Anim Cogn (2009) 12:405–407
DOI 10.1007/s10071-008-0206-8

SHORT COMMUNICATION

Memory for the order of briefly presented numerals in humans as a function of practice

Alan Silberberg · David Kearns

Received: 11 October 2008 / Revised: 29 October 2008 / Accepted: 14 December 2008 / Published online: 30 December 2008

Abstract Inoue and Matsuzawa (Curr Biol 17: R1004–R1005, 2007) showed that with an accuracy of approximately 79%, the juvenile chimpanzee, Ayumu, could recall the position and order of a random subset of five Arabic numerals between one and nine when those numerals were presented for only 210 ms on a computer touch screen before being masked with white squares. None of nine humans working on the same task approached this level of accuracy. Inoue and Matsuzawa (2007) claimed this performance difference was evidence of a memorial capacity in young chimpanzees that was superior to that seen in adult humans. While the between-species performance difference they report is apparent in their data, so too is a large difference in practice on their task: Ayumu had many sessions of practice on their task before terminal performances were measured; their human subjects had none. The present report shows that when two humans are given practice in the Inoue and Matsuzawa (2007) memory task, their accuracy levels match those of Ayumu.

Keywords Memory · Limited-hold test · Ape · Human

Introduction

Recently, Inoue and Matsuzawa (2007) presented data comparing accuracy in human and chimpanzee recall of Arabic numerals presented in two memory tests, one called "masking" and the other "limited-hold". In the masking test, six of the nine numerals from one to nine were presented without replication on a computer touch screen. The numerals presented and their positions on the screen varied randomly from trial to trial. For example, the numbers presented might be 1, 4, 5, 6, 8, 9, and their positions could vary among 40 different locations on the screen. Once a numeral was touched, all remaining numerals were masked by white squares. The sequence of responses that resulted in reward (food for the ape and a chime for the human), was to touch squares in ascending order of the numerals that they masked. When errors occurred, the trial was terminated with the sounding of a buzzer. Although there was wide variation among the 12 humans who performed on this task, the majority did better than did any ape (see Figure S1 in their report).

Such an outcome is consistent with the commonly held view that, excluding specialized sensory and behavioral capabilities seen in some nonhuman species, general cognitive function, including memory, should be superior in humans than in nonhumans (Zentall 2000). For this reason, the present report focuses on the results of their second test, the so-called limited-hold task, where they claim superiority in recall in the juvenile ape, Ayumu. This task was identical to the masking test except that: (a) touching a white circle led to the presentation of the numerals followed, after a delay, by their masking with white squares; (b) the duration of this fixed delay was under experimenter control, not subject control; and (c) five numerals were presented instead of six. Inoue and Matsuzawa (2007) found that when the duration of this delay was 650 ms, the accuracy of their nine human subjects was similar to that of the best-performing ape, Ayumu—in both cases, approximately 79% correct. However, when the latency to masking was reduced to 210 ms, Ayumu's performance was largely unchanged, while that of humans dropped to a mean of about 38% (see Figure 2 from their report).

A. Silberberg (✉) · D. Kearns
Department of Psychology,
American University, Washington,
DC 20016-8062, USA
e-mail: asilber@american.edu

Based largely on Ayumu's performance, Inoue and Matsuzawa (2007) advanced the idea that "young chimpanzees have an extraordinary working memory capability for numerical recollection—better even than that of human adults tested in the same apparatus following the same procedure (R1005)." While this claim may seem consistent with their findings, we note an important methodological difference between their comparison groups that belies this quoted text: the young chimpanzees, such as Ayumu, had many sessions of experience on this task, while their human subjects had none. The goal of the present report is to determine whether practice on the limited-hold task elevates human performances to the levels seen in Ayumu.

Methods

Subjects

The subjects were the authors of this report: Alan Silberberg, a 63-year-old male and David Kearns, a 33-year-old male. Both are employed as university faculty.

Experimental setup

Each subject sat at a personal computer, responding with mouse clicks to images presented on an LCD monitor. Alan's sessions were conducted only at his home, while David's were in both his home and his laboratory.

Procedure

Except as noted below, our procedure was duplicative of Inoue and Matsuzawa's (2007) limited-hold test. The two exceptions to direct replication were that: (a) responding was in the form of a mouse click rather than a screen contact; and (b) the subjects responded for many 50-trial sessions at different masking latencies, not one session at a masking latency as was the case for humans in Inoue and Matsuzawa (2007). The font size (3 cm) and font style (Gothic typeface) of the numerals were the same as in Inoue and Matsuzawa (2007); so too were the number of positions on the screen where numerals could be projected (40 different positions in an 8-by-5 array). As was the case in Inoue and Matsuzawa (2007), a random five numerals were presented without replication from the numeral range one through nine, and all trials in a given session used a single masking latency. Sessions were conducted throughout the day at times that were convenient for the subjects. Although the number of 50-trial sessions conducted was variable for both subjects, Alan tended to complete only three to six sessions per day while David sometimes completed as many as ten.

Results

Although session durations were not timed, both subjects reported completing a typical session in less than 10 min.

