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Metacognition

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The term *metacognition* refers to a broad set of skills that enable people to plan their cognitive efforts, identify their errors, revise their strategies, and accept or reject their conclusions. In other words, metacognition predicts the feasibility and regulates the performance of cognitive actions, i.e., actions with an informational purpose. For example, metacognition helps you determine whether items from your memory can be swiftly retrieved, whether a given problem is within your reach, or whether your solution is likely to be true.

History

Why “meta”?

The Greek prefix “meta” means “about.” Metacognition then, literally means “cognition about cognition,” i.e., it refers to a set of abilities for knowing what one thinks and how one thinks. Metacognition, however, also refers to the mere ability to regulate one’s own cognition. The first attempt at understanding the mechanisms underlying metacognition dealt with the regulation of memory, at a time when the word metacognition had not yet been used.

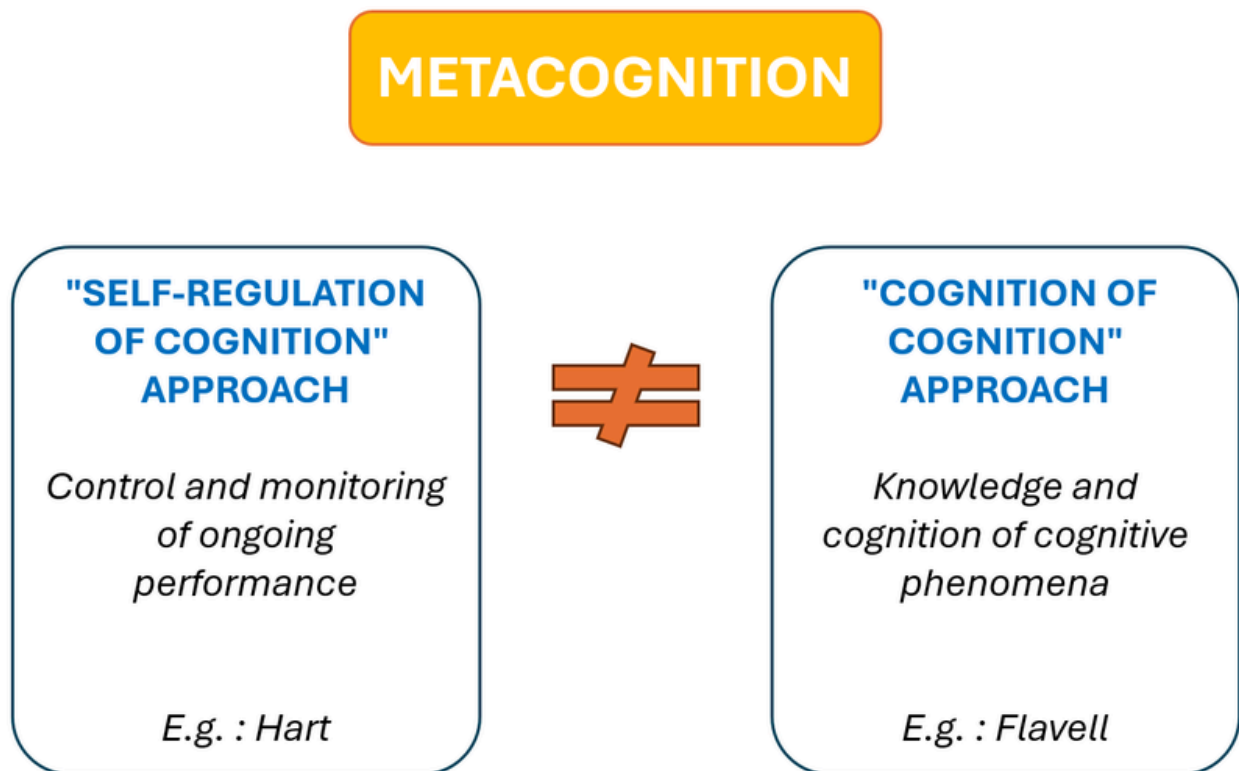


Figure 1
Two definitions of metacognition.

