



Comparison of delayed matching-to-sample performance in monkeys and children



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ABSTRACT

Although research has consistently demonstrated that accuracy on a variety of memory tasks decreases as delay increases, relatively little research has been conducted to quantify this relationship across development in humans or directly compare rates of forgetting between humans and monkeys. This study utilized a delayed matching-to-sample (DMTS) task to compare the relative contributions of proactive interference and attention on the rate of forgetting in monkeys and children. The performance of 1125 children from four to fourteen years of age and 10 adult rhesus monkeys was compared. For this DMTS task, a shape was displayed on the center one of three press-plates. After a delay, the subjects were required to match the original shape with one of three choice shapes to receive a banana-flavored food pellet for monkeys, or a nickel for children. A modified power function provided an excellent fit for the data for monkeys and children. The forgetting rates in children decreased with age, and the forgetting rates for monkeys were most comparable to those of younger children. The data also suggest that proactive interference did not significantly contribute to the forgetting rates for monkeys or younger children. Further, the monkeys appeared to attend to the task at a level similar to that of younger children as evidenced by the similarities in response latencies. The results from this study indicate that the rate of forgetting in monkeys, as well as the mechanisms underlying this rate, appears to share more similarities with that of younger children than of older children.

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Regardless of the procedure, on virtually any memory task, a subject will remember less of what was previously learned as more time passes (see for example, Chelonis et al., 2000; Ebbinghaus, 1885; Overman, 1990; Wixted, 1989; Wixted and Ebbesen, 1991). This forgetting process is often highlighted by a rapid initial decline in the amount of material remembered followed by a more gradual decline thereafter (Kassin et al., 1989). In humans the forgetting process can be influenced by a variety of factors. For example, the presence of a variety of psychological disorders such as Alzheimer's Disease (Money et al., 1992; Sahgal et al., 1992), attention deficit hyperactivity disorder (Kempton et al., 1999; Rhodes et al., 2004), and depression (Elliott et al., 1996; Sweeney et al., 2000) has been

shown to augment the overall rate of decline in recall. Further, recall across delays is sensitive to IQ and also improves with age in typically developing children (Chelonis et al., 2000; Paule et al., 1999). This forgetting process is also not unique to humans, having been observed in a variety of other species as well (Spinelli et al., 2004; Goto and Watanabe, 2009; Wixted and Ebbesen, 1991; Wixted, 1989) and is also sensitive to a variety of procedural (see for example, White, 1985) and physiological (Buccafusco et al., 2009; Paule, 1990; Paule et al., 1998; Prendergast et al., 1998) manipulations. Given that this phenomenon occurs similarly across a variety of species, it is likely that similar mechanisms determine the relationship between recall and delay. Examination of this metric of cognitive function in nonhuman primates and humans may be especially useful because these two species seemingly share many cognitive similarities (Elmore et al., 2011; Roberts, 1996, 2010; Wright and Roberts, 1996; Wright et al., 1985). Therefore, research that explores factors that affect forgetting may lend itself to uncovering similarities between nonhuman primates and humans and,

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thus, may be instrumental in developing more valid nonhuman primate models for specific human psychological disorders that impact forgetting. Having such animal models that lend themselves more readily to rigorous experimentation would allow for a more thorough exploration of the potential psychological mechanisms that affect forgetting.

Although it has been repeatedly demonstrated that forgetting increases as delay increases, there has been relatively little work that has attempted to quantify the rate of forgetting in human subjects, much less to compare rates of forgetting in humans to other species, let alone nonhuman primates. In a series of experiments that used different procedures to assess memory, [Wixted and Ebbesen \(1991\)](#) compared the applicability of a variety of mathematical functions to quantify forgetting rates in humans and pigeons. Of the six functions that were compared, a power function provided the best fit across the different procedures and species. Based on the fit of this power function, pigeons had a significantly steeper rate of forgetting on a delayed matching-to-sample (DMTS) task than did the human subjects who performed two other types of memory tasks. It is unclear whether the initial accuracy (i.e., the y -intercept for the function) was different across species because for one of the human studies the y -intercept was much lower than in the pigeon study, whereas in the other human study, the y -intercepts were approximately equivalent. Further, the use of different procedures in this research to assess forgetting makes comparison across species difficult. Unfortunately, to our knowledge, there has yet been no attempt to similarly quantify the rate of forgetting in nonhuman primates, let alone determine if the values for the parameters generated by these functions, as well as the functions themselves, are comparable to those of humans using similar procedures.