The top row of panels in Fig. 1 shows the performances of Alan at masking latencies of 250 ms (A1), 210 ms (A2), 100 ms (A3), and finally at 210 ms (A4) again. He started at 250 ms after testing his accuracy level briefly at a couple of different masking latencies. The value of 250 ms was selected based on his guess that he would get approximately 50% of the masking sequences correct at that value. David's data are presented in the bottom row of panels. Unlike Alan, David began recording data at 210 ms, the shortest masking latency in the Inoue and Matsuzawa (2007) report. His rationale for not testing his performances at longer latencies was based on experience. He noted that in his many debugging tests of the program he had written, his accuracy levels were improving with practice. Indeed,

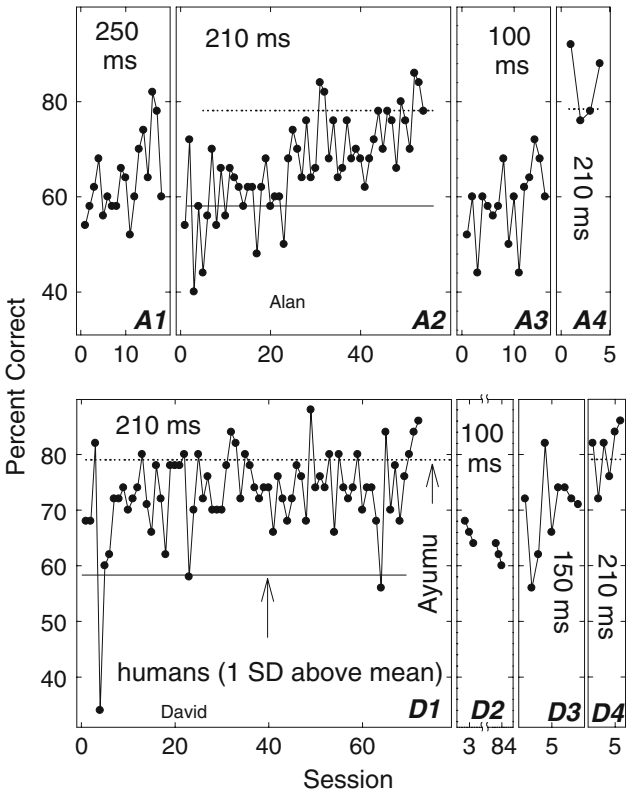

Fig. 1 Results of the limited-hold memory task for two subjects. The *top* and *bottom row of panels* present, respectively, the accuracy levels in percent of Alan and David during each 50-trial session. Inside each panel is the delay in ms between the presentation of five numerals on the computer screen and their masking by *white squares*. The *dotted* and *solid horizontal lines* seen in *panels A2, A4, D1* and *D4*, respectively signify the estimated accuracy level of Ayumu and that of human subjects from Inoue and Matsuzawa (2007) whose accuracy was 1 SD above the mean. In *panel D2*, note that the *x*-axis is broken. David completed 84 sessions, but only sessions 1, 2, and 3, and sessions 82, 83, and 84 are presented to reduce the size of the figure

by the time he considered the program to be valid, he had already seen that his accuracy levels had improved from approximately 30% levels to where he was of superior accuracy to those seen in humans in the Inoue and Matsuzawa (2007) report. For that reason, he thought that even at 210 ms, his accuracy levels might already rival those of the most capable ape, Ayumu. As can be seen in panel D1, his judgment proved correct: in his second session, he matched Ayumu's terminal accuracy level.

In terms of terminal performances at 210 ms (last 3 sessions in panels A2, A4, and D1, D4), both subjects were able to match the accuracy levels of Ayumu. The data from Alan, who began recording data while largely unpracticed in the task, are particularly instructive, for they show a clear across-session practice effect that raised his accuracy levels from those seen in Inoue and Matsuzawa's (2007) human population to those of the highly practiced Ayumu. However, it took him approximately 2,500 trials to match Ayumu's accuracy rate.

Panels A3 and D2 present accuracy levels at 100 ms, a masking latency briefer than any in Inoue and Matsuzawa (2007). Alan showed a small improvement across sessions, while David did not. However, in both cases their terminal performances were more than one standard deviation above the mean accuracy levels of humans at 210 ms in Inoue and Matsuzawa (2007). Alan's last panel (A4) presents performances from a redetermination of the limited-hold test at 210 ms. Once again, his accuracy levels approximated those of Ayumu. David followed his 84 sessions of exposure to the 100 ms condition with 9 sessions at 150 ms (panel D3). As might be expected, his accuracy level fell between that seen at 100 ms (panel D2) and 210 ms (panels D1 and D4), but it was still superior to any human performances in Inoue and Matsuzawa (2007). In his redetermination of the 210 ms condition (panel D4), he once again generated accuracy data comparable to Ayumu's in the Inoue and Matsuzawa (2007) report.

Discussion

The results of Alan and David differed in that only Alan showed a clear improvement over sessions. David's failure to reveal a practice effect likely reflects the fact that in programing the experiment, he had already completed many sessions on the limited-hold task before recording his data in the debugged version of the task. As noted earlier, he reports that when he first began testing the program, his accuracy level at 210 ms was approximately 30%, a level representative of human performances in the Inoue and Matsuzawa (2007) report, and a level that would have created a discernible practice effect function when drawn in the co-ordinates of Fig. 1.

The results of the present report show that, contrary to the claims of Inoue and Matsuzawa (2007), the performance of Ayumu on the limited-hold task with a masking latency of 210 ms does not differ from that seen in humans when those humans, like Ayumu, have practiced on this task. Indeed, the results suggest equivalence of function and capacity between apes and humans on this sensory-memory task. One other conclusion that Inoue and Matsuzawa (2007) advance—that task accuracy is inversely related to a subject's age—is also called into question. Given the ages of the subjects of this report, it is clear that youth is not a prerequisite for success in this task. What is is practice.

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