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Epistemic curiosity and the region of proximal learning

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We propose a framework for understanding epistemic curiosity as a metacognitive feeling state that is related to the individual's Region of Proximal Learning (RPL), an adaptive mental space where we feel we are on the verge of knowing or understanding. First, we review several historical views, contrasting the RPL perspective with alternative views of curiosity. Second, we detail the processes, conditions, and outcomes within the RPL framework which are proposed to be related to curiosity. Finally, we review several lines of evidence relevant to the relation between RPL and curiosity. These include (1) differences in the conditions under which experts and novices mind wander, (2) experiments investigating people's choices of whether to study materials for which they have high versus low feelings of knowing, (3) results related to people's engagement with corrections to errors made with high confidence, and (4) curiosity, attention, and learning data related to the tip-of-the-tongue state.

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Historical overview

Epistemic curiosity is thought to be revealed by what a person voluntarily chooses to pay attention to, study, attempt to solve, retrieve, or explore in the absence of compelling external needs or incentives. Drive theorists proposed that curiosity is an internal motivational force, stimulated by either internal [1,2] or external [3] stimuli. Importantly, curiosity is not derivative on other, more basic, drives (such as was proposed by Freud [4], who believed it originated in the sex drive). Thus, a starving person or a hungry mouse seeking food would not be searching to find food because of *epistemic* curiosity. This type of search behavior would instead be considered what Berlyne [5] called 'perceptual' curiosity, which is available to humans and animals alike. Similarly, we do not consider undirected exploratory behavior, including eye or body movements, in the service of environmental orientation, to be epistemic curiosity. The exploration associated with *epistemic* curiosity is the search for specific knowledge, such as the answer to a query about which one is curious, which is undertaken for its own sake, rather than to attain a basic goal (such as food, sex, safety). The theoretical issue, as noted by Berlyne [3], p. 181), is why does an individual seek to learn one piece of knowledge rather than another? Satisfaction of epistemic curiosity — finding out — is rewarding in its own right, rather than secondary to a different purpose or serving a different reinforcer.

We, like others, propose that epistemic curiosity is metacognitively based. Metacognition is defined as what the individual knows or feels *about* what he or she knows [6,7]. Litman ([8], p. 801) noted that 'the nature of this [curiosity] relationship appeared to depend on the feeling-of-knowing' — a classic metacognitive appraisal. Loewenstein [75] emphasized the critical role of metacognition, noting that 'a failure to appreciate what one does not know would constitute an absolute barrier to curiosity' (pp. 161). To the extent that epistemic curiosity is grounded in metacognition, it should only exist in animals capable of metacognitive reflection. This is not to say that non-metacognitive animals could not exhibit curiosity. But the sort of curiosity such animals exhibit would necessarily be perceptual or exploratory rather than epistemic.

Berlyne [3] noted that people are epistemically curious about those things that are neither too easy nor too difficult. For example, a person with only a minimal knowledge of astronomy might be curious as to why black holes exist, but not why stellar and supermassive black holes do not overlap in mass. This idea is similar to that of Piaget, who believed that concepts that drive curiosity and learning are those that a person is on the verge of knowing, but does not yet fully know: 'The subject becomes interested in novelty and pursues it for its own sake. The more the schemata are differentiated, the smaller the gap between the new and the familiar becomes, so that novelty, instead of constituting an annoyance to be avoided by the subject, becomes a problem and invites searching' (Piaget, 1954 (1999), p. 354). The notion of a space in which people 'almost know' the answer and are especially curious, is similar, then, to the view of curiosity espoused by Incongruity theorists, including Piaget [9], Hebb [2], Hunt [10], McCall and McGhee [11], and Atkinson [12]. It also informs the Region of Proximal Learning (RPL) model ([13,14], see Figure 1), a model that posits that optimal learning occurs when a learner focuses their resources (study time allocation and attention) on to-be-learned items that they perceive to be almost, but not quite known (as opposed to items that are least known/most difficult to learn, see Dunlosky & Hertzog, [73]) and that they persist in studying these items until they perceive that learning has stopped.

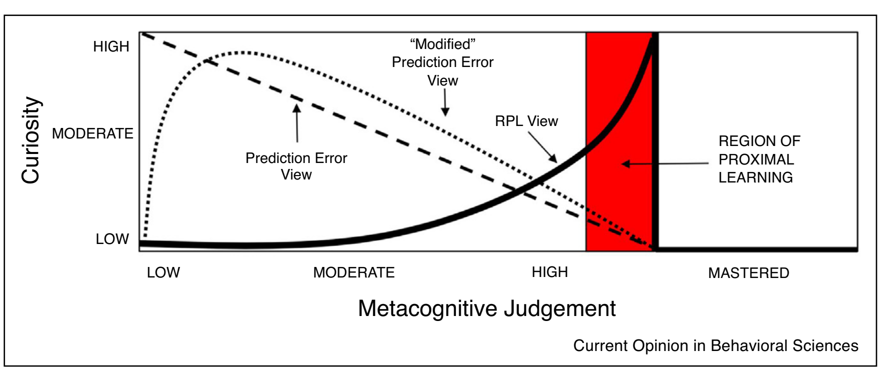
Many researchers have noted a relation between curiosity and reward. Indeed, Kang *et al.* [15] state that "curiosity is anticipation of rewarding information." Reward-based motivation, in neural network models, is thought to be governed by prediction error [16–18]. Marvin and Shohamy [19] have proposed that this characterization also applies to curiosity. Prediction error models (e.g. in Ref. [20]) are highly successful in the context of conditioned learning and primary reinforcers. When the animal is extremely hungry, the expected difference between the current state and the predicted state of need satisfaction (i.e. the prediction error) is high, and the animal will be highly motivated. When the animal is less hungry, the difference between the current state and the expected satisfied state will be smaller, and it will be less motivated. Taking informational uncertainty to be analogous to hunger and applying this logic to curiosity, the prediction error view indicates that the discrepancy between the uncertainty inherent in the current state (or the perceived distance from solution) in relation to the lack of uncertainty that is expected upon solution (the quenched state) should determine the extent of curiosity. The larger the prediction error (i.e. the discrepancy), the greater the curiosity.

