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Does repetition enhance curiosity to learn trivia question answers? Implications for memory and motivated learning

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ABSTRACT
Curiosity, an intrinsic desire to seek new information, benefits motivation and learning. While curiosity is associated with novelty, less is known about how the repetition of a question without its answer affects curiosity and memory. In two experiments, participants viewed 60 trivia questions, half of which were repeated, and rated their curiosity to learn the answers. Repeated questions had their answers revealed during the second presentation, and participants were given a cued-recall test after 24 h. We found that curiosity ratings remained constant across presentations, but when repeated and non-repeated questions were intermixed, participants were more curious about non-repeated questions, which were relatively more novel (Experiment 1). However, when participants guessed answers before studying them (pretesting), they were more curious about repeated questions (Experiment 2). Curiosity ratings also increased across presentations, perhaps reflecting greater cognitive agency motivated by an eagerness to verify one's guess. Overall, the subjective experience of curiosity appears to be influenced by both relative novelty, as manipulated through repetition, and task demands, specifically whether individuals engage in pretesting, indicating that curiosity-based learning is shaped by various cognitive operations.

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Curiosity; repetition; novelty; pretesting; memory

People tend to direct attention towards information that they are most curious to learn about, suggesting that curiosity can act as a powerful source of intrinsic motivation that reinforces the desire to increase one's understanding and skill (Berlyne, 1950; Litman & Spielberger, 2003; Silvia, 2019). As early as infancy, children navigate the world around them in a curious manner that reflects their desire to close knowledge gaps and explore the unknown, such as by displaying high interest in situations of uncertainty with novel toys (Bonawitz et al., 2011; Kidd & Hayden, 2015; Schulz & Bonawitz, 2007). While especially prominent during childhood, curiosity continues to persist throughout the lifespan, impacting what we choose to focus on and later remember. Such motivated behaviour can often be observed in the classroom, where fostering intellectual curiosity (e.g., asking questions, seeking out information) is considered a priority for instructors aiming to improve student engagement and academic performance (Jirout et al., 2018; Von Stumm et al., 2011). At a broader level, curiosity has also been associated with well-being and is thought to be protective against age-related cognitive decline when individuals seek out stimulating or educational activities (Sakaki et al., 2018).

In defining curiosity, many common themes can be identified: exploration driven by novelty and uncertainty, an openness to experience, natural desire for knowledge, etc. Philosopher Cicero (1914), for instance, describes that "So great is our innate love of learning and of knowledge, that no one can doubt that man's nature is strongly attracted to these things even without the lure of any profit", painting curiosity as an intrinsic quality that drives behaviour without the expectation of tangible reward. On the other hand, Loewenstein (1994) focuses more on the uncertainty associated with curiosity, characterising it as "A cognitive induced deprivation that arises from the perception of a gap in knowledge and understanding". In the current study, we focus on curiosity as these short-lived feelings of "not knowing" that motivate subsequent information search to obtain unknown or novel information (Donnellan et al., 2022; Murayama et al., 2019).

The role of curiosity during learning

Generally, people have better memory for information that they are curious about (Bull & Dizney, 1973; Marvin &

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Shohamy, 2016). Curiosity's role in learning has been extensively studied using the trivia question paradigm, in which individuals are presented with questions from various domains (e.g., history, science, geography) designed to evoke different curiosity levels (Kang et al., 2009). After seeing each question, participants rate their curiosity to learn the associated answer before the correct answer is revealed. They then undergo a cued-recall test for all questions. Using this paradigm, researchers found that high states of curiosity predicted later memory for associated answers among younger and older adults, even after a delay (Fandakova & Gruber, 2021; Fastrich et al., 2018; Galli et al., 2018). Increased activation of the anterior cingulate cortex and lateral prefrontal cortex, which stimulate dopaminergic modulation of hippocampal activity, have been proposed as neural mechanisms of these curiosity-related memory enhancements (Gruber & Ranganath, 2019; Kang et al., 2014; Sakaki et al., 2018).

According to the Region of Proximal Learning (RPL) framework, individuals should display high curiosity when they believe that they "almost know" the answer (Metcalfe, 2023; Metcalfe et al., 2020). Here, curiosity depends on the type of metacognitive appraisal – curiosity is low when items are perceived as unfamiliar or too difficult to learn but increases as individuals get closer to a solution. Depending on one's evaluation of existing knowledge (do I know the answer) and current state of progress (am I able to answer the question), individuals may or may not be sufficiently motivated to seek out the correct answer (Goupil & Proust, 2023). Items in individuals' RPL tend to be better remembered, especially when errors made with high confidence are corrected during later test (hypercorrection effect; Butler et al., 2011; Butterfield & Metcalfe, 2001). Such incorrect guesses are considered to be in the RPL zone since they are often semantically similar to the correct answers (individuals are close to the answer) and elicit neural event-related potential signals consistent with being in a high state of curiosity (Butterfield & Mangels, 2003; Sitzman et al., 2015).

Can repetition enhance curiosity and memory?

It is important to better understand what factors can influence curiosity, both for theoretical and applied reasons, as curiosity can lead to better memory and greater exploratory behaviours. In the present study, we were interested in how curiosity may fluctuate based on how frequently someone is presented with certain information. For instance, in educational settings, an instructor may introduce a challenging question at the beginning of class but not provide an immediate answer, instead telling their students to reflect on the solution. Later on, the instructor revisits the question to reveal the answer, check for student understanding, and address common misconceptions. To our knowledge, there has been little research on how repetition, or the number of times a question or prompt is shown without its answer, affects curiosity to learn. However, there is reason to believe that repetition could either enhance, maintain, or reduce levels of curiosity.

Examining curiosity to learn across repetitions

The familiar experience of a knowledge gap produced by a recurrent question may be unpleasant for individuals seeking to quickly satiate their curiosity (Litman & Jimerson, 2004; Loewenstein, 1994). The inability to retrieve the answer may reinforce feelings of deprivation and discomfort, intensifying the urgency to resolve existing uncertainty with every repetition. On the other hand, there is a possibility that repetition has no effect on curiosity. As previously mentioned, feelings of curiosity depend on a series of metacognitive evaluations, notably (1) whether there is an existing knowledge gap and (2) whether it is possible to close the gap through information search (Berlyne, 1954). One may either choose to close the gap by pursuing additional learning activities or forgo such efforts if the gap is perceived as too large (Kornell & Metcalfe, 2006). Considering that the size of the knowledge gap remains consistent prior to information seeking (i.e., before the answer is revealed) and that the amount of prior knowledge does not change across repetitions, levels of curiosity should remain stable as long as individuals are unable to retrieve the correct answer from memory.

