Adaptive memory: Is the animacy effect on memory due to emotional arousal?

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Abstract

Animate entities are often better remembered than inanimate ones. The proximal mechanisms underlying this animacy effect on recall are unclear. In two experiments, we tested whether the animacy effect is due to emotional arousal. Experiment 1 revealed that translations of the animate words used in the pioneering study of Nairne et al. (*Psychological science*, 24, 2099–2105, 2013) were perceived as being more arousing than translations of the inanimate words, suggesting that animacy might have been confounded with arousal in previous studies. In Experiment 2, new word lists were created in which the animate and inanimate words were matched on arousal (amongst several other dimensions), and participants were required to reproduce the animate and inanimate words in a free recall task. There was a tendency towards better memory for arousing items, but robust animacy effects were obtained even though animate and inanimate words were matched on arousal. Thus, while arousal may contribute to the animacy effect when it is not carefully controlled for, it cannot explain the memory advantage of animate items.

Keywords Memory · Animacy effect · Emotional arousal

Nairne, VanArsdall, Pandeirada, Cogdill, and LeBreton (2013) examined the effect of the animate-inanimate distinction on memory. Using an intentional recall task, they asked participants to recall a list of words representing animate (e.g., baby, soldier, duck) and inanimate items (e.g., doll, purse, hat). Participants remembered more animate than inanimate items. This memory advantage for animate items is typically referred to as the animacy effect. Nairne et al. (2013) obtained the animacy effect after controlling for many variables such as concreteness and familiarity. The item's animacy status was a better predictor of its future recall probability than any other property. A large number of studies have thus far confirmed and extended these results. For instance, the animacy effect is

robustly found under different encoding instructions (Gelin, Bugaiska, Meot, & Bonin, 2017) and generalizes to paired-associate learning (VanArsdall, Nairne, Pandeirada, & Cogdill, 2015), to the recall of pictures (Bonin, Gelin, & Bugaiska, 2014), and to the recollection of non-words associated with animate properties (VanArsdall, Nairne, Pandeirada, & Blunt, 2013).

These results have been used to advocate a functional perspective on memory (Bonin et al., 2014; Nairne, VanArsdall, & Cogdill, 2017; Nairne et al., 2013), which is based on the rather uncontroversial assumption that memory evolved to solve fitness-relevant problems (Nairne, 2010). According to this view, better memory for animate items could be conceived of as an adaptive mechanism because animates are evolutionary relevant entities that can represent potential enemies, threats, mating partners, or prey. This is, however, an ultimate hypothesis (Nairne et al., 2013) that does not address the underlying proximate mechanisms of the animacy effect, such as which cognitive or perceptual processes are responsible for the effect. The animacy effect's underlying proximate memory mechanisms have not yet been determined. However, a number of domain-general candidate mechanisms have already been ruled out. Neither differences in sensory experiences between animate and inanimate objects (Bonin et al., 2014) nor elaboration processes (Bonin, Gelin, Laroche,

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Meot, & Bugaiska, 2015) seem to provide a satisfactory explanation of the animacy effect. As discussed by Nairne et al. (2017), it also seems unlikely that the use of categorical cues can explain the effect. VanArsdall, Nairne, Pandeirada, and Cogdill (2017) demonstrated across several experiments that the animacy effect is independent of categorical recall strategies. Likewise, Nairne et al. (2013) found no evidence for categorical clustering during item reproduction for the animate and inanimate items. Thus, it still remains unclear whether words representing animate items are better remembered because they recruit specialized processing mechanisms or whether another, well-known general mechanism is responsible for the memory advantage.

