Adaptive Memory: The Mnemonic Value of Animacy

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Abstract

Distinguishing between living (animate) and non-living (inanimate) things is essential to 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, arguably representing 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.

Key words: Animacy, Memory, Evolution

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 report is on the mnemonic value of animacy, defined here as the distinction between inanimate objects (e.g., violin) and animate beings (e.g., baby). 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 may have evolved hyperactive animate 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 our 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. Item dimensions such as frequency of use, imageablilty, and meaningfulness have been well-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. Animate words, for instance, 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 were able to explore 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. The words provided in Rubin & Friendly (1986) were coded by three independent raters for their animacy status. The raters used a five-point scale with “1” clearly representing a non-living thing, “5” clearly representing a living thing, and “3” being ambiguous. 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 all other cases were designated as ambiguous. Raters were quite consistent, with an overall classification agreement for the words over 90% (P_o = 0.920) and Fleiss’ kappa well above acceptable margins (κ = 0.795).

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 & Friendly) in predicting recall, a series of regression analyses were performed 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 coefficients (β), and the incremental importance (ΔR^2) for each variable (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 are predictive of recall, including animacy, 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 & Friendly (1986) reported that imagery, availability, and emotionality were the largest determinants in free recall, and we see a similar trend in our data: Based on incremental importance, imagery is a large contributor to recall, as is goodness, a measure similar to emotionality. Availability approaches significance with $p < 0.10$.

Most importantly, the analyses revealed that animacy contributes a great deal to the explainable variance. Animacy correlates strongly with recall ($r = 0.42$), and its incremental importance overall is 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 (column *RW*), along with a rescaled version that shows the proportion of R^2 accounted for by each variable (column *RW-RS*). The relative weights confirmed the conclusions obtained using incremental importance. Specifically, animacy and imagery emerged as two of the most important predictors of recall. Contrary to the incremental analysis, the relative importance analysis also highlighted the critical contribution that concreteness makes relative to the other predictors in our understanding of recall. This contribution was masked when examining the incremental analysis due to 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.

Table 1: Average importance estimates for all variables across five lists.

Average R^2= 0.43	**Raw importance estimates**†					**Rescaled estimate**	**Incremental importance**	
Variables‡	r		β		RW	RW–RS	ΔR^2	
Animacy	0.42	**	0.25	**	0.09	0.22	0.043	**
Imagery	0.52	**	0.40	**	0.09	0.21	0.024	**
Goodness	0.17	**	0.11	*	0.02	0.04	0.010	*
K-F Frequency	0.10		0.18	*	0.01	0.01	0.009	*
P-J Availability	0.31	**	0.10		0.03	0.06	0.007	
T-L Frequency	0.19	**	-0.12		0.00	0.01	0.005	
Familiarity	0.14	*	-0.13		0.01	0.01	0.004	
K Availability	0.26	**	0.07		0.02	0.04	0.004	
Emotionality	0.05		0.08		0.01	0.02	0.003	
Emotional Goodness	0.15	*	0.07		0.01	0.03	0.003	
Pronounceability	-0.28		0.08		0.01	0.02	0.003	
Concreteness	0.46	**	0.07		0.07	0.17	0.001	
FOA	0.28	**	0.11		0.01	0.03	0.001	
SOA	0.27	**	0.02		0.01	0.03	0.001	
Meaningfulness	0.33	**	-0.02		0.03	0.06	0.001	
Length in Letters	-0.29	**	-0.02		0.01	0.03	0.001	

**$p<0.01$; *$p<0.05$

†r = zero-order correlations; β = standardized regression coefficients; RW = raw relative weights. RW–RS = rescaled raw relative weights as a proportion of R^2; ΔR^2 = incremental importance as unique contribution of variable to R^2.

‡Animacy was defined as described in the text. All other normed values were taken from the sources reported in Rubin and Friendly (1986). K Availability is Kiss Availability. K-F Frequency is Kucera-Francis Frequency. P-J Availability is Palermo-Jenkins Availability. T-L Frequency is Thorndike-Lorge Frequency. FOA and SOA are 1st- and 2nd-Order Approximations to English.

