Notes and Comment

Short-term memory in pigeons: Modality-specific or code-specific effects?

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In the August 1984 issue of *Animal Learning & Behavior*, Kraemer and Roberts reported on a study of pigeon short-term memory (STM). A major goal "was to compare STM in pigeons for visual and auditory stimuli" (p. 282). Since this appears to be the first published report of the use of auditory samples in delayed matching-to-sample (DMTS) work with pigeons, its potential contribution to knowledge of modality-related characteristics of STM in animals is considerable. Assessment of these characteristics for diverse species is an issue of current concern (e.g., D'Amato & Salmon, 1984; Wallace, Steinert, Scobie, & Spear, 1980). Hence, it is worthwhile to clarify thinking about the distinction between the sensory modality through which to-be-remembered information arrives and the memory code laid down by this information, using Kraemer and Roberts's study as a focal point.

The pigeons in the Kraemer and Roberts's study were given symbolic DMTS tests in which the sample was either visual (red or green houselight) or auditory (3000-Hz or 300-Hz tone from an overhead speaker). In each case the samples were mapped onto the same two visual alternatives (blue and yellow response keys). Since the response alternatives were the same for the visual and auditory conditions, the authors reasoned that any differences in performance between the visual-visual (V-V) and the auditory-visual (A-V) groups would reveal the nature and extent of modality-specific limitations. According to the authors' conclusions, the results offered little support for qualitatively different memories for auditory and visual stimuli. However, this conclusion must be considered tentative, since it appears that both the V-V and A-V groups were remembering visual information; if this was the case, visual and auditory memory would not in fact be compared. The authors themselves suggest as much in their hypothesis that "visual and auditory stimuli are coded immediately into response instructions regarding the comparison stimuli [peck the blue light, or peck the yellow

light]" (p. 282). The common code thus formed contains information about the visual characteristics of the comparison stimuli.

Since the issue of interest is memory for auditory and visual materials, the proper contrast is between the codes that are formed and remembered for the different externally imposed sample stimuli, and not between the sample stimuli themselves. If the codes used by pigeons in the A-V and V-V groups were the same, performance would be expected to differ little qualitatively. Quantitative differences might be expected as a function of the relative difficulty of A-V coding as compared with V-V coding, and this seems to be what the authors mainly found: "that the auditory group generally showed lower accuracy than the visual group" (pp. 282-283). That the coding was more difficult for the A-V group is indicated by the marked differences in training effort: The A-V group required an average of over 2,000 trials to learn the symbolic relationship, compared with an average of 566 trials for the V-V group. Kraemer and Roberts's finding that interpolated light, but not interpolated noise, significantly lowered performance of both the V-V and A-V groups is consistent with a concept of coding interference—interference between two codes along the same physical continuum, one being the visual code for the visual or auditory extrinsic stimuli and the second the presumed visual code laid down by the interpolated light (as contrasted with the presumed auditory code laid down by the interpolated noise). Increasing the intensity of the noise had no effect, showing that code overlap may be more important than stimulus saliency.

The procedures of D'Amato and Salmon (1984) with 2 monkeys (*Cebus apella*) were very similar to those of Kraemer and Roberts in that A-V and V-V DMTS were compared, including effects of interpolated visual and auditory materials. In the A-V condition given the monkeys, the samples were either of two tunes ("charge" or "gliss") and the visual alternatives were a white dot and a plus. These same two alternatives were used in V-V matching, in which the samples were either a red disk or a triangle. A major difference, we believe, between the monkey and pigeon studies was that the same 2 monkeys were tested in both the A-V and V-V conditions, whereas different pigeons were assigned to each condition. The implication is that in the pigeon study, the possibilities for memory codes are straightforward: The code was some representation of either the sample or its corresponding alternative (including a response instruction to that alternative). In the monkey study, there is an additional possibility. Since A-V and V-V matching were intermixed (at least in training) and mapped onto the same two alternatives, sample-to-sample coding could have occurred, in addition to the codes described for the pigeons.

