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Adaptive Memory: The Mnemonic Value of Animacy

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Abstract
Distinguishing between living (animate) and nonliving (inanimate) things is essential for survival and successful reproduction. Animacy is widely recognized as a foundational dimension, appearing early in development, but its role in remembering is currently unknown. We report two studies suggesting that animacy is a critical mnemonic dimension and is one of the most important item dimensions ultimately controlling retention. Both studies show that animate words are more likely to be recalled than inanimate words, even after the stimulus classes have been equated along other mnemonically relevant dimensions (e.g., imageability and meaningfulness). Mnemonic "tunings" for animacy are easily predicted a priori by a functional-evolutionary analysis.

Keywords
animacy, memory, evolution, evolutionary psychology

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Proponents of functional approaches to cognition assume that cognitive processes are "tuned" to solve adaptive problems, particularly ones relevant to ancestral selection pressures. Just as physical systems in the body are uniquely designed to pump blood, extract oxygen, or filter impurities, the processes of perception, reasoning, and memory likely show similar specificity (Tooby & Cosmides, 1992). In the case of memory, which evolved subject to nature's criterion (the enhancement of reproductive fitness), our laboratory has proposed that preferences are given to the processing and retention of fitness-relevant events (e.g., Nairne, Thompson, & Pandeirada, 2007). More generally, the efficiency of cognitive processing is claimed to depend on information content, particularly content that is relevant to enhancing inclusive fitness (see also Sherry & Schacter, 1987).

The focus of the present article is on the mnemonic value of animacy. The animate-inanimate distinction is foundational, appearing very early in infancy (see Opfer & Gelman, 2011), and has been associated with distinct neurophysiological correlates (Caramazza & Shelton, 1998; Gobbini et al., 2011). Animate objects receive priority in visual processing (New, Cosmides, & Tooby, 2007), and the perception of animacy and agency can be induced in simple geometric shapes if the proper movements are generated (Michotte, 1963; Scholl & Tremoulet, 2000). It has been suggested that humans evolved hyperactive animacy-detection systems to maximize the chances of detecting potential predators in their midst (H. C. Barrett, 2005; J. L. Barrett, 2004).

From an evolutionary perspective, it is sensible to propose that memory systems are selectively tuned to process and remember animate things. Predators are animate beings, as are potential mating partners. Surprisingly, though, animacy has yet to be explored as a mnemonic dimension. Word dimensions such as frequency of use, imageability, and meaningfulness have been frequently studied, but little or no data exist on the mnemonic value of animacy. Part of the problem may be inherently methodological—animate and inanimate words differ on a host of dimensions. For instance, animate words, in

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contrast to inanimate words, will tend to be higher in imageability and meaningfulness. One can attempt to control or equate for these dimensions—that was the primary goal of the current research.

Study 1: Regression and Relative-Weight Analysis

Multiple regression is a commonly used statistical tool for identifying variables that contribute to some criterion. Rubin and Friendly (1986) investigated predictor variables for the recall of 925 nouns. Using normative data for a variety of word properties, such as concreteness, frequency, and meaningfulness, Rubin and Friendly explored the various item factors that contribute significantly to recall. Animacy was not a factor considered in that analysis, so we reanalyzed the Rubin and Friendly (1986) data, including animacy as a predictor variable.

Method

We asked three independent raters to code the words provided in Rubin and Friendly (1986) for their animacy status. The raters used a 5-point scale with words clearly representing a nonliving thing coded 1, words clearly representing a living thing coded 5, and ambiguous words coded 3. Words receiving a rating of 4 or 5 by all three raters were classified as animate, words receiving a 1 or 2 were classified as inanimate, and words receiving a 3 were designated as ambiguous. Raters were quite consistent, with an overall classification agreement for the words over 90% and Fleiss's kappa well above acceptable margins ($\kappa = .795$).

The result was a pool of 157 animate words, 640 inanimate words, and 103 ambiguous words (e.g., "devil," "menace"). From this pool, five word lists were created. Each list consisted of all 157 animate words and a random selection of 157 inanimate words, for a total of 314 words per list. To determine the importance of each variable (animacy plus the variables considered by Rubin and Friendly) in predicting recall, we performed a series of regression analyses on each list. Several estimates of importance were used, and these estimates were averaged across lists to provide a general description of the data. These estimates included the average zero-order correlation (r), the average standardized regression coefficient (β), and the incremental importance (ΔR^2) of each variable in predicting recall (LeBreton, Hargis, Griepentrog, Oswald, & Ployhart, 2007).