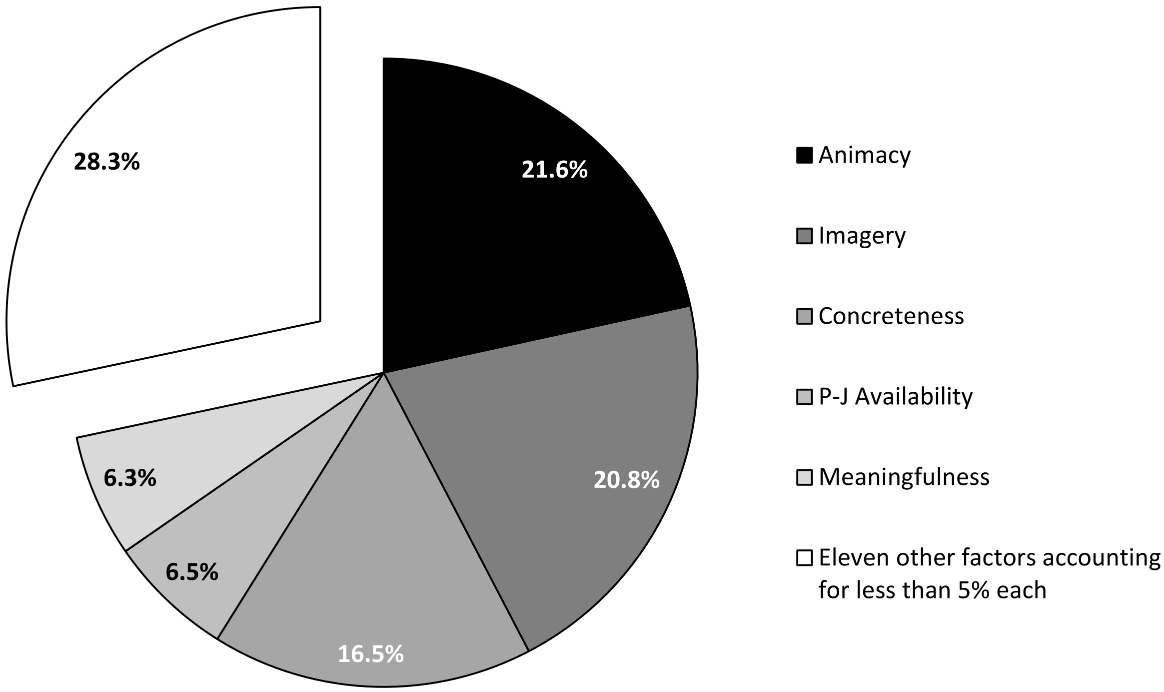

Figure 1: Rescaled Relative Weights for all variables included in the regression analyses

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 that is predictive of recall. Our next step was to test this hypothesis further by directly comparing the recall of animate and inanimate words. Participants were simply asked to memorize and then recall a list of 24 words (12 animate and 12 inanimate); importantly, each class of words had been previously equated along a number of standard mnemonic dimensions.

Method

Participants and apparatus. 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. Stimuli were presented and controlled by personal computers, and participants entered their responses using the keyboard and on paper.

Materials and design. Twenty-four words were chosen, 12 animate and 12 inanimate. The two groups were carefully matched along ten 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 experiment was a within-subject 2 x 3 repeated measures design with word type (animate or inanimate) as a within-subjects factor and recall trial as a repeated factor. Participants were told 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 were animate beings and half were inanimate objects. The 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 inter-trial 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 randomization described above, all aspects of the design, including timing, were held constant across participants.

Table 2: Words used in Experiment 2 (presented in alphabetical order)

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

Table 3: Average values (and SDs) of various dimensions for the animate and inanimate list of items used in Experiment 2.

	Animate	**Inanimate**
AoA[1]	281 (97)	269 (79)
Category Size[2]	22.3 (5.9)	23.1 (6.0)
Category Typicality[2]	.200 (.17)	.238 (.18)
Concreteness[3]	593 (29)	592 (17)
Familiarity[3]	504 (70)	507 (31)
Imagery[3]	589 (37)	578 (30)
KF Written Freq.[3]	21.7 (23)	16.5 (16)
Meaningfulness[3]	448 (56)	438 (32)
No. Letters[3]	5.33 (1.8)	5.00 (1.4)
Relatedness[4]	.114 (.12)	.143 (.12)

[1]*Age of Acquisition*: Values taken from the MRC database (Coltheart, 1981; values based on the Gilhooly & Logie, 1980, norms), Bird, Franklin, & Howard (2001), Morrison, Chappell, & Ellis (1997; these norms were multiplied by 100 to match the remaining norms), and the Stadthagen-Gonzalez & Davis (2006) norms; in all of these references, the method for obtaining the Age of Acquisition was the same and converted to the same scale. [2]*Category Size & Category Typicality*: Values taken from the Van Overschelde, Rawson, & Dunlosky (2004) category norms. An equal number of categories was used for each list. [3]*Concreteness, Familiarity, Imagery, Kucera & Francis Written Frequency, Meaningfulness (Colorado norms), and Number of Letters*: These values were obtained from the MRC Psycholinguistic Database (Coltheart, 1981). [4]*Relatedness:* This dimension was assessed using latent semantic analysis (Landauer, Foltz, & Laham, 1998).

