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Environmental Enrichment and Forced-Exposure Training With Pigeons: Responding to the Replication Crisis

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ABSTRACT. Recent attention to the reliability of scientific literature has focused renewed attention on the role of replications. The present study aimed to evaluate 2 variables that appear to affect suboptimal choice in pigeons but have yet to be replicated. Pigeons were presented with a standard suboptimal choice task in which the suboptimal alternative led to a signaled delivery of food 50% of the time and the optimal alternative always led to food. The type of housing (enriched vs. isolated) and type of training (presence vs. absence of forced-exposure trials) was manipulated. Based on previous research, pigeons housed in isolation and trained with forced-exposure trials were predicted to make the most suboptimal choices of the four groups. Instead, birds in enriched housing and trained with forced-exposure trials chose the suboptimal alternative most frequently. A balanced 2 x 2 ANOVA found that both the main effect of housing, $F(1, 8) = 4.52$, $p = .066$, $\omega^2 = .18$, and training, $F(1, 8) = 5.21$, $p = .052$, $\omega^2 = .22$, did not reach significance, nor did their interaction, $F(1, 8) = 0.37$, $p = .562$, $\omega^2 < .01$. However, Bayes factors indicated weak evidence in support of both the main effect of housing ($BF_{10} = 1.22$) and the main effect of training ($BF_{10} = 1.46$), but not the interaction ($BF_{10} = 0.5$). The present results highlight the need to determine the degree to which initial results are reliable and generalizable prior to becoming cited and viewed as an established finding.

Keywords: replication; preregistration, environmental enrichment, suboptimal choice

Preregistration, Open Data, and Open Materials badges earned for transparent research practices. Preregistration, data, and materials can be viewed at https://osf.io/3e24b/

RESUMEN. La atención reciente a la confiabilidad de la literatura científica ha centrado una atención renovada en el papel de las replicaciones. El presente estudio tiene como objetivo evaluar 2 variables que parecen afectar la elección subóptima en las palomas pero que aún no se han replicado. A las palomas se les presentó una tarea estándar de elección subóptima en la que la alternativa subóptima conducía a una entrega señalizada de alimento el 50% de las veces y la alternativa óptima siempre conducía a comida. Se manipuló el tipo de vivienda (enriquecida versus aislada) y el tipo de capacitación (presencia versus ausencia de ensayos de exposición forzada). Según investigaciones anteriores, se predijo que las palomas alojadas en aislamiento y entrenadas con pruebas de

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exposición forzada tomarían las decisiones menos óptimas de los cuatro grupos. En cambio, las aves en alojamientos enriquecidos y entrenados con pruebas de exposición forzada eligieron con mayor frecuencia la alternativa subóptima. Un ANOVA equilibrado 2 x 2 encontró que tanto el efecto principal de la vivienda, $F(1, 8) = 4{,}52$, $p = 0{,}066$, $\omega^2 = 0{,}18$, como el de la formación, $F(1, 8) = 5{,}21$, $p = 0{,}052$, $\omega^2 = .22$, no alcanzaron significancia, ni tampoco su interacción, $F(1, 8) = 0.37$, $p = .562$, $\omega^2 < .01$. Sin embargo, los factores de Bayes indican evidencia débil que respalda tanto el efecto principal de la vivienda ($BF_{10} = 1{,}22$) como el efecto principal de la capacitación ($BF_{10} = 1{,}46$), pero no la interacción ($BF_{10} = 0{,}5$). Los resultados actuales resaltan la necesidad de determinar el grado en que los resultados iniciales son confiables y generalizables antes de ser citados y vistos como un hallazgo establecido.

Palabras clave: replicación; preinscripción, enriquecimiento ambiental, elección subóptima

The replication crisis in psychology has increased attention in recent years on not only the replicability of research reports, but more generally the degree to which scientific inquiry functions to self-correct (Vazire & Holcombe, 2022). Self-correcting science refers to the cyclical nature of scientific inquiry; inevitable limitations of an individual study can be corrected by the collective process of scientific investigation if new evidence, insights, and critiques continually shape understanding. Without the proper dissemination and discussion of replication studies and nonsignificant results, science cannot self-correct, leaving the literature limited and incomplete, if not distorted.

Replications are often categorized as either direct or conceptual (e.g., Chambers, 2019). Direct replications attempt to recreate a study using procedures as similar as possible to the original research. In contrast, conceptual replications aim to confirm and extend previous findings by incorporating new or altered manipulations and variables. As direct replication studies are crucial in demonstrating internal validity (causality), conceptual replications are crucial in demonstrating external validity (generality; Fabrigar et al., 2020). Throughout this paper, the replication studies discussed will be categorized based on these definitions.