Results

The average values from the regression analyses are shown in Table 1. The zero-order correlations show that many variables, including animacy, are predictive of recall, but the estimates of incremental importance provide a clearer picture of the variables that uniquely contribute to R^2 above and beyond the other predictors. Rubin and Friendly (1986) reported that imagery (the ease with which a visual image can be generated), availability (the ease with which the word comes to mind in free association), and emotionality (the extent to which the word generates an emotion) were the largest determinants in free recall, and we saw a similar trend in our data: Results for incremental importance showed that imagery was a large contributor to recall, as was goodness, a measure similar to emotionality. (Goodness represents how intensely good or bad a word's meaning is to the rater.) Availability was marginally significant ($p < .10$).

Most important, the analyses revealed that animacy contributed a great deal to the explainable variance. Animacy correlated strongly with recall ($r = .42$), and its incremental importance overall was nearly twice that of its nearest competitor, imagery.[1] At the same time, incremental importance can be a flawed indicator of variable importance when variables are correlated (LeBreton et al., 2007). To solve this problem, we applied an additional technique known as relative-weight analysis (see Tonidandel & LeBreton, 2011, for a "user's guide" to relative-weight analysis). Relative-weight analysis incorporates variable intercorrelations into the estimation of relative importance; it yields an additive decomposition of the model R^2. These data are also presented in Table 1, along with a rescaled estimate that shows the proportion of R^2 accounted for by each variable. The relative weights confirmed the conclusions obtained using incremental importance. Specifically, animacy and imagery emerged as the two most important predictors of recall. Contrary to the incremental analysis, the relative-importance analysis also highlighted the critical contribution that concreteness made relative to the other predictors in understanding recall. This contribution was masked in the incremental analysis because of correlations among the predictor variables. Animacy remained a highly significant predictor in each of the five separate replication analyses, in which the 157 animate words were compared with a different random sample of words from the inanimate pool. Figure 1 displays the overall findings graphically.

Study 2: An Experimental Comparison of Animate and Inanimate Words

The reanalysis of the Rubin and Friendly (1986) data revealed strong support for the hypothesis that animacy is an important mnemonic dimension in predicting recall. Our next step was to test this hypothesis further by directly comparing participants' recall of animate and inanimate words. Participants were asked simply to memorize and then recall a list of 24 words (12 animate and 12 inanimate); each class of words had been

Table 1. Results From Study 1: Average Estimates of the Importance of Word Attributes in Predicting Recall Across the Five Word Lists

	Raw importance estimates				
Predictor	*r*	β	Relative weight	Rescaled estimate	Incremental importance (ΔR^2)
Animacy	.42**	0.25**	0.09	0.22	.043**
Imagery	.52**	0.40**	0.09	0.21	.024**
Goodness	.17**	0.11*	0.02	0.04	.010*
Word frequency in Kučera-Francis (1967) norms	.10	0.18*	0.01	0.01	.009*
Availability in Palermo-Jenkins (1964) norms	.31**	0.10	0.03	0.06	.007
Word frequency in Thorndike-Lorge (1944) norms	.19**	–0.12	0.00	0.01	.005
Familiarity	.14*	–0.13	0.01	0.01	.004
Availability in the Kiss, Armstrong, Milroy, & Piper (1973) norms	.26**	0.07	0.02	0.04	.004
Emotionality	.05	0.08	0.01	0.02	.003
Emotional goodness	.15*	0.07	0.01	0.03	.003
Pronounceability	–.28	0.08	0.01	0.02	.003
Concreteness	.46**	0.07	0.07	0.17	.001
First-order approximation to English	.28**	0.11	0.01	0.03	.001
Second-order approximation to English	.27**	0.02	0.01	0.03	.001
Meaningfulness	.33**	–0.02	0.03	0.06	.001
Length in letters	–.29**	–0.02	0.01	0.03	.001

Note: Rescaled estimates show the proportion of R^2 accounted for by the particular variable; ΔR^2 shows incremental importance as a unique contribution of the variable to R^2. Animacy was defined on the basis of whether words represented a "living thing." Imagery refers to the ease with which a visual image can be generated. Goodness represents how intensely good or bad a word's meaning is to the rater. Availability refers to the ease with which the word comes to mind in free association. Emotionality indicates the extent to which the word generates an emotion. First- and second-order approximations to English are measures of the probability of generating a word on a letter-by-letter basis. All other normed values were taken from the sources reported in Rubin and Friendly (1986). Average R^2 = .43.
**p* < .05. ***p* < .01.

previously equated along a number of standard mnemonic dimensions.