In the present study, we tested whether the animacy advantage is due to emotional arousal. It is well established that emotionally arousing stimuli are prioritized in cognitive processing (e.g., Buchanan & Adolphs, 2002; Cahill & McGaugh, 1995; Kensinger & Corkin, 2003) and better remembered than neutral stimuli (e.g., Bradley, Greenwald, Petry, & Lang, 1992; Cahill & McGaugh, 1995; Kensinger & Corkin, 2003; LaBar & Phelps, 1998). Fitness-relevant stimuli such as snakes or spiders are often believed to be particularly memorable because they elicit strong emotional responses that may have profound effects on memory via interactions between emotion-processing regions and memory regions in the human brain (Kensinger, 2007). This line of reasoning raises the possibility that the animacy effect is due to emotional arousal. Animate entities such as animals, people, or body parts may, on average, elicit stronger emotional arousal than inanimate things such as buildings, furniture, or tools. This increased arousal could be responsible for the beneficial effects of animacy on memory. Such an idea would also make sense from a functional perspective because emotional arousal may reflect evolutionary relevance more directly than animacy. Emotionally arousing inanimate entities such as weapons and valuables tend to be highly relevant for the evolutionary goals of survival and reproduction (and should, thus, deserve prioritized processing as well), while emotionally neutral animate entities such as algae or birch trees may be comparatively less relevant. However, even though the hypothesis that arousal, not animacy per se, is the mechanism behind the animacy effect seems to be a compelling idea at first glance, it should not be accepted based on evolutionary storytelling. Whether or not it is scientifically valid is ultimately an empirical question.

The animate and inanimate words used by Nairne et al. (2013) were matched along a number of different variables (e.g., age of acquisition, concreteness, and imagery), but emotional dimensions were not included in the set of variables that were equated between conditions. In a follow-up study on the animacy effect, Bonin et al. (2014) matched emotional valence (i.e., the degree to which a stimulus is perceived as positive or negative), among other dimensions, and found that

the animacy effect persisted. One potential problem with measures of valence is that there are ambivalent items that elicit mixed (both positive and negative) affective responses (Schneider, Veenstra, van Harreveld, Schwarz, & Koole, 2016). These items may appear to be emotionally neutral when negative and positive valence ratings are averaged on a single dimension, but are nevertheless experienced as emotional because they may elicit equally strong negative and positive responses. What is more, research has shown that arousal is much more important than valence in explaining the memory advantage of emotional stimuli (Bradley et al., 1992; Kensinger & Corkin, 2003; Kensinger & Schacter, 2006). It is therefore important to test whether arousal may be responsible for the animacy effect on memory.

A closer look at the words used in the original Nairne et al. (2013) study leaves open the possibility that their animate and the inanimate items may indeed have differed in arousal. The animate category included words like *soldier*, *python*, *baby*, or *spider* whereas the inanimate category listed words like *slipper*, *hat*, *rake*, or *journal*. From these examples one might infer that animate and inanimate items typically differ in the degree to which they elicit emotional arousal, and that the increased arousal in response to animate stimuli, rather than animacy per se, is responsible for their mnemonic benefit.

Here we examine the contribution of arousal to the animacy effect. In Experiment 1, we tested whether the animate and inanimate word lists used by Nairne et al. (2013) differ in arousal. In Experiment 2, we orthogonally manipulated animacy and emotional arousal to establish whether the animacy effect persists when arousal is equated between animate and inanimate word lists.

Experiment 1

Method

Participants Seventy-seven participants (58 female) with a mean age of 23 years ($SD = 5$) were recruited on campus at Heinrich Heine University Düsseldorf.

Materials The 12 animate and 12 inanimate words used by Nairne et al. (2013) were translated into German (see Supplement A).

Procedure and design Participants were tested individually in one of five separate cubicles in a quiet room. In the rating phase, all 24 words were shown in the center of the computer screen, one at a time in a random order. Participants were asked to rate the degree of arousal evoked by the words. Following the example of Kanske and Kotz (2010), we used the seven-point arousal-scale of the Self-Assessment

Mannequin (Bradley & Lang, 1994), ranging from “not arousing” to “very arousing.” After each rating, participants clicked on the “continue” button to initiate the presentation of the next word. The rating task was followed by a short filler task. Participants were asked to evaluate the veracity of 20 mathematical equations (e.g., $13 + 6 = 18$) by clicking on either a “correct” or an “incorrect” button. After the filler task, participants wrote down all of the words from the arousal-rating phase they could recall, in no particular order. The recall phase was not announced beforehand. The experiment lasted approximately 15 min.