Despite the importance of both direct and conceptual replications, there is often indifference, or even hostility, towards replications (Chambers, 2019). Instead, researchers tend to study novel variables, which are understandably more interesting to readers, and are therefore more likely to be published. The unfortunate result is few replications are conducted to confirm findings. For example, Makel et al. (2012) examined 500 articles from the top 100 psychology journals and found that only about 1% were replication studies. Even when replications are published, they are often ignored. For example, von Hippel (2022) analyzed 98 replication studies published in 2015 and found that failed replications only reduced citations of the original study by less than 10%. Also concerning, von Hippel discovered that less than 3% of articles citing an original study also cited the replication.

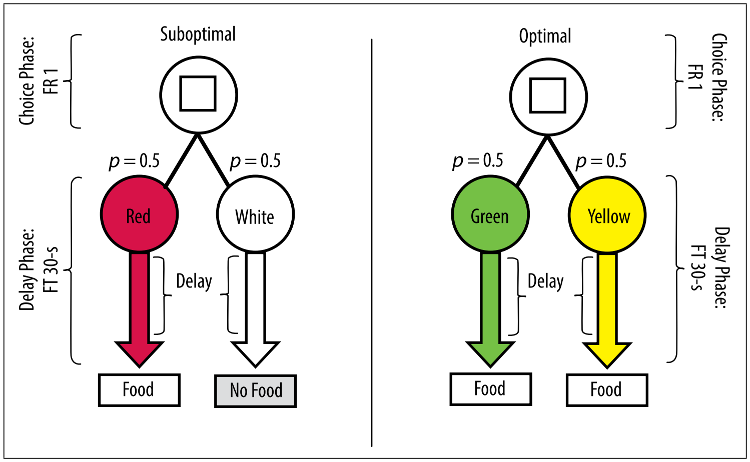
Another issue is publication bias for statistically significant results, which makes it difficult for the scientific record to self-correct once spurious results become published. Studies yielding nonsignificant results are considered failed experiments rather than sources of valuable information regarding the absence of an effect (Locascio, 2017). This is particularly problematic because nonsignificant results, especially in replication studies, can provide crucial information about the existing literature. If replication studies are not produced and disseminated, false positives will continue to be cited without correction. Given that false positives have been estimated to occur about 61% of the time (Simmons et al., 2011), this is a prevalent and ongoing problem.

Various research practices have been suggested to help make scientific research more reliable. For example, LeBel (2015) proposed that one of every five studies conducted by individual researchers should attempt to replicate findings in their area of expertise. The field of psychology would benefit, he argued, even if only a minority of researchers adopt his approach. Similarly, Chambers recommended individual researchers adopt specific practices to improve the reliability of psychological research (2019, p. 213). His first recommendation urged caution regarding findings that have not been replicated, and for researchers to preregister their hypotheses and planned analyses on the Open Science Framework. Preregistering a study before it is conducted is used to reduce the occurrence of "*p*-hacking" and other forms of hidden flexibility that increase unreliable findings. The present research is a response to these calls for reform. Our preregistered study examined two variables related to suboptimal choice behavior that have not yet been successfully replicated.

Suboptimal choice refers to the well-established but surprising finding that pigeons (*Columba livia*) will choose and even favor an option that yields lower overall reinforcement (i.e., food) when predictive cues signal its delivery after a delay (for a recent review see Dunn et al., 2024). Figure 1 shows a standard suboptimal choice procedure (Kendall, 1985; Spetch et al., 1990) and the one used in the present study. In this procedure, pigeons can choose between suboptimal (50% food) and optimal (100% food) alternatives by pecking one of the square stimuli shown in Figure 1. When the suboptimal alternative (shown on the left of Figure 1) is chosen, it always leads to a 30-s delay. The delay always ends with food when the keylight is red, but never ends with food when the keylight is white. Thus, the suboptimal alternative provides food only half of the time, but importantly the stimulus color presented during the delay is perfectly correlated with the outcomes, signaling whether the trial will end in food or no food. When the optimal alternative (shown on the right of Figure 1) is chosen, one of two keylights (yellow or green) is presented during a 30-s delay and is always followed by food. In contrast to the suboptimal alternative, food is provided 100% of the time, making it a dependable choice for securing food. If hungry pigeons are only motivated by food, they would have an exclusive preference for the optimal alternative. However, extensive research has shown that once they have sufficient experience with the two alternatives, they frequently prefer the suboptimal alternative (e.g., Sears et al., 2022; Stagner & Zentall, 2010). This suggests that the choice behavior is controlled more by the stimuli that predict the food than the food itself. In this case, suboptimal preference occurs because choice of the suboptimal alternative immediately provides informative stimuli (i.e., signals correlated with the food and no food outcomes). When the signals are not predictive of the outcomes on the suboptimal alternative, pigeons strongly prefer the optimal alternative (e.g., Stagner & Zentall, 2010).

