Social Choice Theory

Whereas in game theory each agent has its own decision and payoff, in many important cases, such as elections, a group has to make a decision and live with the consequences together. The central question of social choice theory is how individual preferences should be aggregated to result in a group decision.

An important result in social choice theory is Arrow's Impossibility Result. This states that no voting procedure other than dictatorship can satisfy certain reasonable requirements, for example, that if every voter prefers *X* over *Y*, then the group prefers *X* over *Y*. One avenue of research this has led to is finding a voting procedure that best satisfies the constraints we think voting procedures should satisfy.

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See also Allais Paradox; Belief and Judgment; Collective Action; Decision Making, Neural Underpinnings; Dutch Book Arguments; Group Decision Making

Further Readings

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Declarative/Procedural Model of Language

The basic premise of the declarative/procedural (DP) model or theory is that language critically depends on two long-term memory systems in the brain: declarative and procedural memory. Perhaps most importantly, because the computational, anatomical, physiological, molecular, and genetic substrates of these systems are relatively well studied in both animals and humans, this theoretical approach generates a wide range of well-motivated, specific, and testable predictions about the neurocognition of language that one might have no reason to make based on the study of language alone.

This entry summarizes the two memory systems and their interactions, presents the basic predictions of the model, provides an overview of the evidence, and finally discusses implications and future directions.

The Two Memory Systems

Declarative Memory

This system underlies the learning, representation, and use of knowledge about facts and events, such as the fact that Paris is the capital of France or that you had ravioli for dinner last night. The system may be specialized for learning arbitrary bits of information and associating them together. Knowledge in this system is learned rapidly and is at least partly, though not completely, explicit—that is, available to conscious awareness.

The hippocampus and other medial temporal lobe structures learn and consolidate new knowledge, which eventually depends largely on neocortical regions, particularly in the temporal lobes. Other brain structures play a role in declarative memory as well, including a region in frontal neocortex corresponding to Brodmann's areas (BAs) 45 and 47 (within and near classical Broca's area) that underlies the selection or retrieval of declarative memories. Note that for both declarative and procedural memory, the DP model refers to the *entire* neurocognitive system involved in the learning, representation, and processing of the relevant knowledge, not just to those parts underlying learning and consolidating new knowledge.

The molecular basis of declarative memory is beginning to be understood. Declarative memory is affected by estrogen (higher levels improve it in women, men, and rodents) and is modulated by the genes for at least two proteins, BDNF (brain derived neurotrophic factor) and APOE (Apolipoprotein E). Other factors also affect it, including sex (females tend to have an advantage at declarative memory over males), sleep (memory consolidation is improved by sleep), and age (declarative memory improves during childhood, plateaus in adolescence and early adulthood, and then declines).

Procedural Memory

This system underlies the implicit (nonconscious) learning of new, as well as the control of already learned, perceptual-motor, and cognitive skills and habits, such as typing, riding a bicycle, or video game playing. It may be specialized, at least in part, for sequences and rules. Learning in the system requires extended practice, though it seems to result in more rapid and automatic processing of skills and knowledge than does learning in declarative memory. Note that the term *procedural memory* is used by the DP model to refer only to one implicit nondeclarative memory system, not to all such systems.

The procedural memory system is composed of a network of interconnected brain structures rooted in frontal/basal ganglia circuits, including premotor cortex and BA 44 in Broca's area in frontal cortex. Although procedural memory is generally less well understood than declarative memory, evidence suggests that the neurotransmitter dopamine plays an important role in this system, as do the genes for some proteins (e.g., for the proteins FOXP2 and DARPP-32). Other factors may also affect procedural memory, including age (unlike declarative memory, procedural memory seems to be established early in life, after which learning and consolidation in this system may decline).

Interactions

The two memory systems interact both cooperatively and competitively in learning and processing. First, the two systems can complement each other in acquiring the same or analogous knowledge, including knowledge of sequences and rules. Declarative memory may acquire knowledge initially, thanks to its rapid acquisition abilities, while the procedural system gradually learns analogous knowledge, which is eventually processed rapidly and automatically. Second, animal and human studies suggest that the two systems also interact competitively, resulting in a seesaw effect. For example, a dysfunction of one system may result in enhanced functioning of the other. Similarly, estrogen seems not only to improve declarative memory but also to suppress procedural memory functionality.

