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Do animacy effects persist in memory for context?

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Abstract

The adaptive view of human memory assumes that animates (e.g, *rabbit*) are remembered better than inanimates (e.g. *glass*) because animates are ultimately more important for fitness than inanimates. Previous studies provided evidence for this view by showing that animates were recalled or recognized better than inanimates, but they did not assess memory for contextual details (e.g., *where* animates vs inanimates occurred). In this study, we tested recollection of spatial information (Study 1) and temporal information (Study 2) associated with animate versus inanimate words. The findings showed that the two types of contextual information were remembered better when they were related to animates than to inanimates. These findings provide further evidence for an ultimate explanation of animacy effects.

Keywords

Episodic memory; animacy; memory for context; evolutionary psychology

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A growing number of studies provide evidence for the view that human memory systems were shaped to remember information relevant for fitness (i.e., items related to survival and/or reproduction) better than any other kind of information. This is known as the adaptive memory view (Bonin & Bugaiska, 2014; Nairne, 2010 for reviews). Three types of evidence support the adaptive view of memory championed by Nairne and colleagues: survival-processing effects (also referred to as the survival-processing advantage, i.e., words processed with respect to an imagined survival scenario are remembered better than words processed with respect to imagined non-survival scenarios, e.g., moving to a foreign country, or with respect to standard deep processing control conditions, e.g., pleasantness ratings [see Aslan & Bäuml, 2012; Nairne, Pandeirada, & Thompson, 2008; Nairne, Thompson, & Pandeirada, 2007]), contamination effects (Nairne, 2015) and animacy effects (Bonin, Gelin, & Bugaiska, 2014; Nairne, VanArsdall, Pandeirada, Cogdill, & LeBreton, 2013; VanArsdall, Nairne, Pandeirada, & Blunt, 2013). It is the latter type that is addressed in the present article.

To clarify what is meant by animates, Gelman and Spelke (1981) described five fundamental differences between animate and inanimate objects: (a) animate entities are agents that can initiate action in a causal event, whereas inanimate entities are affected by it; (b) animate objects grow and reproduce; (c) they may have mental states such as thinking, perceiving, and feeling; (d) they are composed of parts directly related to biological functions; and (e) only animates are capable of communication and reciprocity. In the context of the present study, animates are defined as entities that are living and that are capable of self-propelled motion (Di Giorgio, Lunghi, Simion, & Vallortigara, 2017).

Several lines of evidence suggest that animates have a processing advantage over inanimates. First of all, the ability to distinguish between animates and inanimates is a fundamental cognitive ability that emerges early in life (Mandler & McDonough, 1998). Second, a number of studies have provided evidence supporting an animate monitoring hypothesis, which postulates that humans are tuned to pay more attention to animals than to artifacts, even to modern familiar ones such as cars (New, Cosmides, & Tooby, 2007). For ancestral hunter-gatherers immersed in a rich biotic environment, animals and human beings

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were important categories that had to be carefully attended to (Orians & Heerwagen, 1992). For example, family members or friends could require particular protection; strangers could constitute either potential mates or enemies; many animals were predators and thus dangerous. Finally, a number of recent studies suggest that human memory systems evolved to remember animates better than inanimates (in adults: Bonin et al., 2014; Bonin, Gelin, Laroche, Méot, & Bugaiska, 2015; Gelin, Bugaiska, Méot, & Bonin, 2017; Nairne et al., 2013; VanArsdall et al., 2013; VanArsdall, Nairne, Pandeirada, & Cogdill, 2015; in young children: Aslan & John, 2016). Animacy effects in memory have been found with non-words associated with animate versus inanimate properties (VanArsdall et al., 2013), with words (Nairne et al., 2013) and with pictures (Bonin et al., 2014). They are robust effects since they have been found in free recall and in recognition tasks (Bonin et al., 2014; Nairne et al., 2013), and also in cued recall (VanArsdall et al., 2015; but see Popp & Serra, 2016, who did not find animacy effects in cued recall[1]).

Given the high number of semantic, lexical, and sublexical dimensions that have been controlled for in studies examining animacy effects in memory performance (e.g. Bonin et al., 2014; Nairne et al., 2013), it seems unlikely that they are due to some uncontrolled variables.[2] In the literature on animacy effects in memory, the evolutionary-functional account of these effects came first. However, proximate explanations are also needed and should be understood as complementary, not opposing processes (Nairne & Pandeirada, 2016). Hence, the proximate mechanisms that underpin animacy effects have begun to be explored and the available evidence suggests that (a) the mechanisms are different from those involved in the survival-processing advantage (Gelin et al., 2017), (b) imagery processes contribute to these effects (Bonin et al., 2015), and (c) importantly, animacy effects in recall rates are not linked to differences in the organizational structure of animates versus inanimates (e.g., Gelin et al., 2017; VanArsdall, Nairne, Pandeirada, & Cogdill, 2017).