The control of one's memory

How do people predict, in a given case, whether they will remember a name that currently escapes them? In 1965, Josef T. Hart demonstrated experimentally that feelings of knowing are used to reliably assess one's ability to remember. It was not until the following decade that child psychologist [John H. Flavell \(1979\)](#) coined the terms *metamemory* and *metacognition* “by analogy with ‘metalanguage.’” Metamemory, Flavell writes, refers to “the individual's knowledge and awareness of his memory.” Metacognition, by analogy, is claimed to refer to “knowledge and cognition of cognitive phenomena,” including “attention, memory, problem-solving, social cognition and various types of self-control and self-instruction.” The two definitions are based on two conflicting hypotheses.

The mindreading hypothesis

In a 1975 paper, John Flavell and Henry Wellman claimed that all the forms of metacognition involve “generalizations about people and their actions in relation to objects.” For them, metacognition is “naturally a form of social cognition.” At the time, young children were considered nonmetacognitive because they easily attributed to themselves skills they did not have, believed themselves capable of solving a problem they failed at, and attributed to themselves knowledge they could not retrieve. Metacognitive skills were not supposed to appear until the end of the preschool period, i.e., until children could attribute mental states to themselves—a capacity called *mindreading* that emerges around the age of 5 years.

The feedback loop hypothesis

In an influential 1960 book entitled *Plans and the Structure of Behavior*, however, George A. Miller, Eugene Galanter, and Karl A. Pribram explored the mechanisms that enable the mind to control its activity ([Miller et al., 1986](#)). They analyzed the crucial role of feedback loops known as *test-operate-test-exit (TOTE) units* (see [Figure 2](#)). In the first test phase, the current state is compared with the desired end state, and discrepancies are identified. This is known as the *incongruity-sensitive mechanism*. Feedback from this test guides action, triggering an operation to resolve the discrepancies. Once the operation has been completed, a new test is required to compare the feedback with the expected final state. If there are no discrepancies, the action is completed and control is transferred to another TOTE unit. On the other hand, if there are discrepancies, a new action is triggered to achieve the final state. These TOTE units act as feedback loops, monitoring the successive states of a system.

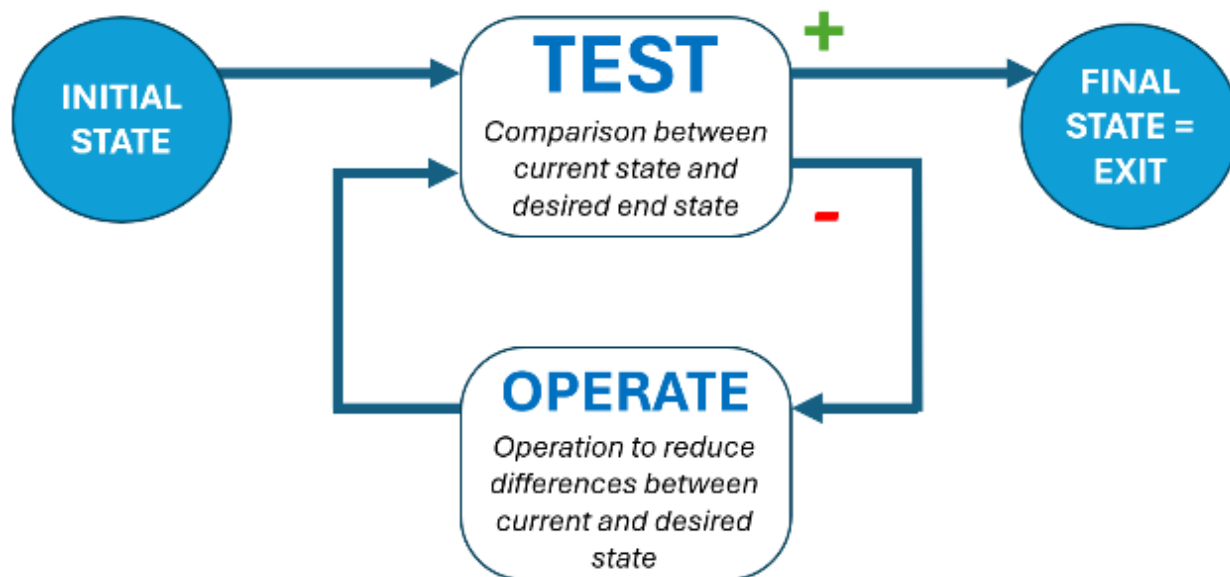


Figure 2
The TOTE procedure.

