

the kitchen light with food and that only then did we present the sound of the can opener and the light together preceding the food. Now the cat would be unlikely to learn to make a conditioned response to the sound. It appears that previously learning to associate the light with food makes the normally effective pairing of sound and food ineffective for association.

The blocking effect can be understood with reference to the functions in Figure 3 for Acquisition Trial 50. Here, the previously trained CS (the light) regularly elicits a CR, reflecting the US_{A2} processing elicited by that CS. The addition of the novel CS (the sound), will result in the overlap of $CS_{A1\text{-sound}}$ with the same US_{A1} and subsequent US_{A2} processing that is elicited already by the conjunction of $CS_{A1\text{-light}}$ and the US. That is, there will be an initial increment in V^- , followed by a comparable increment in V^+ , that will accrue equally for both CSs. Since V^- and V^+ balance out, there is no net increment in either association. The CS_{sound} US association, starting at 0, thereby fails to acquire any σV . That is, the cat will not learn a sound-food association.

Conclusion

SOP is able to explain much of what is known about Pavlovian conditioning, including cue-competition effects. By rationalizing excitatory and inhibitory learning in terms of $A1/A1$ and $A1/A2$ conjunctions in time, it allows us to understand how the outcome of a conditioning trial depends on the order of the CS and US and the difference between simple conditioning and conditioned inhibition training. By rationalizing priming effects in terms of $A1$ and $A2$ effects over time, it allows us to understand blocking (as shown above), as well as short-term habituation and pre-trial CS and US exposure effects. By rationalizing the relationship of a CR and UR as the CR reflecting only US_{A2} processing, without the US_{A1} processing additionally elicited by the US, we can understand why the CR sometimes mimics the UR and sometimes does not.

Extensions of the SOP model have been developed to increase its theoretical power, to allow for an understanding of occasion setting (Brandon and Wagner, 1998), CR timing (Brandon, Vogel, and Wagner, 2002), and various differences in Pavlovian conditioning involving skeletal versus emotional responses (Wagner and Brandon, 1989). Wagner and Donegan (1989) have further indicated how it may relate to the known neural circuitry for eyeblink conditioning.

See also: ALGORITHMS, LEARNING; CONDITIONING, CELLULAR AND NETWORK SCHEMES FOR HIGHER-ORDER FEATURES OF; KAMIN'S

BLOCKING EFFECT: NEURONAL SUBSTRATES; LEARNING THEORY: A HISTORY; LEARNING THEORY: CURRENT STATUS; MATHEMATICAL LEARNING THEORY; NEURAL COMPUTATION: APPROACHES TO LEARNING

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SOURCE MONITORING

Source monitoring refers to cognitive processes involved in making attributions about the origins of mental experiences; for example, attributing a mental experience to something dreamed, something imagined, or a perceived event. The concept of source memory overlaps with, but is more general than, the idea of memory for context. Source monitoring is an important aspect of everyday cognition, for example, in deciding whether one took one's medication or just thought about taking it, read about a space alien invasion in a tabloid or a news magazine, or really saw the defendant at the crime scene with a knife or just heard about the knife later. Errors in source monitoring range from the trivial (telling a joke to the same person you heard it from) to the egregious (mistaking a memory of a dream of being

sexually abused for a memory of a real event from childhood).

Marcia Johnson and her colleagues (1993) have detailed a theoretical framework for understanding the cognitive processes and factors that influence source memory. According to the source monitoring framework, any given mental experience typically does not include a single feature or tag or label specifying what it is (e.g., a memory of a dream, an imagination, a perception). Rather, people attribute some mental experiences to memories based on the experience's features. Events have many features (objects, location, people, color, taste, emotions, ongoing thoughts), some of which are encoded in memory; a few or many of these features may be brought to mind (reactivated) after only a few minutes or years later. What a person calls that later mental experience depends on what features it includes and on the person's beliefs about the differences between mental experiences from different sources. For example, people usually expect memories for events (sometimes called episodic memory) to contain details reflecting such aspects as the who, what, when, where, why, and how of the event. A mental experience that does not have such details might be attributed to, for example, inference, general knowledge, or belief, depending on the particular features it does have.