One important aspect of the data reported by Bonin et al. (2014) relates to animacy effects on hit responses in a recognition task using the "Remember/Know" paradigm. This paradigm, developed by Gardiner (1988), distinguishes between two types of consciousness: autonoetic consciousness, which is the memory of a past event by mentally traveling back in time to relive it in context, and noetic consciousness, which involves general knowledge about our environment without being able to put items in context (Tulving, 1985). According to Tulving (1985), these two states of awareness reflect two mind/brain systems, namely, episodic and semantic memory (see also Wheeler, Stuss, & Tulving, 1997). More precisely, Bonin et al. (2014) reported more "remember" responses for animate than for inanimate items that had been recognized, suggesting that animates benefit from a richer encoding context than inanimates, leading to better recollection of these words. Thus, the animate dimension would increase not only the amount of information stored in long-term memory but also the quality of that information. However, more evidence is needed to substantiate the claim that animates are retained in long-term memory with more contextual details than inanimates. This was precisely the aim and the novelty of the present study. Indeed, we are not aware of any studies to date that have tested whether memory for temporal or spatial contextual information is associated with remembering animate versus inanimate items. In the two studies described below, we tested whether the better recognition of animates than inanimates found in previous studies (Bonin et al., 2014; VanArsdall et al., 2013) is accompanied by better memory of the spatial and temporal contextual aspects of animate than of inanimate items. Memory for context is generally assessed by asking participants to retrieve contextual information linked to the target, such as sensory/perceptual information, spatial and temporal information, or semantic and emotional information (Johnson, Hashtroudi, & Stephen, 1993). A few studies have examined the recall of contextual information for items encoded in survival contexts (Bröder, Krüger, & Schütte, 2011; Nairne, Pandeirada, Smith, Grimaldi, & Bauernschmidt, 2010; Nairne, Pandeirada, VanArsdall, & Blunt, 2015; Nairne, VanArsdall, & Blunt, 2012). Neither Bröder et al. (2011) nor Nairne et al. (2010) (the latter study is also described in Nairne et al., 2012) were able to find a survival-processing advantage in memory for context. Both studies addressed memory for location of the items. Participants had to rate the relevance of words in two different scenarios: the original grassland scenario and a deep encoding control condition (the fancy vacation resort scenario and the moving scenario in Bröder et al., 2011, and the pleasantness rating task in Nairne et al., 2010). In Bröder et al.'s (2011) Study 1, words were presented individually in one of 16 squares that were arranged in a large 4 × 4 square on the computer screen. In their Study 2, and in Nairne et al. (2010), there were only two screen positions (the lower or upper half of the screen, and the right or left of the screen, respectively). In Bröder et al.'s (2011) study, the participants had to decide whether any given word was "new" or "old," whereas in Nairne et al. (2012), they had to recall them. For each recognized ("old") word, or for each recalled word, they had to indicate where it was initially presented on the screen. Across studies, the survival-processing advantage was found on item memory (but see Bröder et al.'s [2011] Study 1, in which the survival-processing advantage on item memory was not found when the vacation resort scenario was used as a control non-survival scenario), but there was no reliable survival advantage in location memory. Given the adaptive significance of memory for contextual information in a survival situation, this null finding was clearly not anticipated. However, both research teams acknowledged that a lack of ecological validity pertaining to the studies addressing this issue could have explained this unexpected result (Bröder et al., 2011; Nairne et al., 2012). However, in a subsequent study, Nairne et al. (2012) provided evidence that location memory is enhanced when the collection or capturing task is critical for the survival of individuals in a group. Finally, other studies found memory for survival-related items. For example, a significant female advantage in location memory for food items has been observed (New, Krasnow, Truxaw, & Gaulin, 2007). Moreover, in a game of pelmanism, the spatial location of evolutionarily relevant stimuli (e.g. "snakes") was memorized better than that of non-evolutionary relevant stimuli (Wilson, Darling, & Sykes, 2011). Finally, Maner, Gailliot, and DeWall (2007) found that remembering the identity of people ("who") and their location ("where") was enhanced when they were seen as potential mates or rivals.

