c-*src*, v-*yes*, and v-*abl* were synthesized by the phosphotriester method on an automated synthesizer (Applied Biosystems 380B). The sequences of the oligonucleotides were: 5'GG (T/G)GC (T/G/A/C)GT CCA (C/T)TT (A/G)AT (G/C)GG3' (SD11); 5'GT CCA (C/T)TT (A/G)AT GGG (A/G)AA (T/C)TT (G/A)GC3' (SD12); and 5'CCA (C/G)AC (G/A)TC (T/C)GA CTT GAT (G/T)G3' (SD13). For screening of the cDNA library, oligonucleotides were labeled with [γ-^{32}P]adenosine triphosphate by T4 polynucleotide kinase to specific activities of 1×10^9 to 2×10^9 cpm/μg.
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Auditory Association Cortex Lesions Impair Auditory Short-Term Memory in Monkeys

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Monkeys that were trained to perform auditory and visual short-term memory tasks (delayed matching-to-sample) received lesions of the auditory association cortex in the superior temporal gyrus. Although visual memory was completely unaffected by the lesions, auditory memory was severely impaired. Despite this impairment, all monkeys could discriminate sounds closer in frequency than those used in the auditory memory task. This result suggests that the superior temporal cortex plays a role in auditory processing and retention similar to the role the inferior temporal cortex plays in visual processing and retention.

DAMAGE TO THE INFERIOR TEMPORAL cortex, the highest order visual cortex, impairs performance on both visual discrimination and visual short-term memory tasks (*1*), indicating that this region is important for both the perception and memory of visual information. Although there is some evidence that damage to the superior temporal cortex, the highest order cortex of the auditory system, impairs auditory discriminative functions (*2*), there has been no convincing evidence that such lesions cause deficits in auditory short-term memory (*3*).

In the few studies that have addressed this issue, monkeys were trained on tasks in which the sample stimuli were acoustic and the comparison stimuli were either visual or spatial. The absence of any clear auditory memory impairments after lesions to the superior temporal cortex may have resulted because the monkeys coded and retained the appropriate comparison stimulus rather than the sample stimulus during the delay period, thereby solving the task by engaging visual or spatial, rather than auditory, memory processes (*4*). To ensure that auditory memory is being assessed, both the sample and comparison stimuli must be auditory. Although most attempts at training monkeys in this manner have met with failure (*5*), we succeeded by using monkeys that had extensive experience discriminating complex auditory stimuli (*6*). We report now that when monkeys are trained in such a task, lesions of the superior temporal cortex severely impair their auditory short-term memory, yet have no effect on their visual memory.

Three *Cebus apella* monkeys, ranging in age between 7 and 9 years, were trained on a successive auditory delayed matching-to-sample (DMS) task with a 3676-Hz high-frequency tone (HT) and a 243-Hz low-frequency tone (LT) as stimuli (*7*). At the end of a 20-s intertrial interval the sample

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stimulus (HT or LT) was presented by means of a speaker located on the right side of the front wall of the chamber. After a 2-s listening period, the first press to the lever located above the right speaker terminated the sample stimulus and initiated a delay interval. This was followed by presentation of the comparison stimulus from the speaker located on the left side of the front wall for a maximum period of 3 s (0.4-s listening period and a 2.6-s response window). A correct response on matching trials (HT-HT and LT-LT) consisted of pressing the lever above the left speaker during the response window, which resulted in delivery of a 190-mg banana pellet. Correct responses on nonmatching trials (HT-LT and LT-HT), which required withholding presses to the lever during the response window, were not rewarded. Pressing on nonmatching trials or withholding presses on matching trials, both defined as incorrect responses, were punished by extinguishing the lights within the chamber for 60 s.

The monkeys were also trained on a procedurally identical visual DMS task (*8*). All three monkeys were extensively overtrained on the auditory and visual tasks for 1 to 2 years before the start of this study, and all had considerably more experience with the auditory than the visual DMS task.

Preoperative retention gradients were obtained as follows. The monkeys were first required to satisfy a criterion of one session with 32 out of 36 correct responses on the baseline visual DMS task, in which the delay interval on all trials was set at 0.5 s. Retention gradients were then generated with delays of 0.5, 4, and 32 s intermixed within a session, and testing was continued in blocks of four sessions until stable gradients were obtained (*9*). The same procedure was then followed for the auditory DMS task. As a result of their extensive exposure to the visual and auditory DMS tasks, each subject required only two blocks (eight sessions) in each modality to obtain stable preoperative retention gradients.