FIGURE 1

Experiment Procedure



Note. Schematic detailing the contingencies experienced when the suboptimal (shown left) and optimal (shown right) alternatives were selected. Example: A choice trial started with an illuminated square on the left and right response keys. If the left square was pecked (the suboptimal alternative), half the time it was replaced with a red stimulus and half the time it was replaced by a white stimulus. When it turned red, it remained illuminated for 30 s and then food was delivered and the trial ended. When it turned white, it remained illuminated for 30 s, no food was delivered, and then the trial ended. If the right square was pecked (the optimal alternative), a green or yellow response key was illuminated for 30 s and the trial always ended with food. In forced-exposure trials, only one alternative was presented. In choice trials, each trial consisted of a choice between the two alternatives. The alternatives were counterbalanced such that the suboptimal alternative was on the left side for half the birds and the right for the other half.

Although suboptimal choice behavior in pigeons has been widely replicated (see Dunn et al., 2024; McDevitt et al., 2016; Vasconcelos et al., 2018; Zentall, 2016, for reviews), some of the variables that appear to modulate it have not. One study found that environmental enrichment slowed down the acquisition of suboptimal preference (Pattison et al., 2013). Enrichment has been operationalized in many different forms, but generally refers to added environmental or social stimulation (e.g., toys, platforms, stimuli, exposure to other animals, larger living area).

Pattison et al. (2013) trained two groups of four pigeons in the same suboptimal choice task, but the birds in the control group were housed in isolation and birds in the other group were provided with enriched housing prior to training and throughout data collection. The enriched housing consisted of a large flight cage that held four pigeons at a time and included places to perch, providing social and environmental enrichment. Pattison et al. found that subjects in the enriched group took significantly longer, 18 sessions on average, to develop a reliable suboptimal preference compared to isolated subjects, which took only 3.2 sessions. Only after 30 sessions of training did the groups have equivalent terminal levels of preference. In other words, both groups of birds ended training with a strong preference for the suboptimal alternative, but birds in the enriched housing took, on average, substantially more sessions to acquire that preference.

Laude and colleagues (2014) attempted to conceptually replicate the enrichment manipulation used in Pattison et al. (2013). They used a suboptimal choice procedure in which a suboptimal alternative provided signaled food 20% of the time and an optimal alternative provided food 100% of the time. The housing conditions were nearly identical to Pattison et al. but included additional enrichment in the form of extra perches and opportunities to bathe. Laude et al. found no significant difference between the two groups of four pigeons in the rate at which preference for the suboptimal alternative developed.

A large literature on the effects of enrichment on learning in nonhuman subjects consistently shows that enrichment is neurologically beneficial, improving a species' ability to learn different contingencies. For example, Woodcock and Richardson (2000) found that rats reared in an enriched environment processed contextual information faster than rats reared in isolated/standard housing during a pre-shock period. Rats living in enriched housing appeared to be able to form a complex representation of the conditioning context and demonstrated improved discrimination between two similar contexts. Cortese et al. (2018) found that even short-term exposure to enrichment has significant effects on hippocampal function. They found that a single month of enriched housing for adult rats improved learning and memory in the Morris water maze and object-recognition behavioral tests. These effects are not just behavioral, but also extend to neurological changes. For example, Cortese et al. found that rats in socially and environmentally-enriched housing showed enhanced metabotropic glutamate receptor-dependent hippocampal long-term potentiation compared to rats housed with only social enrichment. Xu et al. (2022) found that environmental enrichment may moderate neurological effects of early life stress by regulating histone acetylation in the hippocampus and amygdala. Thus, many studies examining different facets of enrichment consistently support the general finding that enrichment enhances learning and memory along with corresponding neurological changes (e.g., Bramati et al., 2023; Heimer-McGinn et al., 2020). Environmental enrichment also appears to mitigate the negative effects of stress and aging (for reviews of these effects, see Hannan, 2014; Macartney et al., 2022; Sahini et al., 2024).