The present study

Recollection can be measured either by subjective reports, for example, using the Remember/Know paradigm, or by objective information such as the context of the item, e.g., where or when the item was presented. These contextual features can act as powerful retrieval cues (Godden & Baddeley, 1975). Likewise, if animacy effects are supported by recollection, they should be observed not only on item memory, as found in previous studies (Bonin et al., 2014), but also on memory for contextual information. From a fitness point of view, in the distant past, remembering having seen a hungry lion or a dangerous snake was important, but remembering exactly *where and when* they were seen was even more important in order to avoid encountering them again. Below, we describe two studies that were designed to determine whether animacy effects are found on memory for context. More precisely, we explored whether the memory advantage of animates over inanimates is linked to contextual information pertaining to spatial information (Study 1) and to temporal information (Study 2).

Study 1: Spatial context, where?

In addition to replicating the animacy effects on recognition (Bonin et al., 2014), the goal of Study 1 was to test whether animacy effects are also found on memory for spatial context. We used the same memory paradigm as Bröder et al. (2011) with some slight alterations to investigate the influence of the animacy dimension.

Method

Participants. A total of 34 students, 28 women and 6 men (mean age 20.35 years, range 17-25 years) from the University of Bourgogne participated in the study in exchange for course credits. None were taking medication known to affect the central nervous system and they were all native French speakers.

Stimuli. A total of 64 nouns were selected from the databases of Snodgrass and Vanderwart (1980) and Bonin, Peereman, Malardier, Méot, and Chalard (2003). Each word referred to either an animate or an inanimate object. The 64 nouns were initially classified into animates and inanimates by the authors. As in Bonin et al. (2015), we gauged the reliability of our classification by asking five independent adults to rate the nouns used in the two studies on a 3-point scale (1 = *clearly referring to an animate*, 2 = *ambiguous*, 3 = *clearly referring to an inanimate*). The agreement between the five raters was perfect (Fleiss' $\kappa = 1$), fully supporting our classification.

Half of the to-be-studied items represented animates and half inanimates; these two sets were matched on various linguistic variables (e.g., number of letters, word frequency, imageability) whose statistical characteristics are reported in Table 1.

In addition, 64 new words (half animates and half inanimates) were used for the "new" responses in the recognition task. These new words ("new") matched the initial experimental words ("old") on subtitle frequency ("old," $m = 20.29$, standard deviation [SD] = 41.57, *min-max* = 0.06-188.41; "new," $m = 13.17$, $SD = 20.64$, *min-max* = 0.11-112.43; $t = 1.22$), book frequency ("old," $m = 23.6$, $SD = 52.6$, *min-max* = 0.07-315.74; "new," $m = 18.02$, $SD = 34.79$, *min-max* = 0.07-199.39; $t < 1$), age of acquisition ("old," $m = 2.57$, $SD = 0.72$, *min-max* = 1.15-4.2; "new," $m = 2.66$, $SD = 0.81$, *min-max* = 1.35-4.62; $t < 1$), and number of letters ("old," $m = 6.41$, $SD = 1.88$, *min-max* = 3-10; "new," $m = 6.73$, $SD = 2.19$, *min-max* = 3-15; $t < 1$).

Procedure. Participants were tested two at a time and were seated comfortably in a quiet room. They were not informed that the experiment involved memory but were merely told to read each word carefully. The words were presented on a Macintosh computer running the Psyscope v.1.2.5 software (Cohen, MacWhinney, Flatt, & Provost, 1993).

Figure 1 illustrates the structure of the learning phase. For each participant, the 64 words were presented randomly in a different order and in a different location on the screen. There were four possible locations corresponding to the four corners of the screen. As in Bonin et al. (2014), the participants were given a brief definition of "animate" versus "inanimate" (e.g., an animate item is capable of self-propelled motion whereas an inanimate item is not) at the beginning of the experiment. They were then told that they would see a series of words and would have to decide whether each word referred to an animate or an inanimate item. We also made sure that animate and inanimate items occurred equally often in each screen

Table 1. Statistical characteristics (means, standard deviations, range, minimum-maximum, *t*-tests of the means) of the control variables for animate and inanimate stimuli.

