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William N. Koller and Tyrone D. Cannon

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BRIEF REPORT

Reduced Benefit of Novelty Detection on Subsequent Memory Judgments in Paranoia

William N. Koller and Tyrone D. Cannon
Department of Psychology, Yale University

Novelty detection is critical to the effective employment of memory-guided behavior. While recent work has found impaired novelty detection in subclinical paranoia, other studies show different patterns. Here, we tested the hypothesis that those higher in paranoia receive less benefit from novelty in their immediate environment when making subsequent mnemonic judgments. Using a continuous recognition task (comprising Old, New, and Similar items) in a sample drawn from an online marketplace ($N = 450$), we found that Similar trial performance was generally enhanced by preceding judgments of "New" versus "Old"—replicating prior work. However, paranoia was associated with a *reduction* of this novelty-based enhancement—a novel finding. Those experiencing paranoia may thus less readily use novelty to adjudicate between the competing mnemonic processes of encoding and retrieval. We interpret this finding in light of the role of novelty detection in maintaining adaptive predictive models, suggesting that this deficit may reduce coherence between one's active predictive model and one's environment, thereby contributing to perceptions of the world as unduly uncertain and threatening.

General Scientific Summary

The detection of novelty in our immediate environment helps to guide our memory systems in encoding new experiences while avoiding undue interference from the past. Prior work has shown that those higher in paranoia—the exaggerated belief that others mean you harm—may struggle with novelty detection, mistaking "New" items as "Old." Here, we demonstrate that paranoia is additionally associated with a reduced ability to use novelty detection to guide *subsequent* memory decisions. Reduced sensitivity to novelty in one's immediate environment may cause memory activity to become decoupled from the demands of the external world, potentially contributing to perceptions of the world as unduly uncertain, and thus threatening.

Keywords: paranoia, delusions, memory, novelty detection

Supplemental materials: https://doi.org/10.1037/abn0000829.supp

Memory impairment extends across the psychosis spectrum and is highly correlated with functional impairments (Aleman et al., 1999; Green, 1996; Seabury & Cannon, 2020), yet its mechanisms remain poorly understood. While the majority of past work in this domain has focused on associations between memory and the negative and disorganized symptom clusters of schizophrenia, recent studies

William N. Koller https://orcid.org/0000-0001-5117-2847
Tyrone D. Cannon https://orcid.org/0000-0002-5632-3154

This study's protocol (2000026576) was deemed exempt by the Yale University Institutional Review Board. Data in this manuscript have not been previously published; these data were presented at the 2022 Congress of the Schizophrenia International Research Society. The experiment reported in this article was preregistered (see https://osf.io/wydvc). Data and code that support the findings reported in this article are available here: https://osf.io/37ukt/.

We have no conflict of interest to disclose.

William N. Koller served as lead for formal analysis, investigation, methodology, visualization, writing–original draft, and writing–review and editing. Tyrone D. Cannon served as lead for supervision and served in a supporting role for formal analysis, methodology, writing–original draft, and writing–review and editing. William N. Koller and Tyrone D. Cannon contributed equally to the conceptualization of the study.

The preregistered design is available at https://osf.io/wydvc.

Correspondence concerning this article should be addressed to William N. Koller, Department of Psychology, Yale University, P.O. Box 208205, 2 Hillhouse Avenue, New Haven, CT 06520-8205, United States. Email: william.koller@yale.edu

have suggested that *positive* symptoms (i.e., paranoia and positive schizotypy) may be characterized by a difficulty with *novelty detection*, as indexed by a greater tendency to commit "false alarm" errors (i.e., mistaking a "New" stimulus as "Old"; Koller & Cannon, 2021; Sahakyan & Kwapil, 2019). This genre of memory error may be reflective of reduced engagement of *pattern separation* relative to *pattern completion* (Tamminga et al., 2012)—the competing hippocampal computations that support *encoding* and *retrieval*, respectively (O'Reilly & McClelland, 1994). In turn, this may result in spurious retrieval events that fuel the aberrant associations characteristic of delusions, insofar as they encourage connections between a current experience and a (weakly related) past representation instead of facilitating new learning (Koller & Cannon, 2022; Tamminga et al., 2010). However, prior findings are in conflict as to whether psychosis spectrum individuals show such a systematic memory bias (Das et al., 2014; Kraguljac et al., 2018; Martinelli & Shergill, 2015; Vass et al., 2022), pointing to a more nuanced relationship between positive symptoms and novelty detection.

