# Learning & Memory

SECOND EDITION

*John H. Byrne, Editor in Chief*

2003

MACMILLAN
REFERENCE
USA™

THOMSON
GALE

New York • Detroit • San Diego • San Francisco • Cleveland • New Haven, Conn. • Waterville, Maine • London • Munich

## SENILITY

*See:* AGING AND MEMORY IN HUMANS; ALZHEIMER'S DISEASE: BEHAVIORAL ASPECTS; ALZHEIMER'S DISEASE: HUMAN DISEASE AND THE GENETICALLY ENGINEERED ANIMAL MODELS; PHARMACOLOGICAL TREATMENT OF MEMORY DEFICITS

## SENSORY MEMORY

Sensory memory is an agency of information storage that not only carries the mark of the sense modality in which the information originally arrived—imagery is the more general term for that—but also carries traces of the sensory processing that was engaged by the experience. Sensory memory is the brain's detailed record of a sensory experience. Thus, we can generate a visual image of an object without actually seeing it, but we cannot thereby have a sensory memory of it. Although auditory and visual verbal stimuli have received the most attention, there are other forms of sensory memory (e.g., for nonverbal shapes, touch, and smell).

### Visual Sensory Memory

Research on visual sensory memory has focused on two phenomena: iconic memory and subjective persistence, descriptions of which follow below.

#### *Iconic Memory*

A single monograph by George Sperling, *The Information Available in Brief Visual Presentations* (1960), abruptly brought both the concept and the methods of visual sensory memory to modern attention. The subjects in Sperling's experiment saw twelve letters (three rows of four) in a brief flash. In a whole-report control condition, the subject was asked to report all twelve of the letters presented; in the partial-report conditions, a tone indicated which row was to be reported, the pitch of the tone corresponding to the row tested (high, medium, and low tones for first, second, and third rows, respectively). The results showed that subjects had about nine letters available to the visual system if the tone indicating which row to report sounded just as the display went off. People could report an average of three out of the four letters on any row. However, partial-report scores dropped to half that figure, almost exactly the level of whole report, if the cue tone was delayed by one second.

#### *Subjective Persistence*

Ralph N. Haber and Lionel Standing briefly showed subjects a three-by-three array much like those used in Sperling's experiments. However, the task was to adjust the timing of two auditory clicks to coincide with the apparent onset and offset of the display. The duration of the display varied from 100 to 1,000 milliseconds. By turning a knob, subjects could control the occurrences of two clicks relative to the visual exposure of the display. For a given objective duration, the mean onset adjustment can be subtracted from the mean offset adjustment to arrive at an estimate of how long the display seemed to last. Haber and Standing found that these subjective durations were longer than the objective durations. This is consistent with the suggestion that some form of visual storage follows the termination of the external display. Various procedures have been used to examine subjective persistence and have arrived at estimates of about 100 to 200 milliseconds.

Max Coltheart distinguished two sorts of memory. One type, visible persistence, refers to the subjective experience that the stimulus remains available to the visual system after stimulus offset, much in the manner of an afterimage. A second type, termed iconic memory by Coltheart, refers to the formal availability of information from the stimulus as measured in Sperling's partial-report technique. The main support for Coltheart's distinction between visible persistence and iconic memory is that the two obey different empirical laws. Experiments on iconic memory (for example, the study by Sperling) show essentially no effect of initial stimulus duration within a reasonable range during the first few hundred milliseconds. Likewise, in iconic memory experiments, the effect of stimulus luminance on performance is either positive or negligible. When techniques measuring visible persistence—subjective duration—are used, however, both display duration and luminance show an inverse effect on the length of persistence. That is, brighter and briefer displays seem to last longer than dimmer and longer ones.

### Auditory Sensory Memory

Different aspects of auditory sensory memory have been clarified through work on precategorical acoustic storage and on recognition masking, discussed below in turn.

#### *Precategorical Acoustic Storage*

Robert G. Crowder and John Morton proposed in 1969 that auditory sensory (that is, precategorical) memory lies behind the consistent advantage of auditory over visual presentation in serial, immediate recall situations. They suggested that following a spoken stream of characters or words, people have access not only to the interpretations they have made of these items (categorical memory) but also to the actual sounds of the most recent item or items. This is why

in modality comparisons the auditory presentation resulted in superior performance, but only for the last few positions in the list. Presentation of an extra item called a stimulus suffix, posing no additional load on memory, erased most or all of this auditory advantage. Subsequent experiments showed that the meaning of this suffix item had no effect on its tendency to reduce performance on the recency portion of an auditory list. However, differences between the list to be remembered and the redundant suffix had a large effect if they were changes in physical properties, such as spatial location or voice quality (male versus female). This sensitivity to physical attributes, along with the insensitivity to conceptual attributes, would be expected of a precategorical memory store.

