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Modularity

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The term “module” is typically used by cognitive scientists to denote mental components or subsystems that are, in some suitable way, distinct and specialized. So construed, debates regarding modularity have been widespread in large measure because of their connection to a core assumption of cognitive science—that human cognitive capacities depend on a system decomposable into specific components and subsystems. Indeed, the task of characterizing this system in terms of its component parts—to provide an account of the *cognitive architecture* of humans—is among the central goals of cognitive science. As such, recent debates regarding modularity are both central to ongoing research and historically related to the millennia old tradition of faculty psychology.

History

Conceptions of modularity in cognitive science are largely due to the work of Jerry Fodor, Noam Chomsky, and, more recently, evolutionary psychologists such as Clark Barrett and Dan Sperber ([Barrett & Kurzban, 2006](#); [Sperber, 1994](#)). Nevertheless, modular accounts of cognition are plausibly a contemporary manifestation of the faculty psychology tradition—henceforth, “the Tradition”—which traces back to antiquity and includes such advocates as Aristotle, Descartes, Reid, and Gall ([Hufendiek & Wild, 2015](#)). Indeed, Fodor and Chomsky explicitly develop their conceptions of modularity with this Tradition in mind. As a result, conceptions of modularity in cognitive science very frequently mirror aspects of the historical debate over mental faculties.

Central to the Tradition is the idea that the mind or soul can be analyzed into distinct, specialized mental faculties. Indeed, by identifying these facilities, the Tradition sought to provide what the enlightenment philosopher David Hume (1999, p. 13) called a “mental geography”: a description of all the “distinct parts and powers” of the mind. Since the Tradition is so longstanding, it is unsurprising that markedly different lists of faculties have been proposed. For example, Aristotle’s initial list of faculties consisted of nutrition, perception, and mind ([Aristotle, 350/1987](#)), whereas from the medieval period onwards, a typical list might include such faculties as perception, memory, will, judgment, intellect, or imagination.

Faculties and capacities

The notion of a faculty is closely related to the notion of a psychological *capacity* (ability or power). Yet historically, this relation is complex for at least three reasons. First, the Tradition combines two quite distinct conceptions of faculties:

- *Capacities conception*: Faculties just are capacities or powers. On this view, for example, the faculty of judgment just is the capacity to render judgment. Descartes, for example, tends to think of faculties in this way ([Schmid, 2015](#)).
- *Structural conception*: Faculties are not mental capacities themselves but rather the states and structures on which such capacities depend. Historically, there is a lot of disagreement regarding what precisely the relevant states and structures are. But the basic idea is that a faculty of, say, judgment is all the

underlying states and structures that allow people to make judgments in the first place. This conception of faculties appears, for example, in the writings of Gall ([Young, 1970](#)).

As will become clear, a similar equivocation carries over to the use of “module” in cognitive science.

A second complication regarding the relationship between faculties and capacities is that, according to the Tradition, not all psychological capacities correspond to distinct faculties. In particular, it is widely assumed that human beings possess a lot more mental capacities than faculties. I have the capacity to play chess, balance checkbooks, and book flights online, for example, but no faculty psychologist would think that I have distinct faculties for each of these capacities. Rather, the notion of a faculty is reserved for those capacities which are, in some sense, *fundamental*. Criteria of fundamentality vary, but two are longstanding and widely adopted. First, faculties are often assumed to be *innate* and so are not acquired by mental processes such as abstraction, induction, or perception. Second, it is often assumed that capacities that are explicable in terms of combinations of other capacities do not correspond to genuine faculties but result instead from interactions between faculties. For instance, Descartes denied that there is a faculty of judgment on the grounds that judgments result from an interplay between the will and the intellect ([Schmid, 2015](#)). Again, both these criteria of fundamentality often carry over to discussions of modularity in cognitive science.