Curiosity is often described as a motivational state that rewards novelty seeking (Kashdan & Silvia, 2009). Prior work suggests that the brain preferentially responds to novel stimuli, as evidenced by increased attention and reward-related neural activity, which subsequently reinforces exploratory behaviours (Oudeyer, 2018; Wittmann et al., 2008). In the current study, repeated questions are shown twice, so a decrease in novelty across exposures may reduce curiosity for such questions. Simultaneously, encountering non-repeated questions interspersed with repeated questions may heighten curiosity for the former due to their relative novelty (they are only shown once before answer presentation). Nevertheless, there remains the possibility that curiosity ratings may be similar since the novelty of the answers is unaffected by repeated questioning. Therefore, we sought to clarify if perceptions of curiosity are influenced by the relative novelty of the questions themselves, as manipulated through repetition, or by the novelty of the answers.

Effects of repeated question presentation on memory

Past studies suggest that there can be an advantage to learning novel items as they are associated with unique encoding contexts and are highly distinct from repeated, familiar items, which may bolster learning through increases in dopaminergic-hippocampal activity (Bunzeck et al., 2010; Reggev et al., 2018; Tulving & Kroll, 1995). Other accounts propose that familiarity with to-be-tested items can improve performance as each repetition provides a new pathway from which information can be retrieved (more encoding variability; Bjork & Bjork, 2019; Cuddy & Jacoby, 1982; Hintzman & Block, 1971). Although various arguments could be made for the mnemonic benefits of novelty and familiarity, such effects seem to be highly specific to the stimuli and type of test used. Effects of repetition are often studied by testing participants' recognition of word lists or word pairs and varying the frequency of some to-be-tested information. Here, we were instead interested in how the repetition of a question affects recall memory for its associated answer.

There may not be an advantage to repeating questions, as answers are only shown once during the experiment (i.e., only one encoding context). Yet, repetition introduces a natural delay in the learning process since answers are not revealed during the initial presentation of questions. In a study by Mullaney et al. (2014), individuals who waited a few seconds before being shown the answers to trivia questions had better memory for answers that elicited high levels of curiosity in comparison to individuals who were shown the answers immediately. It was reasoned that the anticipation of the answer and activation of related semantic concepts during retrieval may have better prepared individuals to encode the correct answer within existing knowledge networks. Studies on the pretesting effect have shown that trying to retrieve an answer from memory, even if attempts are unsuccessful, can foster meaningful learning (Huelser & Metcalfe, 2012; Kornell et al., 2009). Hence, repetition may produce a delay-of-feedback benefit when individuals encounter high-curiosity trivia questions.

The current study

Curiosity plays an important role in the learning process, but the specific ways in which it can be stimulated to enhance memory are still being explored, highlighting the importance of the current research. Related literature has examined how perceived knowledge and testing may impact levels of curiosity (e.g., Potts et al., 2019; Reichardt et al., 2023), and the present study extends this line of research through the investigation of how repeated presentation of trivia questions affects curiosity and recall performance. In Experiment 1, participants were shown trivia questions either once or twice before their associated answers were revealed. Twenty-four hours later, they were administered a cued-recall test for all trivia question answers. To control for prior knowledge, we conducted Experiment 2, during which participants were asked to provide a guess to each trivia question before being shown the correct answer. In both experiments, we measured incidental learning, meaning that participants were not instructed to memorise the questions or answers for a later test.

Experiment 1

In Experiment 1, we explored how repetition of trivia questions affects curiosity to learn associated answers and later memory for those answers. We presented participants with a modified trivia question paradigm in which they were shown trivia questions that were either repeated or were not. Questions that were repeated only had their answers revealed during the second presentation. After seeing each trivia question, participants rated their curiosity to learn the answer. They were tested on their memory for all trivia question answers after a 24-hour delay.

Although the effects of repetition on curiosity have not been directly studied, repetition could enhance or lessen levels of curiosity. Specifically, repetition can place individuals in high states of curiosity when knowledge gaps are repeatedly made salient, facilitating deeper learning when individuals form questions and connections between what they know and desire to learn (Brod & Breitwieser, 2019). If curiosity is dependent on the relative novelty of the stimulus, then there may be a chance that individuals will want to learn more about non-repeated questions, as they are only shown once before the answer is revealed. With regards to recall, repetition may benefit memory performance for trivia questions, especially for answers that participants are highly curious to learn (see Mullaney et al., 2014).

Method

Participants

After exclusions, participants were 139 undergraduate students (110 females, $M_{age} = 20.79$, $SD_{age} = 4.02$) recruited from the University of California, Los Angeles (UCLA) Human Subjects Pool. All participants were fluent in English and 70% were native English speakers. Thirty-six percent of participants identified as Caucasian, 40% as Asian/Pacific Islander, 4% as Black, and 20% as others/unknown. Participants were excluded from analysis if they self-reported cheating (they were told that they would receive credit for their participation regardless of their answer). This process resulted in three exclusions. Informed consent was acquired from all participants, and the two-part online study was conducted with approval from the UCLA Institutional Review Board. There was no a priori sampling plan, but using a web-based application developed by Olvera Astivia et al. (2019), we ran a simulation with 100 replications to estimate effect size in our multilevel logistic regression model. The post-hoc sensitivity analysis indicated that with our sample size of 139 at level 2, sample size of 60 at level 1, alpha of .05, and power = .80, we were able to detect small to medium effects for all variables ($\gamma = .20$; Cohen, 1992).

Materials

Experiment 1 was designed and administered to participants via Collector, an open-source programme used to conduct psychology experiments (Garcia & Kornell, 2014). Sixty trivia questions and their answers pooled from the Fastrich et al. (2018) database were presented to participants (see Appendix for all questions). We decided to present trivia questions to participants because they were likely to have some prior knowledge from the domains in which the questions were sourced (e.g., history, science, geography), and thus the questions were expected to elicit a wide range of curiosity amongst participants. To ensure a balanced representation, questions were categorised into high and low a priori curiosity levels based on the median split of curiosity ratings, which were obtained from an unpublished pilot study with 60 English-speaking participants recruited online via Prolific. During the experiment, participants saw a total of two lists: List 1 contained 15 high and 15 low a priori curiosity questions, and List 2 contained 30 high and 30 low a priori curiosity questions. There were two versions of List 1, which were counterbalanced across participants (List 2 was composed of both versions).