Method

Fifty-four people (33 women) participated in exchange for partial credit in an introductory psychology course. Participants were tested in groups ranging in size from one to four in sessions lasting approximately 30 min each. Stimuli were presented and controlled by personal computers, and participants entered their responses using the keyboard and on paper.

We chose 24 words, 12 animate and 12 inanimate. The two word groups were carefully matched along 10 dimensions from a variety of norm databases: age of acquisition, category size, category typicality, concreteness, familiarity, imagery, Kučera-Francis written frequency, meaning, number of letters, and relatedness (as measured with latent semantic analysis). Each class also contained words drawn from the same number of categories. For additional information about these words and dimensions, see Tables 2 and 3. Four additional "buffer" words were chosen using the same procedure and matched as well.

The study had a 2 (word type: animate, inanimate) × 3 (trial: 1, 2, 3) repeated measures design. Participants were told that they were participating in a memory experiment and were asked to try and remember each word as it was presented. As noted, half of the words referred to animate beings, and half referred to inanimate objects. All 24 words were presented in random order to each participant, with the only constraint that an equal number of both word types appeared in each half of the list. Each word appeared for 5 s, with a 250 ms intertrial interval. At the beginning and end of the list, two buffer words were added (one of each type); these words were not scored in recall. Except for the random order of word presentation, all aspects of the design, including timing, were held constant across participants.

After viewing the final item, participants saw instructions for a short distractor task. For this task, a single-digit number ranging from 1 to 9 appeared on the computer screen, and participants were asked to respond by pressing the letter *E* on the keyboard if the number was even

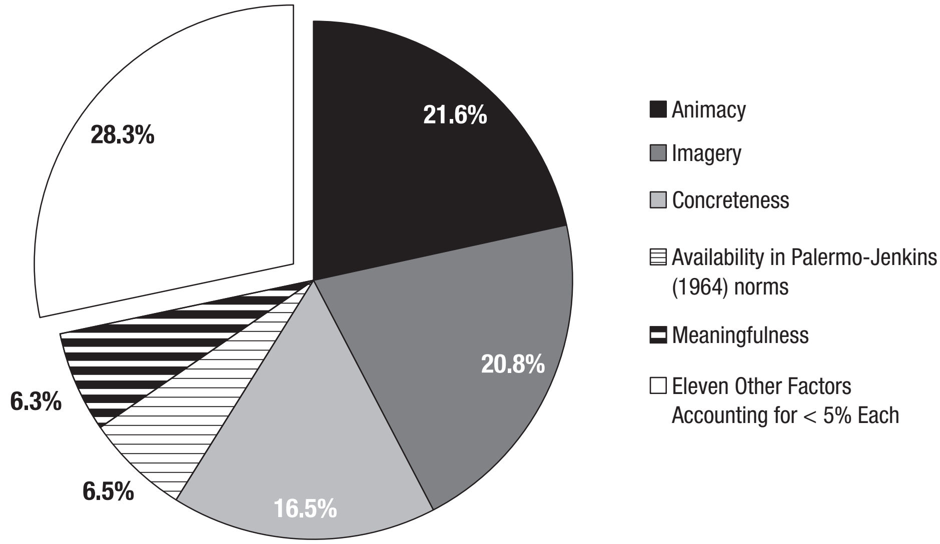

Fig. 1. Results from Study 1: rescaled relative weights for all variables in the regression analyses predicting recall.

and the letter *O* if the number was odd. Participants had 2 s to respond to each digit; this task lasted for 1 min. Participants were then asked to recall the words from the viewing task, in any order, and were given 4 min to complete the task. When participants had finished the recall period, they repeated the viewing, distractor, and recall procedures two more times (for a total of three view-and-recall trials).

Results and discussion

The results of the recall task are shown in Figure 2. A strong recall advantage was present for the animate items on each of the three trials. A 2 × 3 repeated measures analysis of variance confirmed a significant main effect of word type, $F(1, 53) = 44.9$, $MSE = 0.023$, $\eta_p^2 = .459$, and trial, $F(2, 106) = 380.7$, $MSE = 0.014$, $\eta_p^2 = .878$, but no

Table 2. Words Used in Study 2

Animate	Inanimate
baby	doll
bee	drum
duck	hat
engineer	journal
minister	kite
owl	purse
python	rake
soldier	slipper
spider	stove
trout	tent
turtle	violin
wolf	whistle

Note: Words in each category are presented here in alphabetical order.