A final way in which the relationship between faculties and capacities is complex is that there are many potential ways to distinguish mental capacities and, hence, faculties. An especially important distinction is between *horizontal* and *vertical* ways of distinguishing between capacities and faculties ([Fodor, 1983](#)). The horizontal view is by far the more ancient, tracing to Plato and Aristotle. In contrast, the vertical view appears to be relatively recent, perhaps only dating to Franz Joseph Gall’s writings at the end of the 18th century. Both conceptions assume that faculties are *functionally* specialized, in the sense that each produces a distinct kind of effect. Thus, for example, the faculties of imagination and judgment would be functionally specialized because one produces imaginings while the other produces judgments. Yet, despite this similarity, the horizontal and vertical views of faculties differ in that the former characterizes faculties as *domain general*, whereas the latter construes them as *domain specific*. To explain this distinction, consider a paradigm example of a horizontal faculty: the faculty of judgment. Such a faculty would be domain general in the sense that the very same faculty is involved in generating judgments *irrespective of their contents*. Roughly put, whatever precisely the subject matter of the judgment—whether it concern mathematics, politics, geology, biology, economics, music, and so on—the very same faculty is involved. In contrast, on the domain specific (or vertical) conception, one faculty is to be distinguished from the others at least partially in terms of its subject matter or domains of application. Thus, for Gall, there is a faculty for musical aptitude and another for mathematics. So, even if both were to produce judgments, their subject matters would be distinct—music and mathematics, respectively. Once more, this historical theme has analogs in more recent discussions of modularity, in which the notion of domain specificity is widely, although not always, assumed to be central.

The fall and rise of faculty psychology

Despite two millennia of significant influence, by the middle part of the 19th century, faculty psychology was in decline. One major reason was sociological. The notion of a faculty was perceived as intimately tied to the phrenology of Gall and Spurzheim. So, when phrenology fell into disrepute among scientists, faculty-based approaches were also discarded—a kind of guilt by association ([Henley, 2023](#)). Yet, this is not the only reason for the Tradition's decline. Another concerned its persistent explanatory limitations. These limitations both motivated alternative approaches to psychology and became increasingly pressing when these alternatives appeared not to suffer analogous problems.

Perhaps the central complaint against faculty psychology was that it failed to produce genuine explanations. There were several versions of this *explanatory emptiness* complaint, including

- *The placeholder complaint:* Positing a faculty gives no genuine explanation but instead merely acts as a placeholder for the real causes that are currently unknown. Thus, Galen maintained that authors call a mental cause a “faculty” when they are ignorant of its “true essence” ([Galen, 1916](#)).
- *The redescription complaint:* Perhaps positing faculties as placeholders is not problematic if, sooner or later, the details are spelled out by providing a description of what faculties there are, what they do, how they do it, and how they interact with each other. However, this never seemed to happen. Indeed, the Tradition apparently lacked the resources for doing so. Thus, according to this complaint, faculties tend to function as *virtus dormitive* underwriting “explanations” that are little more than redescriptions of the phenomena to be explained. In extreme cases, for example, the explanation of a capacity to perceive is the possession of a faculty of perception, and the explanation of a capacity to reason is the possession of a faculty of reason, and so on ([Leibniz, 1981](#)).

In part due to such concerns, the Tradition waned during the latter 19th century and remained muted for the first half of the 20th century. In that time, alternative approaches to psychology dominated, such as associationism and behaviorism. Yet, the ascent of cognition psychology in the 1950s set the stage for a resurgence of interest in mental faculties. There are at least two reasons for this. First, in contrast to more traditional faculty psychology, computational approaches appear to offer far richer resources for developing accounts of faculties. Thus, for example, computational approaches permit the formulation of precise hypotheses regarding what function a faculty or cognitive system computes, what algorithm the faculty executes, and what sorts of representations are involved in performing these computations. As such, cognitive science seemed well placed to address the charge of explanatory emptiness that dogged the Tradition. Second, the explanation of cognitive capacities in terms of computational processes plausibly commits us to the existence of a *cognitive architecture*: a set of relatively fixed computing systems and structures, which implement these computational processes ([Pylyshyn, 1984](#)). As such, computational approaches to cognition apparently commit us to something very much like faculties—structures in the guise of computing subsystems that underwrite human cognitive capacities. Consequently, the burgeoning field of cognitive science found itself confronting questions reminiscent of those familiar from the Tradition, including

- Is the mind comprised of many or just a few computational systems (faculties)?
- Which specific systems are there, and what do they do?
- What properties do such systems/faculties have?
- How and to what extent do these systems/faculties interact?

It is against this backdrop that debates over modularity are perhaps best viewed.