Procedure

The general procedure is depicted in Figure 1. Participants were told that they would be completing a study related to memory during which they would study trivia questions. They were not instructed to memorise presented questions or answers, nor were they told that they would be tested on all answers 24 h later. During session I, participants saw two lists of trivia items. The first list contained 30 items, and the second contained 60 items (30 of which were repeated). During List 1, participants were first shown a trivia question for 8 s and then were asked to indicate how curious they were to learn the correct answer on a 10-point scale (1 = *not at all curious*, 10 = *extremely curious*). The trivia question was not displayed on the screen when participants made their rating. Curiosity ratings were self-paced. Once all 30 trivia questions had been presented, participants completed a distractor task for one minute, during which they were asked to rearrange presented numbers in descending order. For instance, if the numbers 528 were shown, participants had to type 852. They had three seconds to do this before another series of numbers appeared on the screen (for a total of 20 trials).

Participants were then told that they would be presented with more trivia questions. During List 2, participants were presented with all 60 trivia questions. They were not informed that half of the questions would be ones that had already been shown prior to the distractor task. Again, participants had 8 s to read each trivia question before indicating how curious they were to learn the correct answer on a 10-point scale (1 = *not at all curious*, 10 = *extremely curious*). Following curiosity ratings, which were self-paced, the correct answer was revealed for 5 s before the next question was presented, and this process repeated for all 60 items. For both lists, the order of trivia items was randomised for each participant, and the items that were repeated were counterbalanced across participants.

In session II, which occurred 24 h after session I, participants completed a cued-recall test for all trivia question answers. Trivia questions were presented one at a time on the screen with a text box below to enter the answer. There were no time constraints for recalling answers. The order in which the 60 test items appeared was randomised for each participant.

At the end of both sessions, participants were asked if the experiment went smoothly or if there were problems with the task. Participants were excluded from analyses if they reported significant Internet or task problems. Finally, they were asked if they looked up any of the questions or answers during the task. Participants were told that they would receive credit for their participation in the study regardless of their answer here.

Results

Curiosity ratings

In comparing how curiosity changed across presentations, we conducted a random intercept mixed-effects model with trivia items nested within individuals. First, we ran a model predicting curiosity ratings as a function of time (dummy coded; 0 = *first presentation*, 1 = *second presentation*) within items that were repeated only to assess whether curiosity ratings changed over presentations. The model indicated that curiosity ratings for repeated items on List 1 ($M = 5.14$, $SD = 2.74$) were not significantly different than ratings for those same items on List 2 ($M = 5.07$, $SD = 2.73$), $\beta = -.07$, $SE = .05$, $t(8199) = -1.31$, $p = .191$. Thus, we did not find that curiosity ratings changed from List 1 to List 2 for items that were repeated.

Next, we fit another model predicting curiosity ratings on List 2 only as a function of repetition (dummy coded; 0 = *not repeated*, 1 = *repeated*) within all items to examine whether items that were repeated led to different levels of curiosity than items that were not repeated. The model showed that curiosity ratings for non-repeated questions ($M = 5.26$, $SD = 2.68$) were higher than those for repeated questions on List 2 ($M = 5.07$, $SD = 2.73$), $\beta = -.19$, $SE = .05$, $t(8199) = -3.70$, $p < .001$. Therefore, the items that were novel on List 2 were given higher curiosity ratings than items that were not novel on List 2.

Finally, a model predicting initial curiosity ratings from question type (dummy coded; 0 = *repeated question*, 1 = *non-repeated question*) revealed that curiosity ratings for non-repeated questions on List 2 were greater than curiosity ratings for repeated questions on List 1, $\beta = .12$, $SE = .05$, $t(8200) = 2.28$, $p = .023$. Together, these findings suggest that curiosity did not increase from the first to the second presentation of repeated items. Additionally, repeated items were given lower initial (List 1) and final (List 2) curiosity ratings than non-repeated items.

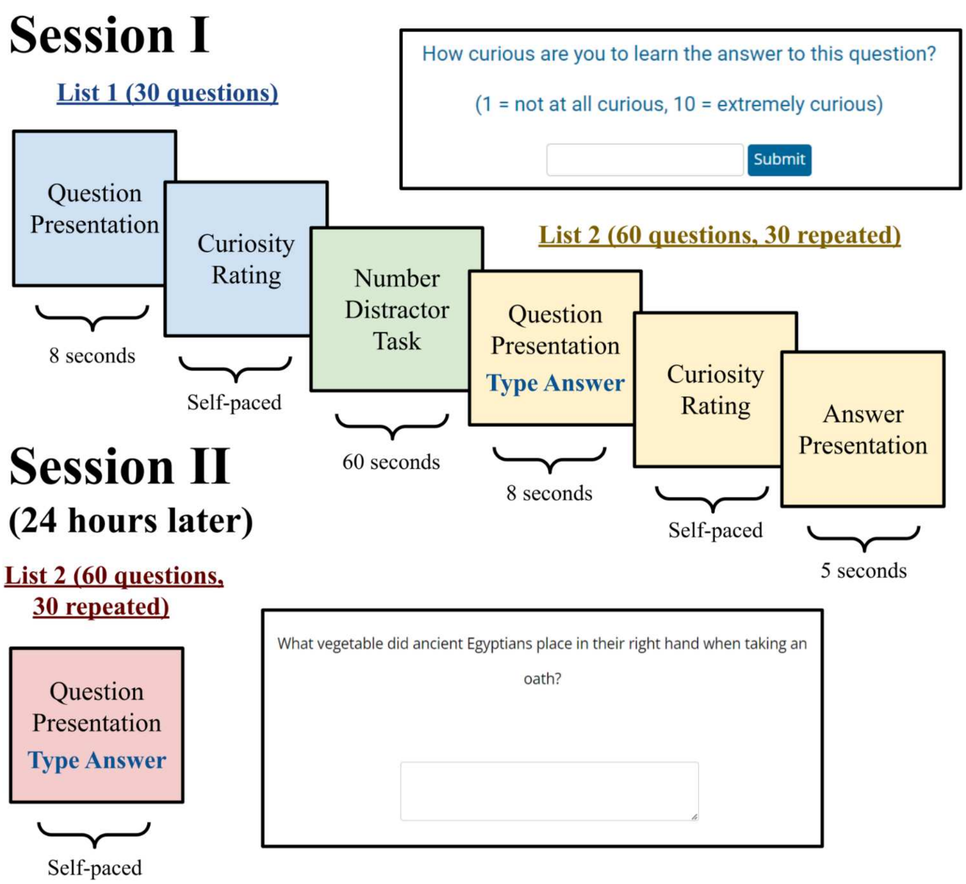

Figure 1. Modified trivia question paradigm used in Experiments 1 and 2. There were two versions of List 1, which were counterbalanced across participants (List 2 was composed of both versions). Only in Experiment 2 were participants asked to provide an answer to each presented trivia question prior to seeing the correct answer during session I.

