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Animacy effects in episodic memory: do imagery processes really play a role?

Margaux Gelin[a], Aurélia Bugaiska[a], Alain Méot[b], Annie Vinter[a] and Patrick Bonin[a]

[a]LEAD-CNRS, Université de Bourgogne Franche-Comté, Dijon, France; [b]CNRS, LAPSCO, Université Clermont Auvergne, Clermont-Ferrand, France

ABSTRACT

Animates are remembered better than inanimates because the former are ultimately more important for fitness than the latter. What, however, are the proximate mechanisms underpinning this effect? We focused on imagery processes as one proximate explanation. We tested whether animacy effects are related to the vividness of mental images (Study 1), or to the dynamic/motoric nature of mental images corresponding to animate words (Study 2). The findings showed that: (1) Animates are not estimated to be more vivid than inanimates; (2) The potentially more dynamic nature of the representations of animates does not seem to be a factor making animates more memorable than inanimates. We compared (Study 3) a condition in which participants had to categorise animate and inanimate words with a condition in which they had to form mental images from them. The animacy effect was significant after categorising but not after forming mental imagery. In Study 4, we compared the recall rates of animates and inanimates after these words had been encoded with or without a concurrent visual-spatial memory load. Again, animates were better remembered than inanimates. Taken overall, the findings do not fit well with the hypothesis that imagery processes support animacy effects in memory.

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Rubin and Friendly (1986) were the first to thoroughly investigate the impact of various item characteristics on memory performance in adults. It is now well-known that item-based characteristics influence lexical processing and long-term encoding and, as a result, that certain important dimensions must be taken into account when selecting materials for the design of memory experiments. However, it is only recently that the investigation of a number of word features, such as number of semantic features (Hargreaves, Pexman, Johnson, & Zdrazilova, 2012), or manipulability of the objects (Madan & Singhal, 2012), has been the focus of specific studies on memory. The different word characteristics include semantic characteristics such as concreteness, imageability, or emotional valence. Importantly, recent studies have found that animacy, which is also a semantic variable, has a prominent role in episodic memory (Bonin, Gelin, & Bugaiska, 2014; Bonin, Gelin, Laroche, Méot, & Bugaiska, 2015; Nairne, VanArsdall, Pandeirada, Cogdill, & LeBreton, 2013; VanArsdall, Nairne, Pandeirada, & Blunt, 2013; see Nairne, VanArsdall, & Cogdill, 2017 for a review).

We adopted the definition of animacy put forward by Popp and Serra (2018): (…) "animacy" *refers to the traits that help us to distinguish living things from non-living things*. One powerful defining trait of animates is self-propulsion (Di Giorgio, Lunghi, Simion, & Vallortigara, 2017). Thus, animates can be defined as *any living entity* that is able *to move by self-propulsion*.[1] VanArsdall et al. (2013) reported that nonwords associated with properties that caused them to appear as animates (e.g., *JODE enjoys cooking*) were remembered better in free recall or in recognition than nonwords linked to properties that made them appear to be inanimates (e.g., *JODE is made of wood*). Nairne et al. (2013) further extended this finding to real words, showing that words referring to animates (e.g., *bird*, *baby*) were recalled better than words referring to inanimates (e.g., *mountain*, *glass*). Interestingly, Nairne et al. (2013) reanalysed the data from Rubin and Friendly (1986) and included animacy as a predictor variable. They found that animacy accounted for a large amount of variance in the recall rates. Furthermore, the animacy effects in memory found by Nairne et al. (Nairne et al., 2017 for an overview) have been replicated with a different set of words and in another language (Bonin et al., 2014) and they have also been found when pictures have been used as stimuli (Bonin et al., 2014). Importantly, using the remember-know paradigm (Gardiner, 1988), Bonin et al. (2014) indicated that animates were recognised better than inanimates on the "remember" responses, but not on the "know" responses, suggesting that these effects are episodic in nature (e.g., Gelin, Bonin, Méot, & Bugaiska [2018] showed that animacy effects are found also on the

CONTACT Patrick Bonin Patrick.Bonin@u-bourgogne.fr LEAD-CNRS (UMR 5022), Université de Bourgogne Franche-Comté, Pôle AAFE - Esplanade Erasme, BP 26513, 21065 Dijon Cedex, France
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remembering of contextual information, i.e., people remember the context in which animates are to be found better than that of inanimates, e.g., "where" and "when"). Also, animacy effects do not vary across different sets of encoding instructions and they are found in both explicit and implicit learning tasks (Gelin, Bugaiska, Méot, & Bonin, 2017). Thus, animacy effects in memory are robust.