The study had a one-factorial within-subjects design (animate, inanimate). Given $\alpha = \beta = .05$ and $N = 77$, a sensitivity analysis showed that effects of partial eta-squared (η_p^2) = .15 could be detected between the two levels of the animacy variable (Faul, Erdfelder, Lang, & Buchner, 2007).

Results

Figure 1 illustrates the mean arousal ratings and the proportions of correctly recalled animate and inanimate words. Animate words received higher arousal ratings than inanimate words, $t(76) = 11.90$, $p < .001$, $\eta_p^2 = .65$. Replicating the original finding of Nairne et al. (2013), there was a clear recall advantage for words representing animate items in comparison to those representing inanimate items, $t(76) = 12.22$, $p < .001$, $\eta_p^2 = .66$. An item-based analysis revealed a significant positive correlation between an item’s arousal and the probability of a successful recall ($r = .64$, $p = .001$).

Discussion

Nairne et al. (2013) matched animate and inanimate word lists on multiple dimensions that are known to affect memory (e.g., imagery, age of acquisition, concreteness, etc.). However, they did not consider arousal as a relevant factor. The results of Experiment 1 reveal a clear difference in the average arousal values between animate and inanimate stimuli entertaining the possibility that the animacy effect may be driven by arousal. Stimuli with high arousal are typically better remembered than stimuli with low arousal, so that arousal differences could have contributed to the emergence of the animacy effect in the original study. The difference in arousal was obtained for the German translations of the word lists used by Nairne et al. (2013), but it seems quite plausible that differences as huge as those observed here are not language-specific.

Having established that differences in arousal could have been responsible for the animacy effect observed by Nairne et al. (2013), it seemed necessary to examine whether the animacy effect prevails when arousal is equated between lists. Experiments 2 served to test this hypothesis by orthogonally manipulating animacy and arousal.

Experiment 2

For a comprehensive test of the role of arousal in the animacy effect, we manipulated animacy (animate, inanimate) and arousal (low, high) in a 2×2 design, making sure that within each level of the arousal variable the average arousal values of animate and inanimate items were matched. If the animacy effect were due to arousal, recall should be better for words with high in comparison to words with low arousal, but there should be no difference in the recall performance between lists representing animate and inanimate items because arousal was matched between these lists.

Method

Participants The sample consisted of 90 participants (69 female) with a mean age of 23 years ($SD = 4$) who were recruited on campus at Heinrich Heine University Düsseldorf.

Materials Forty words were chosen from the Leipzig Affective Norms for German (LANG) database (Kanske & Kotz, 2010) to create four word lists consisting of ten words each: One list with words representing low arousal animate items, one with words representing low arousal inanimate items, one with words representing high arousal animate items, and one with words representing high arousal inanimate items. In a separate norming study, all words from the LANG database were categorized by three raters as representing animate, inanimate, and non-categorizable items. Only words consistently categorized as animate or inanimate by all raters were incorporated into the final word lists. Animate and inanimate words of low and high arousal were selected. Care was taken to match arousal values between animate and inanimate lists to orthogonally manipulate arousal and animacy. In addition, all four word lists were matched on emotional valence, concreteness, age of acquisition, imagery, meaningfulness, word frequency, number of letters, and number of syllables (see Table 1 and Supplement B). These four word lists were combined to create a mixed list (as in Experiment 1) that was presented to each participant during the experiment.

Procedure and design Participants were instructed to memorize the words presented on screen. All 40 words were presented in a random order for 5 s each, with an inter-stimulus interval of 2 s. After the same filler task as in Experiment 1, participants were required to write down as many of the previously presented words as possible. The experiment lasted about 15 min.