One critical function of novelty detection is to help switch the memory system (e.g., the hippocampus) toward an externally oriented mode of processing that favors new encoding (via pattern separation) over the retrieval of existing representations (via pattern completion; Bein et al., 2020; Gomez-Ocadiz et al., 2022; Park et al., 2021; Sinclair et al., 2021). In this way, sensitivity to novelty in our immediate environment may help guide our memory systems in encoding new experiences while avoiding undue interference from the past (Patil & Duncan, 2017). A seminal study by Duncan et al. (2012) supports this notion: Here, participants were more accurate in noticing subtle differences between a current trial and a past lure when this trial was immediately preceded by an instance of novelty detection (i.e., judgment of an item as "New"). The authors interpreted this as one mechanism via which the memory system is sensitive to *context*—that is, novelty detection may serve as a cue that one has entered an unfamiliar environment in which it is beneficial to encode the details of one's surroundings (vs. retrieve stored information).

Present Study

Here, we use a similar paradigm to test whether those higher in paranoia—a dominant theme of delusional beliefs (Freeman, 2016) that is also common in the general population (Freeman et al., 2011)—receive less benefit from novelty in the immediate environment (i.e., novelty detection on a preceding trial) when making mnemonic judgments. This could represent a subtler novelty-related bias that has been overlooked by past work and may reflect one way that memory activity becomes decoupled from objective reality among those endorsing nonnormative beliefs.

To this end, we adapted Duncan et al.'s (2012) task for the online marketplace Prolific (https://www.prolific.co), on which we collected a sample of convenience ($n = 450$). Crucially, we examined performance on "Similar" trials (which varied only subtly from a previous trial) as a function of preceding responses of "New" versus "Old." Participants were also assessed for paranoid ideation and multidimensional schizotypy. Guided by a preregistration (https://osf.io/wydvc), we tested the following hypotheses:

1. Confirming Duncan et al. (2012): In general, participants will show better performance on Similar trials preceded by New versus Old responses (i.e., a main effect of preceding response type [New > Old]).
2. Higher paranoia individuals will receive less benefit from preceding novelty (vs. familiarity) detection: As paranoia increases, Similar trial performance will *benefit less* from preceding New versus preceding Old responses (i.e., an interaction effect of paranoia by preceding response type).

Method

Participants

Guided by *a priori* power analysis of pilot data (see https://osf.io/wydvc), we sought to collect a final sample of convenience of 450 participants to achieve 86% power for the interaction effect of interest. To this end, 559 participants were recruited to take an online survey via Prolific (https://www.prolific.co). Only those over the age of 18 and located in the United States were recruited. Following exclusions ($n = 109$; described in detail in Section S1 of the online supplemental materials), participants included 245 women, 178 men, 25 participants who selected "other" for the question of gender, and two who declined to answer. Average age was 31.42 ($SD = 11.39$). In total, 261 (58.00%) participants reported having received a baccalaureate or postbaccalaureate degree. In sum, 331 (73.56%) participants identified as White, 45 (10%) as Asian, 33 (7.33%) as Black, eight (1.78%) as Native American, and 31 (6.89%) selected "other" for the question of race. See Section S2 (Table S1) in the online supplemental materials for a full report of demographic information.

