

Short-term item memory in successive same–different discriminations

Robert G. Cook*, Aaron P. Blaisdell

Department of Psychology, Tufts University, United States

Abstract

Pigeons were tested in a successive same–different (S/D) discrimination procedure to examine the short-term memory for individual items in sequences of different or identical pictures. Item-by-item analyses of pecking behavior within single trials revealed this S/D discrimination emerged at the earliest possible point in the sequence — the presentation of the second item. Further, by comparing peck rates at points where different types of sequences diverged (e.g. ABA versus ABC), we determined that the pigeons remembered the first item for at least 4–8 s and across one to two intervening items. These results indicate that this S/D discrimination was controlled by relational comparisons of pictorial content across memories of specific items, rather than the detection of low-level perceptual “transients” between items. A second experiment supported this conclusion by showing increased discrimination with longer first item viewing times, consistent with encoding of details about individual pictures. These findings further support a qualitative similarity among birds and primates in possessing a general capacity to judge certain types of stimulus relations, such as stimulus identity and difference. Implications for the temporal continuity of experience in animals are also considered.

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1. Introduction

An air traffic controller is regularly faced with the complex problem of serial tracking a number of airplanes on a radar monitor. The memory demands of this task include encoding new planes as they appear on the screen, forgetting old ones as they move out of range, and updating moment-to-moment changes in the position of the current planes. We face similar, if not as demanding, situations almost continually in our ongoing daily experiences. The moment-to-moment continuity of experience requires the constant integration of current perception with memories of the recent past. The farther these memories extend back into time, the greater the complexity in the serial organization of behavior these memories can support. Although a long-standing problem (Lashley, 1951), how sequential events are integrated by animals is still not well understood. A number of intriguing and innovative empirical results (Barnet et al., 1997; Clayton and Dickinson, 1998; Terrace, 2001) and increasingly sophisticated theoretical tools (Killeen, 2001) are bringing such investigations to the forefront of animal cognition. The most

frequent approach to studying sequential representations has been to look backward from a terminal behavioral state to make inferences about a previous string of events (Alsop and Honig, 1991; Killeen, 2001; Machado and Cevik, 1997; Wright et al., 1985). In the current experiments we took a fresh approach by asking how pigeons temporally integrate previous experiences to guide behavior in an ongoing stream of stimulus-controlled pecking behavior in a successive same–different (S/D) task. This “on-line” approach has been quite useful in revealing the microstructure of behavior in this task (Cook et al., 2003).

In the S/D task, the subject has to respond “same” when all stimuli on a trial are identical and “different” if one or more of the stimuli are different from the others. Using this task, it has been found that pigeons, parrots, dolphins, rhesus monkeys, baboons, and chimpanzees are capable of learning and applying an S/D concept across a wide variety of simultaneously and successively presented visual elements (Bovet and Vauclair, 2000; Cook et al., 1997; Fagot et al., 2001; Mercado et al., 2000; Pepperberg, 1987; Thompson et al., 1997; Wright et al., 1984; Young and Wasserman, 2001).

The current experiments directly grew out of a set of recent successive S/D experiments (Cook et al., 2003). In their experiments, Cook et al. found that pigeons could learn to discriminate *Same* (AAAA... or BBBB...) from alternating *Different* (ABAB...) sequences of color or gray-scale pictures in a go/no-go task. Pecks to *Same* sequences (S+) were reinforced on a vari-

* Corresponding author. Department of Psychology, Tufts University, Medford, MA 02155, United States. Tel.: +1 617 627 2456; fax: +1 617 627 4132.

E-mail address: robert.cook@tufts.edu (R.G. Cook).

URL: www.pigeon.psy.tufts.edu.

able interval schedule, while pecks during *Different* sequences (S–) resulted in a brief time-out. During each 20-s trial, each picture was successively presented for 2 s separated by a brief inter-stimulus interval (ISI). Using this procedure, they showed for the first time that pigeons could perform and transfer such a relational S/D judgment based on differences between only two stimuli (see also Blaisdell and Cook, 2005). The latter was clearly demonstrated by tracking pecking behavior across the successive items in each sequence. They found significant differences in peck rate by the second, and disambiguating, item in the sequence; with peck rates to this item increasing if it were a repetition of the previous item (S+) and decreasing if the second item were different (S–). Further presentations of each item enhanced this difference. It is this capacity to examine the ongoing item-by-item microstructure of when and how such S/D sequences were discriminated by the pigeons that is exploited in the current experiments to reveal further how pigeons temporally integrate S/D information.