As noted above, research has consistently shown that environmental enrichment leads to enhanced learning. This appears to conflict with Pattison et al.'s (2013) findings, which demonstrated slower acquisition of suboptimal preference, a behavior now considered adaptive rather than "suboptimal" in pigeons' natural environments (Vasconcelos et al., 2015, 2018; see discussion below). Given that Laude et al. (2014) did not replicate that result, the fact that the original study is frequently cited, and the breadth of literature suggesting the opposite effect, it is especially important to investigate the influence of environmental enrichment on suboptimal choice. According to our analysis (see Berrebi et al., 2025 for a full description) using Google Scholar, Pattison et al. has been cited approximately 87 times. Of these, 18 journal articles have also cited Laude et al., but the majority (12 of the 18) only cited the Pattison et al. article in support of an enrichment effect on suboptimal choice. Of the six articles that cited both, only three indicated any inconsistency in the results of the two studies.

A more recent study, also related to suboptimal choice, found that the types of trials presented during training appear to modulate the degree of suboptimal preference. McDevitt et al. (2022) compared groups of pigeons with varying numbers of forced-exposure and choice trials during training. A forced-exposure trial presents only one of the two possible choice alternatives at a time; either the suboptimal or optimal alternative is presented. This allows the researcher to ensure that, across trials, each subject has equal exposure to the contingencies associated with each alternative. The drawback is that, by themselves, forced- exposure trials do not provide the researcher with a measure of preference. By contrast, a choice trial presents both the suboptimal and optimal alternative simultaneously, thus allowing the subject to choose between them and providing a measure of preference. However, in the absence of forced-exposure trials, the degree to which the alternatives are experienced is much more dependent on the pigeons' behavior, which can lead to unequal exposure to the contingencies. McDevitt et al. found that sessions consisting of 67% or 100% of forced-exposure trials led to stronger preference for the suboptimal alternative, but the absence of forced-exposure trials (i.e., only choice trials) resulted in greater choice of the optimal alternative. Research on suboptimal choice typically utilizes both types of trials to ensure a subject has been exposed to each alternative while evaluating preference for one or the other (Fortes et al., 2018; López-Tolsa & Orduna, 2021; Macías et al., 2021), but McDevitt et al. is the only study to date that examined whether trial types impact preference. Thus, there have been no replication attempts with respect to forced-exposure training and inconclusive results from the two enrichment studies that have been conducted.

The present study sought to conceptually replicate the effects of both environmental enrichment and forced-exposure training on suboptimal choice in pigeons using a balanced 2×2 independent analysis of variance (ANOVA) design. Determining an appropriate sample size in nonhuman animal research involves balancing the need for sufficient statistical power against ethical and practical constraints (National Research Council, 2011). The earlier studies on enrichment (Pattison et al., 2013; Laude et al., 2014) and training type (McDevitt et al., 2022) employed small sample sizes (n = 4 birds per group), which is common in nonhuman animal research due to the strong experimental control obtained and the preference in animal research towards detecting large effects, both of which enhance statistical power. In the study reported here, 12 pigeons were randomly assigned to four groups: enriched with forced-exposure trials, enriched with choice trials, isolated with forced-exposure trials, and isolated with choice trials (i.e., three subjects per cell). This provided a slightly larger sample for each main effect tested ($n = 6$) compared to Pattison et al. and McDevitt et al. Although a larger sample size would have been preferable, practical constraints within the context of an undergraduate teaching laboratory limited the sample to $N = 12$, which included all of the pigeons available in the lab.

A conceptual replication was chosen for several reasons. First, the two previous research studies (Pattison et al., 2013 and McDevitt et al, 2022) used different variants of the suboptimal choice procedure, making it impossible to study both variables with a direct replication. Given that a significant effect of forced-exposure training was repeated in a second experiment in McDevitt et al, 2022, we opted to employ a suboptimal choice procedure closer to the one used by Pattison et al. (2013). Second, large ceiling effects and heterogeneous variances were observed in the prior studies by Pattison et al. and McDevitt et al., which complicated the analyses of the results and makes an a priori determination of an appropriate sample size difficult. To avoid a ceiling effect, we employed the original suboptimal choice paradigm by Kendall (1974) because it produces less extreme suboptimal preference in pigeons and should promote more homogeneous variances. As a result, our procedure involved a choice between a suboptimal alternative that provided 50% food and an optimal alternative that provided 100% food, which was similar to Pattison et al.'s procedure involving choice between a 50% suboptimal alternative and a 75% optimal alternative.

