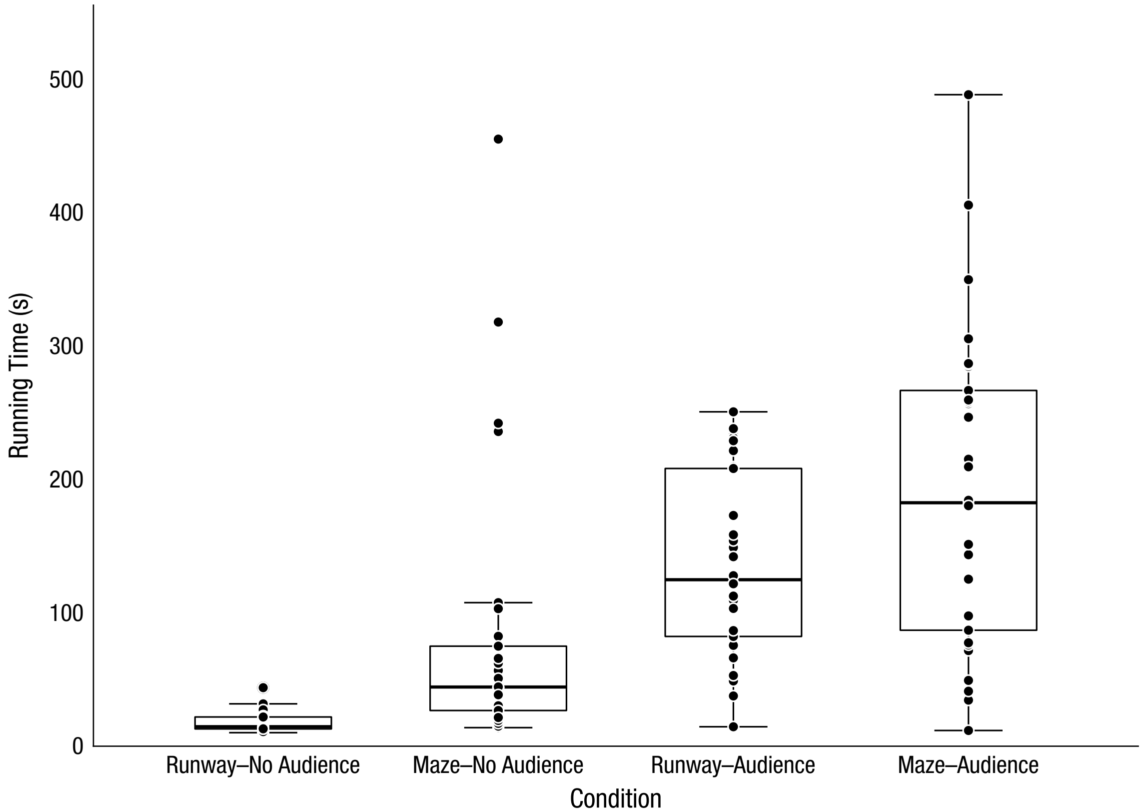

Fig. 1. Box-and-whisker plots showing running time in each condition of the (audience: present vs. absent) × 2 (task difficulty: runway vs. maze) between-subjects design. In each plot, the central horizontal line indicates the median, and the bottom and top edges of the box indicate the 25th and 75th percentiles, respectively. Whiskers extend to a maximum of 1.5 times the interquartile range from the 25th and 75th percentiles. Each circle is an individual data point.

cockroaches were slower (M = 164.59 s, SD = 98.84), compared with the audience-absent condition (M = 49.90 s, SD = 77.81), $F(1, 116) = 55.58$, $p < .001$, η_p^2 = .32, BF_{10} = 6.36e+7. Importantly, this social-inhibition effect was evident for both the complex task, $t(58) = -4.00$, $p < .001$, Cohen's $d = -1.00$, BF_{10} = 132.5 (as predicted), and the simple task, $t(58) = -9.37$, $p < .001$, Cohen's $d = -2.41$, BF_{10} = 1.32e+10 (contrary to predictions). In line with this, the critical test of the Audience × Task Difficulty interaction revealed no evidence for a moderating effect, and the Bayes factor indicated moderate evidence for the null hypothesis, $F(1, 116) = 0.02$, $p = .882$, $\eta_p^2 = .00$, $BF_{01} = 3.88$.