This view is illustrated in Figure 1 by the dashed line. Several functional imaging studies interpret their results as being consistent with this view. Kang *et al.* [15] showed that self-reported curiosity was associated with increased activity in caudate regions including the striatum — brain areas that are implicated in the anticipation and experience of reward [21]. That the dopamine/reward brain circuit (which is usually modelled in terms of prediction error, see Ref. [16], for review) is activated under conditions of curiosity is taken, by some theorists, as direct evidence for the explanation of curiosity in terms of prediction error and reinforcement learning ([19]; c.f., [22]).

There is an intermediate stance which we call the 'Modified' Prediction Error view, which is based on the idea of a 'dynamic information gap' as developed by Loewenstein [23]. He proposed — consistent with prediction error models — that curiosity increases as a direct function of the difference between what one knows at time t (or one's uncertainty) and what one wants to know or one's 'reference point.' The less one knows the more curious one will be, as long as one *wants* to know. However, the individual must first recognize that there is a gap in his or her knowledge. Recognizing the gap depends on how much knowledge one has already. With too little knowledge the person may not even realize that there is a gap and, hence, may not be curious at all. The net result of combining the uncertainty-reduction based curiosity function with the gap-recognition process is in an inverted-U shaped function relating metacognition to curiosity, as shown by the 'modified' prediction error view in Figure 1 (dotted line).

Kang *et al.* [15] described the 'information gap' proposal as postulating 'that the aspired-to level of knowledge increases sharply with a small increase in knowledge, so that the information gap grows with initial learning. When one is sufficiently knowledgeable, however, the gap shrinks, and curiosity falls. If curiosity is like a hunger for knowledge, then a small "priming dose" of information increases the hunger, and the decrease in curiosity

Figure 1



The relation of metacognition to curiosity as given by the RPL framework (solid black line), the Prediction Error model (dashed line), and the 'Modified' prediction error model (dotted line), which is based upon the 'information gap' perspective. The red shaded area represents the Region of Proximal Learning (RPL).

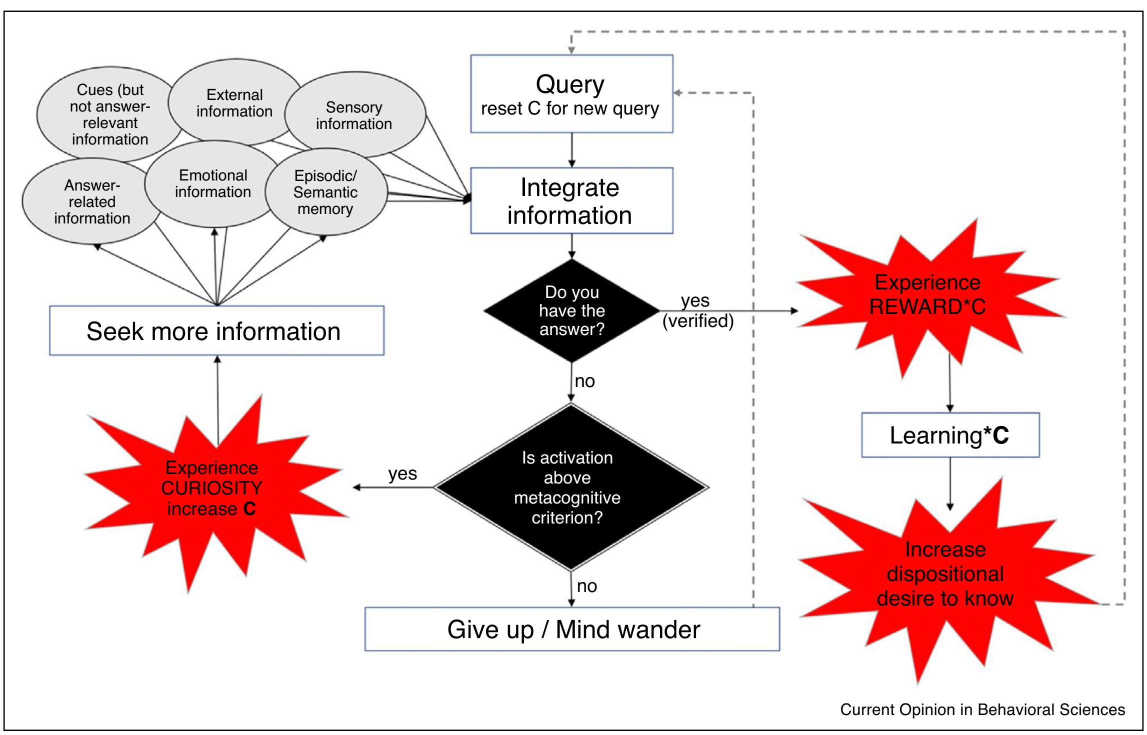
from knowing a lot is like being satiated by information.' (p. 963). Both the prediction error view and the modified prediction error 'gap' view posit that as the individual gets close to a solution, curiosity decreases. In contrast, the RPL view predicts that it increases under these circumstances.