Core concepts

Given cognitive science's widespread commitment to the assumption that the mind is decomposable—that it can be “broken down” into distinct components—the term *module* is often used to talk about subsystems that are thought to be, in some sense, explanatorily central. However, because different research programs have divergent goals and theoretical commitments, there is considerable variation in the sorts of components deemed central. Consequently, the term *module* gets used to denote different sorts of components and systems and therefore expresses different but related notions of a module. The following focuses on three such notions: Fodorian modules, Chomskyan modules, and a notion of modularity associated with evolutionary psychology.

Fodorian modules

The most influential conception of cognitive modules is credited to Jerry [Fodor \(1983\)](#), who sought to elaborate Gall's conception of faculties for the purposes of cognitive science. Specifically, Fodor reserves the term *module* for functionally characterizable cognitive mechanisms that possess all or most of the following features to some interesting degree (e.g., to an extent greater than other faculties) [see [Mechanistic Explanation](#)]:

- Domain specificity: They operate on a limited range of inputs, defined by some task domain such as color vision or sentence parsing.
- Informational encapsulation: They have limited access to information in other systems.
- Innateness: They are components of the mind that are not learned.
- Inaccessibility: Other mental systems have only limited access to a module's computations.
- Shallow outputs: Roughly put, their outputs do not involve abstract, theoretical concepts.
- Mandatory operation: They respond automatically to inputs.
- Speed: Their operation is relatively fast.
- Neural localization: They are associated with distinct neural regions.
- They are subject to characteristic and specific breakdowns.
- Their developmental trajectories exhibit a characteristic pace and sequence.

It is important to appreciate that Fodor does not view the above as a precise definition of modularity. Rather, he views the notion of a module as a *cluster concept*, in which a mechanism counts as modular if it possesses most or all the above properties to a significant degree ([Fodor, 1983](#), p. 3). As such, Fodor's notion of a module is both vague and gradable. Nevertheless, he thinks the notion is still important

because it picks out a kind of system that is important for the purpose of explaining cognition ([Fodor, 1983](#), p. 44). Specifically, he maintains that the class of cognitive modules is more or less coextensive with what he calls *input systems*—roughly, perceptual mechanisms that deliver their outputs to *central systems* such as those responsible for reasoning and decision-making.

Another point to appreciate is that not all the characteristics on Fodor's list are of equal theoretical import. Specifically, he tends to view domain specificity and informational encapsulation as theoretically most central and many of the others as mere symptoms of this more central pair. Both concern restrictions on *information flow*—restrictions on the sorts of representations modules can access—although the restrictions involved are different. For Fodor, domain specificity is a restriction on the inputs that a mechanism can process. A mechanism is domain specific (as opposed to domain general) to the extent that it can only process a highly restricted range of inputs. Standard candidates include mechanisms for low-level visual perception and face recognition. In contrast, encapsulation is a restriction on the kinds of information a mechanism can utilize once it has started processing some input. Roughly, a cognitive mechanism is encapsulated to the extent that it cannot access lots of information that the organism possess. Standard candidates include mechanisms for low-level visual perception and phonology that cannot draw on the organism's beliefs and goals ([Fodor, 1983](#)).

Chomskian modules

Chomsky uses *module* more or less interchangeably with *faculty* and *mental organ*. He is very sympathetic to the thesis that the human mind is modular in its organization, containing many distinct cognitive faculties, each with its own specific structures and principles of operation. Commonly cited examples include a faculty of number (or number sense), a faculty for intuitive physics, various systems for vision, and, of course, the language faculty (e.g., [Chomsky, 1980](#)). Like Fodor, Chomsky construes modules as prototypically domain specific and innate. However, Chomsky's conception of a module is clearly different from Fodor's in crucial respects. Indeed, two different conceptions of modularity are widely associated with Chomsky, each quite different from Fodor's.

Intentional modules

According to the first conception, modules are innate bodies of mental representations—or innate databases—for relatively specific domains such as language and arithmetic ([Samuels, 1998](#); [Segal, 1996](#)). The paradigm candidate of an *intentional module* is the language faculty construed as a body of innate representations regarding the structure of possible human languages ([Fodor, 1983](#), p. 7). However, other candidates might include innate, domain-specific *theories* of the sort posited by some developmentalists—for example, for intuitive physics, theory of mind, and folk biology ([Gopnik & Meltzoff, 1997](#)). If infants possess such innate theories, these too would be intentional modules.