Measures

Questionnaires

Self-reported paranoia was measured using the Revised Green Paranoid Thoughts Scale, part B (R-GPTS-B; Freeman et al., 2021). The R-GPTS-B consists of 10 items, which query thoughts and feelings one may have had about others in the past month. The scale includes statements such as "I was convinced there was a conspiracy against me." Participants were instructed to indicate the extent to which they experienced these feelings on a scale of 0 (*not at all*) to 4 (*totally*). Paranoid ideation was indexed using the sum of each participant's responses on the R-GPTS-B. 26.44% of the sample (119 participants) scored above the threshold for moderate paranoia (11; Freeman et al., 2021), suggesting oversampling of individuals scoring higher on paranoia (which has been suggested to show a ~20% prevalence rate in the general population; Freeman et al., 2011). Finally, the Multidimensional Schizotypy Scale (MSS; Kwapil et al., 2018) was additionally collected (see Section S3 in the online supplemental materials).

The internal consistency of questionnaire measures was indexed using Omega total (McDonald, 1999). This metric is the result of a factor analysis of all items on a scale, followed by an oblique rotation and extraction of a general factor. It can be interpreted using similar cutoffs as Cronbach's alpha (i.e., a value of 0.9 reflecting excellent internal consistency). Descriptive statistics and Omega total for the R-GPTS-B can be found in Table 1; for the MSS, see Table S2 in Section S3 of the online supplemental materials.

Table 1
Descriptive Statistics and Omega Total of R-GPTS-B

Questionnaire	*M* (*SD*)	Omega total (ω_t)
R-GPTS-B	7.84 (9.22)	$\omega_t = .94$

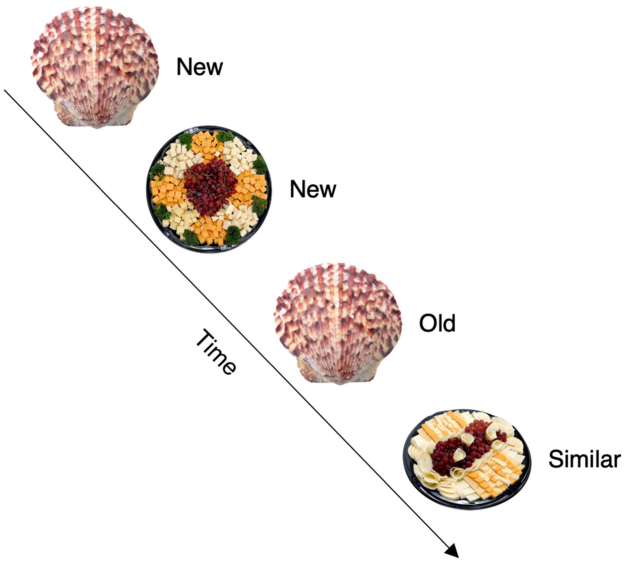
Note. R-GPTS-B = Revised Green Paranoid Thoughts Scale, Part B.

Continuous Recognition Task

Participants completed a continuous recognition memory task based on Duncan et al. (2012) and adapted for online use via jsPsych (de Leeuw, 2015). During the task, participants observed a continuous stream of images depicting everyday items, one after the other. Each image belonged to one of three trial types: "New" (presented for the first time), "Old" (previously presented), and "Similar" (subtly different from an Old trial). See Figure 1 for examples of each stimulus type. The stimuli used in this task were retrieved from https://osf.io/uq5jb/.

During each trial, participants were asked to indicate whether the presented image was New, Old, or Similar using a key press (see Procedure section for more detail). Similar stimuli acted as the critical trial type used to index sensitivity to response on the preceding trial. Importantly, the differences between Similar and Old stimuli were quite subtle. As such, if an observer's memory system was biased toward *pattern completion* by a preceding response of "Old," we would expect them to be more likely to erroneously identify a Similar stimulus as "Old." If an observer's memory system was instead biased toward *pattern separation* by a preceding response of "New," we would expect them to be more likely to notice the subtle differences between Similar stimuli and their Old counterparts, increasing the odds of a correct identification of "Similar." In this way, Similar trials were uniquely poised to reveal an observer's sensitivity to preceding instances of novelty detection when making discriminatory judgments. Note that preceding responses of "Similar" were excluded from further analysis given that we had no a priori hypotheses regarding this response type.