Predictions of the Model

According to the DP model, each of the two memory systems is expected to play roles in language that are analogous to those they play in animals and humans in other domains. Declarative memory should underlie all idiosyncratic knowledge in language—that is, the mental lexicon—across linguistic subdomains (e.g., simple words and their meanings, irregular morphology, syntactic complements). Procedural memory should underlie the rule-governed sequencing of complex forms, again across subdomains, including phonology, morphology, and syntax (e.g., *walk* + *-ed*, *the* + *cat*). However, complex forms can *also* be learned and processed in declarative memory for example, as chunks (e.g., *walked*, *the cat*). Thus, complex forms can rely on either memory system. Which one they rely on will depend on multiple factors, such as which system functions better. Note that the DP model is compatible with the possibility that either memory system may be subspecialized for aspects of language (evolutionarily or emergent through learning) and that additional specialized circuitry for language may exist external to the two systems.

Evidence

Overall, converging evidence from multiple lines of experimentation, including behavioral, neurological, developmental, neuroimaging, and electrophysiological studies, suggests the following. Consistent with the basic claims of the DP model, idiosyncratic linguistic knowledge seems to be learned, stored, and processed by declarative memory. Disorders of declarative memory impair this knowledge. For example, the amnesic patient H. M. had trouble learning new words, and patients with damage to portions of temporal neocortex have problems with previously learned words (e.g., in semantic dementia or Alzheimer's disease) while remaining relatively spared at using rule-governed complex forms.

Rule-governed complex forms often depend on procedural memory. Adult-onset disorders affecting procedural memory brain structures, such as Parkinson's disease, can impair the use of these forms (e.g., patients might say "Yesterday I walk over there," leaving off the rule-governed *-ed* suffix). In contrast, unsuppressed output from the basal ganglia to frontal cortex, as is found in Huntington's disease and Tourette's syndrome, can result in the overapplication of rules (e.g., *walkeded*, *dugged*) or faster processing of complex forms.

Complex forms can also be learned and processed in declarative memory. Which of the two memory systems they rely on seems to depend on a variety of subject-, task-, and item-level factors. For example, individuals who are better at declarative memory (e.g., women vs. men) or worse at procedural memory (e.g., those with developmental disorders that affect this system, such as specific language impairment or with *FOXP2* mutations) appear to rely more on declarative and less on procedural memory. And consistent with the finding that declarative memory improves during childhood, while procedural memory shows a different pattern, adult second language learners appear to rely more on declarative than procedural memory for complex forms, when such learners are compared to native language speakers.

Future Directions

However, much remains to be examined. For example, there has been little work on the endocrine or genetic predictions of the model. Additionally, the model's pharmacological and pedagogical ramifications may prove important for the rehabilitation of language disorders as well as for second language learning. Future studies will provide a better understanding of the model and its implications.

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See also Amnesia; Bilingual Language Processing; Gender Differences in Language and Language Use; Memory, Neural Basis

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Deductive Reasoning

Deductive reasoning is the kind of reasoning in which, roughly, the truth of the input propositions (the premises) logically guarantees the truth of the output proposition (the conclusion), provided that no mistake has been made in the reasoning. The premises may be propositions that the reasoner believes or assumptions that the reasoner is exploring. Deductive reasoning contrasts with inductive reasoning, the kind of reasoning in which the truth of the premises need not guarantee the truth of the conclusion.

For example, a reasoner who infers from the beliefs

1. if the room is dark, then either the light switch is turned off or the bulb has burned out;
2. the room is dark;
3. the light switch is not turned off;

to the conclusion

4. the bulb has burned out

is reasoning deductively. If the three premises are true, the conclusion is guaranteed to be true. By contrast, a reasoner who infers from the belief

1. all swans that have been observed are white;

to the conclusion

2. all swans are white

is reasoning inductively. The premise provides evidential support for the conclusion but does not guarantee its truth. It is compatible with the premise that there is an unobserved black swan.