Based on the Pattison et al. (2013) study, we expected diminished suboptimal choice for subjects housed in the enriched environment. Conversely, following McDevitt et al. (2022), we expected increased suboptimal choice with subjects exposed to training with forced-exposure trials. The present study was preregistered on the Open Science Framework, and all data and analyses are publicly available there (Berrebi et al., 2025).

Method

Subjects

The subjects were 12 adult pigeons with experience in concurrent chains and simple discrimination procedures and were cared for in accordance with the Guide for the Care and Use of Laboratory Animals (National Research Council, 2011). They were maintained at approximately 85% of their free-feeding weights by grain obtained during experimental sessions and immediate postsession feedings when necessary. Half of the pigeons were housed in individual cages and half in a larger group cage, all under a 12-hr light/dark cycle, with water and grit freely available.

Apparatus

Eight operant chambers (approximately 360 mm wide, 320 mm long, and 350 mm high) were used. Three translucent response keys, 25 mm in diameter, were mounted on the front panel 260 mm above the floor and 72.5 mm apart. Each side key could be illuminated from the rear by standard IEE 28-V 12-stimulus projectors. A 28-V 1-W miniature lamp, located 87.5 mm above the center response key, provided general chamber illumination for the duration of each session, except during blackout periods as noted below. Directly below the center key and 95 mm above the floor was an opening (57 mm high by 50 mm wide) that provided access to a solenoid- operated grain hopper filled with mixed grain. When activated, the food hopper was raised for 5 s and illuminated from above with white light by a 28-V 1-W miniature lamp. A computer and a MED-PC interface, located in an adjacent room, controlled experimental events.

Procedure

Pretraining

Prior to beginning the experiment, each bird received pretraining for seven days during which keypecks to the stimuli used in the experiment were reinforced according to a fixed-ratio (FR) schedule. To ensure that each subject was reliably pecking all stimuli before starting the experiment, the schedule was gradually increased from FR 1 to FR 20.

Training

An overview of the procedure is shown in Figure 1. Two alternatives were presented in training. The suboptimal alternative was presented on one side key and consisted of a square stimulus that, when chosen with a single peck, was replaced with one of two possible delay stimuli (e.g., a red or white keylight) that remained illuminated for 30 s. The delay stimuli appeared equally often ($p = .50$). One stimulus (e.g., red) was always followed by

5-s access to the food hopper. The other (e.g., white) was followed by 5-s termination of the houselight (blackout) and no food. Overall, the suboptimal alternative ended with food 50% of the time, and the color of the delay stimuli signaled which outcome would be presented.

The optimal alternative was presented on the other side key and consisted of a square stimulus that, when chosen, was replaced with a color delay stimulus (e.g., a green or yellow keylight) that remained illuminated for 30 s. Both delay stimuli appeared equally often ($p = .50$) and were always followed by 5-s access to the food hopper. Thus, the optimal alternative ended with food 100% of the time.

The stimulus locations were constant (green and yellow on one response key, white and red on the other), but the side associated with each alternative was counterbalanced across subjects so that the optimal alternative was presented on the left for half of the birds and the right for the others. A 5-s intertrial interval separated each trial. Each bird completed 22 sessions and each session was terminated at the completion of 80 trials or 90 min, whichever occurred first.

Independent Variables

The 12 birds were randomly assigned to one of four groups manipulating two variables as per a balanced 2 x 2 independent ANOVA design. The four groups ($n = 3$) consisted of enriched housing with only forced-exposure trials, enriched housing with only choice trials, isolated housing with only forced-exposure trials, and isolated housing with only choice trials.

Enrichment Manipulation. Environmental enrichment consisted of a group cage with three chambers that totaled 24.6 ft^3 (.7 m^3), housing three birds at a time. This cage also included various enrichment toys including bells, swings, perches at different heights, ropes, cardboard boxes, and a tub of water for bathing. Birds in the isolation group were housed in individual cages of approximately 1 ft^3 (.03 m^3). There were no birds on either side of the isolated subjects' cages. All subjects were housed individually prior to the study.

Forced-Exposure Manipulation. A forced-exposure trial consisted of the presentation of a single alternative (i.e., a square stimulus on either the right or the left response key). A choice trial consisted of the presentation of both alternatives (i.e., a square stimulus on both the right and left response keys).

