Adaptive Memory and Learning

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Synonyms

Evolution and memory; memory adaptation

Definition

The concept of *adaptive memory and learning* has two defining assumptions: First, the capacity to preserve and recover information over time is adaptive, meaning that the systems that enable memory and learning are goal-directed and functionally-designed. Rather than domain-general, operating the same regardless of input and domain, species' retention systems are "tuned" to solve particular problems (such as remembering the locations of food sources or predators). Second, as products of natural selection, these systems likely bear the specific imprint of nature's criterion—the enhancement of fitness (survival en route to

differential reproduction). As a result, the ability to *learn* and *remember* will likely be influenced by the fitness-relevance of the information and tasks involved.

Theoretical Background

Most of the adaptive tasks animals have to solve during their lifetime do not have a stable solution. Animals cannot know ahead of time where the most abundant food sources will be found or where predators or potential mates are likely to be encountered. In fact, many important features of the environment are unpredictable; consequently, animals benefit from mechanisms that allow them to fine-tune their behavior to the current (or recently experienced) parameters of an environment. An animal equipped with the capacity to preserve and recover information adaptively—that is, to learn and remember—can exploit the stable properties of the environment while keeping track of any environmental events that necessitate behavior change.

Because different species must meet different ecological demands and are affected by different environmental features, each species' learning abilities should be fine-tuned to those environmental characteristics with the greatest impact on their <u>inclusive fitness</u>. In other words, we should expect cross-species variation in the ability to learn about different environmental variables. This expectation has been confirmed by an enormous amount of data. Food-storing specialists such as Clark's nutcrackers or marsh tits which rely on *spatial memory* to retrieve hidden seeds are known to outperform closely related non-storing (or with less predisposition to store) species in laboratory-based spatial memory tasks. In the *Pavlovian conditioning* domain, the classic work of Garcia and Koelling (1966) demonstrates that rats easily avoid a flavor previously paired with illness as well as audiovisual stimuli previously paired with electric shock but seem unable to learn when the cues are swapped. Presumably, this pattern is due to prevailing conditions in the environments in which rats evolved—peripheral pain was most frequently caused by external agents with particular visual and/or auditory properties, not by a particular flavor; conversely, illness was most frequently caused by specifically flavored meals rather than by visual or auditory stimuli. This pattern of biased learning to promote success in species-specific fitness relevant problems has also been observed in *instrumental learning* preparations in which animals must perform a particular response to obtain a reward or avoid a negative consequence. Rats, for example, rapidly learn to avoid an impending electric shock when the required avoidance response is part of their repertoire of defensive reactions (e.g., running), but this ability

declines as the required response becomes incompatible with their typical reactions to danger (e.g., rearing).

Whether nature's criterion—the enhancement of fitness—has left a similar mark on human cognitive functioning is more controversial (see Nairne, 2010). Human memory researchers usually propose domain-general memory mechanisms—that is, researchers assume that our retention systems operate similarly across materials and domains and are unaffected by information content. For example, it is often claimed that successful retention is determined simply by the functional "match" between the conditions present at *encoding* and those existing at the point of *retrieval*. Processing information at time 1 establishes a memory record that, in turn, dictates what retrieval cues can effectively access that record at time 2 (Tulving & Thomson, 1973). Encoding tasks that promote the generation of multiple retrieval cues through *elaboration*, or the linking of the target item to other information in memory, increase the chances that an effective (matching) retrieval cue will be encountered later. However, the process itself is domain-general. Retention is controlled by the presence of a diagnostic retrieval cue and it is the chance characteristics of the retrieval environment, rather than the content of the information per se, that determines when (or if) an effective cue will be present. There are no inherent memory "tunings," only taxonomies relating encoding and retrieval contexts.

From a fitness perspective, of course, not all occurrences are equally important. It is much more important to remember the location of food, the appearance of a predator, or the activities of a prospective mate than it is to remember events and activities that are unrelated to fitness. Indeed, the ability to relive past experiences through *episodic memory*, which may be a uniquely human characteristic, may be an evolved *adaptation* designed specifically to help us interact in the social world. Ancestrally, humans lived in small groups and needed the ability to develop a sense of personal identity and to differentiate among other members of the social group (e.g., track coalitional structure, identify cheaters, develop accurate personality assessments; track the activities of kin versus non-kin); the capacity to remember is a crucial ingredient of each of these tasks. One can also imagine memory playing a vital role in navigational abilities—everything from recognizing landmarks to remembering diagnostic weather patterns or relevant constellations (Nairne & Pandeirada, 2008).