It is instructive to view the distinction between intentional modules and Fodorian modules within the broader tradition of faculty psychology. Both seek to elaborate on the structural conception of faculties. However, whereas Fodor's modules are computational mechanisms for processing mental

representations, intentional modules *just are* systems of mental representations. Presumably, there might be modules in both senses. Indeed, on the common assumption that mental capacities depend on both cognitive mechanisms and mental representations, the two sorts of module are complementary aspects of a broader account of cognitive architecture.

Competence modules

Several cognitive scientists have recently maintained that Chomsky does not think of modules as bodies of mental representations (e.g., [Allott & Smith, 2021](#)). According to this alternative, Chomsky's notion of a module abstracts from cognitive architecture as well as from what David [Marr \(2010\)](#) termed the algorithmic and hardware levels of explanation. Such *competence modules*, as they are sometimes called, are not identified with the grounds for human cognitive capacities. Rather, they seem to be a contemporary version of the capacities conception of faculties, albeit one driven by some distinctive methodological commitments, which require explanation.

As noted above, the Tradition tended merely to label faculties (or mental capacities) without describing them in any detail. In contrast, Chomsky thinks that an account of faculties should do far more than this. However, because he also thinks almost nothing is known about the neural or computational details of faculties, he proposes that the initial goal should be to provide precise, empirically constrained descriptions of faculties in a manner akin to Marr's computational level explanations ([Marr, 1982](#)). In other words, cognitive scientists should aim to characterize each faculty in terms of the function it computes. In practice, this involves describing the principles and constraints that characterize the capacity in a highly abstract and probably idealized manner. Thus, just as a person's capacity to perform addition may be characterized in terms of a function from pairs of numbers to their sums, so too the language faculty may be characterized abstractly in terms of constraints upon how speakers "perceive, produce, and otherwise cognitively access linguistically structured material" ([Collins, 2017](#), p. 227). On this view, the language faculty is just the innate, domain-specific capacity so characterized. More generally—and crucially for issues of modularity—Chomsky contends that once cognitive scientists try to construct such abstract theories, it becomes clear that there are very few general principles spanning cognition broadly. Rather, different mental capacities—for language, arithmetic, vision, and so on—appear to be "organized along quite different principles." As such, Chomsky maintains that there would appear to be many cognitive modules in the present sense.

Evolutionary psychological modules

Although historically influential, Fodor and Chomsky's conceptions of modularity tend not to dominate more recent discussions, especially those associated with evolutionary psychology. Like Fodor and Chomsky, evolutionary psychologists view the mind/brain as an information processing system characterizable in computational terms. However, they adopt a pair of additional commitments that naturally lend themselves to a distinctive conception of modularity.

The first of these commitments is the *adaptationist* thesis that human minds are largely the product of natural selection. On this view, minds are primarily composed of *adaptations*: traits with distinctive cognitive functions produced by natural selection during the species' evolutionary history to solve *adaptive problems*—problems whose solution contributed to the survival and reproductive success of the evolutionary ancestors of humans.

The second commitment has come to be known as *massive modularity* ([Samuels, 1998](#); [Sperber, 1994](#)). Evolutionary psychologists suppose that the human mind must solve a great many adaptive problems and that highly specialized solutions tend to outperform more general-purpose ones. Consequently, they suppose that human minds will reflect this diversity of problems by containing a *great many specialized adaptations*. Finally, since evolutionary psychologists typically use the term *module* to denote such adaptations, they conclude that the human mind is likely to be composed largely, or even entirely, of a great many specialized cognitive adaptations or *modules* ([Samuels, 1998](#); [Sperber, 1994](#); [Tooby & Cosmides, 1992](#)). In short, they endorse the massive modularity hypothesis.

Massive modularity is discussed further below (see the section “Questions, controversies, and new developments”). For the moment, however, it may be useful to contrast the evolutionary psychologists' notion of a module with those discussed earlier. In contrast to Fodor and Chomsky, evolutionary psychologists tend not to characterize modules in terms of domain specificity, innateness, or (in Fodor's case) informational encapsulation. Although they think that cognitive modules can possess such properties, they propose that the notion of *functional specialization* associated with evolutionary biology is more central ([Barrett & Kurzban, 2006](#)). Specifically, according to evolutionary psychologists, a module is a cognitive system that possesses a specific evolved function—that is, the effect for which it was naturally selected during evolutionary history ([Mercier & Sperber, 2017](#)).