Overview of the RPL framework

Within the RPL framework, shown in Figure 2, when a query is posed, the individual attempts to integrate all accessible information to generate an answer. The parameter, C, indicates a numerical value reflecting the extent of the individual's curiosity about the item in question. When the individual is presented with a new query, this parameter has a neutral value and no particular feeling is associated. However, this parameter changes as a result of metacognitive appraisal. Conscious feeling states are associated with high (and possibly low–but not neutral) values of this parameter. As is illustrated by the grey ovals, information may come from many sources, both external (e.g. library searches, Google, asking an instructor or fellow student, etc.) and internal (e.g. episodic and semantic memory, sensory, emotional, or motor information), and it may be accurate or inaccurate. Information integration may depend on the individual's expertise and knowledge of the subject matter, the salience of the information, priming, time constraints, the participant's personality, perseverance, and regulatory focus. If the individual has accumulated sufficient information to generate an answer (Decision 1, shown in the top black diamond), they do so. With sufficient information an answer may be easily and fluidly generated. But should this occur, there is no increase in C. Indeed, only metacognitive decisions, such as the second decision in the flow chart, result in changes to C. To increase C, the person must spend time exploring and going through the loop on the left-hand side of the figure. Attaining a solution without cognitive work (or desirable difficulties, [24]) does little to enhance curiosity, exploratory behavior, learning, or the feeling of reward felt with success.

If the learner has insufficient information to output an answer immediately, or if they output an answer but learn that it is incorrect, they must make a second decision. *This second decision is* ***metacognitive,*** *and it is the linchpin of the model.* The learner evaluates whether they have enough information to continue trying. Factors (such as cue familiarity [25]; perceptual fluency, [26]; mental set, [27]; personality, [28]; and perseverance, [29]) that bias or obscure metacognition can influence this crucial evaluation. If there is too little information, the person will decide not to try: they may either give up entirely or start to mind wander. When this occurs, the pathway that increases C is circumvented. The model is uncommitted–awaiting further empirical research–as to whether this pathway decreases C or not. But if the amount of

Figure 2



The Region of Proximal Learning model of curiosity.

information is perceived to be in the 'almost known' RPL zone, then the person enters the left-hand loop and C increases. They will be more motivated to try to attain information. Curiosity-based increases in attention will be engaged, which in turn leads to more learning. The reward associated with the answer (see Refs. [19,30]) increases, as does their dispositional need to know. Thus, curiosity creates a positive feedback loop. This RPL framework, then, proposes that people are most curious when they *think* they almost know. It is the individual's 'quirky' (see Ref. [31]) metacognitive feeling state that matters.

Evidence

Four lines of evidence provide support for the RPL framework. People (i) mind wander more when they are not in their own RPL, (ii) choose to study items more if they are in their RPL, (iii) are engaged, pay attention and learn very well when they find out that they have made high confidence errors, and (iv) are extremely curious about items that are on the tips of their tongues.

(i) Mind wandering decreases, and attention increases, when in RPL. Mind wandering can be considered the antithesis of curiosity. When people are curious, they avidly pursue the answer, but when they are bored, their attention flags, and they mind wander. As such, the expectation would be that a prime condition under which we would find people mind wandering is when they are outside of their RPL. Conversely, they should maintain their eagerness to discover when they are in their RPL. Of course, people's RPLs differ depending upon their expertise for the subject matter at hand: for novices the material that is 'almost known' will consist of easy items. For experts, easy material will not be in their RPL because it is already learned, and they should find that materials that are difficult for others are, for them, 'almost known.'

This pattern of mind wandering was demonstrated by Xu and Metcalfe [32], who asked students to study English-Spanish pairs of translations, blocked by difficulty level. After many such pairs at a particular difficulty level, participants were queried on whether they were mind wandering or not. Novices tended to mind wander on the difficult materials whereas experts tended to mind wander on the easy materials. In a subsequent study, Xu *et al.* [33] examined people's event related potentials (ERPs). Being on task, as opposed to mind wandering, resulted in a distinctive ERP pattern — a high amplitude late (350–800 ms) positive voltage potential, that, in other research (see Refs. [34,35]) has been related to enhanced attention and improved memory.