Table 3. Average Values of Various Dimensions for the Animate and Inanimate List of Items Used in Study 2

Dimension	Animate	Inanimate
Age of acquisition	281 (97)	269 (79)
Category size	22.3 (5.9)	23.2 (6.0)
Category typicality	.200 (.17)	.238 (.18)
Concreteness	593 (29)	592 (17)
Familiarity	504 (70)	507 (31)
Imagery	589 (37)	578 (30)
Kučera-Francis written frequency	21.7 (23)	16.5 (16)
Meaningfulness	448 (56)	438 (32)
Number of letters	5.33 (1.8)	5.00 (1.4)
Relatedness	.114 (.12)	.143 (.12)

Note: Standard deviations are given in parentheses. Age-of-acquisition values were taken from the MRC Psycholinguistic Database (Coltheart, 1981; values based on the Gilhooly & Logie, 1980, norms); Bird, Franklin, and Howard (2001); Morrison, Chappell, and Ellis (1997; these norms were multiplied by 100 to match the remaining norms); and the Stadthagen-Gonzalez and Davis (2006) norms. In all of these studies, the method for obtaining the age of acquisition was the same and was converted to the same scale. Values for category size and category typicality were taken from the Van Overschelde, Rawson, and Dunlosky (2004) category norms. An equal number of categories was used for each list. Values for concreteness, familiarity, imagery, Kučera-Francis written frequency, meaningfulness (Toglia & Battig, 1978), and number of letters were obtained from the MRC Psycholinguistic Database (Coltheart, 1981). The relatedness dimension was assessed using latent semantic analysis (Landauer, Foltz, & Laham, 1998).

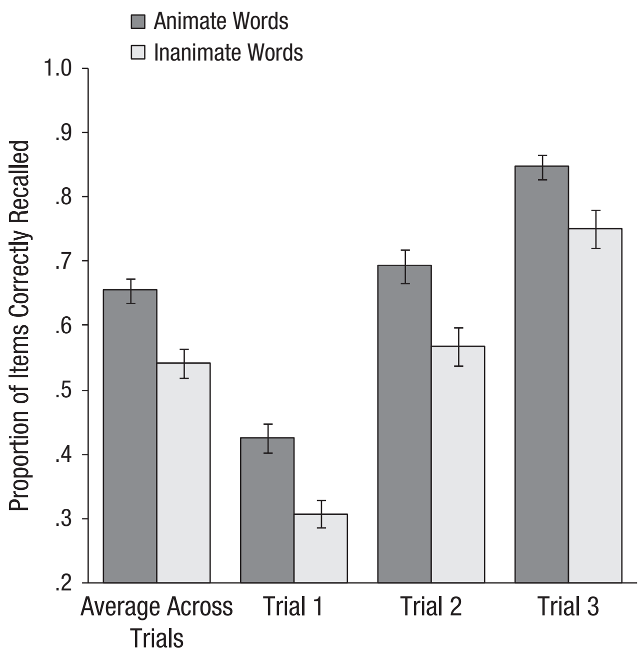

Fig. 2. Results from Study 2: mean proportion of items correctly recalled as a function of trial and word type. Data are shown averaged across the three recall trials and separately for each trial. Error bars represent standard errors of the mean.

interaction between the two factors, $F(2, 106) = 0.408$, $MSE = 0.014$, $\eta_p^2 = .008$. To examine whether participants tended to recall by word type, we calculated the adjusted-ratio-of-clustering (ARC) score (Roenker, Thompson, & Brown, 1971) for each participant as well. An ARC score of zero indicates chance-level clustering, whereas a score of 1 indicates perfect clustering. Two of the 54 participants were excluded from this analysis because of very low recall or because their recall record did not allow the identification of the order of recall. The average ARC score was close to zero (average = −.064, $SD = .35$). Additionally, a repeated measures analysis of variance comparing recall for animate and inanimate words adding ARC score as a covariate still revealed a strong main effect of word type, $F(1, 50) = 22.96$, $MSE = 0.014$, $\eta_p^2 = .308$.

General Discussion

Are cognitive systems, including memory, selectively "tuned" to solve adaptive problems? Work in our laboratory (and other laboratories as well) has shown that conditions in which information is processed for its survival relevance can lead to enhanced retention relative to a variety of powerful control conditions (e.g., Nairne, Pandeirada, & Thompson, 2008). Given that memory evolved subject to nature's criterion—the enhancement of inclusive fitness—it is perhaps not surprising that fitness-relevant processing leads to particularly good retention (for some boundary conditions on the survival-processing advantage, see Kroneisen & Erdfelder, 2011; Savine, Scullin, & Roediger, 2011).