Empirically, there is strong evidence that human learning and memory systems may be selectively tuned to process and retain information that is relevant to fitness. For example,

analogous to the cue-to-consequence work of Garcia and Koelling (1966), studies have consistently found that people easily associate fitness-relevant stimuli, such as snakes and spiders, to aversive events such as shock but not as easily to positive consequences (Öhman & Mineka, 2001). Both children and adults report strong and vivid memories for highly emotional events, such as situations in which their lives were in danger. Fitness-relevant information, such as information about social interactions or heroic exploits, also tends to transmit easily and effectively from individual to individual and across cultures.

Additional evidence comes from the survival processing paradigm, a procedure in which people are asked to process information with respect to a survival situation prior to a surprise retention test (Nairne, Thompson, & Pandeirada, 2007). In one case, people were asked to rate the relevance of random words to an imaginary grasslands scenario in which they were stranded without food and water and susceptible to predators. People later remembered words rated with respect to this scenario much better than a host of control conditions, such as forming a visual image of the words, relating the words to a personal experience, or intentionally trying to remember them. Such comparison conditions are widely recognized to enhance memory—in fact, these are the encoding manipulations typically championed in human memory textbooks—yet survival processing produced the best retention. From an evolutionary perspective, of course, this is the anticipated result. Natural selection sculpted our learning and memory systems based on nature's criterion—the enhancement of fitness— so the footprints of that criterion remain apparent in their operating characteristics. Our learning and memory systems evolved because they helped us retain things such as the location of food or the recent appearance of a predator.

Important Scientific Research and Open Questions

At the same time, it is extremely difficult to build a definitive case for evolved cognitive adaptations—that is, to place the locus of adaptive memory "tunings" in specialized structures that were sculpted by natural selection. There are no "fossilized" memory traces, and our knowledge about the ancestral environments in which our cognitive systems actually evolved is limited. Adaptive solutions to recurrent problems can arise indirectly, by relying on adaptations that evolved for different reasons (*exaptations*), or as a result of natural constraints in the environment (e.g., the physical laws of nature or genetic constraints). The proximate mechanisms that enable us to read and write, for example, did not evolve directly for those ends even though reading and writing are very adaptive abilities. Our cognitive

systems were also not built from scratch—natural selection "tinkers," which means that changes usually emerge from existing structures. The design of these structures, in turn, introduces constraints that influence how the adaptive problems that drive *evolution* are ultimately solved. Thus, even if we could correctly identify the ancestral selection pressures that drove the development of adaptive memory, it would still be difficult to predict how nature solved the relevant adaptive problems.

However, it is possible to collect relevant data. For example, there is growing evidence that human cognitive systems may show ancestral priorities—i.e., it may be easier to perceive and remember events that are congruent with the adaptive problems faced during the environment of evolutionary adaptedness. People are able to identify evolutionarily-relevant stimuli, such as snakes and conspecifics, more easily and quickly than familiar stimuli that are fitness-relevant but rooted in modern environments (such as guns). Specific phobias are more apt to develop to ancestral stimuli (e.g., spiders) than to aversive stimuli experienced exclusively in modern environments (e.g., weapons). In the survival processing paradigm, people show better memory for information processed with respect to ancestral scenarios, ones that tap hunter-gatherer activities such as searching for edible plants, than fitness-relevant scenarios that describe modern fitness-relevant activities (such as locating a pharmacy to buy antibiotics). These data suggest that current learning and memory processes remain sensitive to the selection pressures that led to their development (Nairne, 2010).

Regardless of where one looks in the physical body (e.g. heart, lungs, kidneys) one finds structures that reflect function—pumping or filtering blood, respiration, and so forth. These physical structures evolved subject to nature's criterion (fitness enhancement) and faithfully perform functions to reflect that end. The capacity to learn and remember evolved as well, so it is not surprising that our cognitive systems are not only adaptive but functionally designed as well.

Cross-References

Adaptation and learning

Biological and evolutionary constraints of learning

Episodic learning

Evolution of learning

Fear conditioning in animals and humans

Functional learning

Human cognition and learning

Learning and evolutionary game theory

Memory for "what," "where," and "when" information in animals

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Key terms

Memory: Refers to the ability to store, retain and recall information and experiences. This ability allows one to use past experience to plan future actions.

Learning: Refers to knowledge, behaviors or skills that have been acquired by the organism. This acquisition may occur through a variety of mechanisms such as classical conditioning, instrumental conditioning, practice, habituation, among others.

Natural selection: Refers to a natural process through which heritable traits or characteristics that make the organism better adjusted to an environment are more likely to be perpetuated in the species. This is accomplished by the organism's better ability to survive and reproduce afforded by those traits or characteristics.

Inclusive fitness: Refers to the fitness of an individual organism as measured in terms of its own reproductive success, and that of its kin (with each relative being valued according to the probability of shared genetic information).