(ii) People choose to selectively study items in their RPL. The Oxford dictionary defines curiosity as: 'a strong desire to know or learn something.' It can be examined directly by looking at people's choices about what they desire to learn. Thiede and Dunlosky [36] and Son and Metcalfe [37] showed that adults do not choose materials that are *least learned*. Particularly when time is short, they chose, instead, the easier unlearned materials — consistent with RPL. Son and Metcalfe [37] also found that people's *interest* judgments — closely related to curiosity, of course — drove study choice. Furthermore, Metcalfe [13] showed that choices depended on expertise: highly expert learners tended to choose to study the most difficult and shun the easier materials, whereas novices gravitated toward easier materials, (a pattern that is entirely consistent with the above cited mind-wandering study). Kornell and Metcalfe [38] allowed participants to select for further study a subset of unlearned items that varied from high JOL to low JOLs for each individual. Participants consistently chose items that were close to being known (high JOL) — indicating that they wanted to engage more with items in their RPL. Their study choices were sometimes honored, but sometimes not. Participants not only chose to engage with the easiest as-yet-unlearned items, just as the RPL/curiosity model suggests, but their final memory performance indicated that this was the best strategy.

(iii) High Confidence Errors. In Figure 2, the first decision concerns whether people know the answer or not. If they do know it, they simply generate it. But what if they get feedback that the answer was actually wrong? There is now considerable research indicating that, as long as corrective feedback is provided, the generation of errors (e.g. Refs. [39–41]) promotes learning. But the errors that *particularly* foster learning are those that people have committed with high confidence — those that they were very certain about. Corrective feedback (as well as false feedback, see Ref. [42]) to these errors is learned even more readily than is the feedback to low confidence errors — a phenomenon called the 'hypercorrection' effect [43–51].

This phenomenon is of particular interest in the context of curiosity because there is evidence that the incorrect answers that are given with high confidence are semantically close to the correct answers [52,53]. Second guess procedures also indicate that both children [54] and adults [55], 'almost know' the correct answers. In short, these high confidence errors are firmly situated in people's RPL.

Furthermore, the corrective feedback to high confidence errors elicit a distinctive P3a ERP signature that is associated with surprise, attentional focusing, and with enhanced memory encoding — as might be expected if the learner were interested or curious [56,57]. Similarity, the fMRI neural response to the feedback to high as compared to low confidence errors showed increased activation of the anterior cingulate, the dorsolateral prefrontal cortex, and the temporal parietal junction [58].

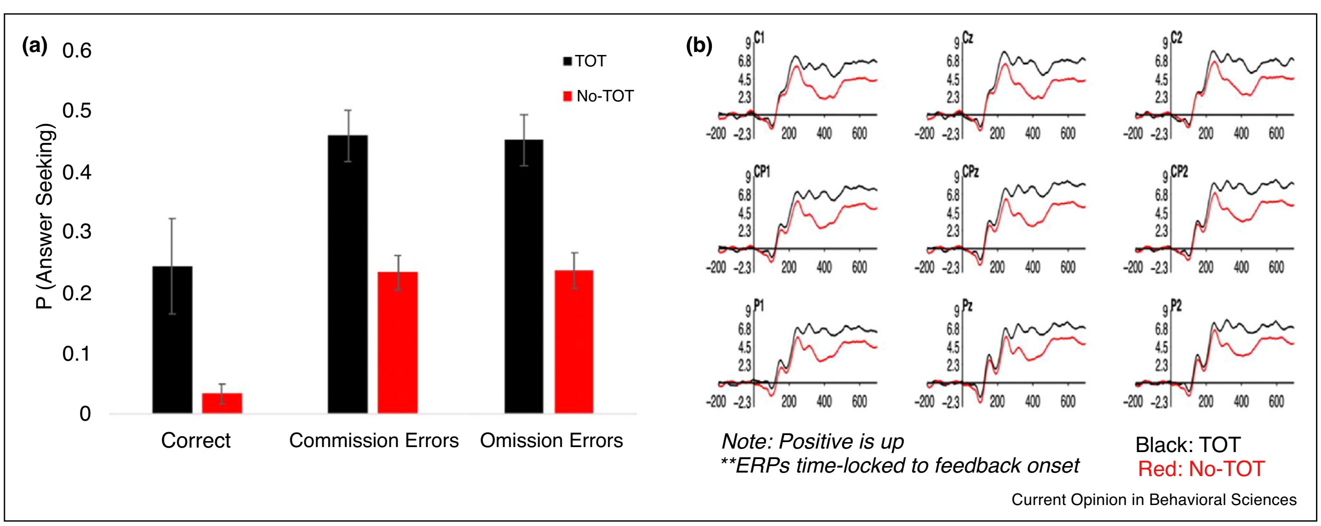
In terms of the curiosity framework in Figure 2, high confidence errors are attempted as responses because of the large amount of information accumulated. But then they are disconfirmed. As such, they would be expected to have sufficient information to pass the critical metacognitively-based decision criterion (i.e., to be in the person's RPL) and enter the curiosity loop. The behavioral data converge on the likelihood that people do become curious when they learn that they were wrong, but direct tests have yet to resolved the issue. Fastrich *et al.* [59] showed that people give somewhat higher than average curiosity ratings to high confidence errors. Unfortunately, feedback was not provided to the participants before they made their curiosity judgments, so it is not clear whether people actually knew that they had made an error. For this reason, the results are difficult to interpret, and further empirical research is needed [60].