It is important to stress that animacy was recently revealed to be an important mnemonic dimension because Nairne and colleagues adopted an evolutionary framework to study episodic memory (Nairne, 2010, 2015). According to this theoretical framework, certain functional characteristics of human memory were sculpted due to selective pressures faced by our ancestors in the distant past. Thus, animates (e.g., *tiger*) are remembered better than inanimates (e.g., *stone*) because the former items are of greater importance for survival and/or reproduction than the latter items, that is to say that they are of greater fitness value (e.g., animates can be dangerous animals). This ultimate explanation of animacy effects has to be complemented by proximate explanations. The present research focused on this latter type of explanations and addressed the issue of how animacy effects in memory emerge, i.e., what are the mechanisms underpinning these effects. More precisely, our aim was to further address the role of imagery processes in animacy effects in memory (Bonin et al., 2015).

Several hypotheses have been put forward in the literature to account for animacy effects in memory – attentional capture or mental arousal (Bugaiska et al., in press; Popp & Serra, 2016; but see Popp & Serra, 2018, concerning arousal), imagery processes (Bonin et al., 2015) – but none of these accounts is able to provide a full account of animacy effects. We shall return to the different hypotheses of animacy effects in memory that have been proposed in the General Discussion. As mentioned above, we focus here on one explanation of animacy championed by Bonin et al. (2015), namely the hypothesis that animates are remembered better than inanimates because the memory of animates relies more strongly on imagery processes than that of inanimates. In Bonin et al.'s (2015) Study 4, participants were assigned to one of the following two encoding conditions: interactive imaging versus animacy categorisation. In the animacy categorisation condition, they were given a brief definition of what is meant by "animates" *and* "inanimates" at the start of the experiment. They were then told that they would have to decide, as quickly as possible, whether any given word presented on the screen referred to an animate or to an inanimate item. In the interactive imagery condition, participants had to imagine, for each word, a situation in which they were interacting with the object, animal or person, the word referred to. They were further instructed that the situation could be real or fictional, i.e., perhaps they had never interacted with this object, but this might happen. After this study phase, there was a short distractor phase, after which the participants were given a surprise free recall test. In the interactive imagery group, the animacy effect on recall rate was reliable but it was smaller than the animacy effect found in the categorisation group. Importantly, the reduction of the animacy effect was entirely due to inanimates being recalled better when an interactive imagery strategy was used, as compared to a condition in which the participants were not explicitly told to use this type of encoding. According to Bonin et al. (2015), interactive imagery could be one proximate mechanism underpinning animacy effects in episodic memory.

In the present studies, our aim was to further explore the role of imagery processes in animacy effects in memory. In the first study, we tested whether the mental images generated from animate words tend to be associated with greater vividness than images generated from inanimate words. Vividness is a property of mental images that refers to the clarity and richness of mental images (Hayakawa & Keysar, 2018) and is different from imageability which corresponds to the ease with which a mental image can be generated from a word. In principle, two words can be judged to be equally imageable, but one of the two words may yield more vivid images (to anticipate our results, *dinosaur* and *shirt* are examples of such words, with imageability Z-scores of −.13 and −.03 but whose vividness Z-scores are −1.9 and 1.11 respectively). This property of mental images has not been taken into account in previous experiments on this topic and could be related to the memory performance on animate vs. inanimate words. In a second study, we assessed the role of motoric information in the mental images generated from animate words. It is possible that animates may lead to the creation of mental images that are more dynamic and motoric in nature than the mental images generated from inanimates, the latter being possibly more static in nature. The dynamic and motoric nature of mental images of animates could render their representations richer and thus easier to retrieve at recall than those of inanimates. Given the findings of Studies 1 and 2, in a third study, we investigated the effect of simply instructing participants to form mental images on the recall of animate versus inanimate words. Finally, we tested the involvement of imagery processes more directly in a fourth and final study using a memory load paradigm. The rationale of Studies 3 and 4 will be presented later.