The study had a two-factorial design with animacy (animate, inanimate) and arousal (high, low) as within-subject variables. Given $\alpha = \beta = .05$ and $N = 90$, a sensitivity analysis showed that effects of $\eta^2 = .13$ could be detected between the

Fig. 1 The left graph illustrates the mean arousal rating for the animate and inanimate word lists in Experiment 1 (range from 1 = “not arousing” to 7 = “very arousing”). The right graph shows the mean proportion of

correctly recalled words from the animate and inanimate word list. The error bars represent the standard errors of the means

two levels of the animacy and the arousal variables (Faul et al., 2007).

Results

The results are illustrated in Fig. 2. Most importantly, there was a significant animacy effect: Words representing animate items were better remembered than words representing inanimate items, $F(1, 89) = 53.71, p < .001, \eta_p^2 = .37$. The difference between high-arousal and low-arousal words failed to reach significance, $F(1, 89) = 1.76, p = .19, \eta_p^2 = .02$. The interaction was also not significant, $F(1, 89) = 3.28, p = .07, \eta_p^2 = .04$.

Discussion

While the beneficial effect of arousal on recall failed to reach significance (despite a tendency towards better recall of high-arousal words), the memory advantage for words representing

animate items was robustly obtained, even though arousal was equated between lists of words of the animate and inanimate categories. This is in line with Nairne et al.’s (2013) conclusion that the animacy effect is even stronger than the influence of other well-known determinants of memory. Apparently, the animacy effect cannot be reduced to an effect of arousal.

General discussion

In recent studies, a memory advantage for animate in comparison to inanimate stimuli was found (e.g., Nairne et al., 2013). The present results provide further evidence for this animacy effect on memory. In both experiments, animate words were better remembered than inanimate words. It remains an open empirical question *why* words representing animate items are better remembered than words representing inanimate items. Nairne et al. (2013) wrote: “At present, the proximate mechanism through which these priorities are achieved remains

Table 1 Mean values of the dimensions that were matched between the word lists for Experiment 2

Dimension (scale values)	Animate (low arousal)	Inanimate (low arousal)	Animate (high arousal)	Inanimate (high arousal)
Arousal (1–9)	2.71 (0.39)	2.71 (0.45)	5.27 (0.74)	5.24 (0.81)
Valence (1–9)	5.14 (0.24)	5.19 (0.34)	5.17 (1.29)	5.01 (1.42)
Concreteness (1–9)	3.11 (1.22)	3.1 (0.63)	3.16 (1.28)	3.07 (0.75)
Age of Acquisition (1–7)	4.08 (1.84)	4.34 (0.78)	3.58 (1.29)	4.18 (1.25)
Imagery (1–7)	5.10 (1.07)	4.29 (0.69)	5.08 (1.11)	5.01 (1.03)
Meaningfulness (1–7)	4.32 (0.78)	3.46 (0.49)	4.59 (1.15)	4.36 (1.19)
Frequency	12.7 (1.77)	12.5 (2.01)	13 (2.58)	13.5 (0.85)
Number of Letters	5.7 (1.16)	5.8 (0.79)	5.2 (0.79)	6.2 (0.63)
Number of Syllables	1.8 (0.42)	1.8 (0.42)	1.8 (0.42)	1.7 (0.48)

Values for arousal, valence, concreteness, frequency, number of letters, and number of syllables were calculated based on the norms provided by the Leipzig Affective Norms for German (LANG) Database (Kanske & Kotz, 2010). Values for age of acquisition, imagery, and meaningfulness were taken from our own norming study with $N = 16$ raters. Except for the arousal dimension, which differs as intended between lists with high and low arousals, the word lists do not significantly differ on any dimension. The values in parentheses represent standard deviations. See Supplement C for a detailed overview of the values for the individual items

Fig. 2 The figure shows the mean proportion of correctly recalled items as a function of animacy (animate, inanimate) and arousal (high, low) in Experiment 2. The error bars represent the standard errors of the means

unknown” (p. 2103). Several promising candidate mechanisms have already been ruled out. Bonin et al. (2014) showed that the effect cannot be attributed to the richness of sensory and perceptual features of animate items. VanArsdall et al. (2017) showed that a categorical recall strategy cannot explain the animacy effect. We may now add to this list that arousal, too, cannot explain the animacy effect (at least not completely).