(iv) Tip-of-the tongue (TOT) state. If any state typifies how people *feel* when they 'almost know,' it is the TOT state—a spontaneously occurring metacognitive state [61–63]. This state is widely documented (see Ref. [64]), occuring in college students, elementary school children [65] and older adults [66] alike. Brennen *et al.* [67] showed that even non-literate speakers of Q'eqchi' in Guatemala had a TOT equivalent. The 'almost-but-not-quite-known' quality, which is evidenced by access to partial target information including the first letter, number of syllables, and aspects of the semantics, puts it squarely within the individual's RPL, and in the sweet spot in which people should seek information, devote attention, learn readily, feel reward upon resolution, and be motivated for further learning.

While several groups [8,68,23,15] have suggested that there might be a connection between the TOTs and curiosity, there is little research on it, because the TOT state is rare, tricky to induce in the lab, and resolves readily. However, by asking very quickly about people's TOT states, and their curiosity Metcalfe *et al.* [69] and Bloom *et al.* [71] were able to collect systematic data.

Five main findings emerged from these two studies. First, in the TOT state, curiosity — defined by people indicating that they wanted to know the answer —was much higher than when not in a TOT state. Participants were roughly twice as likely to want to see the answer when they were in a TOT state as when they were not (Figure 3, left panel). Second, the increase in curiosity occurred regardless of whether people had been unable to provide a response, had made an overt mistake (e.g. a commission error) or even when they had given the correct answer. Third, people were unaware, at a global level, that the desire-to-know is associated with the TOT state. The Metcalfe *et al.* [69] study — which overwhelmingly showed that people were curious about TOT items — also included an mTurk survey asking participants to introspect whether, if they were in a TOT state, they would they have an enhanced urge to find out an answer. Only 25% said they would. Instead, people's introspections were consistent with the prediction error model: Thirty-nine percent thought they would be most likely to seek information when they were sure they did not know. Fourth, people were much more likely to remember answers given to them when they were in a TOT state (75% recall) versus a non-TOT state (52% recall),

Figure 3



(a) Aggregated data from Metcalfe *et al.* [69] as a function of whether the participant was in or was not in a tip-of-the-tongue state, showing the probability of answer seeking given that the response was correct, a commission error, or an omission error. Error bars: standard error of the mean. **(b)** Event related potentials during the initial tip-of-the-tongue/feedback phase from Bloom *et al.* [33], which shows an enhanced late positivity in centro-parietal electrodes as a function tip-of-the-tongue state.

consistent with the results of Kang *et al.* [15], of Gardiner *et al.* [70] and of Gruber *et al.* [30]. Fifth, just as in the mind wandering study described above, there was a neural signature — a late positivity in the ERP voltage deflection — that was associated with being in a TOT state ([71], as shown in the right panel of Figure 3). This ERP deflection was, itself, associated with subsequent memory.

Conclusion

Despite much progress on understanding curiosity, many questions remain. Is curiosity the same when the reference state is the solution of deep unsolved scientific problems as it is for the materials typically studied in the lab? How is curiosity related to reward? Is the feeling of being curious pleasant and playful — as some would have it [8] — or an aggravating, annoying feeling of deprivation [74]? Is the achievement of the answer — the quenching of curiosity — deeply rewarding, as the neuroimaging data would suggest, or disappointing and sad, as Loewenstein [23] suggested? Theoretical and empirical work is needed to reconcile the curiosity-related brain dopamine/reward system activation with the behavioral and phenomenological data in a manner that will shed light on the psychological processes coupled with curiosity and their relation to the neural mechanisms underlying reward. However, the literature reviewed here, namely that people mind wander more when they are not in their own RPL, choose to study items more if they are in their RPL, learn from their high confidence mistakes, and are extremely curious about items that are on the tips of their tongues, supports the view that epistemic curiosity is a metacognitive feeling state that is related to an individual's RPL.

There may be both theoretical and practical consequences to exploring the implications of the conjecture that is the focus of our model — that curiosity is fundamentally metacognitive. When people are in the state of curiosity, they seek out information, and when they do come upon the answer, they hyper encode it —resulting in enhanced learning and memory, as well as enhanced reward in learning. But, if curiosity is metacognitive, as we propose here, then it may be possible to induce curiosity by manipulating people's metacognition. Many experiments have shown that a large variety of metacognitive assessments can be manipulated by factors that leave knowledge unaffected [72]. Usually this fluidity is taken as a bad thing because it means that people's metacognitions are inaccurate, and will necessarily lead to poor learning [7]. Here we suggest that it might be possible to use this metacognitive fluidity to good end, though: to induce or to change people's curiosity, and thereby enhance learning.