Cook et al. (2003) argued that their results were most consistent with the proposition that pigeons have the capacity to form generalized S/D concepts across successive and simultaneous temporal arrangements (Cook et al., 1997; Wasserman et al., 1997). Of course, such important species claims need to be carefully examined and alternative accounts considered to be sure that no simpler account might be responsible for the observed discrimination and transfer (Mackintosh, 2000). One possible alternative account of Cook et al.'s (2003) results is that the pigeons simply detected the presence or absence of low-level visual transients at the change between temporally adjacent pictures. A number of simple and strong visual changes (color, overall brightness, etc.) occur on *different* trials that are not present on *same* trials. Thus, it was possible that the pigeons might have only attended to this coarse perceptual quality of the sequences rather than making true S/D comparisons across time among specific pictures and their details. Arguing against such a simple perceptual transient hypothesis, Cook et al. (2003) found that the pigeons could tolerate ISI separations of over 2 s between the items, consistent with a more complete encoding of a sequence's pictorial content rather than its "flickering" properties. Nevertheless, we wanted to further test this idea by directly examining the specificity of the memories guiding this S/D performance. Any evidence for item memory would help rule out perceptual transients as the direct source in S/D behavior. Thus, the central question posed in the current experiments was whether specific memories for the individual items in the sequence were controlling S/D behavior. Further, if item-specific memories were involved, how were they combined and integrated with other stimuli and memories into the ongoing stream of behavior? The capacity to examine peck rates at different points in the sequence was critical to this determination.

Our approach examined the fate of the initial item in each *same* and *different* sequence. The initial item was selected because its fortunes were most unambiguous to determine early in the sequence. In the typical alternating *different* trial (e.g. ABAB...) used by Cook et al. (2003), each successive transition further decreased peck rate — as information that the trial would not be reinforced accumulated. It is important to note,

however, that this alternating ABAB... "different" sequence contains some inherent ambiguities (see Fig. 1). Specifically, consider the third item in the sequence when the A item is repeated for the first time. When compared back to the second B item, it contributes "different" information about the sequence and should thus decrease peck rate. If compared back in time to the first item, however, it would indicate that this is an S+ "same" sequence and should increase peck rate. The observed peck rate to the third item thus may be a combination of these two conflicting tendencies. This experiment attempted to isolate and reveal the presence of exactly this internal competition. This was done by adding a new type of *different* sequence consisting of a series of three different pictures — producing an ABC sequence. By comparing pecking behavior during and after the third item in these two types of sequences (ABA versus ABC), it is possible to assess the effects of repeating the initial item A at the third serial position. If peck rates to the repetition of A in the ABA sequence are higher than to a new third item C in the ABC sequence, it would indicate that a memory for the first presentation of A is still active and results in a partial "same-like" response. This difference would also indicate that the short-term memory for A is sufficiently detailed that it can be recognized upon its re-presentation after several seconds and intervening items. Moreover, the transition from the second B item to the third A item of ABA sequence involves the same degree of perceptual transient as the transition from the second B item to the third C item of the ABC sequence. Thus, any peck rate difference between these sequences to the third item would argue against any such perceptual transients account.

2. Experiment 1

Two different tests were conducted using this general approach in order to decompose the memories controlling the serial organization of the pigeons' S/D behavior. The first tested a number of *different* conditions in which the initial re-presentation of the first item was systematically positioned at progressively later serial positions in the sequence. Specifically, we looked for memories of the initial item during serial positions 3–6 of a sequence. In the second test, we varied the ISI between the items to examine the effects of temporal separation and delay on this item memory.

2.1. Method

2.1.1. Animals

Three male White Carneaux pigeons (*Columba livia*) were tested. They were maintained at 80–85% of their free-feeding weights in a colony room with a 12:12 light–dark cycle and had free access to water and grit in their home cages. Prior to this experiment, they had participated in Cook et al. (2003) and needed no training for the current tests.

2.1.2. Apparatus

Testing was done in a flat-black Plexiglass chamber (38 cm wide × 36 cm deep × 38 cm high). The stimuli were presented on a color computer monitor (NEC MultiSync C500;

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