The results of Experiment 1 provide empirical evidence that the animate and inanimate word lists that were used by Nairne et al. (2013) differed in arousal, suggesting that animate words may, on average, elicit more emotional arousal than inanimate words. Based on these results, it seemed possible to speculate that arousal could in fact be the overlooked factor in determining the animacy effect. However, the critical test is not whether or not animate and inanimate words differ in arousal, but whether or not these differences are indeed responsible for the mnemonic advantage of words representing animate items. If this hypothesis were true, we would expect that the animacy effect should disappear when arousal is carefully controlled. This hypothesis was tested in Experiment 2 by orthogonally manipulating animacy and arousal. The results show that recall was better for words representing animate items than for words representing inanimate items. Although there was a tendency towards remembering high-arousal words better than low-arousal words, the effect was smaller than the animacy effect, and failed to reach the conventional level of statistical significance. This was the case even though we used mixed lists that have been found to be more likely to produce memory advantages for arousing words compared to pure-list designs (e.g., Hadley & MacKay, 2006; Talmi, Lohnas, & Daw, 2017). These results therefore disconfirm the hypothesis that the animacy memory advantage is solely due to arousal. The finding of a smaller effect of

arousal ($\eta_p^2 = .02$) compared to the effect of animacy ($\eta_p^2 = .37$) in Experiment 2 is in line with the results reported by Nairne et al. (2013) showing that the animacy dimension is even more important in determining memory performance than other dimensions that have often been discussed in the memory literature (e.g., imagery, concreteness, or meaningfulness). Although it is possible that differences in arousal may have contributed to the animacy effect in previous studies (and should therefore be carefully controlled in future studies), arousal does not seem to be responsible for the memory advantage of animate over inanimate items. During the peer-review process of this article, we learned of another study that examined the influence of arousal on the animacy effect. In this study, a single animate list was compared with a single inanimate list while arousal was controlled for. In line with the findings presented here, Popp and Serra (2018) found a robust advantage of animate items. Those independently obtained data strengthen the conclusion that the animacy effect is not caused by differences in emotional arousal, and, as a consequence, they weaken emotional explanations of the animacy effect.

Beyond that, there is currently no clear understanding of the characteristics of the processing of animate as opposed to inanimate stimuli that lead to their high memorability. It is possible that mechanisms such as a higher propensity to attract attention (Calvillo & Hawkins, 2016; Earl Y. Popp & Serra, 2016) or perceived agency (Lowder & Gordon, 2015) are responsible for the animacy effect. Humans are probably not born with a concept of the animacy dimension but rather learn it from experience in that particular stimuli become associated with animate qualities (e.g., self-propelled or goal-directed movement). Natural selection may thus have equipped us with a tendency to pay attention to and to remember things holding these qualities rather than with a module that responds to animacy per se. The present results confirm that animacy is an important factor in determining recall. Further understanding the underlying mechanisms of the animacy effect therefore will provide valuable insight into the functioning of memory.

References

- Bonin, P., Gelin, M., & Bugaiska, A. (2014). Animates are better remembered than inanimates: Further evidence from word and picture stimuli. *Memory & Cognition*, 42, 370–82.
- Bonin, P., Gelin, M., Laroche, B., Meot, A., & Bugaiska, A. (2015). The “how” of animacy effects in episodic memory. *Experimental Psychology*, 62, 371–384.
- Bradley, M. M., Greenwald, M. K., Petry, M. C., & Lang, P. J. (1992). Remembering pictures: Pleasure and arousal in memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18, 379–390.
- Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: The self-assessment Manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry*, 25, 49–59.