On completion of preoperative testing all monkeys received lesions of the auditory association cortex in two stages, with testing after each unilateral operation (*10*). The lesions corresponded closely to cytoarchitectonic area TA of von Bonin and Bailey (*11*), sparing primary (area TC) and secondary (area TB) auditory cortex (Fig. 1). Retention gradients were generated after each operation by using the same procedures as followed for generating the preoperative gradients.

Visual DMS performance was completely unaffected by the auditory cortex lesions (Fig. 2, top). After each operation, the subjects satisfied the criterion of 32 out of 36 correct responses on the baseline visual DMS task in 1 to 2 sessions. They then required 4 to 16 sessions to regain preoperative retention levels, with performance in the final block of 4 sessions usually superior to preoperative levels (*12*).

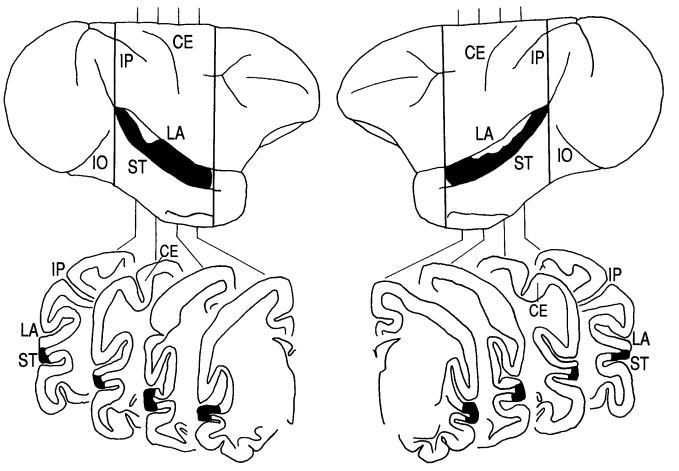

Fig. 1. Reconstruction of a lateral view of the brain of monkey T together with representative cross sections. The black areas represent the extent of the lesion. The region between the vertical solid lines indicates the area of reconstruction. Abbreviations: CE, central sulcus; IO, inferior occipital sulcus; IP, intraparietal sulcus; LA, lateral sulcus; and ST, superior temporal sulcus.

After the first operation, monkeys M, T, and B achieved the criterion on the baseline auditory DMS task in 1, 2, and 3 sessions, respectively (Fig. 2, bottom). Although tested over a 3-month period, monkey B was unable to recover retention to preoperative levels. Monkeys M and T, on the other hand, recovered preoperative retention levels in 20 to 24 sessions.

In contrast to the relatively mild deficits that followed the unilateral lesions, severe impairments in auditory short-term memory were observed after the second operation (Fig. 2, bottom). Monkey M was able to satisfy the criterion on the baseline auditory DMS task in 4 sessions, but nevertheless displayed a severe retention loss at all tested delays, with little evidence of recovery over a 4-month period. The auditory deficits were even more pronounced for monkeys T and B. Despite extensive retraining efforts distributed over a 4- to 5-month period, they were unable to satisfy the criterion on the baseline auditory DMS task.

The intactness of visual DMS performance rules out any motivational impairment as the basis for the auditory DMS deficits. It is also difficult to account for the auditory memory deficits on the basis of impairments in auditory sensory abilities. Although some discriminative loss was apparent after the second operation (*13*), all three animals were able to discriminate between sounds separated by one octave in the LT frequency range