	Animate				Inanimate				*t*-test
	Mean	SD	Range	Min-max	Mean	SD	Range	Min-max	
Number of letters[a]	6.38	1.88	7	3–10	6.44	1.87	7	3–10	0.90
Bigram frequency (per million words)[a]	8745.56	3125.12	14120	2963–17083	9787.63	2570.5	11616	2360–13976	0.16
Book frequency[a]	16.12	33.09	186.89	0.07–186.96	31.07	65.78	315.67	0.07–315.74	0.26
Subtitle frequency[a]	20.77	43.16	188.26	0.15–188.41	19.82	39.9	176.04	0.06–176.1	0.93
Age of acquisition (1–5)[b]	2.47	0.62	2.6	1.15–3.75	2.67	0.79	2.97	1.23–4.2	0.26
Number of orthographic neighbors[a]	2.66	4.43	20	0–20	2.81	4.65	20	0–20	0.89
Orthographic uniqueness point[a]	4.81	2.13	10	0–10	5.03	2.56	9	0–9	0.72
Conceptual familiarity (1–5)[b]	2.21	0.85	3.48	1.07–4.55	2.65	0.98	3.79	1.18–4.97	0.07
Imageability (1–5)[c]	4.43	0.36	1.32	3.64–4.96	4.24	0.48	1.72	3.24–4.96	0.10
Image variability (1–5)[b]	2.72	0.64	2.45	1.85–4.3	2.61	0.62	2.42	1.65–4.07	0.49
Concreteness (1–5)[c]	4.6	0.34	1.27	3.64–4.91	4.68	0.34	1.95	3.05–5	0.36
Emotional valence (1–5)[c]	3.26	0.73	3.24	1.32–4.56	3.1	0.67	2.84	1.52–4.36	0.36

SD: standard deviation.

[a] Values taken from Lexique (http://www.lexique.org; New, Pallier, Brysbaert, & Ferrand, 2004).

[b] 5-point scales, with values obtained from Bonin et al. (2003) and from Alario and Ferrand (1999).

[c] 5-point scales, with values obtained from Bonin, Méot, et al. (2003).

position. However, they were not told to pay attention to where the words appeared on the screen. The learning phase was followed by two interference tasks lasting about 5 min: the "X-O" letter-comparison task (Salthouse, Toth, Hancock, & Woodard, 1997) and the "plus-minus" task (from Jersild, 1927; Spector & Biederman, 1976). After completing these two tasks, participants performed a memory test for screen position. This consisted of a recognition test with a set of 128 words (64 targets and 64 fillers), presented randomly in the middle of the screen, with no time limit. For each word, participants had to indicate whether or not they recognized it from the set presented previously by pressing a key. For each word they recognized, they indicated where it initially appeared on the screen (top left, top right, bottom left or bottom right). The next word appeared immediately after they had given this information or indicated that they had not recognized the word. After the 128 test words had been presented, the participants were thanked and debriefed. The experiment lasted about 20 min.

Results

Encoding times. Inanimate words took significantly longer to categorize ($m = 1289.63$ ms, $SD = 789.56$) than animate words ($m = 1209.88$, $SD = 777.44$), $t(33) = 2.24$, $p < .05$, $d = 0.20$.

Item memory. The hit rates, corrected hit rates, false alarm rates, and A′ measures (Neath & Surprenant, 2003) for both animate and inanimate words are shown in Table 2. The dependent variable of item memory was based on hits minus false alarms. We also computed a nonparametric discrimination index from signal detection theory (A′, e.g., Donaldson, 1992). Below, we report the results on the A′ index only. (The results for corrected hit rates, i.e., hits minus false alarms, and false alarms can be found in the Supplementary materials.)

Animate words were recognized better than inanimate words, $t(33) = 5.12$, $p < 0.001$, $d = 0.98$ (according to Cohen, 1988, $d > 0.80$ is a large effect).

Memory for context. To assess contextual memory performance, we used the conditional source identification measure (Murnane & Bayen, 1996), which is based on correctly recognized items only and therefore does not confuse item memory and contextual memory. For each participant, we calculated the number of animate versus inanimate words for which the contextual information was correctly identified, i.e., #context animates versus #context inanimates (e.g., one participant correctly identified the location on the screen of 14 animate and 8 inanimate words). We then examined the corresponding number of hits for animates (#hits animates) and inanimates (#hits inanimates) (e.g., the participant correctly recognized 27 animate and 18 inanimate words). Finally, we computed the proportion of animates whose contextual information had been correctly identified, i.e., #context animates/#hits animates, and the proportion of inanimates whose contextual information had been correctly identified, i.e., #context inanimates/#hits inanimates.

For these correctly recognized items, the mean proportion of correct judgments for screen position made by each participant was 0.49 ($SD = 0.15$). Importantly, accuracy for contextual information differed significantly from chance level (25%), $t(33) = 9.09$, $p < 0.001$.