Conflict of interest statement

Conflict of Interest and Authorship Conformation Form
Please check the following as appropriate:

- All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.
- This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.
- The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript

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References

1. Fowler H: *Curiosity and Exploratory Behavior*. New York: Macmillan; 1965.
2. Hebb DO: **Drives and the C. N. S. (conceptual nervous system)**. *Psychol Rev* 1955, **62**:243-254.
3. Berlyne DE: **A theory of human curiosity**. *Br J Psychol* 1954, **45**:180-191.
4. Freud S: **Analysis of a phobia of a five year old boy**. *The Pelican Freud Library (1977), Vol 8, Case Histories 1*. 1909:169-306.
5. Berlyne DE: **Novelty and curiosity as determinants of exploratory behavior**. *Br J Psychol* 1950, **41**:68-80.
6. Koriat A: **How do we know that we know? The accessibility model of the feeling of knowing**. *Psychol Rev* 1993, **100**:609-639.
7. Dunlosky J, Metcalfe J: *Metacognition*. Thousand Oaks, CA: Sage; 2009.
8. Litman JA: **Curiosity and the pleasures of learning: wanting and liking new information**. *Cogn Emot* 2005, **19**:793-814.
9. Piaget J: *The Construction of Reality in the Child*. Abingdon, England (1999 Edition): Routledge (Taylor & Francis); 1954.
10. Hunt JMc V: **Motivation inherent in information processing and action**. *Motivation and Social Interaction: Cognitive Determinants*. New York: Ronald; 1963.
11. McCall RB, McGhee PE: **The discrepancy hypothesis of attention and affect in infants**. In *The Structuring of Experience*. Edited by Užgiris I&crn, Weizmann F. Boston, MA: Springer; 1977.
12. Atkinson RC: **Optimizing the learning of a second-language vocabulary**. *J Exp Psychol* 1972, **96**:124-129.
13. Metcalfe J: **Is study time allocated selectively to a region of proximal learning?** *J Exp Psychol: Gen* 2002, **131**:349-363.
14. Metcalfe J, Kornell N: **The dynamics of learning and allocation of study time to a region of proximal learning**. *J Exp Psychol: Gen* 2003, **132**:530-542.
15. Kang MJ, Hsu M, Krajbich IM, Loewenstein G, McClure SM, Wang JT, Camerer CF: **The wick in the candle of learning:**

epistemic curiosity activates reward circuitry and enhances memory. *Psychol Sci* 2009, **20**:963-973

Based on a serious of 3 experiments, Kang *et al.* argue that curiosity is related to reward anticipation. In all 3 experiments, participants answered trivia questions on various topics, rated their curiosity and confidence in knowing the answer, and were given the correct answer. In the first study, fMRI revealed brain activations in caudate regions, previously associated with reward anticipation, in response to items that participants rated as evoking higher curiosity. Second, the authors investigated pupil dilation — a physiological proxy for the level of interest, arousal, or interest that has also been shown to be involved in reward anticipation — as a function of self-reported high, medium and low levels of curiosity. They report a positive correlation between pupil dilation and level of curiosity. Finally, the authors explored the conditions under which participants would expend resources (in this case, tokens or time) to find out the correct answer to the trivia questions. They found that more resources were exerted for items rates as eliciting higher curiosity. The combination of these results leads the authors to conclude that curiosity is tied to reward anticipation.

16. Daw ND, Tobler PN: **Value learning through reinforcement: the basics of dopamine and reinforcement learning**. *Neuroeconomics: Decision Making and the Brain*. Second Edition. Elsevier Inc; 2013:283-298.

17. Glimcher P: **Understanding dopamine and reinforcement learning: the dopamine reward prediction error hypothesis**. *Proc Natl Acad Sci U S A* 2011, **108**:15647-15654.

18. O'Doherty JP: **Reward representations and reward-related learning in the human brain: Insights from neuroimaging**. *Curr Opin Neurobiol* 2004, **14**:769-776.

19. Marvin CB, Shohamy D: **Curiosity and reward: valence predicts choice and information predictions errors enhance learning**. *J Exp Psychol: Gen* 2016, **145**:266-272.

20. Rescorla RA, Wagner AR: **A theory of Pavlovian conditioning: variations in the effectiveness of reinforcement and nonreinforcement**. In *Classical Conditioning II: Current Research and Theory.* Edited by Black AH, Prokasy WF. New York: Appleton Century Crofts; 1972:64-99.

21. Delgado MR: **Reward-related responses in the human striatum**. *Ann New York Acad Sci* 2007, **1104**:70-88.

22. Metcalfe J, Kennedy-Pyers T, Vuorre M: *Curiosity and the desire for agency: Wait, wait . . . Don't tell me!* . (under review) 2020.

23. Loewenstein G: **The psychology of curiosity: a review and reinterpretation**. *Psychol Bull* 1994, **6**:75-98.

24. Bjork RA: **Creating desirable difficulties to enhance learning**. In *Best of the Best: Progress.* Edited by Wallace I, Kirkman L. Carmarthen: Crown House Publishing; 2017:81-85.

25. Reder LM, Ritter FE: **What determines initial feeling of knowing? Familiarity with question terms, not with the answer**. *J Exp Psychol: Learn Mem Cogn* 1992, **18**:435-451.