For subjects that received only forced-exposure trials, each block of four trials consisted of two presentations of the suboptimal alternative and two presentations of the optimal alternative. The order of trials within each block was randomly determined. These subjects received two test sessions at sessions 11 and 22. Test sessions consisted of only choice trials.

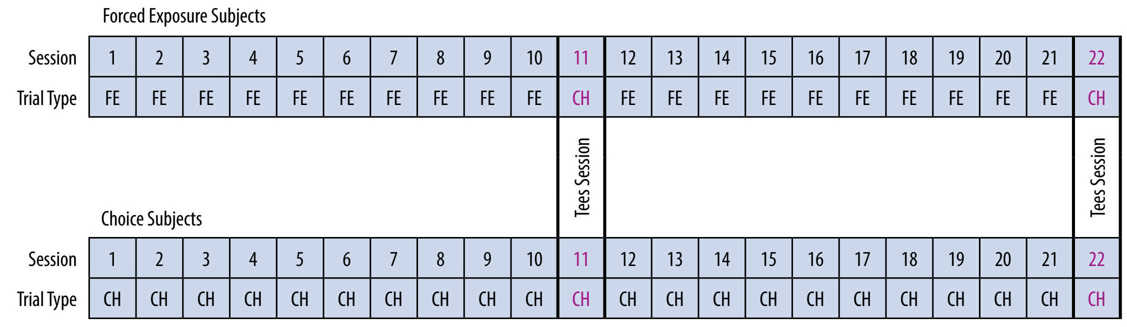
For subjects that received only choice trials during training, all sessions were identical and consisted of only choice trials. In sum, for FE-only subjects, sessions 1–10 and 12–21 each consisted of 80 forced-exposure trials, half optimal alternative, and half suboptimal alternative. For sessions 11 and 22, the FE-only group received only choice trials to test progress. For the only choice group, all 80 trials for all 22 sessions were choice trials. Figure 2 provides an overview of the trial types presented during training and testing.

Dependent Variable

The dependent variable was the proportion of choices made to the suboptimal alternative. Choice proportion was calculated as the number of responses to the suboptimal alternative divided by the total number of choice responses for each subject during test sessions 11 and 22. Only sessions 11 and 22 permitted comparisons across all groups of birds because those were the only sessions in which birds in

FIGURE 2

Overview of Training and Testing



Forced Exposure Subjects

Session	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Trial Type	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	CH	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	CH

Choice Subjects

Session	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Trial Type	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH

Note. FE denotes a session of only forced-exposure trials; CH denotes a session of only choice trials.

forced-exposure training made choices. The test sessions allowed for an assessment of preference at both an early and later stage of training.

Results

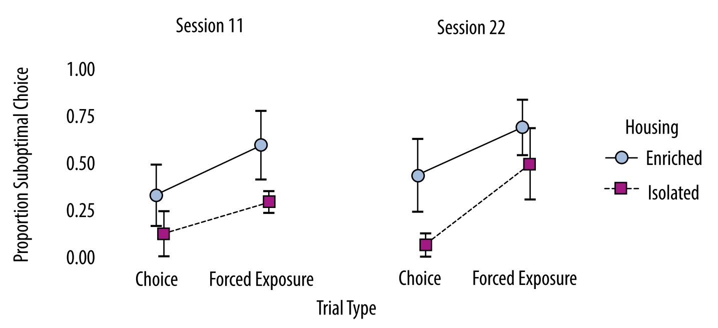
Graphical and statistical analyses were conducted using R software (v4.3.2) and the 'tidyverse' (v2.0.0) ,'effsize' (v0.8.1), and 'BayesFactor' (v0.9.12.4.7) packages (Morey & Rouder, 2024; R Core Team, 2024; Torchiano, 2020; Wickham et al., 2019). Copies of both the data and R code are readily accessible to the public via the Open Science Framework (Berrebi et al., 2025). To mitigate the influence of ceiling and floor effects, all inferential analyses were conducted with an arcsine transformation applied (Kirk, 2013). All descriptive statistics are presented in their original untransformed state. All Bayes factor calculations (BF10) were conducted using the default medium Jeffreys-Zellner-Siow prior scale (Morey & Rouder, 2024). For the two-way ANOVA, each main effect and the interaction were tested against an intercept-only null model.