Following this analysis of behavior control, [Thomas O. Nelson and Louis Narens \(1992\)](#) provided a convincing definition of metacognitive processing in terms of feedback loops. They hypothesized that it involved three principles:

1. Cognitive processes are divided into a meta level and an object level.
2. The meta level contains a dynamic model (a mental simulation) of the object level.
3. “Control” and “monitoring” are defined in terms of these levels, with an object level collecting feedback from current activity and a meta level sending new commands in the light of feedback.

The dual-processing hypothesis

This point of view reconciles the two ways in which metacognition can be “about cognition.” Asher Koriati and his colleagues have shown that metacognitive regulation can be based on both experience and concepts ([Koriati & Levy-Sadot, 1999](#)).

Experience-based monitoring depends on the *noetic feelings* generated by processing an ongoing task, such as the feeling of knowing, the feeling of ease of processing, or the tip-of-the-tongue phenomenon. Research has shown that these feelings depend directly on the representational vehicle (underlying neural dynamics), rather than on the semantic content of the cognitive tasks being monitored. Thus, the reliability of these feelings is based on their having been previously associated with a specific task outcome, such as success or failure. In some cases, however, feelings may be elicited by cues that are either irrelevant to the task at hand or actually interfere with it. For example, the perceived ease with which information is processed (*fluency*) often correlates with correct memory retrieval or correct perceptual discrimination. In hurried reasoning, however, agents overlook aspects relevant to problem-

solving; the perceived fluency of their own responses creates an illusion of correctness ([Ackerman & Thompson, 2017](#)). Experience-based metacognition is also referred to as *procedural* or *implicit* in that the underlying cues that generate conscious predictions of likely success are selected unconsciously.

Concept-based monitoring, on the other hand, depends on forming beliefs about one's own likely success or error, based on one's perceived abilities in a task. Theories and verbal feedback from others often play a major role in shaping students' confidence in their own learning abilities; this is notably the case for sociocognitive stereotypes and related conceptions, such as "men are better at math" or "women are better at literature." Concept-based metacognition is also referred to as *analytic* or *explicit* because it generates conscious, reportable reasons for one's evaluations about the ongoing cognitive activity.

Core concepts

Comparative metacognition

Comparative studies over the past three decades have contributed significantly to the debate on the structure and function of metacognition ([Smith, J. D., Shields, W. E., & Washburn, D. A., 2003](#)). They brought evidence that nonlinguistic animals, such as monkeys, dolphins, rodents, and corvids, are able to monitor and control their perceptual discrimination and memory retrieval even though they lack mindreading abilities ([Beran, 2019](#)).

However, the experimental paradigms involved were initially criticized because they allowed animals' decisions to be conditioned by the receipt of trial-by-trial rewards. A series of computer simulations further suggested that the response profiles observed in these behavioral experiments could be explained equally well by a metacognitive strategy, an associative strategy (when each response is rewarded), and a stimulus avoidance strategy (difficult items followed by time-out punishment; [Le Pelley, 2012](#)).

To address these objections, experimental paradigms carefully operationalized the distinction between a primary task involving trials of variable difficulty, in which animals' responses can be assessed for accuracy, and a secondary behavior in which animals are able to regulate their primary responses ([Hampton, 2009](#)). In light of these new tests, there is now a stronger consensus that the performance seen in many tests of animal metacognition are evidence for procedural metacognition, i.e., evaluative skills based on past outcomes rather than beliefs or theories (as is the case for explicit metacognition in humans).

Behavioral studies of animal metacognition within comparative psychology were first conducted independently from the study of neural correlates of metacognition in animal species. The situation dramatically changed when neuroscientists realized that behavioral measures can be used to study confidence assessments by animals trained in cognitive decision-making.