26. Rhodes MG, Castel AD: **Memory predictions are influenced by perceptual information: evidence for metacognitive illusions**. *J Exp Psychol: Gen* 2008, **137**:615-625

In this now classic paper, Rhodes and Castel demonstrate a metacognitive illusion, namely that the bigger the font, the higher the judgment of learning. Although the authors interpret this as a fluency effect, there is now a decade of research debating whether the font-size illusion is an example of a problem in interpreting fluency or the function of erroneous beliefs about memory.

27. Sparrow B, Lui J, Wegner DM: **Google effects in memory: cognitive consequences of having information at our fingertips**. *Science* 2011, **333**:776-778.

28. Higgins ET, Friedman RS, Harlow RE, Idson LC, Ayduk ON, Taylor A: **Achievement orientations from subjective histories of success: promotion pride versus prevention pride**. *Eur J Soc Psychol* 2012, **31**:3-23.

29. Dweck C: *Mindset: The New Psychology of Success*. New York: Ballantine Books; 2006.

30. Gruber MJ, Gelman BD, Ranganath C: **States of curiosity modulate hippocampus-dependent learning via the dopaminergic circuit**. *Neuron* 2014, **84**:486-496.

31. Cleary AM, Schwartz BL: *Memory Quirks: The Study of Odd Phenomena in Memory*. Routledge Press; 2020. (edited volume)

This book is based on the view that quirks or oddities of memory and metamemory have much to tell us about the underlying processes. Each chapter outlines a quirk of memory and then explores its nature, what it tells us about memory theory, and what practical implications there may be for that quirk.

32. Xu J, Metcalfe J: **Studying in the region of proximal learning reduces mind wandering**. *Mem Cogn* 2016, **44**:681-695.

33. Xu J, Metcalfe J, Friedman D: **Attenuation of deep semantic processing during mind wandering: an ERP study**. *NeuroReports* 2018, **29**:380-384.

34. Friedman D, Johnson R: **Event-related potential (ERP) studies of memory encoding and retrieval: a selective review**. *Microsc Res Techn* 2000, **51**:6-28.

35. Paller KA, Wagner AD: **Observing the transformation of experience into memory**. *Trends Cogn Sci* 2002, **6**:93-102.

36. Thiede KW, Dunlosky J: **Toward a general model of self-regulated study: an analysis of selection of items for study and self-paced study time**. *J Exp Psychol: Learn Mem Cogn* 1999, **25**:1024-1037.

37. Son LK, Metcalfe J: **Metacognitive and control strategies in study-time allocation**. *J Exp Psychol: Learn Mem Cogn* 2000, **26**:204-221.

38. Kornell N, Metcalfe J: **Study efficacy and the region of proximal learning framework**. *J Exp Psychol: Learn Mem Cogn* 2006, **32**:609-622.

39. Kornell N, Hays MJ, Bjork RA: **Unsuccessful retrieval attempts enhance subsequent learning**. *J Exp Psychol: Learn Mem Cogn* 2009, **35**:989-998.

40. Kornell N, Klein PJ, Rawson KA: **Retrieval attempts enhance learning but retrieval success (versus failure) does not matter**. *J Exp Psychol: Learn Mem Cogn* 2015, **41**:283-294.

41. Richland LE, Kao LS, Kornell N: **The pretesting effect: do unsuccessful retrieval attempts enhance learning?** *J Exp Psychol: Appl* 2009, **15**:243-257.

42. Metcalfe J, Eich TS: **Memory and truth: correcting errors with true feedback versus overwriting correct answers with errors**. *Cogn Res: Princ Implications* 2019, **4**:221-233.

43. Butterfield B, Metcalfe J: **Errors committed with high confidence are hypercorrected**. *J Exp Psychol: Learn Mem Cogn* 2001, **27**:1491-1494.

44. Butterfield B, Metcalfe J: **The correction of errors committed with high confidence**. *Metacogn Learn* 2006, **1**:1556-1623.

45. Cyr AA, Anderson ND: **Updating misconceptions: effects of age and confidence**. *Psychon Bull Rev* 2013, **20**:574-580.

46. Eich TS, Stern Y, Metcalfe J: **The hypercorrection effect in younger and older adults**. *Aging Neuropsychol Cogn* 2013, **20**:511-521.

47. Fazio LK, Marsh EJ: **Surprising feedback improves later memory**. *Psychon Bull Rev* 2009, **16**:88-92.

48. Fazio LK, Marsh EJ: **Correcting false memories**. *Psychol Sci* 2010, **21**:801-803.

49. Metcalfe J, Finn B: **People's correction of high confidence errors: did they know it all along?** *J Exp Psychol: Learn Mem Cogn* 2011, **37**:437-448.

50. Metcalfe J, Miele DB: **Hypercorrection of high confidence errors: prior testing both enhances delayed performance and blocks the return of the errors**. *J Appl Res Mem Cogn* 2014, **3**:189-197.

51. Sitzman DM, Rhodes MG: **Does the hypercorrection effect occur when feedback is delayed?** *Poster presented at the 2010 Psychonomics Society Annual Meeting, #5090* 2010.

52. Sitzman DM, Rhodes MG, Tauber SK: **Prior knowledge is more predictive of error correction than subjective confidence**. *Mem Cogn* 2014, **42**:84-96.