Figure 1
Example Stimulus Sequence



Note. The label next to each image denotes trial type (New, Old, or Similar). See the online article for the color version of the figure.

Procedure

Participants first completed the continuous recognition task, which began with a set of instructions and images that oriented participants to the three trial types (New, Old, and Similar). Participants were instructed to use their keyboard ("J," "K," and "L") to indicate whether a displayed image was New, Old, or Similar. To ensure comprehension, participants completed a practice round in which 11 images were presented, one after another. During each trial, participants had 1,500 ms to indicate whether the image was New, Old, or Similar. Text on the screen provided a reminder of the three response options and their corresponding keys. When a key was pressed, the corresponding text would turn red to indicate that a response had been logged. If the response was correct, participants received written feedback that read "Correct—good job!" and automatically proceeded to the next trial; if incorrect, it read "Oops—try again!" and the trial repeated. Each trial was followed by a fixation cross for 750 ms. The task progressed to the test blocks only when all practice trials had been answered correctly. The test blocks were identical to the practice round except for the fact that no written feedback was provided. Each of the three test blocks was composed of 319 images (150 New, 50 Old, 100 Similar, and 19 fillers) presented continuously, separated by fixation crosses for 750 ms. After each of the three test blocks, which lasted roughly 12 min, participants took a 1-min break. See Section S4 in the online supplemental materials for additional details on stimulus selection and balancing.

After completing this task, participants responded to the R-GPTS-B, the MSS, and a number of demographic questions.

Analyses

Analyses were conducted in line with our preregistered hypotheses (https://osf.io/wydvc). Any analyses that deviate from the preregistration are labeled accordingly. The continuous recognition task was scored by comparing the participant's response to a given image (New, Old, or Similar) to that image's trial type (New, Old, or Similar). A score of 1 indicated a correct response, and a score of 0 an incorrect response. At the group level, accuracy was indexed by taking the mean of these scores by trial type and multiplying them by 100 to convert the values to percentages (see Table 2 for a summary). Subject-level accuracy summary scores were computed in similar fashion. Finally, a "preceding response" variable was created for each trial n by denoting the response given (New, Old, or Similar) for trial $n-1$. Note that while we preregistered additional hypotheses regarding preceding *trial* type (see Section S6 in the online supplemental materials

Table 2
Group-Level Performance on the Continuous Recognition Task

Trial type	Mean accuracy (*SD*)	Number of trials
New	86.87% (12.80%)	450
Old	67.50% (17.05%)	150
Similar	51.92% (15.83%)	300
Total	72.02% (10.25%)	900

for this analysis), this manuscript focuses on preceding *response* type. This is justified for two reasons. First, in the original paradigm, effects of interest were found to be driven by participants' *subjective* responses over and above *objective* trial type (see the supplementary materials of Duncan et al., 2012). Second, an identical pattern was found in the present study, demonstrating that subjective judgments exerted the greatest influence on subsequent Similar trial performance (see Section S7 in the online supplemental materials).

We created a single mixed-effects binary logistic regression model of trial-level data representing score on Similar trials (0 and 1 s) to assess how performance on Similar trials varied as a function of preceding response type (Hypothesis 1) and its interaction with paranoia (Hypothesis 2). This analysis was conducted in R using the glmer function of the lme4 package (Bates et al., 2015). The model included terms for preceding response (New vs. Old), self-reported paranoia (R-GPTS-B score, ranging from 0 to 40), and a paranoia by preceding response interaction. Based on Akaike information criterion model selection, variables representing age, gender, education, and race were included as covariates. Responses of "New" were used as the baseline category for the preceding response term. The paranoia variable was square-root-transformed to achieve model convergence.