This way of characterizing modularity flows naturally from the distinctive theoretical commitments mentioned above. It is natural to rely on the notion of functional specialization given the commitment to adaptationism about cognitive systems. Further, the commitment to massive modularity demands—on pain of obvious implausibility—that modules need not be domain specific, encapsulated, automatic, and so on. Indeed, as Peter [Carruthers \(2006, p. 12\)](#) points out: “If a thesis of massive mental modularity is to be remotely plausible, then by ‘module’ we cannot mean ‘Fodor-module.’”

Questions, controversies, and new developments

Over the past few decades, notions of modularity have been at the heart of several related debates in cognitive science. The main ones concern the extent to which the human mind is modular. These may be divided into local and global debates.

Local modularity debates

Cognitive scientists often agree on what cognitive capacities human beings possess—language production and comprehension, face recognition, visual perception, reasoning, and so on. Nevertheless, they often

disagree about the extent to which such capacities depend on modular systems. “Local” debates concern whether a specific capacity depends on some kind of module. Here are some examples of such debates (along with highly selective references to influential proponents):

- *Visual perception*: Perceptual mechanisms, especially for vision, are often construed as paradigmatic modules. Such mechanisms appear to possess many of the properties associated with Fodorian modules. Yet, the extent to which vision is informationally encapsulated—or as it is often put, *cognitively impenetrable*—remains a topic of ongoing dispute ([Firestone & Scholl, 2016](#); [Pylyshyn, 1999](#)) [see [Cognitive Penetrability](#)].
- *Face perception*: Various domain-specific perceptual mechanisms have been posited, including those for visually identifying and recognizing faces. From Nancy [Kanwisher \(2000\)](#) onwards, the primary issue tends to be whether there is a neurally localized, domain-specific mechanism for face perception.
- *Language*: Language remains among the most highly contested contexts in which modularity debates play out. The historically most influential of these debates concern Chomsky’s claim that there is an innate, domain-specific language faculty ([Chomsky, 1980](#)). Additionally, [Fodor \(1983\)](#) proposes the existence of a Fodorian module for speech perception [see [Language Acquisition](#)].
- *Folk physics*: From very early in development, humans appear capable of predicting the behavior of inanimate physical objects, such as their trajectories when moving through space. Several influential theorists propose that human beings possess one or more dedicated cognitive system for this capacity (e.g., [Carey, 2009](#); [Leslie, 1994](#); [Spelke, 2022](#)) [see [Intuitive Theories](#)].
- *Theory of mind*: It has been argued that human beings possess a domain-specific cognitive mechanism for theory of mind—roughly, the capacity to attribute mental states to agents and by doing so to predict and explain their behavior ([Baron-Cohen, 1997](#); [Scholl & Leslie, 1999](#)) [see [Theory of Mind](#)].
- *Number*: Research on number cognition has led to the hypothesis that human beings possess one or more specialized mechanism for representing numerical magnitude ([Dehaene, 1997](#); [Spelke, 2022](#)) [see [Numerical Cognition](#)].
- *Probabilistic reasoning*: Evolutionary psychologists have argued that human beings possess highly specialized, evolved cognitive mechanisms for reasoning about probabilities ([Cosmides & Tooby, 1996](#); [Gigerenzer, 1998](#)) [see [Bayesianism](#); [Foundations of Rationality](#)].
- *Social contract reasoning*: Evolutionary psychologists have argued that human beings possess highly specialized, evolved cognitive mechanisms for reasoning about social exchanges or social contracts ([Cosmides & Tooby, 1992](#); [Gigerenzer & Hug, 1992](#)) [see [Cooperation](#)].
- *Reason*: Further developing the idea that human reasoning depends on specialized cognitive adaptations, [Mercier and Sperber \(2017\)](#) argue that *reason* is an evolved module that performs a range of important social functions [see [Reasoning and Argumentation](#)].