Different types of encoding processes (e.g., seeing, hearing, thinking, dreaming) and different types of events (e.g., movie, telephone call) tend to produce memorial representations that are characteristically different from each other. For example, memories of imagined events typically have less vivid perceptual, temporal, and spatial information than perceived events and more information about intentional cognitive operations (e.g., actively generating images while thinking). Therefore, if a mental experience had substantial perceptual detail, one would tend to attribute it to a perceived event (e.g., something one saw). However, there is variability among memories from any particular source, and the distributions of features from different sources overlap. For example, some dreams are more vivid or plausible than some waking events. Thus, remembering always involves evaluating the quality and quantity of activated characteristics in light of expectations about typical characteristics of mental experiences from various sources.

Source attributions are often made rapidly and without deliberation based on heuristic judgments about activated features. However, source monitoring sometimes entails more systematic processes that are typically slower and more deliberate, including retrieving additional information, extended reasoning, and so on. For example, a vivid memory of Frank

talking to Paul at a party might be contradicted by retrieving additional information that places Frank out of town at the time of the party. Similar distinctions between relatively automatic and more controlled processes of remembering have been made by L. Hasher and R. Zacks (1979), L. Jacoby and C. Kelley (1989), and other researchers. Both heuristic and systematic source attributions are affected by a rememberer's biases, goals, agendas, and meta-memory beliefs. For example, one will usually engage more systematic source monitoring processes if the cost of a mistake is high, but engage only relatively automatic, heuristic processes for most everyday remembering.

Historical Context

The concept of reality monitoring was introduced in the early 1980s by M. K. Johnson and C. L. Raye (1981) to explain how memories for internal events (e.g., thoughts, imaginations) are discriminated from memories for external, perceived events, and why they are sometimes confused. This concept was subsumed by the more general source monitoring framework in the early 1990s. The theoretical ideas incorporated in the source monitoring framework were proposed to help organize and understand diverse findings and guide additional research. For example, studies in the 1950s and 1960s showed that people falsely recall (Deese, 1959) or falsely recognize (Underwood, 1965) associates of presented words: Hearing *thread*, *haystack*, *sharp*, and so on, can lead people to misremember hearing *needle*, presumably because they thought of *needle* during study and later mistake the thought for an actual presentation of the word. In the 1970s, M. K. Johnson and J. D. Bransford and colleagues (1973) showed that people falsely recognize ideas that were only implied in sentences. For example, after hearing, "The man *dropped* the delicate glass pitcher on the floor" people often remember hearing, "The man *broke* the delicate glass pitcher on the floor." The 1970s and 1980s produced many studies showing that people's memory for experiences tends to be shaped by their expectations or schemas (see Alba and Hasher, 1983, for a review). For example, W. F. Brewer and J. C. Treyens (1981) showed that people who had briefly waited in an office were likely to falsely remember items such as books, which were not in the office but might be expected to be, and to not remember unexpected items that were there (e.g., a skull). E. F. Loftus and colleagues (1978) showed that information introduced when people were questioned about an event was later sometimes (mis)remembered as part of the original event.

Such findings illustrate that people confuse information from different sources. For example, as part

of their normal comprehension processes, people think of related information during encoding or remembering (or both) and misattribute this information to the actual event. Other times, they confuse what they saw with what they heard or read, or confuse two similar experiences. Yet, sometimes memory is quite accurate. The source monitoring framework specifies the factors that influence the likelihood that memory will be accurate or distorted.

Factors Affecting Source Monitoring

Source monitoring depends on the type, amount, and quality of activated information, the extent to which the active information helps uniquely specify the source, the judgment processes engaged, the weights assigned to different features, and the criteria used when making the source attribution. Neither the activated features (representations) nor the processes that act on them are perfect, and thus errors occur. A basic tenet of the source monitoring framework is that inaccurate source monitoring (sometimes called source confusions, source misattributions, source errors, source amnesia, source forgetting, memory distortions, or false memories) and accurate source monitoring arise via the same mechanisms.

Anything that disrupts the encoding, consolidation, or retention of the features of events will negatively affect source monitoring. For example, at encoding, divided attention or focusing on one's own emotions rather than event details can increase source monitoring errors, presumably because useful source-specifying information fails to be, or is weakly, bound to other features of the event. Errors increase when the diagnosticity of available source information is reduced, for example, when semantic or perceptual similarity between events from different sources is increased. Errors also increase when more lax criteria are used to evaluate mental experiences, features are weighted inappropriately, attention is divided at test, or the time that is available to make a source judgment is limited. Individual motives and the social/cultural context can influence all of these factors.