Figure 3 shows the obtained suboptimal preference across the manipulations of housing and training type for sessions 11 and 22 respectively. The consistency in preference demonstrated in Figure 3 across the two testing sessions suggests the pigeons' preferences had stabilized by session 11. This is supported by responses made to the delay stimuli in the five sessions preceding session 11, with all pigeons but one exhibiting clear discrimination of the food predictive stimulus on the suboptimal alternative; $t(11) = 5.52$, $p < .001$, $g = 1.47$, $BF_{10} > 150$. Consequently, to streamline the analyses, the results of both session 11 and 22 were averaged.

Across the 6 birds tested in each type of housing, enriched subjects showed higher levels of suboptimal preference ($M = 0.51$, $SD = 0.30$) than the isolated subjects ($M = 0.24$, $SD = 0.24$). The type of training received showed similarly discrepant preferences as birds exposed to only choice trials exhibited lower levels of suboptimal choice ($M = 0.23$, $SD = 0.27$) than birds given forced-exposure trials only ($M = 0.51$, $SD = 0.26$). A balanced 2 x 2 ANOVA found that both the main effect of housing, $F(1, 8) = 4.52$, $p = .066$, $\omega^2 = .18$, and training, $F(1, 8) = 5.21$, $p = .052$, $\omega^2 = .22$, did not reach significance, nor did their interaction, $F(1, 8) = 0.37$, $p = .562$, $\omega^2 < .01$. However, Bayes factors indicate weak evidence in support of both the main effect of housing ($BF_{10} = 1.22$) and the main effect of training ($BF_{10} = 1.46$), but not the interaction ($BF_{10} = 0.5$).

FIGURE 3

Session 11 and 22 Results



Note. Interaction plots displaying the mean proportion of suboptimal choice for each test session, shown by housing condition and trial type manipulations. Choice proportions were calculated as the number of suboptimal choices divided by the total number of choices made in the session. Both the housing and trial type manipulations were conducted using independent groups. Error bars represent one standard error above and below the mean. Parallel lines indicate the absence of an interaction.

Discussion

The present study evaluated two variables of interest, of which the effects have limited support. These variables were selected in an effort to increase the reliability of psychological research in the wake of the replication crisis (Chambers, 2019). Pigeons were trained on a suboptimal choice procedure in which one alternative always led to food and the other, suboptimal alternative, led to food only half of the time. Previous research has demonstrated that pigeons will frequently choose the suboptimal alternative when it provides differential signals (i.e., one stimulus that always precedes food delivery and a different stimulus that always precedes no food). During training, two variables were manipulated: housing (enriched vs. isolated) and forced-exposure training (all forced-exposure trials vs. all choice trials).

Overall, birds in enriched conditions exhibited a greater choice of the suboptimal alternative than those in isolated housing. Although the main effects were not statistically significant and the evidence remains weak, it is notable that the results are directionally opposite to those reported by Pattison et al. (2013), who found delayed suboptimal preference with enriched housing. This contrast is intriguing given that one of the most widely supported explanations for pigeons' suboptimal preferences is that it is due to the conditional reinforcement provided by the suboptimal alternative (Dunn et al., 2024). Thus, the development of suboptimal preference can be understood as a form of learning that, although not particularly adaptive within an operant chamber, likely offers advantages in natural environments.

Specifically, through a conditioning process, the pigeons learn which stimuli predict food and direct their choices towards those stimuli. In the wild, animals benefit from both pursuing clear signals for food and disengaging in response to clear signals for the absence of food. This allows them to conserve energy and focus their efforts on more promising areas (Vasconcelos et al., 2015, 2018). In contrast, within the constraints of an experimental chamber, animals cannot escape from the no-food signal, making the selection of the "suboptimal" alternative appear maladaptive in this artificial context. Given this and the broader enrichment literature, enriched housing might be expected to accelerate the acquisition of "suboptimal" preference, not delay it as Pattison et al. found. Consequently, Pattison et al.'s findings are, in some respects, counterintuitive. If suboptimal choice behavior reflects an adaptive process as is argued, the trend toward stronger suboptimal preference observed under the enrichment condition in the present study would align with the numerous nonhuman enrichment studies suggesting that enrichment benefits learning. However, if suboptimal preference is viewed as undesirable, delaying the acquisition of that preference may be considered an adaptive advantage.

To summarize the evidence relevant to the question of whether environmental enrichment affects suboptimal choice, one study reported that enrichment delayed, but did not change the final level of preference (Pattison et al.), and two studies (Laude et al., 2014 and the present study) found no significant effects. It is not clear what may account for the discrepancy in the results of the three studies, but it does not seem likely that it is due to the strength of the enrichment manipulation. Pigeons in Pattison et al. (2013) were placed in the group cage for 4 hr per day, 5 days per week. Laude et al. (2014) extended the duration to up to 6 hr per day, and the present study extended it to 24 hr per day, 7 days per week in an attempt to strengthen the manipulation.