Finally, to assess objective trial type effects during recognition memory performance, we created a nonpreregistered mixed-effects linear regression model of subject-level accuracy scores (i.e., mean proportion correct) as a function of trial type (New, Old, and Similar), paranoia, and their interaction. See Section S8 in the online supplemental materials for more details on this analysis, along with other exploratory analyses.

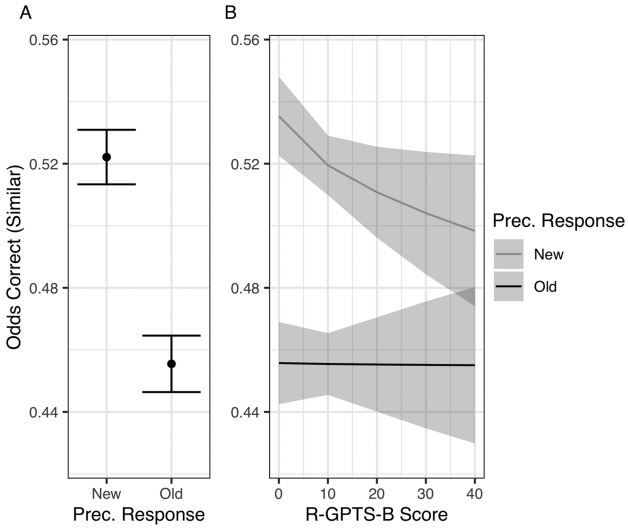
Results

Zero-order correlations can be found in Section S5 (Table S3) of the online supplemental materials. Mean accuracy on the continuous recognition task was 72.02% when collapsing across all trial types, indicating that group-level performance was well above chance (33.33%). As summarized in Table 2, performance was highest on New trials (86.87% accuracy), followed by Old trials (67.50% accuracy). Performance was lowest on Similar trials (51.92% accuracy), which is unsurprising given that Similar trials differed only subtly from previously presented images. Critically, the commonest errors on Similar trials were incorrect responses of "Old," suggesting that these trials were most likely to be mistaken as having been previously presented (see Section S9, Table S4 in the online supplemental materials for more details).

In line with Hypothesis 1, a mixed-effects binary logistic regression model of score on Similar trials (0 or 1) revealed a statistically significant main effect of preceding response, $z = -10.96$, $p < .001$. The odds ratio was 0.71, 95% confidence interval (CI) [0.67, 0.75], meaning that the odds of responding correctly to a Similar trial preceded by a response of "Old" were 0.71 times lower than that of a Similar trial preceded by a response of "New" (see Figure 2A). This represents a striking replication of the Duncan et al.'s (2012) memory penumbra effect, in which the detection of novelty (i.e., a New response) on trial $n-1$ boosts discriminatory performance on trial n. In other words, our results corroborate the notion that, in general, participants' ability to correctly identify Similar stimuli is enhanced when these trials were preceded by subjective judgments of novelty (vs. subjective judgments of familiarity). Our model predicted a roughly 6% boost in performance for Similar trials preceded by responses of "New" versus "Old," holding constant all other model terms.

Figure 2

Performance on Similar Trials as a Function of (A) Preceding Response and (B) Paranoia by Preceding Response



Note. Error bars/shaded areas represent *SE.* R-GPTS-B = Revised Green Paranoid Thoughts Scale, Part B.