Repetition, curiosity, and recall

To examine the extent to which repetition and curiosity affected memory performance (Figure 2), we tested a random intercept logistic mixed-effects model with accuracy (0 = *incorrect*, 1 = *correct*) as the dependent variable and repetition (dummy coded; 0 = *not repeated*, 1 = *repeated*) and final curiosity (cluster centred) as fixed effects, as well as the interaction between repetition and curiosity. Final curiosity refers to the curiosity ratings made when all 60 items were shown (i.e., during List 2). As used in McGillivray et al. (2015), the interpretation of this model depended on the exponential of the coefficient, Exp(β), which reflects the odds ratio (OR), or how much the odds of recalling an answer will change for a one unit increase in the predictor variable, where an OR of 1 is a null result.

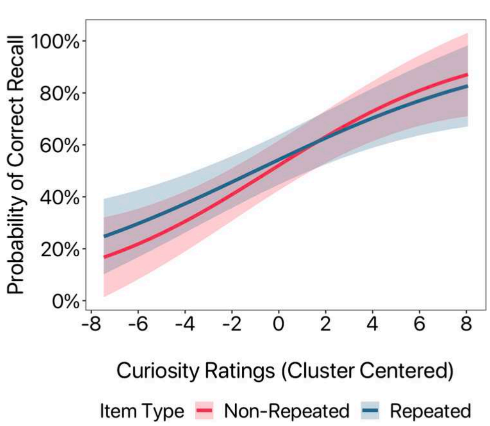

Figure 2. Results of random intercept logistic mixed-effects model in Experiment 1. Shaded areas represent 95% confidence intervals.

Results revealed that memory performance did not depend on whether questions were repeated ($M = .54$, $SD = .50$) or not ($M = .53$, $SD = .50$), $OR = 1.10$, $SE = .05$, $z = 1.80$, $p = .073$. Curiosity significantly predicted performance, suggesting that the more curious a participant was to learn the answer to a trivia question, the higher the likelihood they would correctly recall the answer during a later test, $OR = 1.25$, $SE = .02$, $z = 14.08$, $p < .001$. There was a significant interaction between repetition and curiosity, $OR = .95$, $SE = .02$, $z = -2.47$, $p = .014$, such that the effect of curiosity was more pronounced for non-repeated items. Using the simple-slopes technique, we further probed the interaction and found that repetition had a statistically significant effect on recall for low-curiosity items (−1 *SD* from the individual mean, $p < .001$), but the effect was not different from zero for high-curiosity items (+1 *SD* from the individual mean, $p = 0.611$).

Discussion

In Experiment 1, we sought to investigate the interplay between repetition, curiosity, and memory performance for trivia question answers. Curiosity did not decrease across presentations, suggesting that levels of curiosity may remain stable as long as individuals' metacognitive feelings about their lack of knowledge do not change (i.e., amount of prior knowledge is the same and the answer is still unretrievable; Goupil & Proust, 2023). Interestingly, when repeated and non-repeated questions were intermixed (List 2), curiosity was generally higher for non-repeated questions, suggesting that the relative novelty of a question may impact one's motivation to learn. It appears that participants may have recognised that some questions were repeated (though this was not explicitly stated), as List 1 curiosity ratings for repeated questions were lower than List 2 curiosity ratings for non-repeated questions. When participants made these ratings, all questions were novel since they were being shown for the first time, yet participants seemed to be more interested in the non-repeated questions when they were presented with repeated questions. Therefore, while the magnitude of curiosity remains consistent despite delays in feedback, as was the case for repeated questions, individuals may still be more inclined to learn newer information, demonstrating a preference for non-repeated over repeated items.

With regards to memory performance, we observed that as curiosity increased, the likelihood that participants correctly recalled the answer also increased, replicating past findings (see Fastrich et al., 2018; Halamish et al., 2019). High states of curiosity thus supported the encoding and remembering of trivia question answers. In addition, test performance was not significantly different between repeated and non-repeated questions. Since participants were not learning the answers to the trivia questions twice, which is what they were ultimately tested on, it was unsurprising that repeating the question did not improve memory for the answers. We found that higher curiosity ratings were associated with better memory performance for both repeated and non-repeated questions, but the effect was stronger for non-repeated items. Therefore, repetition may alter the nature of the relationship between curiosity and memory, such that curiosity corresponds more with memory when items are novel.

Experiment 2

In Experiment 2, we sought to replicate Experiment 1's findings while controlling for participants' prior knowledge. Participants were asked to guess the answer to each trivia question before seeing the associated answer to assess whether they already knew the answer, and items that were correctly guessed were removed from analyses. To rule out the possibility of repetition interacting with timing of pretesting, the act of testing before receiving formal instruction, this guess occurred when all questions were presented (initial presentation of non-repeated questions, second presentation of repeated questions).

Method

Participants

After exclusions, participants were 141 undergraduate students (110 females, $M_{age} = 20.67$, $SD_{age} = 5.00$) recruited from the UCLA Human Subjects Pool. All participants were fluent in English and 65% were native English speakers. Thirty-five percent of participants identified as Caucasian, 48% as Asian/Pacific Islander, 5% as Black, and 12% as others/unknown. Participants were excluded from analyses if they self-reported cheating (they were told that they would receive credit for their participation regardless of their answer). This process resulted in three exclusions. Informed consent was acquired from all participants, and the two-part online study was conducted with approval from the UCLA Institutional Review Board. We aimed to recruit a similar sample size as that of Experiment 1.

Materials and procedure

The same materials from Experiment 1 were used, and the procedure was similar to that of Experiment 1 (see Figure 1). Participants were told that they would be completing a study related to memory during which they would be presented with trivia questions and again were not informed about the later test. List 1 was the same as in Experiment 1, where 30 trivia questions were presented and curiosity ratings were collected. After List 1, participants completed a one-minute number distractor task. They were then told that they would be studying more trivia questions, but that after each trivia question was revealed, they would have to provide a guess as to what the associated answer was. If participants could not think of a guess, they were told to put "NA" as their answer. As in Experiment 1, List 2 had all 60 trivia questions (with 30 repeated from List 1) shown for 8 s each, except that participants were asked to enter a guess. The page automatically advanced after 8 s, regardless of if an answer was provided or not, after which participants rated their curiosity to learn the correct answer on a 10-point scale (1 = *not at all curious*, 10 = *extremely curious*), which was self-paced. Then, the answer to each trivia question was displayed for 5 s, and this process repeated for all 60 items. Twenty-four hours later, participants completed a cued-recall test for all trivia questions, which was the same as in Experiment 1.