In order to facilitate comparisons of forgetting rates across species, it is essential to utilize a behavioral procedure that can be administered to a variety of species with little or no modification. One task that has often been used to assess the effects of delay on forgetting across species is the delayed matching-to-sample task. Variations of DMTS tasks have been used extensively to assess the effects of delay on forgetting in humans (see for example, [Chelonis et al., 2000](#); [Elfering and Sarris, 2006](#); [Hartman et al., 2001](#); [Picchioni et al., 2007](#)), monkeys ([Buccafusco, 2008](#); [Nemanic et al., 2004](#); [Rodriguez et al., 2010](#)), rats ([Bushnell, 1990](#); [Harper et al., 2005](#); [Panlilio et al., 2011](#); [Sloan et al., 2006](#)), pigeons ([Kangas et al., 2010](#); [Nevin et al., 2008](#); [Wixted, 1989](#)), as well as other species ([Goto and Watanabe, 2009](#); [Kusmieriek and Kowalska, 1998](#); [Roitblat et al., 1990](#); [Zhang et al., 2005](#)). Although there are a wide variety of DMTS tasks, the procedures for each share many similarities. DMTS tasks typically present one stimulus to an organism for a brief period of time. After the organism views the stimulus, it is removed and a delay period is initiated. Following the delay, two or more choice stimuli are presented, one of which matches the original sample stimulus. At this point, the organism must then match the original stimulus and often receives some type of reinforcer for a correct match. Following a response to the choice stimuli, another trial is initiated. A common variation of this procedure is known as the delayed non-matching-to-sample (DNMS) task that requires the organism to select an item that is different from the initial sample stimulus rather than one that matches it. Other than these differences, DMTS and DNMS procedures are typically very similar and all have been used to assess the effects of delay on forgetting ([Barnes et al., 2000](#); [Blanchet et al., 2000](#); [Chelonis et al., 2000](#); [Paule et al., 1998](#); [White, 1985](#); [Wixted and Ebbesen, 1991](#)).

DMTS tasks can be useful for examining forgetting, because they provide for the experimental manipulation of a variety of procedural parameters to explore the underlying psychological mechanisms of forgetting. One such psychological mechanism that can be readily explored with a DMTS procedure is proactive

interference. Proactive interference occurs when an organism has difficulty recalling current information due to interference from prior information. The DMTS task lends itself to studying this phenomenon because multiple trials can be used in which the correct response on one trial may actually be an incorrect response on the next trial. Research across species has demonstrated that in procedures that generate high levels of proactive interference, forgetting tends to be greater ([Grant, 1975](#); [Hogan et al., 1981](#)). This has also been specifically found in monkeys ([Bigelow and Poremba, 2013](#); [Reynolds and Medin, 1981](#)) as well as humans ([Hartman et al., 2001](#)). The research that examined proactive interference in nonhuman primates and humans typically employed two choice procedures that generate high levels of proactive interference. Although these procedures can generate high levels of proactive interference, they do not lend themselves to a determination of the specific contribution of proactive interference on performance. For two choice trials, there is only one incorrect alternative on each trial which does not allow for a more detailed examination of the potentially underlying causes for an incorrect response. In contrast, for a three choice DMTS task, a subject has the option of making an incorrect response to the stimulus that was previously correct or to a stimulus that was not presented on the previous trial. Hence, the proportion of errors made to the stimulus that was correct on the previous trial can be computed, and the specific contribution of proactive interference to forgetting can be ascertained.

Another factor that may affect the rate of forgetting is the ability to attend to the task.

Research has suggested that attention can affect recall, with decreased attention resulting in more difficulty with recall ([Elmore et al., 2011](#)), and presumably, a higher rate of forgetting. Attention to the task may be assessed by examining how long it takes an organism to make a response on the DMTS task. Research has demonstrated that even on a simple cued reaction time task, children who have longer reaction times engage in more off task behavior than children who have shorter reaction times ([Krupski and Boyle, 1978](#)). Here, reaction times also increased as the preparatory interval before the stimulus appeared increased, and this was accompanied by more off task behavior in children, regardless of their initial reaction time. Further, children with ADHD have been found to have longer reaction times than control children on simple reaction time tasks as well ([Mitchell et al., 1990](#)), presumably as a result of decreased attention to the task. The previous research indicating that choice response latency increases across delays while accuracy decreases across delays ([Chelonis et al., 2000](#); [Elliott et al., 1996](#)) is consistent with the theory that as attention to the task decreases so does accuracy. Also consistent with this theory is that children with ADHD exhibit impairments in accuracy across delays compared to control children, especially at longer delays ([Kempton et al., 1999](#); [Rhodes et al., 2004](#); [Shang and Gau, 2011](#)) and children with ADHD also exhibit longer overall choice response latencies than control children ([Shang and Gau, 2011](#)). Additionally, stimulant medication appears to attenuate the deficits in response latency as well as accuracy in children with ADHD ([Chelonis et al., 2002](#)). Therefore, an examination of response latencies on a DMTS task, as well as an examination of choice response latencies across delays should provide some insight regarding the contribution of attention to the rate of forgetting in nonhuman primates and humans.

The purpose of the present study was to compare the relative contributions of such psychological constructs as attention and proactive interference on the rate of forgetting in monkeys and human children. This study used human children rather than adults as a basis for comparison to the monkeys because the cognitive abilities of the human subjects were still developing, and therefore similarities and differences in the performance of children at various stages of development and the performance of adult monkeys

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