The neuroscience of metacognition

Following the lead of comparative psychologists of metacognition, the rate of decline responses (where animals reject trials that are likely to be failed) and rate of post-decision wagering (where animals place a bet on the anticipated value of their response after their choice is made) were used as indexes for confidence in rats and rhesus monkeys. Firing rates measured in the orbitofrontal cortex while the animals performed an olfactory categorization task were shown to reliably assess confidence, i.e., decision (un)certainty. Furthermore, these measures were shown to be unrelated to recent reward history ([Kepecs & Mainen, 2012](#)). This evidence contradicted earlier hypotheses that animals were merely conditioned to accept or reject a task as a function of prior rewards. Studies of patients' deficits in various clinical conditions suggest that, in humans, the right ventromedial prefrontal cortex and the dorsal anterior cingulate cortex support predictive confidence assessments (such as the feeling of knowing), whereas rostro-lateral prefrontal regions support retrospective confidence judgments ([Fleming & Dolan, 2012](#)).

Developmental findings about metacognition

The comparative literature has also prompted developmental researchers to explore the procedural dimension of metacognition. Some researchers hypothesized that young children should be able to monitor their confidence in a perceptual or memory task as well as rhesus monkeys do, in order to guide their cognitive decisions long before they can reason about their states of mind. In these instances of procedural metacognition, the predictive feedback from processing a cognitive task manifests as specific emotions, such as a feeling of knowing, ease of processing, or understanding.

Experimental evidence supported this hypothesis using a nonverbal opting-out memory task with 3-year-old children similar to one used in primatology to test nonhuman metacognition ([Balcomb & Gerken, 2008](#)). In this study, children performed better on trials they chose to accept than those they opted out of, as demonstrated by subsequent forced-choice recognition responses. This suggests that even young children can make reliable confidence judgments about what they can remember before they can identify and reason about their mental states (i.e., before developing mindreading abilities).

However, there is debate among developmental psychologists about the procedural character of the process through which children express their confidence. For example, 3-, 4-, and 5-year-olds exhibit parallel opting-out responses and verbal confidence reports ([Lyons & Ghetti, 2013](#)). This is interpreted as evidence that children's confidence evaluations are based on a self-attribution process, where children report their own mental states. This particular study, however, included a pretest phase where children were trained to link their feelings of uncertainty with verbal reports. Another study demonstrated that, without such training, 3-year-olds are able to adaptively accept or skip trials even if they fail false-belief tests ([Bernard et al., 2014](#)).

A critical test of the independence between control-and-monitoring (procedural metacognition) and verbal self-attribution of mental states involves demonstrating metacognitive sensitivity in nonverbal

children. A distinction between the two basic metacognitive processes—confidence-based decision and error monitoring—are present in infants as young as 12 and 18 months ([Goupil & Kouider, 2016](#)). Although toddlers do not talk about their mental states until their third year of life, another study showed that 20-month-olds can strategically seek help from caregivers by selectively turning to them when they cannot remember the location of a toy ([Goupil et al., 2016](#)). These findings clearly demonstrate that procedural metacognition operates independently of verbal self-attribution of mental states.

Cognitive actions

To clarify the role of metacognition in cognitive actions, it is helpful to consider it in light of the following definition of an action: A behavior qualifies as an action “when its course is subject to adjustments that compensate for the effects of forces that would otherwise interfere with it” ([Frankfurt, 1978](#), p. 160).

Cognitive actions are actions whose goal is to acquire information (based on perception, memory, inference, testimony, etc., termed *informational goals*). Metacognition compensates for interference in the case of cognitive actions: This is why it is part and parcel of cognitive actions. While pragmatic goals are pursued for their instrumental value (e.g., food shopping), informational goals are often pursued on the basis of intrinsic motivations (i.e., motivations that do not depend on having further ends), such as learning or understanding.

Cognitive control

Cognitive control designates the mechanisms responsible for flexibly adapting information processing to the demands of present goals. In spite of its name, it applies to all kinds of action, not only cognitive actions. A main function of cognitive control is to prevent goal conflicts due to competition between different tasks. For example, cognitive control is needed to perform the “Stroop test” where participants must filter out what a color word says (“RED”) to report its ink color (blue). Cognitive control (aka *executive control*) ensures that agents keep focused on their goal until it is reached and only switch attention to other tasks when it is adaptive to do so.

Metacognitive control and monitoring

Metacognitive control serves functions similar to the control of pragmatic actions: selecting a goal, keeping it active in working memory, updating and redirecting it, and assessing the final outcome. As shown in [Table 1](#), this control structure also applies to metacognition. Metacognition, however, is a specialized form of cognitive control. Rather than simply stabilizing agents’ attention toward a current goal, its role is to optimize the accomplishment of informational goals as a function of time and cognitive resources. As defended by the dual-processing hypothesis, metacognitive control depends on affective and conceptual monitoring.