Results

Participants correctly answered an average of 5.21% (*SD* = 22.23%) of questions prior to studying the trivia question answers. Questions that were repeated ($M = 5.70\%$, $SD = 23.18\%$) were more likely to have been correctly guessed compared to questions that were not repeated ($M = 4.73\%$, $SD = 21.23\%$), $OR = 1.22$, $SE = .10$, $z = 2.06$, $p = .039$. Curiosity ratings on List 2 were greater for questions that participants guessed incorrectly ($M = 5.71$, $SD = 2.74$) versus correctly ($M = 5.61$, $SD = 2.83$), $\beta = -.27$, $SE = .11$, $t(8336) = -2.46$, $p = .014$. Trivia questions that participants provided an accurate guess to were removed from subsequent analyses.

Curiosity ratings

To examine differences in curiosity ratings across presentations, we conducted the same random intercept mixed-effects analyses as in Experiment 1. First looking at curiosity ratings for repeated questions only as a function of list, the model indicated that curiosity to learn trivia question answers increased from first to second presentation, meaning that curiosity ratings were higher the second time a question was shown ($M = 5.77$, $SD = 2.77$) compared to the first time it was shown ($M = 5.36$, $SD = 2.75$), $\beta = .41$, $SE = .05$, $t(7833) = 7.53$, $p < .001$. Next, in a model predicting curiosity ratings for all items on List 2 as a function of repetition, curiosity for repeated questions ($M = 5.77$, $SD = 2.78$) was greater than curiosity for non-repeated questions ($M = 5.66$, $SD = 2.71$), $\beta = .13$, $SE = .05$, $t(7875) = 2.59$, $p = .010$.

Repetition, curiosity, and recall

To examine the extent to which repetition and curiosity affected memory performance (Figure 3), we tested a random intercept logistic mixed-effects model with accuracy (0 = *incorrect*, 1 = *correct*) as the dependent variable and repetition (dummy coded; 0 = *not repeated*, 1 = *repeated*), curiosity ratings on List 2 (cluster centred), and their interaction as fixed effects. There was no significant effect of repetition, indicating that memory performance did not differ between repeated ($M = .56$, $SD = .50$) and non-repeated questions ($M = .55$, $SD = .50$), $OR = 1.01$, $SE = .05$, $z = .11$, $p = .916$. In addition, high states of curiosity predicted a greater likelihood of correct recall, $OR = 1.22$, $SE = .02$, $z = 11.99$, $p < .001$. The interaction between repetition and curiosity was not significant, $OR = .99$, $SE = .02$, $z = -.45$, $p = .651$.

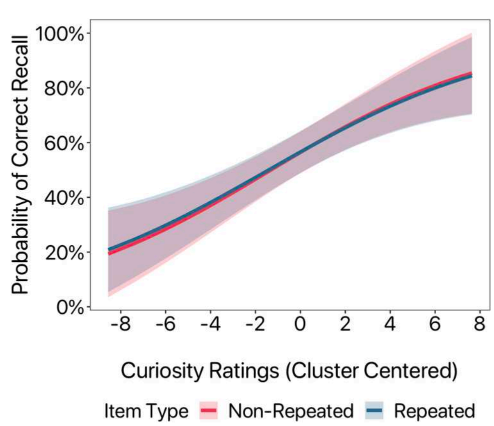

Figure 3. Results of random intercept logistic mixed-effects model in Experiment 2. Shaded areas represent 95% confidence intervals.

Overt guessing and recall accuracy

We conducted additional analyses examining if overtly guessing an answer would affect curiosity and memory for the correct answer. Since correctly guessed questions were excluded, we only looked at questions that participants provided an incorrect guess or no guess (i.e., participants wrote NA or left answer blank) for. On average, participants provided an incorrect guess to 57% of presented trivia questions. We were interested in whether participants were more likely to submit guesses to questions that they were initially curious about, so we conducted a random intercept logistic mixed-effects model predicting whether participants provided an overt guess (0 = *no guess*, 1 = *guess*) as a function of initial curiosity (cluster centred). We specifically focused on repeated questions, as curiosity ratings were only solicited after pretesting for non-repeated questions. We saw that initial curiosity was related to a greater tendency to guess an answer during the second presentation, $OR = 1.13$, $SE = .02$, $z = 8.00$, $p < .001$. Moreover, when participants guessed an incorrect answer to repeated and non-repeated questions ($M = 6.02$, $SD = 2.62$), final curiosity (curiosity ratings in List 2) to learn the correct answer was greater compared to when they had not provided a guess ($M = 5.31$, $SD = 2.84$), $\beta = .55$, $SE = .06$, $t(7984) = 9.77$, $p < .001$. Trivia questions that participants provided an incorrect guess to ($M = .61$, $SD = .49$) were more likely to be answered correctly on the delay test compared to questions that participants did not provide a guess to ($M = .49$, $SD = .50$), $OR = 1.71$, $SE = .05$, $z = 9.82$, $p < .001$.

We hypothesised that curiosity may mediate the relationship between guessing and recall, suggesting that overtly guessing an answer would increase curiosity to learn the correct answer to a trivia question, which may thereby increase the likelihood of later recall. Figure 4 depicts the mediation analysis with path coefficients. Due to the dichotomous nature of the outcome variable and the hierarchical structure of the data, we decided to use a Bayesian approach to estimate a multilevel mediation model in R using the *bmlm* package (Vuorre & Bolger, 2018). Items were clustered within participants, such that Level 1 variables refer to items and Level 2 variables refer to participants. In the mediation analysis, we focused solely on Level 1 variables (i.e., guess, curiosity, recall). Guessing (0 = *no guess*, 1 = *guess*) and recall (0 = *incorrect*, 1 = *correct*) were binary variables and curiosity was a continuous variable (1 = *not at all curious*, 10 = *extremely curious*) that we standardised prior to analysis, per prior recommendations (Mackinnon & Dwyer, 1993; Winship & Mare, 1993). Since the Bayesian approach uses a Markov chain Monte Carlo (MCMC) estimation procedure

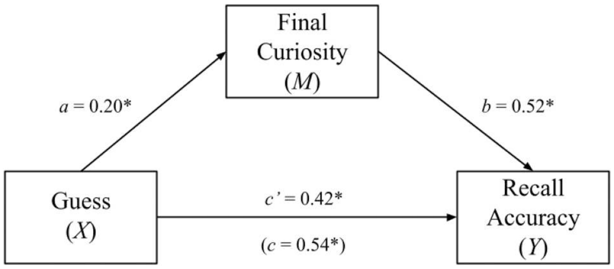

Figure 4. Regression coefficients for the relationship between guessing and likelihood of correct recall as mediated by final curiosity (standardised) in Experiment 2. * indicates that the confidence interval did not contain zero.

to fit the model, 95% confidence intervals were provided for all path coefficients. Guessing was the independent variable (X), final (List 2) curiosity was the mediator (M), and recall accuracy was the outcome (Y).