Study 1. Vividness ratings of animates and inanimates

Episodic memories have several properties, one of which is that they are often represented in the form of visual images (Conway, 2009). These memories may come to mind with different levels of vividness. Vividness corresponds to the phenomenological experience of perceiving in one's head an object, a smell, a sound, etc., as if we were actually experiencing it with our senses. This property refers therefore to the clarity and richness of mental images (Hayakawa & Keysar, 2018). Indeed, our personal (autobiographical) memories vary as a function of the vividness of the details they comprise: Highly important personal experiences are often made up of vivid details (e.g., my first kiss was with a shy black-haired girl). While certain studies suggest that vivid items are recalled better (Collins, Taylor, Wood, & Thompson, 1988; D'Angiulli et al., 2013; Shedler & Manis, 1986), other studies have failed to find evidence that the vividness of information increases its memorability (e.g., Frey & Eagly, 1993).

One issue related to animacy effects is whether animates are inherently more vivid than inanimates, and whether this specific property of mental images could account, at least in part, for their better memorability. It is important to remember that animacy effects have been found when the imageability and concreteness factors were controlled for (e.g., Bonin et al., 2014). Thus, animacy effects are not merely due to the fact that animate items are easier to imagine (or more concrete) than inanimate items. However, the characteristics of episodic memories of animates versus inanimates – and in particular their degree of vividness – have not as yet been explored extensively. Study 1 therefore addressed this issue. Participants were given a list of words that referred to either animate concepts or to inanimate concepts and had to rate their degree of vividness using Likert scales.

Method

Participants

Twenty-three adults (13 women, mean age: 32.57 years old) were involved. There were psychology students together with employed adults.

Stimuli

The word stimuli ($N = 77$) were animate and inanimate words that had been used in our previous studies (Bonin et al., 2014, 2015; Gelin et al., 2017).

Procedure

The questionnaire was sent by email and completed at home by the participants. The words were presented in a list and, for each word, the participants were asked to rate the vividness of the visual imagery generated from it using a 5-point scale with 1 = "no image at all", 2 = "vague and dim", 3 = "moderately clear and vivid", 4 = "clear and reasonably vivid" and 5 = "perfectly clear and as vivid as normal vision". The instructions were adapted from the French translation by Santarpia et al. (2008) of the Vividness of Visual Imagery Questionnaire (VVIQ, Marks, 1973).

Results and discussion of study 1

The vividness ratings were reliable (Cronbach's alpha interrater reliability = .80).

The distributions of vividness scores for animates and inanimates are depicted in Figure 1. There was no reliable difference between the distributions of animates and

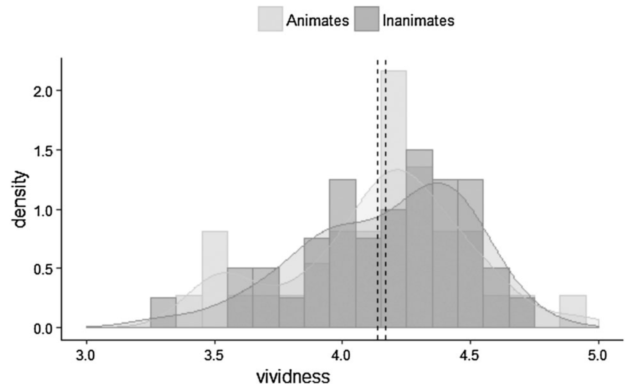

Figure 1. Density estimations of vividness scores for animates and inanimates.

Notes: Plain lines = density estimations; dashed lines = means of the two categories; histogram = percentage of words; histogram rescaled to give the density an area equal to 1.

inanimates (Kolmogorov–Smirnov test: $D = .155$, $p > .10$; Mann–Whitney test: *Mdn*(Animates) = 4.18, *Mdn*(Inanimates) = 4.23, $U = 795.5$, $p > .10$).