The general view that remembering is not a simple matter of "retrieving" memory traces but rather a subjective experience with phenomenal qualities that differ in important ways has generated new interest in assessing the subjective qualities of memories. One approach asks people to distinguish between items they *know* and items they *remember*; another uses memory characteristics questionnaires to elicit more detailed ratings of features of memories. For example, such studies have shown that, on average, false memories tend to be rated as having less perceptual detail than true memories.

Brain Regions Involved in Source Monitoring

Neuroimaging data (e.g., from functional magnetic resonance imaging) together with neuropsychological studies of brain damaged patients with amnesia indicate that the hippocampus plays a central role in the binding of features into complex representations—a process critical for later source monitoring. Profound disruptions in source monitoring, such as delusions, hallucinations, and confabulations, can arise from damage to frontal brain regions, indicating that these regions are critical for source monitoring. Neuroimaging studies that show activation of frontal regions during source monitoring in healthy individuals provide converging evidence. Children and older adults have more difficulty with source monitoring than do college-aged adults, particularly as the similarity of the sources increases. Researchers have suggested that such findings may reflect the relatively late maturation of frontal functions in children and the increased probability of pathology in frontal regions associated with aging. One goal of current neuroimaging work is to more clearly delineate the brain circuits underlying the encoding, revival, and evaluation of memories.

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SPACED TRAINING

See: DISTRIBUTED PRACTICE EFFECTS

SPATIAL LEARNING: ANIMALS

Resources that animals need are usually distributed patchily within their home range, and many animals learn where they are and how to reach them. Stuart Altman describes how one troop of baboons responded to ripe berries on an isolated bush in the center of their home range as a sign of their availability elsewhere and trekked to a remote patch of bushes bearing the same fruit.

Some animals cache food when it is abundant, remember the precise locations of the caches for long periods, and return to empty the caches when food is scarce. Clark's nutcracker provides a dramatic example. The birds collect tens of thousands of pine seeds in the autumn for recovery during the subsequent winter and spring. Scrub jays caching food in the laboratory remember not only where they have cached it but also which items they have stored in which locations. Proof came from an experiment by Nicola Clayton and Anthony Dickinson in which birds were given two different foods to cache. Before the birds were allowed to recover either food, they were prefed with one. Prefeeding caused the birds to focus their search

on sites containing the other untasted and so more appealing food—a result that implies that birds know where they have hidden particular food items. By using food that rapidly rots, the same experimenters showed that scrub jays also know when they made the cache. Lastly, birds remember that they have emptied a cache, and they avoid revisiting empty sites. Other resources that animals remember include watering sites, nests, places where mates are to be encountered, shelters, and bolt holes. Spatial knowledge is closely integrated with other forms of knowledge that may influence what spatial information is stored, when it is retrieved, and how long it is remembered.

Some animals have evolved set procedures for acquiring needed navigational information. Indigo buntings learn the constellations of stars around the North Star, and they use that constellation for guidance in their migration. The birds are preprogrammed to learn the unique pattern of stationary stars that lies close to the Earth's axis of rotation and so do not move across the night sky. Wasps and bees perform highly structured learning or orientation flights when first leaving a new feeding site or their nest. The flight is designed to emphasise landmarks that are close to the goal and that can thus provide precise navigational information. In a single such flight, they learn enough about the arrangement of landmarks to be able to return there. Rats explore a new environment and reexplore a familiar one when changes occur. During exploration they learn the layout of the environment without the benefit of any immediate reward. In one experiment to demonstrate such learning, rats explored a T-maze with two visually distinct goal boxes and with all extra-maze cues screened off. After the rats had explored the empty maze several times, they were placed singly in one of the goal boxes and allowed to eat there. When re-placed at the entrance, most rats returned directly to the box where they had been fed. A control group fed in one goal box without prior exploration of that particular maze showed no tendency to return to the same box. Exploration allows the rats to learn the paths to different recognized locations that only later come to be associated with a valued resource.

It is remarkable that a wide array of animals, from insects to primates, acquire and store the same two distinct types of spatial information. One kind is derived from dead reckoning, also known as path integration. An animal leaving its home base continuously monitors the direction and distance of the path that it takes and uses this path-derived information to keep an updated record of its direction and distance from home. Consequently, it is always able to take a direct path home, even after a circuitous outward journey. On finding a good source of food, both in-