53. Sitzman D, Rhodes M, Tauber S, Liceralde V: **The role of prior knowledge in error correction for younger and older adults**. *Aging Neuropsychol Cogn* 2015, **22**:502-516.

54. Metcalfe J, Finn B: **Hypercorrection of high confidence errors in children**. *Learn Instr* 2012, **22**:253-261.

55. Finn B, Metcalfe J: **Scaffolding feedback to maximize long term error correction**. *Mem Cogn* 2010, **38**:951-961.

56. Butterfield B, Mangels JA: **Neural correlates of error detection and correction in a semantic retrieval task**. *Cogn Brain Res* 2003, **17**:793-817.

57. Metcalfe J, Casal-Roscum L, Radin A, Friedman D: **On teaching old dogs new tricks**. *Psychol Sci* 2015, **26**:1833-1842.

58. Metcalfe J, Butterfield B, Habeck C, Stern Y: **Neural correlates of people's hypercorrection of their false beliefs**. *J Cogn Neurosci* 2012, **24**:1571-1583

This article investigates the neural concomitants via fMRI of the receipt of corrective feedback to highly confident, but erroneous, responses to general information questions. Anterior cingulate activation suggests both conflict monitoring concerning the error and heightened encoding of the correction. Dorsolateral prefrontal activation suggests the engagement of working memory (and perhaps suppression of the incorrect response). The right temporal parietal junction activation suggests that processing related to theory of mind, that is, that one's own belief is contradicted by what others hold to be true, is recruited when the correct responses are processed.

59. Fastrich GM, Kerr T, Castel AD, Murayama K: **The role of interest in memory for trivia questions: an investigation with a large-scale database**. *Motiv Sci* 2018, **4**:227-250 http://dx.doi.org/10.1037/mot0000087.

60. Metcalfe J, Eich TS, Towner E, Vuorre M: **High confidence errors are associated with increased curiosity even when people are not told that they are wrong**.. (under review) *J Exp Psychol: Gen* 2020.

61. Brown AS: **A review of the tip-of-the-tongue experience**. *Psychol Bull* 1991, **109**:204-223.

62. Schwartz BL: **The relation of tip-of-the-tongue states and retrieval time**. *Mem Cogn* 2001, **29**:117-126.

63. Schwartz BL: **Working memory load differentially affects tip-of-the-tongue states and feeling-of-knowing judgment**. *Mem Cogn* 2008, **36**:9-19

This article investigates the effect that working memory load has on the likelihood of TOT states and whether being in a TOT state interferes with working memory performance. The results show that when participants must maintain a moderately high load that TOTs decrease. When people are in TOTs, they show worse performance on a digit span task.

64. Schwartz BL: **Sparkling at the end of the tongue: the etiology and phenomenology of tip-of-the-tongue states**. *Psychon Bull Rev* 1999, **6**:379-393.

65. Wellman HM: **Tip of the tongue and feeling of knowing experiences: a developmental study of memory monitoring**. *Child Dev* 1977, **48**:13-21.

66. Cohen G, Faulkner D: **Memory for proper names: age differences in retrieval**. *Br J Dev Psychol* 1986, **4**:187-197.

67. Brennen T, Vikan R, Dybdahl R: **Are tip-of-the-tongue states universal? Evidence from an unwritten language**. *Memory* 2007, **15**:167-176.

68. Litman JA, Hutchins TL, Russon RK: **Epistemic curiosity, feeling-of-knowing, and exploratory behaviour**. *Cogn Emot* 2005, **19**:559-582.

69. Metcalfe J, Schwartz BL, Bloom PA: **The Tip-of-the-tongue (TOT) state and curiosity**. *Cogn Res: Principles Implications* 2017, **2**:31.

70. Gardiner FM, Craik FIM, Bleasdale FA: **Retrieval difficulty and subsequent recall**. *Mem Cogn* 1973, **1**:213-216.

71. Bloom PA, Friedman D, Xu J, Vuorre M, Metcalfe J: **Tip–of-the-tongue states predict enhanced feedback processing and subsequent memory**. *Conscious Cogn* 2018, **62**:206-217

This article investigates the neural response, via event related potentials, to the resolution of TOT states during which people are highly curious. It also investigates the consequences for memory. An exacerbated late positivity is observed, as a function of the TOT state. Both the late positivity and the TOT state,are related to subsequent enhanced recall.

72. Undorf M: **Fluency illusion in metamemory**. In *Memory Quirks: The Study of Odd Phenomena in Memory.* Edited by Cleary AM, Schwartz BL. Routledge Press; 2021:150-174.

73. Dunlosky J, Hertzog C: **Aging and deficits in associative memory: What is the role of strategy production?** *Psychology and Aging* 1998, **13**:597-607.

74. Loewenstein G: **The psychology of curiosity: A review and reinterpretation**. *Psychological Bulletin* 1994, **116**:75-98.

75. Loewenstein G: **Affect Regulation and Affective Forecasting**. In *Handbook of Affect Regulation.* Edited by Gross ms. New York: The Guilford Press; 2007:180-203.