Affective monitoring is related to information conveyed by feelings that signal opportunities and risks. Felt valence (perceived probability of success or error) elicits a desire to engage or disengage from the current cognitive action. The intensity of a feeling has an arousal value in that it determines the resources

to be allocated to a response. In addition, valence and intensity play roles at different stages of the action (see [Table 1](#)). Before action, feelings help assess the importance and likely success of a cognitive goal. Curiosity, for example, stimulates agents' motivation to learn target content that is perceived as currently lacking but learnable. During action, metacognitive feelings signal unexpected difficulties, errors, inadequacies or unexpected progress to the goal. At the end of a cognitive action, feelings assess the outputs for their validity or interest. Their function is to accept correct results and store them in memory for further use.

Table 1. Taxonomy of metacognitive feelings based on action stages (from [Goupil & Proust, 2023](#)).

Table 1		
Goal-related predictive feelings (examples)	Process-related evaluative feelings (examples)	Result-related evaluative feelings (examples)
Feelings of curiosity	Feelings of error	Feelings of being right/wrong
Feelings of familiarity	Feelings of incomprehension	Feelings that one learned
Feelings of knowing	Feelings of incoherence	Eureka feelings
Feelings of prospective confidence	Feelings of interest/boredom	Feelings of retrospective confidence
Tip-of-the tongue	Feelings of confusion	

Explicit metacognition

Explicit metacognition enables people to revise decisions made on the basis of metacognitive feelings in light of their background knowledge. For example, even if something seems hard to understand, you can tell yourself that it is worth concentrating on it. Concept-based metacognition also helps to convince others: Verbal assertions must be justified, explanations provided, and the subjectively felt level of certainty reported. Interestingly, there are cases where explicit metacognition cannot overcome the influence of metacognitive feelings. For example, when participants' attention is divided (they have to do two things simultaneously), they can no longer filter out anagrams whose solutions they know from those they predict will be easy for naive subjects ([Nussinson & Koriati, 2008](#)).

Questions, controversies, and new developments

The architecture controversy

The controversy between monists and dualists is focused on three issues (see [Table 2](#)). First, there is debate about whether uncertainty monitoring (as well as other forms of metacognitive control) needs to engage beliefs about one's own mind. Monists consider that subjective uncertainty only qualifies as

metacognitive if it is explicitly represented by a judgment of one's own uncertainty—a metarepresentation ([Carruthers, 2009](#)). Consistent with this view, developmental evidence suggests that metacognition only becomes efficient when children become able to read their own minds ([Lyons & Ghetti, 2011](#); [Perner, 2012](#)). In contrast, dualists propose that uncertainty can also be implicitly represented by metacognitive feelings. Nonhuman animals and infants rely on them when they manifest curiosity or realize that they cannot remember an object's location ([Kornell et al., 2007](#); [Goupil & Kouider, 2016](#)).

A second, related point of contention is whether metacognitive monitoring is involved in nonhuman and infant decision-making, such as seeking information, trying to remember, etc. Monists take these behaviors to be directly controlled by the corresponding basic functions (memory, perception, etc.). A more economical account, for them, is that infant and nonhuman responses are based on simple learning processes based on the probability of reward ([Carruthers, 2017](#)). Dualists, on the other hand, point to neural and behavioral evidence demonstrating that the probability of success and probability of reward compete to influence behavior ([Kepecs & Mainen, 2012](#); [Nussinson & Koriat, 2008](#)).

A third topic of controversy has to do with the potential ubiquity of metacognition throughout brain activity. If experience-based control depends on nonconscious predictive processes, monists argue, then it is unclear why the process of keeping one's balance should not qualify as metacognitive—which might be viewed as an absurd consequence ([Nagel, 2014](#)). Dualists respond by differentiating levels of control. Metacognition is specialized in assessing the informational quality of cognitive activities, such as categorizing, remembering, or problem-solving. Furthermore, in contrast to subpersonal homeostatic processes, metacognitive feelings involve conscious subjective experience ([Koriat, 2000](#)).

Table 2. The main points of controversy about metacognitive architecture.