Over the whole set of items, words referring to animate concepts (A) were not rated as more vivid than words referring to inanimate concepts (I): $A = 4.14$, $I = 4.17$, $|t(75)| < 1$. In addition, this was the case with: (1) The 32 words taken from Gelin et al.'s (2017) Experiment 4 ($A = 4.24$ versus $I = 4.29$, $|t(30)| < 1$); (2) The 28 words taken from Bonin et al.'s (2015) Experiments 1–3 ($A = 4.01$ versus $I = 4.11$, $|t(26)| < 1$); (3) The 56 words taken from Bonin et al.'s (2014) Experiments 1–4 ($A = 4.09$ versus $I = 4.10$, $|t(54)| < 1$). Thus, contrary to our hypothesis that the visual images generated from animate words are more vivid than those generated from inanimates, the current findings show that this property cannot account for animacy effects in episodic memory.

In order to explore the role that vividness may play in connection with recall rates, together with its possible interaction with the animacy dimension, we introduced vividness and its interaction with the original independent variables as predictors in the reanalyses of the five experiments conducted by Bonin et al. (2015). These additional analyses (see Supplementary Material A for details) showed that vividness did not interact with the other independent variables (except with animacy in one of the five studies) and, importantly, the same patterns of results, and more particularly animacy effects, were found whether or not vividness was included in the analyses.

It might be argued that the fact that the vividness of the images generated for animate and inanimate items was similar when participants performed the task at their leisure at home does not necessarily mean that the vividness of the images would have been the same had they provided their ratings in a somewhat more stressful and time-constrained environment. Therefore, in order to address this concern, we decided to design another experiment which was more time-constrained, and also much more similar to the experimental settings used when evaluating animacy effects in memory. Words were thus rated in a laboratory setting resembling that used to assess animacy effects in memory. This did not alter the results: Animates were not rated as more vivid than inanimates. The details corresponding to this experiment and the full results are given in the Supplementary Material B.

It is important to note that, until now, studies on animacy effects in memory have controlled for the imageability dimension of the words but they have not specifically taken account of the vividness of the mental representations generated from animate and inanimate words. At a methodological level, the current finding is important since it rules out the interpretation that animacy effects in memory could be linked to this uncontrolled dimension.

Given that vividness is a property of mental images, the findings do not fit well with the hypothesis that imagery processes are involved in animacy effects in memory. However, another dimension of mental images could be involved: the dynamic/motoric dimension. It could be that animates yield mental images that are more dynamic/motoric in nature than those produced by inanimates, and that this dimension underpins the memory advantage of the former items. This issue was addressed in the next experiment.

Study 2. Are animacy effects due to the more dynamic/motoric nature of the representations of animate things?

Bonin et al. (2015) found that when participants were instructed to encode words by generating images in which they imagined certain interactions with the items denoted by the words (e.g., *glass*: taking a glass to their mouth; *fly*: trying to catch a fly with their hand), there was a long-term memory benefit for words referring to inanimates but not for words referring to animates, as compared to a control encoding situation where both types of words were simply categorised as animate versus inanimate. This pattern of findings suggests that animates give rise to mental images that are more dynamic/motoric in nature than inanimates for which the mental images are more static in nature. One of the core defining traits of animates is that they are living entities that are capable of self-propelled motion (Di Giorgio et al., 2017). One hypothesis is that motion is present in the mental representations corresponding to animate words and that this property makes them more memorable than inanimates. Likewise, the memory trace of animates would be richer than that of inanimates in terms of motoric information. Indeed, this hypothesis is related to a more general account holding that animate items are remembered better because, on average, they possess richer attributes (Nairne et al., 2017). A large body of work has provided evidence that variations in the amount of sensory-motor experience elicited by words may lead to differences in processing, and words that are rich in terms of sensory and/or motoric features enjoy processing benefits in a variety of lexical tasks (e.g., Pexman, Hargreaves, Siakaluk, Bodner, & Pope, 2008; Yap, Tan, Pexman, & Hargreaves, 2011). In particular, it has been found that words with a greater number of semantic features are remembered better in a free recall task (Hargreaves et al., 2012). To test the "dynamic/motoric hypothesis" of animacy effects, in contrast to Bonin et al.'s (2015) Study 4 in which participants had to imagine interacting with the referents of the items, the participants in the present Study 2 had to "freeze" their mental representations for both animates and inanimates, that is to say for any given word they had to imagine the corresponding referent as a static image, as if they were photographs of objects, animals, or people. If animates are remembered better than inanimates because their corresponding representations are in a more dynamical/motoric format (e.g., a bird is mentally represented as flying, a lion as running), then "freezing" as an encoding strategy should give rise to impoverished representations of animates. We therefore predicted that the animacy effect should be reduced in this encoding situation because animates would be less well remembered than in a control encoding situation in which the participants were not explicitly directed to process words using mental imagery. Indeed, we hypothesised that, perhaps by default, most animates are represented in a dynamic way. In contrast, most inanimates should produce mental representations that are, in general, more static in nature. The latter should therefore not be altered by the freezing encoding situation. This hypothesis was tested in Study 2.