In contrast, the results related to the type of training are more aligned with previous research. On average, subjects who were in the all forced-exposure conditions demonstrated more suboptimal choices than birds who only experienced choice trials. The observed trend towards more suboptimal choices when forced-exposure trials are present is consistent with the results of McDevitt et al. (2022). However, the difference between forced-exposure and choice training did not reach significance, and thus more work is needed to establish the strength and generality of trial types on suboptimal choice.

One possible explanation for the difference in the present results compared to earlier work may be the specific procedure used. The present study used the original suboptimal choice procedure developed by Kendall (1974). The prior related works (Laude et al., 2014; McDevitt et al., 2022; Pattison et al., 2013) each utilized accepted variants of the original procedure which altered food amount or probability of food across the two alternatives in ways that generate much more extreme preferences than Kendall's original procedure (Dunn et al. 2024). It is therefore likely that these procedural differences account for the differing results, but regardless of procedure, if a general effect exists, it should not be limited to a specific version of the suboptimal choice task.

The terminal degree of suboptimal preference (session 22) obtained in the present study with forced-exposure training (.59) is consistent with prior work. In fact, the aggregated weighted mean choice proportion for 40 subjects across four studies (Belke & Spetch, 1994; McDevitt et al., 1997; Spetch et al., 1990; Spetch et al., 1994) that employed the same procedure (including initial- and terminal-link schedules) was .59 for the suboptimal alternative (for a large data set for the suboptimal choice procedure, see Dunn et al., 2023).

The lack of significant findings points to the statistical power of the current study being too limited. As noted in the introduction, this reflects practical limitations inherent to the design and available resources at the time of data collection. Although efforts were made to enhance statistical power by increasing the sample size per main effect compared to the prior studies (Laude et al., 2014; McDevitt et al., 2022; Pattison et al., 2013), those earlier studies faced methodological challenges such as ceiling and floor effects, as well as heteroscedasticity. In response, the present study adopted a suboptimal choice procedure originally developed by Kendall (1974), which has been widely utilized in the suboptimal choice literature (e.g., Belke & Spetch, 1994; McDevitt et al. 1997; Spetch et al. 1990; Zentall et al. 2019; for a review see Dunn et al. 2024). However, these issues and modifications severely complicate any power calculations and generalizations that might be attempted. In retrospect, the adoption of the Kendall procedure increased between-subject variability, which likely obscured the statistical detection of main effects. Although increasing the sample size would likely address this issue, such an approach may not be feasible for many laboratories. A potential solution may lie in employing procedures, such as those used by Stagner and Zentall (2010), that are associated with lower between-subject variability, along with modifications aimed at mitigating these studies' strong preference for the suboptimal alternative and resultant ceiling effects, such as by extending the choice phase or reducing the delay phase (McDevitt et al. 2018; Pisklak et al. 2019; Spetch et al. 1990). Despite the present study's aforementioned constraints, it offers meaningful insights that contribute to the ongoing discourse and provides a foundation for more robust investigations. Thus, although the findings may be limited, they nonetheless serve as a critical step toward more comprehensive research.

The replication crisis is a wide-reaching problem impacting almost every scientific discipline. With a lack of replication studies, and importantly, the exclusion of failed replications from the literature, science cannot self-correct. The present work adds to the scant literature on the influence of two variables on suboptimal choice. Regarding the possible effect of environmental enrichment on suboptimal choice with pigeons, our data yielded results contrary to the original work. With regard to forced-exposure training, the findings, though weak, were consistent with the previous research. We believe both manipulations add valuable information to the evolving understanding of both phenomena. Replication attempts are a necessary part of the solution to the crisis of credibility facing psychology. We hope that our work encourages others to answer LeBel's (2015) call to more systematically and intentionally direct some of their efforts towards replicating prior work.

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Author Note

The present study was preregistered. Preregistered a priori hypotheses can be found at https://osf.io/rvuk5. Data and analysis code can be accessed at https://osf.io/3e24b/. We have no known conflict of interest to disclose.

Data collection was completed by undergraduate students, Isabella Berrebi and Sarah Leizear, in spring 2023. The present study was used for Sarah Leizear's senior capstone project.

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