The model showed that without controlling for curiosity, guessing was a significant predictor of recall ($c = 0.54$, CI: 0.42–0.66), meaning that items that participants submitted a guess to were more likely to be answered correctly during a later test. Guessing predicted curiosity ($a = 0.20$, CI: 0.14–0.26), indicating that guessed items received higher curiosity ratings during List 2. Controlling for guessing, higher states of curiosity predicted greater recall accuracy ($b = 0.52$, CI: 0.45–0.60), and guessing remained a significant predictor of recall when the effect of curiosity was partialled out ($c' = 0.42$, CI: 0.30–0.54). Zero was not in the confidence interval of the indirect effect (mediated effect = 0.12, CI = 0.08–0.17), suggesting that curiosity was a mediator of the effect of guessing on memory for trivia question answers. In other words, by making a prediction, individuals' curiosity may increase, thereby improving recall.

Discussion

In Experiment 2, we saw that curiosity increased across presentations and was greater for repeated versus non-repeated questions. While we did not anticipate that pretesting would alter the relationship between repetition and curiosity, nor was it our intention to investigate the effects of pretesting on curiosity, we offer some potential explanations for the contrasting results obtained from our two experiments. Asking participants to overtly provide a guess may have reintroduced familiar feelings of discomfort associated with existing knowledge gaps, subsequently boosting curiosity across presentations and resulting in more curiosity for repeated questions compared to non-repeated questions. Additionally, pretesting may have evoked a different form of curiosity distinct from that measured in Experiment 1 – curiosity ratings in Experiment 1 (no pretesting) may reflect genuine curiosity to learn the answer to trivia questions (i.e., learning for the sake of gaining knowledge itself), but ratings in Experiment 2 (pretesting) may more so represent curiosity to verify a guess that is sensitive to repetition. If such differences exist, it would be difficult to disentangle the effects, but perhaps asking participants post-task what factors they considered when making their ratings (e.g., intrinsic desire to learn, tip-of-the-tongue, high confidence in guess, eagerness to confirm guess accuracy, etc.) during each list could provide some insight.

Similar to Experiment 1, we saw that higher levels of curiosity, but not repetition, predicted better recall accuracy. The effect of repetition on memory performance did not depend on level of curiosity, possibly due to the mnemonic effects of pretesting. Beyond stimulating curiosity, pretesting has been shown to promote memory, even when retrieval attempts are unsuccessful (Pan et al., 2020; Richland et al., 2009). Pretesting may facilitate future learning by activating long-term memory structures that prepare individuals to effectively encode presented information (Grimaldi & Karpicke, 2012; Nelson & Dunlosky, 1991; see Kornell & Vaughn, 2016 for a review). We also saw that participants who incorrectly guessed the answer to a trivia question were more likely to recall the correct answer on the delay test compared to those who did not submit an answer and that this relationship was mediated by curiosity. If participants were aware that they had provided an incorrect guess and/or wanted to verify the accuracy of their guess, it is possible that they would have been put in a high state of curiosity, subsequently strengthening memory for both repeated and non-repeated questions. Asking participants to guess may have also facilitated greater connections with existing knowledge – if participants made a prediction, it could be reflective of more prior knowledge in that domain, and subsequently, greater curiosity (Wade & Kidd, 2019).

Findings from this analysis should be taken with caution, as pretesting was not manipulated across items in Experiment 2 (i.e., participants were told to make a guess for all questions). Future studies could directly investigate how pretesting (explicitly being told to retrieve an answer from memory) versus no pretesting (no instruction) impacts curiosity for repeated information and subsequent learning of associated answers.

General discussion

In prior work, curiosity has been demonstrated to be a strong predictor of learning and motivation. While curiosity is generally thought to be a positive trait that persists throughout the lifespan, less research has been done on what factors can increase levels of curiosity and promote memory. In the current study, we sought to examine the impact of repetition, or the number of times a question is repeated without its answer, on the relationship between curiosity and test performance. In Experiment 1, participants were not asked to guess the answers to presented trivia questions, whereas in Experiment 2, participants were asked to make overt guesses prior to seeing the correct answers. All participants completed a delayed cued-recall test for the trivia questions 24 h later.

Repetition does not change curiosity to learn

Curiosity reflects a metacognitive state in which individuals are aware of knowledge gaps that they are motivated to close, largely depending on individuals' appraisal of what they believe they know and do not know. Hence, curiosity is positively related to one's prior knowledge, increasing as more information is obtained and one gets closer to their "reference point" (what one wants to know; Loewenstein, 1994) or when the answer is almost known (Metcalfe et al., 2020). In Experiment 1, we saw that presenting a trivia question twice did not affect curiosity to learn. Considering that curiosity is dependent on the perception of how close one is to the answer, it is likely that if individuals did not know the answer to the question when it was first presented, they would still be unable to retrieve the answer during the second presentation. Therefore, the size of the knowledge gap plays a key role in determining whether feelings of curiosity are evoked and to what degree.

A study by Shin et al. (2024) looked at how providing hints during learning (thereby lessening the size of the gap) affects curiosity to learn answers to interesting and boring trivia questions. What distinguished the questions from being interesting versus boring depended on various factors: prior knowledge in the subject matter, personal relevance (is it useful for me to know the answer), and salience or ability to capture attention (is there sufficient stimulation or a sense of urgency to resolve uncertainty). The researchers found that hints (e.g., size, number of letters, initial consonant, unique characteristics) related to associated answers increased curiosity for boring but not interesting questions; providing hints may have enabled individuals to access knowledge networks helpful for answering the question, increasing motivation to learn. Thus, unless individuals perceive that they are getting closer towards the correct answer, such as by receiving hints, curiosity should not change over presentations.

Curiosity reflects a preference for relative novelty

Curiosity is often described as a state of novelty seeking during which individuals exhibit strong preferences for stimuli and situations unlike those they had encountered before (Jaegle et al., 2019). We observed that participants were more curious to learn the answers to non-repeated questions when they were intermixed with repeated questions. In addition, curiosity ratings for repeated questions in List 1 were significantly lower than those for non-repeated questions in List 2, suggesting that participants may have compared the relative novelty of each presented question. Curiosity could be described as a time-sensitive state – if feedback is delayed, individuals are likely to be more interested in learning newer information. Indeed, time-to-resolution, or how long it took to resolve the knowledge gap, was greater for repeated questions due to them not having their associated answers being shown immediately. Any negative feelings experienced during the delay may have influenced participants' ratings.