In the present studies, we were interested in whether similar mnemonic advantages might be present for animate beings. Indeed, our reanalysis of the Rubin and Friendly (1986) data suggested that animacy is an extremely significant mnemonic dimension. The regression analyses revealed that animacy was one of the strongest predictors of recall, certainly as strong as imagery, frequency of use, or familiarity. We then directly compared the recall of animate and inanimate words in a new study to confirm this conclusion: Participants were significantly more likely to recall the animate words, even though both the animate and inanimate stimuli had been carefully equated along numerous mnemonic dimensions. These findings are important, regardless of one's theoretical orientation, because animacy represents a potentially uncontrolled variable in cognitive research.

The prediction that animate stimuli should be easier to remember than inanimate stimuli follows nicely from a functional-evolutionary perspective. Animacy is a foundational dimension, appearing early in development, and assigning priorities to both the detection and retention of animate beings seems likely to have enhanced inclusive fitness at some point in humans' ancestral past (New et al., 2007). Note that this is an evolutionary (or ultimate) hypothesis, not a hypothesis about the proximate mechanisms that underlie the advantages (Scott-Phillips, Dickins, & West, 2011). At present, the proximate mechanism through which these priorities are achieved remains unknown. It is possible that animate stimuli are remembered well because of perceptual or attentional priorities, rather than mnemonic tunings, or that traditional memory variables (such as elaboration or distinctiveness) can be invoked to explain the animacy advantage. Another possibility is that animate stimuli afford encoding along multiple sensorimotor dimensions, perhaps because animate stimuli are more likely than inanimate stimuli to be simulated cognitively during study (e.g., Rueschemeyer, Glenberg, Kaschak, Mueller, & Friederici, 2010). Explaining the "how" of the animacy advantage should be a topic for future research.

It will also be important to deconstruct the animacy dimension. The category "animate" can be defined in various ways. At its most general level, one can consider any living thing to be animate, including nonhuman animals, plants, and perhaps even bacteria or viruses. In contrast, cognitive biases may require agency (the ability to initiate causal action), movement, mental states (such as knowing or emotion), or even the ability to communicate in order for something to be considered animate (e.g., Rakison & Poulin-Dubois, 2001). In our reanalysis of the Rubin and Friendly (1986) data, we classified words as animate simply on the basis of whether they represented a "living thing," and many nonhuman animals and plants were included. Our behavioral study included nonhuman animals but not plants. At this point, we are unable to comment on the range of the animacy advantage or on the necessary and sufficient animate properties that are required to produce the effect.

Cognitive researchers rarely adopt a functional or evolutionary perspective (Klein, Cosmides, Tooby, & Chance, 2002; Nairne, 2005). The focus tends to be exclusively on the "how" of remembering and almost never on the "why." Recognizing the origins of cognitive systems, as well as nature's criterion—which relies on the promotion of inclusive fitness—can lead to the discovery of new empirical phenomena and the generation of new hypotheses. In the present case, our results join other findings to suggest that human cognitive systems are not content independent. Instead, they show sensitivities to the selection pressures and content dimensions (e.g., survival, animacy) that led to their development.

Author Contributions

J. S. Nairne developed the study concept. J. S. Nairne, J. E. VanArsdall, J. N. S. Pandeirada, and M. Cogdill contributed to the design of the studies and the selection of stimulus materials. All authors contributed to the analyses of the data. The analysis of Study 1 was supervised by J. M. LeBreton. The manuscript was written by J. S. Nairne with help from J. E. VanArsdall and J. N. S. Pandeirada. All authors commented on and approved the final version of the manuscript for submission.

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J. N. S. Pandeirada is also affiliated with Purdue University and the Institute of Biomedical Research in Light and Image (IBILI). J. M. LeBreton is now in the Department of Psychology at Pennsylvania State University.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Note

1. Although we used animacy as a dichotomous variable to categorize words as either animate or inanimate, it was possible to average raters' animacy ratings and use those averages as predictors of recall (giving each word a value from 1 to 5) for the entire set of 900 words (157 animate, 640 inanimate, and 103 ambiguous). Animacy remained a highly reliable predictor of recall ($p < .01$) in this analysis as well.

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