- Buchanan, T. W., & Adolphs, R. (2002). Chapter: The role of the human amygdala in emotional modulation of long-term declarative memory. In *Emotional cognition: From brain to behaviour* (pp. 9–34). Amsterdam, Netherlands: John Benjamins Publishing Company.
- Cahill, L., & McGaugh, J. L. (1995). A novel demonstration of enhanced memory associated with emotional arousal. *Consciousness and Cognition: An International Journal*, 4, 410–421.
- Calvillo, D. P., & Hawkins, W. C. (2016). Animate objects are detected more frequently than inanimate objects in inattentional blindness tasks independently of threat. *Journal of General Psychology*, 143, 101–115.
- Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, 39, 175–191.
- Gelin, M., Bugajska, A., Meot, A., & Bonin, P. (2017). Are animacy effects in episodic memory independent of encoding instructions? *Memory*, 25, 2–18.
- Hadley, C. B., & MacKay, D. G. (2006). Does emotion help or hinder immediate memory? Arousal versus priority-binding mechanisms. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 32, 79–88.
- Kanske, P., & Kotz, S. A. (2010). Leipzig affective norms for German: A reliability study. *Behavior Research Methods*, 42, 987–991.
- Kensinger, E. A. (2007). Negative emotion enhances memory accuracy: Behavioral and neuroimaging evidence. *Current Directions in Psychological Science*, 16, 213–218.
- Kensinger, E. A., & Corkin, S. (2003). Memory enhancement for emotional words: Are emotional words more vividly remembered than neutral words? *Memory & Cognition*, 31, 1169–1180.
- Kensinger, E. A., & Schacter, D. L. (2006). Processing emotional pictures and words: Effects of valence and arousal. *Cognitive, Affective, & Behavioral Neuroscience*, 6, 110–126.
- LaBar, K. S., & Phelps, E. A. (1998). Arousal-mediated memory consolidation: Role of the medial temporal lobe in humans. *Psychological Science*, 9, 490–493.
- Lowder, M. W., & Gordon, P. C. (2015). Natural forces as agents: Reconceptualizing the animate-inanimate distinction. *Cognition*, 136, 85–90.
- Nairne, J. S. (2010). Chapter: Adaptive memory: Evolutionary constraints on remembering. In Ross, Brian H (Ed). *The psychology of learning and motivation: Advances in research and theory*, Vol. 53 (pp. 1–32). San Diego, CA: Elsevier Academic Press.
- Nairne, J. S., VanArsdall, J. E., & Cogdill, M. (2017). Remembering the living: Episodic memory is tuned to animacy. *Current Directions in Psychological Science*, 26, 22–27.
- Nairne, J. S., VanArsdall, J. E., Pandeirada, J. N. S., Cogdill, M., & LeBreton, J. M. (2013). Adaptive memory: The mnemonic value of animacy. *Psychological Science*, 24, 2099–2105.
- Popp, E. Y., & Serra, M. J. (2016). Adaptive memory: Animacy enhances free recall but impairs cued recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 42, 186–201.
- Popp, E. Y., & Serra, M. J. (2018). The animacy advantage for free-recall performance is not attributable to greater mental arousal. *Memory*, 26, 89–95.
- Schneider, I. K., Veenstra, L., van Harreveld, F., Schwarz, N., & Koole, S. L. (2016). Let's not be indifferent about neutrality: Neutral ratings in the International Affective Picture System (IAPS) mask mixed affective responses. *Emotion*, 16, 426–430.
- Talmi, D., Lohnas, L., & Daw, N. (2017). A retrieved context model of the emotional modulation of memory. *bioRxiv*, 175653.
- VanArsdall, J. E., Nairne, J. S., Pandeirada, J. N. S., & Blunt, J. R. (2013). Adaptive memory: Animacy processing produces mnemonic advantages. *Experimental Psychology*, 60, 172–8.
- VanArsdall, J. E., Nairne, J. S., Pandeirada, J. N. S., & Cogdill, M. (2015). Adaptive memory: Animacy effects persist in paired-associate learning. *Memory*, 23, 657–663.
- VanArsdall, J. E., Nairne, J. S., Pandeirada, J. N. S., & Cogdill, M. (2017). A categorical recall strategy does not explain animacy effects in episodic memory. *The Quarterly Journal of Experimental Psychology*, 70, 761–771.