Method

Participants

Sixty-nine students (61 women, mean: 19.63 years) from the University of Bourgogne took part in the experiment in exchange for course credits. They were divided into two groups according to the encoding condition (static imagery versus animacy categorisation). None were taking any medication known to affect the central nervous system and they were all native French speakers. The sample size was determined on the basis of an a priori power analysis performed using the results of Bonin et al.'s (2015) Study 4 because here we anticipated an interaction between the animacy and type of encoding variables just as in the latter study. In effect, in Bonin et al. (2015), we found that the difference in recall rates between animates and inanimates was larger in the categorisation condition than in an interactive imagery condition. Here, we predicted that if the animacy effect is due to the more dynamic/motoric nature of the representations of animate things, freezing the image should reduce the difference in recall rates between animates and inanimates compared to when both types of words have merely to be categorised as animates vs. inanimates. (Indeed, the effect

Table 1. Statistical characteristics (mean, standard deviations, range, minimum-maximum, *t*-tests of the means) of the control variables in Study 2 for animate and inanimate stimuli.

	Animate				Inanimate				*t*-test
	Mean	SD	Range	Min-max	Mean	SD	Range	Min-max	
Number of letters[a]	7	1.94	6	4.0–10	6.63	1.9	8	4.0–12	$p = .60$
Bigram frequency (per million words)[a]	8759.69	2339.42	8345	4462–12807	8699.31	2274.68	7199	5151–12350	$p = .94$
Book frequency[a]	19.38	27.17	108.92	1.35–110.27	47.78	79.33	340.61	0.47–341.08	$p = .20$
Subtitle frequency[a]	18.06	22.17	84.73	0.69–85.42	23.55	26.48	110.95	0.49–111.44	$p = .54$
Age-of-acquisition (1–5)[b]	2.08	0.41	1.45	1.35–2.8	2.26	0.48	1.65	1.35–3	$p = .26$
Number of orthographic neighbours[a]	2.94	3.99	14	0–14	1.88	2.62	8	0–8	$p = .40$
Orthographic uniqueness point[a]	5.19	2.32	9	0–9	5.69	2.11	9	0–9	$p = .54$
Conceptual familiarity (1–5)[b]	2.57	0.72	3.15	1.4–4.55	3.02	1.12	3.3	1.53–4.83	$p = .20$
Imageability (1–5)[c]	4.62	0.23	0.84	4.12–4.96	4.44	0.36	1.52	3.32–4.84	$p = .11$
Image variability (1–5)[c]	2.88	0.57	2.27	1.9–4.17	2.85	0.72	2.27	1.6–3.87	$p = .91$
Concreteness (1–5)[c]	4.63	0.32	1.22	3.69–4.91	4.79	0.21	0.86	4.14–5	$p = .14$
Emotional valence (1–5)[c]	3.3	0.77	3.19	1.25–4.44	3.32	0.62	2.68	1.64–4.32	$p = .95$
Mention frequency[d]	0.27	0.3	0.98	0–0.98	0.29	0.32	0.84	0.01–0.85	$p = .88$

[a]Values taken from Lexique (www.lexique.org; New, Pallier, Brysbaert, & Ferrand, 2004).
[b]All the scales are 5-point scales. The values were obtained from Bonin, Peereman, et al. (2003), and from Alario and Ferrand (1999).
[c]All the scales are 5-point scales. The values were obtained from Bonin, Méot, et al. (2003).
[d]The values were obtained from Bueno and Megherbi (2009).