After viewing the final item, instructions for a short distractor task appeared. For this task, a single-digit number ranging from 1 to 9 appeared on the computer screen and participants were asked to respond with the letter *E* on the keyboard if the number was even 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 are shown in Figure 2. A strong recall advantage was present for the animate items on each of the three study-test trials. A 2 x 3 repeated measures analysis of variance confirmed a significant main effect of word type, $F(1, 53) = 44.9$, $MSE = 0.023$, $\eta^2_p = 0.459$, and recall trial, $F(2, 106) = 380.7$, $MSE = 0.014$, $\eta^2_p = 0.878$, but no interaction, $F(2,106) = 0.408$, $MSE = 0.014$, $\eta^2_p = 0.008$. To examine whether participants tended to recall by word type, we calculated the Adjusted Ratio of Clustering (ARC scores; 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 = - 0.064, SD = 0.35). Additionally, a repeated measures analysis comparing recall for animate and inanimate words adding ARC score as a covariate still revealed a strong main effect of word type, $F(1,50) = 22.96$, $MSE = 0.014$, $\eta^2_p = 0.308$.

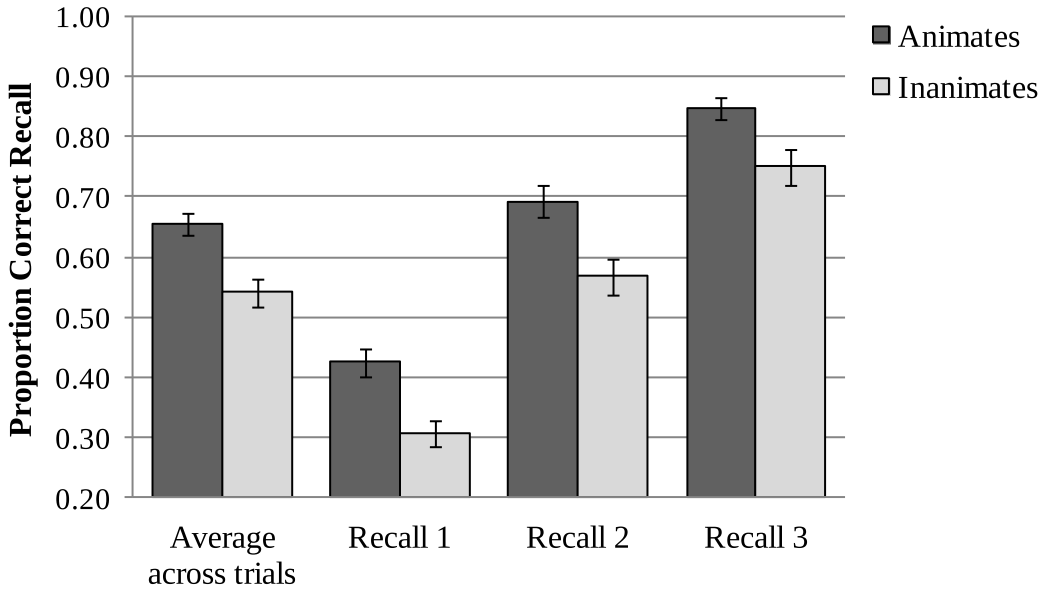

Figure 2. Proportion Correct Recall averaged across the three recall trials, and for each recall trial, for Animates and Inanimates in Experiment 2. Error bars represent Standard Errors of the Mean.

General Discussion

Are our cognitive systems, including memory, selectively "tuned" to solve adaptive problems? Work in our laboratory (and other laboratories as well) has shown that processing information for its relevance to a survival situation 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 case, 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 experiment 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 animates should be easier to remember than inanimates 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 our ancestral past (New et al., 2007). Note 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 animates 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 animates are more likely 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. On the other hand, cognitive biases may require agency (the ability to initiate causal action), movement, the presence of mental states (such as knowing or emotion), or even the ability to communicate (e.g., Rakison & Poulin-Dubois, 2001). In our reanalysis of the Rubin and Friendly (1986) data, words were chosen simply on the basis of whether or not they represented a "living thing" and many nonhuman animals and plants were included. Our experiment 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 in the suggestion 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.

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Footnote

[1] Although we used animacy as a dichotomous variable to categorize words as either animate or inanimate, it is 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 remains a highly reliable predictor of recall ($p < .01$) in this analysis as well.