The modality-suffix findings on immediate memory were confidently attributed to precategorical acoustic storage until experiments by Kathryn T. Spoehr and William J. Corin (1978) and by Ruth Campbell and Barbara Dodd (1980) showed that the original hypothesis had been too simple. These authors demonstrated that silent lipreading and related procedures produced results in immediate memory that were almost indistinguishable from auditory presentation and were readily distinguishable from visual presentation.

### *Recognition Masking*

In 1972 Dominic W. Massaro delivered to subjects one of two possible pure tones, twenty milliseconds long and pitched at either 770 or 870 Hz. The main task was to identify which of the two tones had been presented. After this target, and at delays of from 0 to 500 milliseconds, a masking tone (820 Hz) was presented. In general, presentation of the masking tone reduced subjects' abilities to identify correctly or to recognize which of the two tones had come before, especially if the mask came within about 250 milliseconds of the target. The logic of this experiment is that if the original target tone had been fully processed before the mask arrived, there would have been no decrement in its identification. But if the target was still being processed when the mask arrived, there must have been a sensory trace of it still available somewhere in the auditory system. Comparable experiments with speech have given much the same result.

From a detailed review of results and models of auditory integration and auditory persistence, Nelson Cowan (1984) distinguished two types of auditory sensory memory: short and long. The short auditory store is believed to have a useful life of about 250 milliseconds and is represented in the experiments on recognition masking and related techniques. The long auditory store may last as long as two to ten seconds, roughly a logarithmic step longer, and underlies the suffix and modality comparisons.

## Developments since 1990

Research since 1990 has addressed the mechanisms of sensory memory. In the previous edition of this volume, storage and proceduralist views of sensory memory were compared. The storage view suggests that there are dedicated storage repositories in the brain for sensory information, whereas the proceduralist view states instead that retention is a natural consequence of the information processing that was originally aroused by the experience in question. There are still puzzles that remain to be sorted out for each view. If there are dedicated storage repositories, they must be complex enough to explain why sensory memory of a stimulus seems to be influenced by the context of preceding stimuli in that modality. If retention is a consequence of processing, though, it must be complex enough to explain why there can be brain damage that interferes with the memory for short lists of spoken words while leaving the ability to perceive spoken words intact (as discussed, for example, by Alan D. Baddeley and Robert H. Logie).

The truth may lie in between these views. In a 1995 book, *Attention and Memory: An Integrated Framework*, Nelson Cowan argued that there actually are short and long sensory stores in all modalities, not just the auditory modality. If so, it may be that a proceduralist view is more suitable for the short store, which is intricately tied to perception and is experienced as continuing sensation, than for the long store, which is experienced as memory.

The contradiction between visual information persistence and subjective persistence has been addressed, for example by Dominic W. Massaro and Geoffrey R. Loftus (1996), with the idea that both could result from a single underlying process, with properties that seem to match Cowan's (1995) short store. The change in the intensity of the process over time would determine the subjective experience of the iconic image, whereas the accumulation or integration of this process over time would determine the available information about the visual stimulus. In 1987, Cowan proposed something similar for sounds.

Sensory memory is interesting as a bridge between what we experience and what we remember. A simple view in which sensory memory fades inevitably in a few seconds, like a fizzling sparkler, has proved to be too simplistic. Sensory memory rides upon perceptual processing but then seems to outlast it in a weakened form. Some residue even seems permanent, as in the memory that allows recognition of the voices of one's close friends.

*See also:* MODALITY EFFECTS

## Bibliography


Baddeley, A. D., and Logie, R. H. (1999). Working memory: The multiple-component model. In A. Miyake and P. Shah, eds., *Models of working memory: Mechanisms of active maintenance and executive control.* Cambridge, UK: Cambridge University Press.

Campbell, R., and Dodd, B. (1980). Hearing by eye. *Quarterly Journal of Experimental Psychology 32,* 85–99.

Coltheart, M. (1980). Iconic memory and visible persistence. *Perception and Psychophysics 27,* 183–228.

Cowan, N. (1984). On short and long auditory stores. *Psychological Bulletin 96,* 341–370.

——— (1987). Auditory sensory storage in relation to the growth of sensation and acoustic information extraction. *Journal of Experimental Psychology: Human Perception and Performance 13,* 204–215.