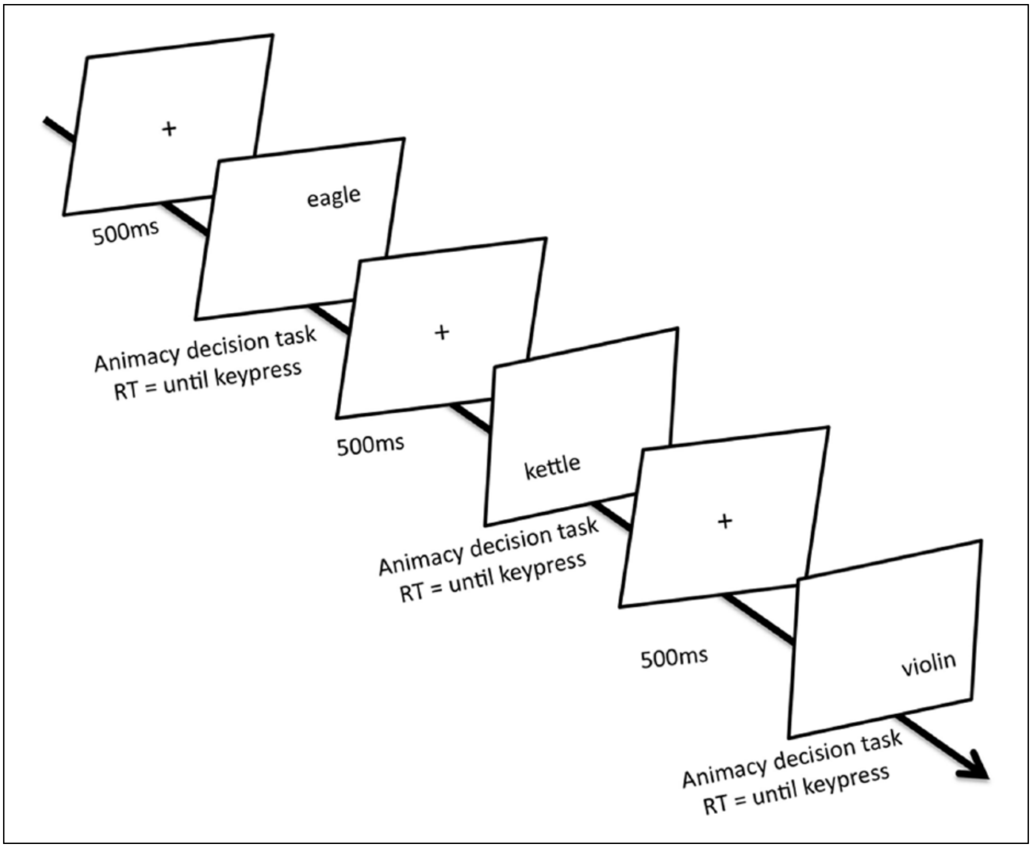

Figure 1. Structure of the learning phase in Study 1.

Table 2. Hit rates, corrected hit rates, false alarm rates, and A′ as a function of type of word in Studies 1 and 2. Standard deviations are provided in parentheses.

	Hit rates	Corrected hit rates	False alarm rates	A′
Study 1				
Inanimate words	0.68 (0.14)	0.60 (0.16)	0.08 (0.06)	0.88 (0.06)
Animate words	0.80 (0.09)	0.74 (0.11)	0.06 (0.07)	0.93 (0.04)
Study 2				
Inanimate words	0.69 (0.16)	0.60 (0.16)	0.09 (0.09)	0.88 (0.06)
Animate words	0.78 (0.11)	0.69 (0.15)	0.09 (0.09)	0.91 (0.05)

As can be seen in Figure 2, there was a significant difference between animates ($m=0.53$, $SD=0.19$) and inanimates ($m=0.46$, $SD=0.16$), $t(33)=2.58$, $p<0.05$, $d=0.42$.

Discussion of Study 1

The findings on encoding times are fully consistent with previous data on animacy effects. As in Bonin et al. (2014) and VanArsdall et al. (2013), animates were categorized faster than inanimates (see also Gelin et al., 2017). We also replicated the finding of better recognition for animates than inanimates. Finally, and more importantly given the purpose of the study, the findings regarding memory for context are consistent with those observed with the Remember/Know paradigm in Bonin et al. (2014). Thus, animacy effects in memory are supplemented by the recall of contextual details, here screen position. Many studies of memory for contextual information are interested in different types of contextual details. The next study thus involved memory for temporal information associated with animates versus inanimates.

Study 2: temporal context, when?