Critically, in line with Hypothesis 2, this model also revealed a statistically significant paranoia by preceding response interaction effect, $z = 2.49$, $p = .013$. The odds ratio for this interaction term was 1.03, 95% CI [1.01, 1.05], indicating that for each unit increase in paranoia, the odds of responding correctly to a Similar trial preceded by a response of "Old" increased by 1.03 times relative to that of a Similar trial preceded by a response of "New." Put simply, this indicates that individuals higher in paranoia were *less benefitted* by preceding subjective judgments of novelty (relative to familiarity; see Figure 2B). More specifically, our model predicted that the performance boost of a preceding response of "New" would be roughly halved when comparing those lowest in paranoia (predicted to receive a ~8% performance boost) to those highest in paranoia (predicted to receive only a ~4% performance boost), holding constant all other variables. Interestingly, there was no statistically significant main effect of paranoia ($p = .25$), suggesting that paranoia was *not* associated with a decrease in Similar trial performance. Thus, despite this null association between paranoia and overall performance on Similar trials, performance *was* differentially modulated by preceding novel cues such that discriminatory judgments were less influenced by preceding instances of novelty detection among participants higher in paranoia.

Finally, a mixed-effects multiple linear regression model of accuracy across the three trial types (New, Old, and Similar) revealed that paranoia was associated with decreased accuracy on both New and Old trials, but not on Similar trials. See Section S8 in the online supplemental materials for the full results of this model.

Discussion

This study demonstrates that paranoia-prone members of the general population are less *benefitted by preceding instances of novelty detection* when making mnemonic judgments in a continuous

recognition memory task. Namely, those at the highest level of paranoia were predicted to receive roughly half the benefit of a preceding New response on a subsequent memory judgment than those at the lowest (~4% vs. ~8% performance boost, respectively). These findings build on mixed results seen in prior studies. Koller and Cannon (2021) and Sahakyan and Kwapil (2019) demonstrated that paranoia and positive schizotypy, respectively, were associated with impaired novelty detection (i.e., false recognition), suggestive of overactive retrieval writ large. Yet another study showed positive schizotypy to be associated with an *improved* ability to correctly reject similar lures (Vass et al., 2022); still another suggested *no such association* (Kraguljac et al., 2018). Our results are in line with a more nuanced model of novelty-related impairment among paranoid individuals: Even when novelty *is* detected, it less effectively triggers the typical shift toward an "encoding mode," via pattern separation (vs. a "retrieval mode," via pattern completion). This, in turn, could produce varied patterns of memory performance based on the sequence of stimuli or subject-level patterns of responding. Notably, this observed effect may reflect in part a downstream consequence of other memory errors, given that a "miss" (i.e., misjudging an Old item as "New") likely constitutes a *less potent* instance of novelty detection than a "correct rejection" (i.e., correctly judging a New item as "New"; see Section S7 in the online supplemental materials). This could represent one source of dilution to the normative influence of novelty detection among those higher in paranoia, who made more of this type of error (see Section S9 in the online supplemental materials).

Importantly, at the group level (i.e., irrespective of individual differences in paranoia), we strongly replicated Duncan et al. (2012). Performance on Similar trials was strikingly benefited by preceding New versus Old responses: Holding constant all other variables, preceding New responses were predicted to confer a 6% performance boost (comparable to a 9% boost in the original study).

Implications for Paranoia

This genre of novelty-related deficit carries important implications for paranoia. For one, it may reflect an underlying insensitivity to one's immediate context, such that prior mnemonic or perceptual experiences have a weakened impact on current processing—a process theorized to be central to psychosis in a classical account by Hemsley (1993). Similar patterns of findings have been reported among individuals on the psychosis spectrum in "context processing" tasks, in which participants must use information presented on previous trials to guide decision-making on the current trial (e.g., Cohen et al., 1999; Servan-Schreiber et al., 1996). Furthermore, recent computational work has revealed that positive symptoms, including delusions, are similarly linked to difficulty integrating prior experience with new information (e.g., Bansal et al., 2022; Nassar et al., 2021). Our work points to an analogous breakdown that manifests in the domain of memory.