of freezing on the animacy effect should be comparable to that of imagining interacting with the referents of the words.) With an *F* equal to 7.13 for the interaction effect in the Bonin et al. (2015) Study 4, the partial omega square was estimated at .064 (see Keppel & Wickens [2004] for the estimation formulae). With such an effect size, thirty-two participants per encoding conditions were necessary to obtain a power of .80. We planned to test 35 participants per condition. However, one participant failed to follow the instructions, and there were 34 participants in the imagery condition. It is important to note that this sample is larger than those used in most previous published studies (including our own studies) on animacy effects in episodic memory.

Stimuli

The word list was the same as the one used in Gelin et al.'s (2017) Study 4. Thirty-two nouns were selected from the Snodgrass and Vanderwart (1980), the Bonin, Peereman, Malardier, Méot, and Chalard (2003) and from the Bueno and Megherbi (2009) databases. Each word referred to either an animate or to an inanimate object that belonged to one of the following eight categories: insects, birds, animals with four legs and humans (determined by professions) for the animate stimuli, and furniture, tools, clothes, and musical instruments for the inanimate stimuli.

The words were divided into two sets of 16 items (animates versus inanimates) matched for the *surface variables* of number of letters and bigram frequency; the *lexical variables* of book and subtitle frequency, age-of-acquisition, number of orthographic neighbours, orthographic uniqueness point; and the *semantic variables* of conceptual familiarity, imageability, image variability, concreteness, emotional valence and mention frequency. The statistical characteristics of the words are in Table 1.

Procedure

The participants were tested two by two in a quiet room. They were randomly assigned to one of the two encoding conditions (static imaging versus animacy rating). The instructions for the animacy rating condition were the same as used in the Gelin et al. (2017) and the Bonin et al. (2014) studies, and more precisely:

> I am going to present you with a list of words. For each word, you will have to decide whether it refers to an animate or to an inanimate item. A word refers to an animate item if it refers to something that is living, something that can move on its own, as is the case of human beings and animals. For example, the words "indian" and "fish" refer to animates. Conversely, a word refers to an inanimate item if it refers to something that is not living, something that cannot move on its own. For example, the words "knife" and "stone" refer to inanimates. For each word, press the "A" key for animate and the "I" key for inanimate in order to provide your answer.

The specific instructions used in the static imaging condition were:

> I am going to present you with a list of words. For each word, I am going to ask you to imagine a static image, like a photograph of the object, animal, or person which the word refers to. In addition, I want you to rate each word on a scale to indicate whether the task of imagining this static image of the object, animal or person was easy or very difficult. In order to do this, you will have a 5-point scale, with 1 indicating "very difficult to imagine this object, animal, or person" and 5 indicating "very easy to imagine this object, animal, or person".

The encoding phase was followed by two interference tasks: the "X–O" letter-comparison task (Salthouse, Toth, Hancock, & Woodard, 1997) and the "plus-minus" task (from Jersild, 1927; and Spector & Biederman, 1976). The two interference tasks lasted for 5 min. The participants were then asked to recall in writing as many of the words as they could remember during a period of 5 min.

Results

Animate words were not categorised or rated reliably faster ($m = 1853$ ms, $sd = 672$) than inanimate words ($m = 1803$, $sd = 650$), $F(1, 67) = .55$, $p = .46$, $\eta_p^2 = .01$. The words in the animacy decision condition were rated reliably faster

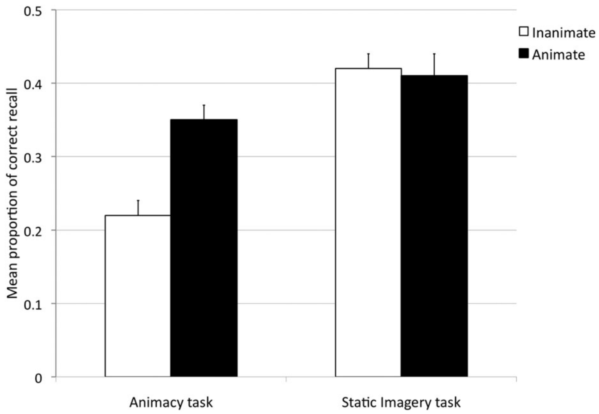

Figure 2. Mean proportions and standard errors of correct recall as a function of encoding condition (Animacy task versus Static Imagery task) and type of words (animate versus inanimate words) in Study 2.