To our knowledge, no study has as yet explored memory for temporal information in the context of adaptive memory. However, from an adaptive perspective, it also seems important to remember the temporal context of fitness-related

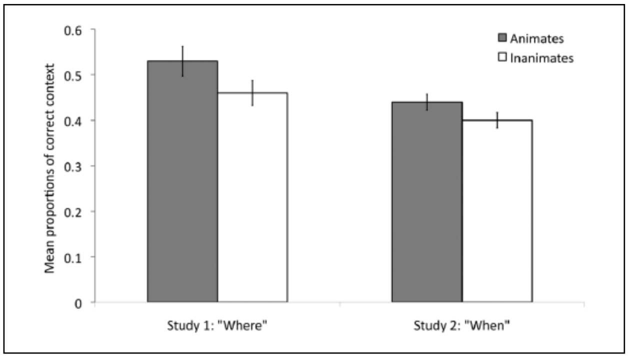

Figure 2. Mean proportions and standard errors of correct context as a function of Type of word (animates versus inanimates) and Type of context ("Where": Study 1 and "When": Study 2).

information. For example, it is important for hunters to remember not only where potential prey come to drink water, but also *when* they usually come. Hence, it could be predicted that temporal information would be remembered better when it is related to animates than to inanimates.

Method

Participants. A total of 38 students at the University of Bourgogne took part in the study in exchange for course credits, but only 34 (30 women, 4 men, mean age 20.97 years, range 17-25 years) were included in the analyses (below). None were taking medication known to affect the central nervous system and all were native French speakers.

Stimuli. The same word stimuli as in Study 1 were used.

Procedure. The procedure was the same as in Study 1 except that the words always appeared in the center of the screen, alongside a text indicating "beginning of the presentation," "middle of the presentation," or "end of the presentation." The participants were told that they would see a series of words and would have to decide whether each word referred to an animate or an inanimate item. However, they were not instructed to attend to the items' temporal position. They then completed the same two interference tasks used in Study 1, lasting approximately 5 min. Finally, they were tested for their memory. First, they had to indicate whether each word was "old" (i.e. they recognized it from the initial phase of the experiment) or "new." Next, in order to evaluate the temporal dimension of contextual memory, the participants were asked to indicate whether an "old" word had appeared at the beginning, in the middle, or at the end of the presentation. As in the previous study, care was taken to ensure that animate and inanimate words occurred equally often in each temporal order. The next word appeared as soon as they had given this information, or indicated that they did not recognize the word. After all the test words had been presented, participants were thanked and debriefed. The whole experiment lasted about 20 min.

Results and discussion of Study 2

Encoding times. Participants took significantly longer to categorize inanimate ($m=1481.12$ ms, $SD=544.40$) than animate words ($m=1326.95$, $SD=466.34$), $t(33)=4.11$, $p<0.001$, $d=0.30$.

Item memory. The hit rates, corrected hit rates, false alarm rates, and A' measures for animate and inanimate words are shown in Table 2. Here also, animates were recognized better than inanimates, $t(33)=2.48$, $p<0.05$, $d=0.54$.

Memory for context. Memory for context was measured as in the previous study. The mean proportion of correct context judgments made by each participant was 0.42 ($SD=0.07$). Context accuracy differed significantly from chance level, which was 0.33, $t(33)=7.68$, $p<0.001$. For each participant, we computed the proportions of animate and inanimate words in memory for context. There was a significant difference between animates ($m=0.44$, $SD=0.10$) and inanimates ($m=0.40$, $SD=0.10$), $t(33)=2.06$, $p<0.05$, $d=0.50$ (see Figure 2).

As in Study 1, not only were animates categorized faster than inanimates, but they were also recognized better. Finally, they were also better localized in the temporal context of their presentation.

General discussion

According to the adaptive view of memory, evolutionary pressures encountered in the distant past sculpted our memory systems to retain fitness-related information (Nairne, 2010, 2015). Animates have greater fitness value than inanimates, and they should therefore be remembered better. This advantage of animates over inanimates has been replicated several times, by different research teams (e.g. Aslan & John, 2016; Bonin et al., 2014; VanArsdall et al., 2013). The findings of the current studies once again confirm the robustness of animacy effects. Moreover, as in previous studies (Bonin et al., 2014), animates were recognized better than inanimates when the animate items were displayed for a short time.[3] However, one important aspect of animacy effects in memory that had not previously been examined was whether they would be found in memory for context; adopting an evolutionary framework suggests that they should be. We conducted two studies to assess the recollection of spatial information (i.e., screen location in Study 1) and temporal information (i.e., within-list temporal location in Study 2) related to animate versus inanimate items. We found that both types of information were remembered better when they were related to animates than to inanimates.[4] It is important to stress that these findings in memory for context occurred even though the words were processed quickly and that encoding was incidental, two conditions that have sometimes been shown to impede memory for context (Brewer, Marsh, Clark-Foos, & Meeks, 2010; Meiser & Sattler, 2007).