According to Noordewier and van Dijk (2017), time-to-resolution can change the subjective experience of curiosity but not the magnitude of curiosity itself. They observed that participants experienced less positive affect when they had to wait a longer period of time (30 min versus one minute) to watch an interesting video. Yet, curiosity to see the video did not decline over the 30-minute waiting period, indicating that intensity was not affected by temporal proximity. Overall, curiosity does not decrease as long as the knowledge gap remains unfilled, but the discomfort associated with waiting for an answer may lead to a preference for newer information. Since we did not explicitly manipulate time-to-resolution in the current study (timing of answer presentation varied since List 1 and List 2 question order was randomised), further research is needed to clarify how sensitive curiosity is to delayed feedback.

Pretesting increases curiosity for repeated questions

In Experiment 2, we sought to control for participants' prior knowledge of trivia questions and replicate the findings from Experiment 1. We found that curiosity increased across presentations, and participants were more curious to learn the answers to repeated questions relative to non-repeated questions. Considering that the only procedural change was the addition of pretesting, having participants provide a guess before learning may have increased their desire to know the correct answers. Pretesting, the act of testing before instruction, can promote curiosity to learn. A study by Potts et al. (2019) demonstrated that individuals learning pairs of rare English words and their definitions gave higher curiosity ratings when they had to guess a definition and when ratings were solicited after, and not prior to, the act of generation.

There are several explanations as to why the intensity of curiosity changed over presentations despite the size of the knowledge gap remaining consistent: (1) The opportunity to guess an answer during the second presentation heightened participants' sense of cognitive agency. If participants mentally generated an answer during the first presentation and built upon this initial response to produce an overt guess during the second presentation, they may feel more personally invested in the learning process. (2) Cognitive demands may have been greater when participants tried to make an overt guess, prompting more effortful retrieval attempts during the second compared to first presentation (Kubik et al., 2020; Tauber et al., 2018). (3) We saw that participants preferred learning the answers to repeated over non-repeated questions. Pretesting may have increased the salience of existing information gaps disproportionately. In combination with anticipation of feedback and familiar feelings of uncertainty (i.e., I still do not know the answer), this likely intensified curiosity to learn over presentations and more so for repeated compared to non-repeated questions, although more work is needed to verify these claims.

There is a chance that we were measuring distinct facets of curiosity across experiments. Theoretically, being in a high state of curiosity should result in better memory for all information presented within the pretesting context (see Gruber & Ranganath, 2019). However, Hollins et al. (2023) argue that the effects of pretesting are inconsistent with being in a generalised state of curiosity, as the benefits of guessing appear to be specific to target and not incidental information presented during encoding. Participants generating predictions based on existing schemas, during which related semantic concepts were activated, may also induce high levels of uncertainty that motivate information seeking, especially if they want to verify the correctness of their answers (Singh & Manjaly, 2021; Wade & Kidd, 2019). Further research is needed to examine whether curiosity after guessing can be portrayed as an intrinsic desire to learn, similar to what is theoretically experienced with general curiosity, or if it only represents a specific aspect of curiosity (e.g., curiosity to verify a guess). It is possible that both facets were represented in Experiment 2, producing greater curiosity for repeated questions and across presentations if the process of revisiting trivia questions stimulated a desire to confirm guesses on top of a broader motivation to explore.

Given that participants had 8 s to make a guess for each question, we acknowledge that participants may have known the correct answer but had insufficient time to write it down. However, rates of pre-study accuracy were similar to that found in McGillivray et al. (2015), for which participants were given more time to guess, indicating that the time constraint did not substantially affect participants' ability to recall or submit potential answers. We also recognise that Experiment 2 was not designed with the intention of examining the effects of pretesting, but given the contrasting results, we sought to offer various explanations as to why curiosity increased across presentations within the new procedure.

Curiosity, not repetition, predicts memory for trivia answers

In daily life, we are often presented with more information than we can remember, meaning that we must be selective about what information is retained. Prior work has shown that individuals prioritise learning information that they are curious about, revealing that curiosity can have positive effects on learning and memory (Berlyne, 1954; Litman & Spielberger, 2003; Oudeyer et al., 2016; Schiefele et al., 1992). Across both experiments, we demonstrated that curiosity can promote recall. Anticipatory activation of the hippocampus, a brain region involved in encoding and memory consolidation, in response to prediction errors stemming from low prior knowledge (novelty of stimulus) may explain why there was greater recall of high-curiosity questions (Gruber et al., 2016; Poh et al., 2022). In addition, engagement of the noradrenergic system may help direct attentional focus and increase processing of relevant information under high states of curiosity (Bunzeck & Düzel, 2006; Sakaki et al., 2018).

We did not find support that repetition benefitted memory for trivia question answers. Generally, as the number of times an item is presented increases, the accuracy of later recall and recognition improves and retrieval time decreases (Hintzman & Block, 1971). The repetition effect has been mainly studied in the context of word lists, while in the current study, we define repetition as the repeating of questions without their paired answers. Since associated answers were only shown once and were what participants were tested on, the repeated presentation of questions alone was insufficient to establish multiple retrieval cues that individuals could rely on during delayed recall.

It is difficult to interpret the interaction between repetition and curiosity, considering that curiosity ratings depended on whether or not participants made a guess before learning. In Experiment 1, there was a significant interaction such that repetition supported recall of low, but not high, curiosity answers. If individuals are highly curious to learn an answer, they are likely to recall the answer at a later time regardless of whether the question had been repeated or not. However, cognitive resources may have been directed towards low-curiosity answers if participants recognised the question (familiarity) or retrieved the specific episode in which they had originally seen the question (source memory). In Experiment 2, we did not find a significant interaction between repetition and curiosity. Retrieving information from memory, even if unsuccessful, and making an overt guess may have enhanced memory for both repeated and non-repeated questions by encouraging deeper processing of the question relative to passively reading it (Bjork, 1975; Richland et al., 2009). Additional work is needed to examine how different aspects of curiosity (curiosity to learn versus curiosity to verify a guess) and retrieval processes may both influence recall. Please refer to the Supplemental Material section if interested in the results of a cross-experiment comparison.

Conclusion

Curiosity, an intrinsic desire to seek novel information, benefits motivation and learning. It is thought to be an innate part of human nature, encouraging individuals to gain new knowledge and maintain positive emotional states by reducing uncertainty in the environment (Carstensen, 1995). Furthermore, satiating one's curiosity when motivated by knowledge acquisition can be a rewarding experience (Deci & Ryan, 1985), creating a positive feedback loop whereby individuals continue to explore their interests and learn (Murayama, 2022). In other words, the satisfaction of resolving a knowledge gap may drive future information seeking, which thereby supports more curiosity-driven learning as individuals formulate new questions (awareness of new knowledge gaps; Murayama et al., 2019; van Lieshout et al., 2020).