($m = 1045$, $sd = 198$) than the words in the static imagery condition ($m = 2635$, $sd = 1498$), $F(1, 67) = 37.27$, $p < .001$, $\eta_p^2 = .36$. The interaction between the two factors was not significant, $F(1, 67) = 2.59$, $p = .11$, $\eta_p^2 = .04$.

As far as the ratings in the static imagery condition are concerned, inanimates were not given lower scores ($m = 4.35$, $sd = .50$) than animates ($m = 4.29$, $sd = .65$), $t(34) = .52$, $p = .61$.

More words were correctly recalled in the static imagery condition than in the animacy decision condition, $F(1, 67) = 23.78$, $p < .001$, $\eta_p^2 = .26$. Also, more animate than inanimate words were recalled correctly, $F(1, 67) = 13.28$, $p < .001$, $\eta_p^2 = .17$. Importantly, the interaction between Encoding condition and Type of words was significant, $F(1, 67) = 15.80$, $p < .001$, $\eta_p^2 = .19$. Post-hoc Tukey tests revealed a significant difference between animates and inanimates in the animacy decision condition, $p < .001$, but not in the static imagery condition, $p = .99$ (see Figure 2). Also, the recall rate of animate words was not significantly different between the static imagery and the animacy decision conditions, $p = .17$, whereas more inanimate words were correctly recalled in the static imagery encoding condition than in the animacy decision encoding condition, $p < .001$.

The analysis performed on the number of intrusions revealed a significant difference between the "animacy" group and "static imagery" group, $F(1, 67) = 33.16$, $p < .001$, $\eta_p^2 = .33$. (The numbers of intrusions were $m = 2.48$, $sd = 2.04$ and $m = .35$, $sd = .59$ respectively.) However, the effect of Type of words failed to reach significance, $F(1, 67) = 3.52$, $p = .06$, $\eta_p^2 = .05$, as did the interaction between Type of words and Condition, $F(1, 67) = 3.52$, $p = .06$, $\eta_p^2 = .05$.

Discussion of study 2

The findings of Study 2 are clear-cut regarding the hypothesis that animacy effects in episodic memory are due to animates having more dynamic/motoric representations than inanimates. Freezing the mental representations of both animates and inanimates had the same effects as imagining interacting with the referent of both types of words. Indeed, compared to a control condition in which participants had to categorise words on the animacy dimension, the recall rate of inanimates was increased whereas the recall rates of animates did not vary reliably. Thus, if the observation that animates were remembered better than inanimates was due to the fact that the representations of animates are more dynamic/motoric in nature, the freezing condition should have caused animates to be recalled less well than in the control condition, whereas the recall of inanimates should have been unchanged. Bonin et al. (2015) found that interactive imagery boosted the recall of inanimates, but not that of animates, suggesting that animates more readily prompt representations that include motoric interactions. For example, when reading the word *dog*, people imagine themselves petting a dog. Recently, Nairne et al. (2017) reported an experiment in which participants had to read sentences describing one animate interacting with an inanimate (e.g., *the mouse is touching the sled*) or describing one inanimate interacting with another inanimate (e.g., *the lamp is touching the bottle*). Importantly, the same inanimate words were coupled either with animate or with inanimate words. The participants had to imagine the situation described by each sentence and then provide a vividness rating. A surprise memory test was given and revealed that inanimates that had been imagined touched by animates were remembered better than inanimates touched by inanimates. On the basis of this interesting finding, Nairne et al. (2017) suggested that the boost in the recall of inanimates in the interactive imagery condition in Bonin et al.'s (2015) Study 4 was due to "yourself" (an animate thing) imagining interacting with inanimates. However, when participants were asked to freeze their mental representations, they no longer imagined themselves interacting with inanimates. Despite this, inanimates still exhibited a memory boost compared to a control condition in which participants had to categorise the items as animates or inanimates (indeed, the same control condition as used in Bonin et al.'s [2015] study).