We suggest that such a breakdown could contribute to predictive models that are decoupled from objective reality among those experiencing paranoia. One critical function of the memory system is to generate predictions of the future based on past experience (Bar, 2009; Lisman & Redish, 2009; Stachenfeld et al., 2017). Under normative circumstances, the detection of novel or surprising information serves as a powerful signal that an update is needed (Bein et al., 2020; Park et al., 2021; Sinclair et al., 2021), allowing our predictive models to remain responsive to our immediate environment. In this way, an attenuated influence of the detection of novelty on subsequent processing could undermine one's ability to access and update relevant predictive maps—perhaps via *overactive updating* of predictive models (i.e., overemploying encoding resources following novelty detection) and/or *perseverative access* of weakly relevant predictive models (i.e., overemploying retrieval resources following novelty detection). Together, these processes may weaken the concordance between one's active predictive model and the evidence available in one's current context. To the extent that this loss of predictive coherence persists over time (and is perhaps accompanied by concurrent challenges to other aspects of salience attribution systems; Kapur, 2003), it may increasingly fuel a perception of the world and the people in it as unpredictable and thus threatening (Feeney et al., 2017). While this is undoubtedly a speculative model, it highlights the important role that novelty detection plays in maintaining flexible predictive models of the world and illustrates one pathway via which breakdowns in the memory system could manifest as rigid beliefs that are at odds with consensus reality.

Strengths and Limitations

Drawing from neuroscientific models of human memory (e.g., Duncan et al., 2012; Patil & Duncan, 2017), the present study yielded new insights about the nature of novelty-related impairments in paranoia. This was facilitated by a priori power analysis, careful task adaptation and implementation, and fine-grained analysis of task data (i.e., modeling preceding response effects). This level of analysis helped to address potentially confounding group differences in visual perception (as raised by Martinelli & Shergill, 2015): While visual perception may impact overall performance on Similar trials, it is less plausible that a visual deficit would affect performance on trial n as a function of judgments on trial $n-1$. This is further supported by the fact that, in our sample, there was *no* evidence of paranoia-related differences in the ability to identify the Similar stimuli themselves. Importantly, exploratory analyses also revealed that the effect of interest persisted when covarying for positive and negative (but not disorganized) symptoms of schizotypy (see Section S10 in the online supplemental materials), suggesting that it may not be an artifact of other correlates of persecutory ideation (e.g., hallucinatory experiences, amotivation). However, it remains unclear whether this effect is specific to paranoia per se or whether paranoia simply represents a more common (i.e., powered) trait in the general population. Future research should thus assess specificity to paranoia versus disorganized symptoms or schizotypy more broadly.

Furthermore, given relatively poor performance on our online version of the task (52% accuracy vs. 64% in the original; Duncan et al., 2012), in-person replication may be informative (although the fact that we replicated the main effect of the original study bolsters confidence in task validity). Importantly, in-person replication facilitates more formal cognitive testing, the results of which would likely help to clarify the specificity of observed effects to paranoia (vs. cognitive deficits and/or disorganized symptoms). What's more, the effect size of the interaction of interest was small, requiring a sizable sample ($n = 450$) to detect. This highlights the importance of a priori hypothesizing and conservative power analysis, especially given that inadequate power represents a recurring challenge for psychopathology research in the general population (especially for interaction effects; Leon & Heo, 2009). Future research should seek to replicate and assess the functional significance of this subtle effect.

Replication with more complex (e.g., emotionally valenced) stimuli embedded within richer contexts may also bolster external validity. Finally, the majority of participants in our sample self-identified as White. Future work should assess whether results generalize to more racially diverse samples.

Conclusion

In the present study, we established that paranoia is associated with a reduced benefit of novelty detection to subsequent mnemonic judgments. This suggests that those higher in paranoia may struggle to use novelty in their immediate environment to effectively engage the competing mnemonic processes of encoding versus retrieval. Memory is instrumental to our ability to generate predictions about the external world, and the detection of novelty normatively guides the selection and maintenance of adaptive predictive models. As such, this reduction in the influence of novelty on subsequent mnemonic states may contribute to paranoid ideation by decoupling one's predictive models from the demands of one's environment, leading to perceptions of the world as uncertain and threatening.

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