Through two experiments, we investigated how repeating a trivia question may affect curiosity to learn associated answers. We observed that individuals were more curious to learn about non-repeated questions than repeated questions, evident of a preference for newer information that may be time-sensitive to resolution (i.e., when knowledge gaps are closed). However, when individuals overtly generated an answer prior to study, curiosity increased across presentations and was greater for repeated questions. In this case, curiosity may reflect a greater sense of cognitive agency, motivated by an eagerness to verify the accuracy of one's guess after the first presentation. Overall, the subjective experience of curiosity appears to be influenced by both the relative novelty of presented questions, as manipulated through repetition, and the demands of the task at hand, specifically whether individuals are pretested or not, suggesting that curiosity-based learning can be influenced by a variety of cognitive operations that engage learners.

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No potential conflict of interest was reported by the author(s).

Data availability statement

The experiments reported in this article were not formally preregistered. The stimuli and data have been made available on the Open Science Framework here https://osf.io/rjmek/?view_only=a1c491691c1b4ff19f2b52c900353b59.

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Appendix

Table A1. Complete list of trivia questions, their answers, and a priori curiosity level.

Question	Answer	A priori curiosity level	A priori curiosity	Version
What is the name of the island country that lies off the southeast coast of India?	Sri Lanka	Low	3.23	A
What vegetable did ancient Egyptians place in their right hand when taking an oath?	Onion	Low	3.30	A
There are five halogen elements including Fluorine, Chlorine, Bromine, and Astatine. What is the name of the fifth?	Iodine	Low	3.53	A
What gas forms almost 80% of Earth's atmosphere?	Nitrogen	Low	3.87	A
What was a gladiator armed with in addition to a dagger and spear?	Net	Low	4.03	A
What unit of measurement is used for fuel wood?	Cord	Low	4.43	A
Who was the first person to use the V sign as a victory sign?	Winston Churchill	Low	4.47	A
What seventeenth century artist painted more than 60 self-portraits?	Rembrandt	Low	5.03	A
What organ of the buffalo did Plains Indians use to make yellow paint?	Gallbladder	Low	5.23	A
In parts of India, the older brother must marry first. If he cannot find a wife, what can choose to marry?	A tree	Low	5.27	A
What product is second, only to oil, in terms of the largest trade volumes in the world?	Coffee	Low	5.30	A
What is the name of the scientific scale used for measuring the hardness of rocks?	Moh's scale	Low	5.43	A
What was the first animated film to be nominated for an Oscar for best picture?	Beauty and the Beast	Low	5.63	A
What was the first nation to give women the right to vote?	New Zealand	Low	5.73	A
What note do most American car horns beep in?	F	Low	5.77	A
What organ destroys old red blood cells?	Spleen	High	5.93	A
What is the oldest written code of law in history?	Hammurabi's code	High	6.03	A
What industry used 20% of China's harvested plants?	Medicine	High	6.07	A
What handicap did Thomas Edison suffer from?	Deafness	High	6.07	A
The Gold Coast is now known as what country?	Ghana	High	6.13	A
What is the slowest swimming fish in the world?	Seahorse	High	6.17	A
What was Dr. Frankenstein's first name?	Victor	High	6.40	A
What mammal sleeps the shortest amount each day?	Giraffe	High	6.43	A
What was the only type of product ever promoted by Elvis Presley in a television commercial?	Donuts	High	6.57	A
What is the longest common English word without any vowels?	Rhythm(s)	High	6.63	A
What did girls in medieval Spain put in their mouths to avoid unwanted kisses?	Toothpicks	High	6.70	A
What part of a woman's body were ancient Chinese artists forbidden to paint?	Foot	High	6.97	A
What trade was Greek philosopher Socrates trained for?	Stonecutting	High	7.33	A
What is the only consumable food that won't spoil?	Honey	High	7.33	A
Before the barometer, what animal did German meteorologists use to predict air pressure changes?	Frog	High	7.53	A
What novel contains the longest sentence in literature with 832 words?	Les Miserables	Low	3.23	B
What is the monetary unit of Korea?	Won	Low	3.30	B
What is the only type of bird that has nostrils at the tip of its beak?	Kiwi	Low	3.53	B
What is the name of the instrument used to measure wind speed?	Anemometer	Low	3.87	B
Which scientist was the first to receive the Nobel Prize twice?	Marie Curie	Low	4.03	B
What Beatles song lasted the longest on the American charts?	Hey Jude	Low	4.43	B
What city has the only drive thru post office in the world?	Chicago	Low	4.47	B
What is the biggest constellation in the sky?	Hydra	Low	5.03	B
With what product did the term "brand name" originate?	Whiskey	Low	5.23	B
What country has the highest population density?	Monaco	Low	5.27	B
What world capital city has the fewest cinemas in relation to its population?	Cairo, Egypt	Low	5.30	B
In what country is Angel falls, the tallest waterfall, located?	Venezuela	Low	5.43	B
What reptile, according to ancient legend, was able to live in fire?	Salamander	Low	5.63	B
What fish produces more than 200 million eggs at a time?	Sunfish	Low	5.73	B
What American novel was the first to sell over 1 million copies?	Uncle Tom's Cabin	Low	5.77	B
What was the first product to have a bar code?	Wrigley's gum	High	5.93	B
Which metal is the best conductor of electricity?	Silver	High	6.03	B
What city has the shortest name in the world?	Y (France)	High	6.07	B
What is the only country in the world that has a bible on its flag?	Dominican Republic	High	6.07	B
What is the most common first name in the world?	Mohammed	High	6.13	B
What city is referred to as the Pittsburgh of the South?	Birmingham, Alabama	High	6.17	B
What instrument was invented to sound like a human singing?	Violin	High	6.40	B
What animal's excrements are consumed as a luxury food?	Bats	High	6.43	B
What food will make a drug test show up positive?	Poppy seeds	High	6.57	B
What was the name of Smokey the Bear's mate?	Goldie	High	6.63	B
What is the only planet in our solar system that rotates clockwise?	Venus	High	6.70	B
What is the hardest natural substance known?	Diamond	High	6.97	B
What snack food can be used as an ingredient in the explosive dynamite?	Peanuts	High	7.33	B
Who was the first Christian Emperor of Rome?	Constantine	High	7.33	B
Setting a world record, how many days can a human stay awake?	11	High	7.53	B