In sum, the present research increases our knowledge about animacy effects in memory by providing evidence that animacy effects persist in memory for context. Skeptical readers might think that a potential limitation of our findings lies in the fact that we chose an animacy categorization task at encoding. This task could give participants a clue about the nature of the upcoming memory test. Moreover, if participants encoded items stressing the animacy dimension, animate words could be more congruent with the encoding context and consequently remembered better because congruency is known to improve memory (Craik & Tulving, 1975).[5] However, we do not think that our findings are undermined by the choice of an animacy-inanimacy categorization task at encoding for the following reasons. First, before beginning the categorization task, the participants were given a brief definition of what is meant by animate *and* inanimate. Thus, animates were not given greater emphasis than inanimates. Second, an animacy effect has been obtained in previous studies (e.g. Bonin et al., 2015; Gelin et al., 2017; VanArsdall et al., 2013) in which intentional learning was used and in which attention was not drawn to the animacy dimension. Third, if, for whatever reason, the participants became aware of the future memory test during the specific encoding task used in the current studies, and if this led animates to be remembered better than inanimates, then why were there no reliable differences in false alarm rates between animate and inanimate items in the two studies (the results can be found in the Supplementary materials)? If greater attention was drawn to animate items during encoding, one would expect a bias toward false recognition of animates during the recognition phase. Fourth, we computed B''_{D} as an index of bias (Donaldson, 1992) in both studies. The difference between animates (Study 1: $B''_{\mathrm{D}} = 0.59$; Study, 2: $B''_{\mathrm{D}} = 0.48$) and inanimates (Study 1: $B''_{\mathrm{D}} = 0.68$; Study 2: $B''_{\mathrm{D}} = 0.59$) was not significant in either study (Study 1: $t(33) = -1.19$, *ns*; Study 2: $t(33) = -1.37$, *ns*). Thus, the participants were not biased more toward animate than inanimate items.

It is important to stress that the present studies are the first in the field of adaptive memory to report animacy effects on context memory. Earlier studies on adaptive memory focused on survival processing and item memory. They found that processing items (words or pictures) in relation to survival issues (e.g., judging whether a *bottle* is useful for collecting food, or for protecting oneself from predators) for just a few seconds led to a memory boost compared to processing the same items in relation to non-survival issues (e.g., judging whether a *bottle* is useful when moving to a foreign country; is pleasant) (see Bonin & Bugaiska, 2014; Nairne & Pandeirada, 2016 for reviews). Even though boundary conditions have been identified for survival-processing effects (e.g., they are not found with stories [Seamon et al., 2012], faces [Savine, Scullin, & Roediger, 2011], or in implicit memory tasks [Tse & Altarriba, 2010]), the survival-processing advantage and animacy effect appear to be robust empirical phenomena. Regarding the survival-processing advantage, Nairne (2016) indicated that it has been widely replicated, since it was found reliable in 106 out of 132 published studies. Animacy effects are more recent in the memory literature, and more work is thus needed to gain an overview of their robustness. So far, only one study (Popp & Serra, 2016) has found a reverse animacy effect in cued recall, which suggests that there are other boundary conditions for these effects that need to be identified in future studies.

What remained unclear was whether the survival-processing advantage extended to context memory. As reviewed in the Introduction, some earlier studies failed to find a survival-processing advantage in memory for contextual information (Bröder et al., 2011; Nairne et al., 2010). However, these studies were criticized on the grounds that they lacked ecological validity (Nairne et al., 2012). What is striking, however, is that in our current studies, we found that contextual information linked to animates was better remembered than contextual information linked to inanimates, even though we used a procedure to test context memory that was similar to those used by Bröder et al. (2011) and Nairne et al. (2010). In Bröder et al.'s (2011) Experiment 1, individual words were presented in one of 16 squares displayed on the computer screen, while in their Experiment 2 and in Nairne et al.'s (2010) study, there were only two screen locations (bottom or top in Bröder et al., 2011, and left or right in Nairne et al., 2010). Thus, our experiments could also be criticized on the grounds that they lacked ecological validity, and we acknowledge that our findings do not allow firm conclusions to be drawn, insofar as they did not test for contextual information related to dangerous animals (e.g., where was the snake) or enemies. We suggest that contextual memory may be more difficult to assess within the context of survival processing. However, other studies have found evidence for contextual information when processing items related to survival issues (Nairne et al., 2012; New et al., 2007), for example, evolutionarily dangerous animals such as snakes (Wilson et al., 2011), or in a mating context (Maner et al., 2007). Here, we found animacy effects in memory for context relating to both spatial *and* temporal information. However, as far as survival effects are concerned, it is important to note that no study to date has tested whether processing survival-related items leads to better memory of contextual temporal information.