——— (1995). *Attention and memory: An integrated framework.* Oxford Psychology Series, No. 26. New York: Oxford University Press.

Cowan, N., Saults, S., and Nugent, L. (2001). The ravages of absolute and relative amounts of time on memory. In H. L. Roediger III, J. S. Nairne, I. Neath, and A. Surprenant, eds., *The nature of remembering: Essays in honor of Robert G. Crowder.* Washington, DC: American Psychological Association.

Crowder, R. G. (1976). *Principles of learning and memory.* Hillsdale, NJ : Erlbaum.

——— (1978). Sensory memory systems. In E. C. Carterette and M. P. Friedman, eds., *Handbook of perception,* Vol. 9. New York: Academic Press.

——— (1983). Iconic memory. *Philosophical Transactions of the Royal Society of London B302,* 283–294.

——— (1989). Modularity and dissociations of memory systems. In H. L. Roediger III and F. I. M. Craik, eds., *Varieties of memory and consciousness: Essays in honor of Endel Tulving,* pp. 271–294. Hillsdale, NJ: Erlbaum.

Crowder, R, G., and Morton, J. (1969). Precategorical acoustic storage (PAS). *Perception and Psychophysics 5,* 365–373.

Dixon, P., and Di Lollo, V. (1994). Beyond visible persistence: An alternative account of temporal integration and segregation in visual processing. *Cognitive Psychology 26,* 33–63.

Efron, R. (1970). The minimum duration of a perception. *Neuropsychologia 8,* 57–63.

Haber, R. N., and Standing, L. (1970). Direct estimates of the apparent duration of a flash. *Canadian Journal of Psychology 24,* 216–229.

Kolers, P. A., and Roediger, H. L. III (1984). Procedures of mind. *Journal of Verbal Learning and Verbal Behavior 23,* 425–449.

Massaro, D. W. (1972). Preperceptual images, processing time, and perceptual units in auditory perception. *Psychological Review 79,* 124–145.

Massaro, D. W., and Loftus, G. R. (1996). Sensory and perceptual storage: Data and theory. In E. L. Bjork and R. A. Bjork, eds., *Memory.* San Diego: Academic Press.

Sakitt, B. (1976). Iconic memory. *Psychological Review 83,* 257–276.

Sperling, G. (1960). The information available in brief visual presentations. *Psychological Monographs 74* (498).

Spoehr, K. T., and Corin, W. J. (1978). The stimulus suffix effect as a memory coding phenomenon. *Memory & Cognition 6,* 583–589.


*Robert G. Crowder*
*Revised by Nelson Cowan*

# SERIAL ORGANIZATION

A critical form of memory organization, and one people frequently use, is retention of events in the temporal order in which they occurred. Consider, for example, your memory for the events that occurred last summer. If someone asked you what you did during your summer vacation, most likely you would discuss the events in the sequence in which they occurred, beginning with those that occurred at the start of the summer and concluding with those that occurred at the summer's end. Alternatively, you could report together all the parties you attended and report as another group all the times you went hiking or swimming. However, retention in terms of temporal sequence, or serial order, is most common.

## Definitions and Distinctions

To study the retention of serial order in the laboratory, the information pertaining to temporal sequence must be distinguished and isolated from other types of related information. The relevant distinctions can be made clear by considering the following hypothetical situation: Imagine a waiter in a restaurant who is taking dinner orders from the people sitting around a table. Usually in such a situation the individuals make their requests in a temporal sequence that follows the spatial arrangement of the seats around the table. However, in the present situation this ordinary practice is not observed. Instead, the waiter takes the requests in an order determined by the individuals' ages and genders, starting with the oldest woman and ending with the youngest man. This situation is illustrated in Figure 1. The first order is for ham, the second for liver, the third for steak, and the fourth for chicken. The temporal sequence of the requests is thus ham, liver, steak, and chicken, a sequence that does not correspond to the spatial arrangement around the table. Hence, the temporal and spatial orders are not the same. When the waiter returns to deliver the dinners, he serves the first person liver, the second turkey, the third steak, and the last chicken. The waiter thus makes two mistakes. In the case of the turkey, he brings a dinner requested by nobody, and in the case of the liver, he gives a dinner ordered by one person to another. The first type of mistake is an item error because the identity of the dinner item is incorrect. The second type is an order error because a correct item is brought but is placed in the wrong position in the temporal sequence. For a discussion of laboratory methods used to distinguish between the retention of item, temporal order, and spatial order information, see Alice F. Healy et al. (1991).