Table 2		
Arguments	Metacognition theory	
	Monist	Dualist
Source of metacognitive uncertainty	Judgments of uncertainty	Metacognitive feelings and judgments of uncertainty
Source of control	Simple learning processes	Specialized predictions concerning probability of success and reward
Specialization	Metacognition should not apply to subpersonal control (e.g., control of balance)	Control is level-specific. Metacognitive control is conscious.

What feelings of confidence track

A classic assumption in metacognitive studies is that confidence judgments track the distance of a given response to an objective world property (which only the experimenter is in a position to identify). On this assumption, confidence is supposed to refer to the posterior probability that a decision is correct, given the evidence. The function of confidence, from this perspective, is to help agents detect true properties or objective states of the world.

An alternative construct takes confidence to refer instead to self-consistency, i.e., the reproducibility of a decision. Experiments on perceptual decision-making suggests that observers' perceptual confidence tracks the subjective reliability (i.e., self-consistency) of internal representations ([Caziot & Mamassian, 2021](#)). Similar evidence has been found when studying participants' confidence in their general knowledge, social beliefs, and personal preferences ([Koriat, 2024](#)). A related puzzling finding is that the confidence and speed with which an answer is given to a two-alternative forced-choice question predicts the likelihood that the same choice will be made by a majority of other participants, whether correct or not. Far from being an indicator of likely accuracy, the distribution of high and low confidence correlates with the degree of the consensus of specific responses (right and wrong alike) and the speed at which they are provided. This seems to be an unanticipated effect of participants' sharing common *wisdomware* (background knowledge).

Wisdom of crowds

These results contribute to the understanding of the “wisdom of the crowd” phenomenon. This expression derives from the finding that aggregated opinions within a group tend to be more accurate than the opinion of the best single expert within the group. Group decisions have also been found to be more accurate when more decision weight is given to the most confident persons. However, if self-consistency rather than accuracy determines confidence, group reasoning might be predicted to be subject to false consensus. To address this structural difficulty, it has been suggested that participants be encouraged to actively think differently. For example, they could be asked to try to contradict themselves (in order to experience internal disagreement) in order to blind themselves to their previous judgments. Another method is to increase interpersonal diversity in group composition ([Herzog & Hertwig, 2014](#)).

Broader connections

The evolution of metacognition

Evidence from biology, psychology, anthropology, and linguistics is needed to identify the role of metacognition in the evolution of communication. Three types of hypotheses have been considered.

First, according to dual-inheritance theories, culture and biology are considered parts of one interacting system, with feedback going both ways ([Jablonka & Lamb, 2007](#)). From this viewpoint, cultural traditions may influence, as well as be influenced by, the genes controlling linguistic communication.

Second, according to the cultural epidemiology view, cultural processes have their own nongenetic selection mechanisms, based on copying and social learning, either through high-fidelity replicators ([Blackmore, 2000](#)) or creative reconstruction of target inputs ([Sperber & Hirschfeld, 2004](#)).

Finally, according to the suprapersonal hypothesis, explicit metacognition is singled out as the thing that allows humans (unlike other primates) to reliably select who to copy or learn from ([Heyes et al., 2020](#)). It was selected to allow higher efficiency in the cognitive control of epistemic cooperation in hominin groups. On this view, explicit metacognition used for intrapersonal control is a side effect of suprapersonal forms of control applied to coordinated cognitive actions ([Shea et al., 2014](#)).

The regulation of communication

If explicit metacognition involves sharing one's own uncertainty with other members of the group, then could the normative rules that apply to communication have been generated with explicit metacognition? In support of a positive answer, accuracy, informativeness, ease of processing, economy, and relevance—the central informational standards targeted by Paul Grice's maxims of conversation—appear to involve higher-order communicative intentions (i.e., metarepresentations of speakers' intentions). The study of animal signaling, on the other hand, suggests that procedural metacognition may have shaped nonhuman communicators' sensitivity to trade-offs between informativity and clarity or between cognitive effort and survival significance ([Proust, 2023](#)). This hypothesis sheds new light on human communication. The pragmatic rules governing it could be based in part on metacognitive compromises inherited from biology. This view is reflected in the distinction between basic and mentalistic forms of communication ([Sperber & Wilson, 2024](#)).

Acknowledgments

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Further reading

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