Discussion

We replicated Zajonc et al.'s (1969) study to explicitly test the moderating effect of task difficulty on the effect of the mere presence of other individuals on performance. This effect was the central conclusion presented in the original article, although it has not been statistically tested directly (e.g., Aronson et al., 2018; Kassin et al., 2014). Our analyses revealed evidence clearly speaking against the proposed interaction: In line with the original study, our results showed social inhibition in the complex task; however, we found no social facilitation in the simple task but robust evidence for the very opposite. Also, in the simple task, the presence of an audience led to inhibition, as shown by significantly longer running times. Sanders and Baron's (1975) distraction-conflict explanation of social facilitation assumes that distraction during a task owing to the presence of an audience can produce response conflicts resulting in facilitation effects associated with heightened drive. Our results are in line with a qualification within this theory, which is that some distractions are so disruptive that they impair performance in simple and complex tasks" (Baron, Moore, & Sanders, 1978). We deem it plausible that this might have been the case in our study.

Two limitations of our study should be mentioned. First, we are aware that the use of a different type of cockroach could be considered a major weakness of our replication. However, both the type we used and the type used by Zajonc et al. (1969) manifest similar relevant behavioral tendencies for social-facilitation and social-inhibition effects (i.e., photophobia and pheromonal communication) given this study design. Moreover, because the social-facilitation effect has been found to generalize across species, we see no reason to assume why it should not generalize within species. Second, possibly because of the use of different cockroaches, the running times in our study were shorter than in Zajonc et al.'s study. Nonetheless, we believe that our data provide valid and robust evidence against the social-facilitation hypothesis. Even if the cockroaches in the audience-absent condition already ran at maximum speed and social facilitation could have produced no faster running because of bottom effects, audience presence certainly should not have resulted in clearly *longer* running times—with a very large effect (*d*) of −2.41.

To be very clear, we are not stating that the failure to replicate the social-facilitation effect reported by Zajonc et al. (1969) means that the whole concept of social facilitation is incorrect. Actually, there is meta-analytical evidence for a small social-facilitation effect in humans (Bond & Titus, 1983). Nevertheless, we see substantial additional value in our well-powered, preregistered direct replication. First, meta-analyses are rarely free of biases or they contain studies using questionable research practices, which jeopardize their validity (see Corker, 2020), especially in light of the fact that all studies included in Bond and Titus's meta-analysis were not preregistered—in 1983 when the meta-analysis was published, there simply was no preregistration. We deem it possible that the frequency of questionable research practices and the likelihood of publication biases might have been rather high (note that Bond and Titus themselves acknowledged that the likelihood of a file-drawer problem for the social-facilitation effect was high, as the fail-safe *N* was rather low). Second, although we conducted a direct replication of the original design, we also provided a novel, clear-cut statistical test of the critical interaction between task difficulty and audience. We are therefore confident that our study is a valuable modern remake of a social-psychology classic, particularly as it provides the hitherto missing test of a central conclusion. In a wider perspective, our study should be understood as a recollection of and homage to one of the most influential psychological scientists of the last century.

During the revision of the present article, Neider, Fuse, and Suri (2019) independently published a Stage 1 registered report for another direct replication attempt of Zajonc et al.'s (1969) study. Because Neider and colleagues plan to conduct their study with the same species of cockroaches as used in the original study and plan to use an even larger sample size than in our replication, we are very curious whether their findings will support or challenge our results. If the former is the case, one might start to question the validity of Zajonc et al.'s conclusions that Zajonc's (1965) drive theory is generalizable and thus well suited to explain social-facilitation and social-inhibition effects across different species. One important implication of Zajonc et al.'s study is that it seemed to demonstrate the generality of the drive theory, which could be applied to species as diverse as humans and cockroaches. Cumulative failure to replicate Zajonc et al.'s results would suggest that the proposed interaction effects (and the underlying theoretical account) may not apply to such a diverse range of species.

Editor's Note: As a general rule, Preregistered Direct Replications are restricted to reports of replications of effects initially published in *Psychological Science*. But the Editor may consider exceptions to that rule when the original work has been particularly influential and the case for a replication is strong, as in the present study.

Transparency

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Author Contributions

J. A. Häusser developed the study idea. E. Halfmann and J. A. Häusser planned the study and constructed the study material. Testing and data collection were supervised by E. Halfmann and J. Bredehöft. E. Halfmann analyzed and interpreted the data. E. Halfmann drafted the manuscript, and J. A. Häusser and J. Bredehöft provided critical revisions. All authors approved the final version of the manuscript for submission.

Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

Open Practices

All data and materials have been made publicly available via the Open Science Framework and can be accessed at https://osf.io/c7t6k. The design and analysis plans were preregistered at https://osf.io/h8mxu. The complete Open Practices Disclosure for this article can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797620902101. This article has received the badges for Open Data, Open Materials, and Preregistration. More information about the Open Practices badges can be found at http://www.psychologicalscience.org/publications/badges.

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