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That is, through the common associates, the charge tune might have been mapped onto the red disk and the gliss onto the triangle. Hence, specifying the memory code or codes actually used is problematic. That D'Amato and Salmon's results were equivocal (e.g., the retention gradients as a function of type of matching were not comparable across the 2 monkeys, nor were the effects of interpolated materials) may reflect the utilization of different codes across monkeys, or even some variation in the codes used within monkeys. It is simply too difficult to tell within the procedures described.

In sum, to assess auditory STM, it must be assured that an auditory code is present in memory. In DMTS studies, this can be achieved with most certainty through auditory-auditory (A-A) matching procedures. However, it remains to be shown whether pigeons can learn A-A (or even V-A) matching. Monkeys, highly proficient at visual matching, experience extreme difficulty with auditory matching; we might expect the same from pigeons, which, like monkeys, appear to be visually dominant animals. Worsham and D'Amato (1973) concluded in their study of delayed matching in capuchin monkeys:

The case for modality-specific interference would be much stronger if it could be shown that delay-interval illumination does not interfere with auditory delayed matching. . . . we were unable to get our animals to acquire reliably a discrimination based on tonal frequency differences. Judging from information received through informal channels, the problem, which still occupies us, is not an uncommon one with primates. (p. 104)

Colombo and D'Amato (1985) recently reported success in teaching capuchin monkeys A-A matching, using a go/no-go procedure in which the monkeys were required to respond to the locus of a single sound if it matched the previous sample sound, or to withhold response if it did not match. Only 4 of 8 monkeys tested were successful; these were all animals whose first training experience (prior to Colombo and D'Amato's study) was with auditory materials and who subsequently had moderate to extensive experience on visual tasks (D'Amato, personal communication, September 1985). The remaining 4 had extensive initial experience in visual tasks before exposure to auditory tasks. One wonders whether the latter 4 attempted to form visual codes in response to the auditory stimuli, or context-related components of those stimuli; such visual codes would be ineffective for solving the task. Colombo and D'Amato concluded that there was little doubt, in spite of the success of 4 monkeys, that primates generally fared better with visual than with auditory tasks. Possibly, this simply means that monkeys are more efficient at forming visual than auditory codes.

A fundamental question in animal cognition, then, is the presence of coding limitations in memory and the implications for the structure, function, and flexibility of animal memory. It is important to determine what types of codes may be formed and their level of abstraction.

Dolphins, highly proficient at A-A matching, have difficulty with V-V matching, although with training in the use of an intermediate auditory code, V-V matching has been obtained (reviewed in Herman, 1980). Recently, however, we have completed a study showing that a language-trained dolphin can perform generalized V-V matching directly and efficiently (Hovancik, Herman, Forestell, Gory, & Bradshaw, 1985). We do not yet know, however, how the visual materials are represented by this dolphin, which was trained in an auditory-based language (Herman, Richards, & Wolz, 1984).

Rats have been reported to be capable of both V-V and A-A matching, but to be better at the latter (Cohen, Escott, & Ricciardi, 1984; Wallace et al., 1980). However, the Konorski paradigm used did not test memory for *specific* auditory or visual events, as has been the case with pigeons, dolphins, and monkeys. Instead, the rats were required only to match modalities. If they heard two successive sounds (A-A) or saw two successive lights (V-V), they were required to press a lever. But, if given a sound followed by a light (A-V) or a light followed by a sound (V-A), they were required to withhold response. There was no requirement to identify a particular sound or light and discriminate it from a different stimulus in the same modality, that is, to form unique visual or auditory codes. The first and second sounds were always the same, as were the first and second lights. Remembering where one has been stimulated must involve a relatively simple sensory code, compared with remembering the nature of different stimuli. It remains to be shown whether or not rats are able to perform standard stimulus matching in either or both the V-V and A-A modes.

If pigeons cannot be taught A-A matching, or can be taught only with difficulty, we would conclude that there are marked constraints in the ability to generate the complex codes required for representing arbitrary auditory stimuli. This limitation, of course, would be important to know, of itself. If pigeons could be taught A-A matching, however difficult, then we would be in an enviable position to test for modality-specific effects by, for example, applying visual and auditory interference stimuli. Similar considerations would apply to testing for modality-related memory effects in other species, with proper attention given to code-specific effects.

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