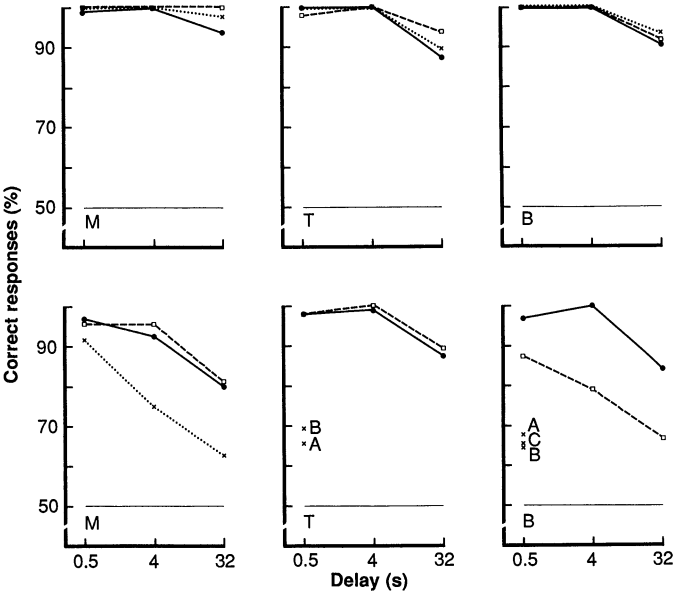

Fig. 2. Performance on the visual DMS (top) and auditory DMS (bottom) tasks preoperatively (●) and after the first (unilateral, □) and second (bilateral, x) lesions of the auditory association cortex. The thin solid line represents chance performance. The auditory gradient for monkey M obtained after the second operation was generated 121 to 124 days after surgery. For monkey T, points A and B represent the means of ten sessions on the baseline auditory DMS task obtained 33 to 43 and 167 to 176 days, respectively, after the second operation. The gradient shown for monkey B after the first operation was generated 117 to 120 days after surgery. Points A, B, and C for this animal represent the means of ten sessions on the baseline auditory DMS task obtained 24 to 33, 91 to 99, and 119 to 128 days, respectively, after the second operation.

(306 and 613 Hz) and sounds separated by even less than one octave in the HT frequency range (2688 and 4808 Hz) (*14*). The sounds used in the auditory DMS task (243 and 3676 Hz) were separated by almost four octaves.

The three monkeys exhibited differing degrees of impairment. Reconstruction of the lesions showed that although the amount of ablated cortex on the lateral surface of the superior temporal gyrus and the upper bank of the superior temporal sulcus was similar for all three animals, the amount of damage to the lower bank of the lateral fissure was correlated with the degree of auditory deficits. However, it was not clear whether lesion locus or lesion size was the relevant variable.

The results of this study show that when monkeys are trained on a task known to engage auditory processing and retention mechanisms, lesions of the auditory association cortex have dramatic effects on auditory short-term memory. To what extent the deficits reflect impairments in the processing or the storage of auditory information, however, remains to be determined.

The finding of auditory memory impairments that are difficult to explain on the basis of impairments in basic auditory sensory abilities parallels in many ways the visual recognition memory deficits that occur after lesions of the inferior temporal cortex. This result, plus the fact that the two modalities share similar patterns of cortical and subcortical connections (*15*), supports the idea that the mechanisms underlying short-term memory in the two systems are similar. Together with the findings of Heffner and Heffner (*16*) that monkeys may possess a precursor to Wernicke's area located in the superior temporal gyrus, these results may prove relevant to the understanding of the neurological mechanisms underlying auditory memory and language processing in humans.

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9. All sessions consisted of 39 trials, the first 3 serving as warm-up trials and therefore not included in the data analysis. The remaining 36 trials were equally divided into matching and nonmatching trials. During retention gradient testing, the 36 usable trials were divided into 12 trials dedicated to each of the three delay intervals.
10. Monkeys B and T received lesions of the left auditory association cortex first and monkey M that of the right auditory association cortex first. Surgery was performed in an operating room with sterile procedures. During the operation the monkeys were immobilized with 0.02 mg kg^{-1} $hour^{-1}$ of pancuronium bromide, respirated with 68.5% nitrous oxide and 30% oxygen, and anesthetized with 1.5% halothane.
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Survival of Adult Basal Forebrain Cholinergic Neurons After Loss of Target Neurons

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Target cells are thought to regulate the survival of afferent neurons during development by supplying limiting amounts of neurotrophic factors, but the degree to which afferent neurons remain dependent on target-derived support in the adult is uncertain. In this study, uninjured basal forebrain cholinergic neurons did not die after excitotoxic ablation of their target neurons in young adult rats, indicating that they are either not dependent on neurotrophic factors for survival or can obtain trophic support from other sources after target neurons are lost. This finding suggests that cholinergic cell death in neurodegenerative conditions such as Alzheimer's disease is not due solely to a loss of target neurons or factors provided by them.

REGRESSIVE EVENTS DURING NEURAL morphogenesis in vertebrates, such as naturally occurring cell death and retraction of collaterals, are regulated by dynamic interactions between afferent neurons and their targets (*1*). Studies on the molecular nature of these interactions in peripheral neurons that innervate nonneuronal targets have demonstrated that a target-derived substance, nerve growth factor (NGF), is required to sustain sympathetic neurons and neural crest-derived sensory neurons (*2*). Evidence that NGF may be active in the central nervous system (CNS)

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