Global modularity debates

In addition to local debates regarding the existence of specific modules, there are also longstanding “global” debates regarding the overall architecture of the human mind. Roughly put, the core issue is this:

To what extent is the organization of the human mind modular? Answers to this question may admit of degree—from entirely modular to entirely nonmodular—and they may also vary with respect to the precise sorts of modularity involved. However, it is useful to divide up the options into three main sorts:

- *Amodal views*: At one extreme is a family of views on which the human mind is highly nonmodular in its organization. Some of these views are more caricatures than serious hypotheses. For instance, one might think that the human mind is one big von Neumann computer or a single, undifferentiated neural network—what Steven [Pinker \(1997\)](#) lampooned as the “connectoplasm” view of cognition. Perhaps more plausibly, some propose that the minds of newborn infants only contain a small number of systems—perceptual systems and domain-general learning mechanisms—and that any additional systems adult minds contain are a product of interactions with the environment. Such a view is sometimes associated with empiricist approaches to cognitive development ([Laurence & Margolis, 2024](#)).
- *Peripheral modularity*: Famously, [Fodor \(1983\)](#) proposed that the modular structure of the mind is restricted to *input systems* (those responsible for perception, including speech perception) and *output systems* (those responsible for motor control). On this view, *central systems*—those responsible for such “higher” cognitive capacities such as reasoning and decision-making—are nonmodular. As one might expect, the relevant notion of a module here is Fodor’s own, in which domain specificity and informational encapsulation play a central role. Thus, he maintains, for example, that vision and speech comprehension are modular in this sense, whereas central systems are both domain general and unencapsulated ([Fodor, 1983](#), part IV). Although not always framed in terms of modularity, dual process theorists often adopt a quite similar view of the overall architecture of the mind ([Evans & Stanovich, 2013](#)).
- *Massive modularity*: As mentioned earlier (see the section “Evolutionary psychological modules”), evolutionary psychologists tend to endorse the massive modularity hypothesis, which differs from Fodor’s peripheral modularity in two main respects. First, it posits many more cognitive modules than Fodor appear to countenance—“hundreds or thousands of functionally dedicated computers (often called modules)” ([Baron-Cohen, 1995, foreword by Tooby & Cosmides](#), p. xiii). Second, it maintains that modularity is found not merely at the periphery of the mind—input and output systems—but also those *central systems* responsible for reasoning and decision-making. Similar views may be found in other traditions (e.g., [Minsky, 1988](#)).

Global debates regarding modularity are, of course, greatly influenced by local modularity debates such as those mentioned above. However, there are also several theoretical arguments that exert a significant influence on global debates. These include various evolutionary arguments ([Fodor, 1983](#); [Tooby & Cosmides, 1992](#)), arguments concerning computational tractability ([Samuels, 2005](#)), and arguments regarding the apparent flexibility of human cognition ([Carruthers, 2006](#); [Fodor, 1983](#)). Interestingly, arguments of each sort have been marshalled both for and against the modularity of cognition.

Broader connections

The issues regarding modularity outlined above bear connections to several ongoing areas of research in cognitive science and beyond.

Neuroscience

The issues regarding cognitive modularity discussed above are widely thought to bear important and complex relationships to issues regarding brain organization. Specifically, issues about cognitive modularity are widely supposed to bear interesting connections to ongoing debates regarding the localization of function in the brain (e.g., [Anderson, 2014](#)). Relatedly, it should be noted that notions of modularity distinct from those sketched earlier play an ongoing role in neuroscience (e.g., [Meunier et al., 2010](#)).

Organismal biology

The notion of modularity is central in the emergence of evolutionary developmental biology ([Callebaut & Rasskin-Gutman, 2005](#)) and has increasingly become a major focus of research across multiple disciplines within biology, including genetics, developmental biology, functional morphology, and population and evolutionary biology ([Zelditch & Goswami, 2021](#)).

Modularity and predictive processing

The relationship between modularity hypotheses and predictive processing approaches to perception is a contentious one, with some arguing that the two are incompatible (e.g., [Hohwy, 2013](#); although, see [Drayson, 2017](#)).

The distinction between perception and thought

Since [Fodor \(1983\)](#), philosophers who are interested in how to draw the distinction between perception and thought have explored the possibility that some notion of modularity is of central importance ([Block, 2023](#), especially chapter 11; [Burge, 2022](#), especially chapter 19).

Further reading

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