Finally, although there is evidence suggesting that animacy effects are episodic in nature (Bonin et al., 2014) and rely on proximate mechanisms related to imagery (Bonin et al., 2015; Popp & Serra, 2016), survival-processing effects seem to be more difficult to define. They appear to be unique in that they are not reducible to another form of deep encoding (Nairne et al., 2015), and also, importantly, because their precise underlying proximate mechanisms have not as yet been clearly identified (Nairne, Cogdill, & Lehman, 2017).

We believe that the finding that animacy effects persist in memory for context is very important as it strengthens the ultimate explanation of animacy effects. However, even for researchers who do not adhere to the evolutionary-functional account of animacy effects, the animacy variable cannot simply be ignored because it accounts for a significant amount of variance in memory performance and plays as important a role as imageability, which is acknowledged to be a major factor that must be controlled for when designing memory experiments (Nairne et al., 2013). Thus, at the very least, animacy is a factor that should be taken into account for methodological reasons. The influence of animacy in memory is a relatively new discovery in the memory literature, and even though some research work has been devoted to the proximate mechanisms underpinning animacy effects (e.g., Bonin et al., 2015; Popp & Serra, 2016; VanArsdall et al., 2017), future studies are clearly needed in order to achieve a better understanding of how exactly these effects come about.

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Supplementary Material

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Notes

1. In line with previous findings (Bonin, Gelin, & Bugaiska, 2014; VanArsdall, Nairne, Pandeirada, & Blunt, 2013), Popp and Serra (2016) found that animates were remembered better than inanimates, but a reverse effect of animacy was found in cued recall (e.g. *bottle, clock* recalled better than *bear, camel*). Certain readers might well be tempted to take this finding as running counter to an evolutionary account of animacy effects in memory. As discussed in-depth by Nairne and Pandeirada (2016) regarding the survival-processing advantage in memory, the observation of boundary conditions of this effect—and of an animacy effect in the present case—should not be taken as ruling out an ultimate account. For instance, while a basic reflex disappears when a relevant neurotransmitter is blocked, this does not mean that the reflex is not an adaptation. In the case of the reverse animacy effect in cued recall, as explained by Popp and Serra (2016), the same proximate mechanism—attention capture or mental arousal—involved in animacy effects in memory can, depending on the task, alter the relationship between animacy and memory, without challenging the ultimate explanation of these effects.
2. In effect, it is important to stress that virtually all important psycholinguistic variables known to affect lexical processing have been investigated either methodologically or statistically in studies examining animacy effects (e.g. Bonin et al., 2014; Gelin, Bugaiska, Méot, & Bonin, 2017).
3. Readers may have noticed that the rating times were longer in Study 2 than in Study 1. However, a supplementary analysis run on the rating times from the two studies, with Type of context and Type of word included as factors, revealed that rating times did not reliably differ between the two studies. The only reliable effect was that of Type of word, $F(1, 66)=20.52$, $p<0.001$. In any case, as previously suggested (Bonin et al., 2014), the rating times indicate that the animacy effect in recognition cannot be due to animates being processed for a longer time than inanimates. (However, the results of such a joint analysis should be interpreted with caution, as participants were not fully randomized across all conditions.)
4. Interestingly, a supplementary analysis of the contextual recollection scores from the two studies with Type of context and Type of word included as factors revealed that the memory advantage of animates over inanimates was similar across both types of contextual information—the animacy factor was significant, $F(1, 66)=10.88$, $p<0.001$, as was the Context factor, $F(1, 66)=6.74.$, $p<0.05$, whereas the interaction between Type of context and Type of word was not, $F<1$. Power analysis revealed that in order for an (interaction) effect of this size to be detected (80% chance) as significant at the 5% level, a sample of 298 participants would be required. (As mentioned in Footnote 3, the results of such a joint analysis should be interpreted with caution, as participants were not fully randomized across all conditions.)
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