In line with the idea that animates elicit more dynamic/motoric mental representations than inanimates, one possibility could be that animates generally refer to items which the body can interact with more easily than is generally the case with inanimates (e.g., it is easier to interact with a *cat* than with a *mountain*). This characteristic is referred to as body–object interaction (BOI). BOI has been shown to facilitate the processing of words in several lexical-semantic tasks (Siakaluk, Pexman, Aguilera, et al., 2008; Siakaluk, Pexman, Sears, et al., 2008) and in memory tasks (Madan & Singhal, 2012; Sidhu & Pexman, 2016). Madan and Singhal (2012) found that highly manipulable objects (e.g., *camera*) were remembered better than less manipulable objects (e.g., *table*). According to the authors, this memory benefit would be due to the automatic activation of motoric representations (see also Sidhu & Pexman, 2016). Thus, these studies suggest that animates might be remembered better than inanimates because the former are associated with greater amounts of bodily information.[2] At the very least, one cannot exclude the possibility that animacy effects in memory are (at least in part) the result of experimenters using a biaised selection process when designing experiments, with relatively high-BOI animate words and low-BOI inanimate words being chosen more often than the reverse.

However this may be, we decided to address this issue by using Siakaluk, Pexman, Aguilera, et al.'s (2008) procedure to collect BOI ratings for animate and inanimate words that have been used in previous studies of our own (Bonin et al., 2014, 2015; Gelin et al., 2017). Complete information regarding this rating study, the data used for the analyses and the results can be found in the Supplementary Material C. The findings indicated that animates were rated as being less easy for the body to interact with than inanimates, further suggesting that if animates are remembered better than inanimates, this is not because their referents are intrinsically easier for the body to interact with.

Study 2 indicates that motoric information – another property of mental images – does not account for the fact that animates are remembered better than inanimates. This finding, again, does not fit well with the hypothesis that imagery processes are involved in animacy effects in episodic memory. Could it be that the requirement to imagine words mentally boosts the memorisation of inanimates, but not that of animates, because imagery processes are more strongly involved for animates than for inanimates? This issue was addressed in Study 3.

Study 3. Creating mental images from animate and inanimate words

What is common to in the procedure used in Bonin et al.'s (2015) Study 4 and the present Study 2 is that the participants were induced to create mental images from words. It is possible that the single instruction to imagine the referents of the words brought about a memory boost for inanimates and not animates, because imagery processes are less strongly involved for the former than for the latter type of words. Stated differently, animates generally rely more heavily on imagery processes than inanimates and, since imagery processes can boost memory (e.g., Elliott, 1973; Lupiani, 1977; Oliver, Bays, & Zabrucky, 2016; Winnick & Brody, 1984), animates are remembered better than inanimates. Although the precise instructions varied between Bonin et al.'s (2015) Study 4 and Study 2, the participants were required to create mental images from the words. The outcome was that inanimates were remembered better when mental images were generated than when they were categorised. This was not the case of animates whose recall rates did not vary as a function of the orienting tasks. It is therefore possible that simply encoding words by creating mental images for both types boosts the memory of inanimates, but not of animates, because animates engage imagery processes more readily than inanimates. This hypothesis was tested in the following study.

Method

Participants

Sixty native French-speaking students (52 women, mean age: 19.95 years) took part in the experiment. They were all students from the University of Bourgogne and were rewarded with course credits. They were divided into two groups according to the encoding condition groups, namely mental imagery versus animacy categorisation. None were taking any medication known to affect the central nervous system. We planned to get a sample of thirty participants per encoding condition given that in Study 2, the interaction effect between type of encoding condition and animacy turned out to be even greater than the interaction effect found in Bonin et al.'s (2015) Study 4. The partial omega-squared was estimated at .114 in Study 2, leading to an a priori power of .80 with only eighteen participants per condition.

Stimuli

The stimulus set was the same as that used in Gelin et al.'s (2017) Study 1. Twenty-eight French nouns were selected from the Snodgrass and Vanderwart (1980) and Bonin et al. (2003) databases. The words were divided into two sets, 14 animate objects and 14 inanimate objects, matched for the *surface variables* of number of letters and bigram frequency; the *lexical variables* of book and subtitle frequency, age-of-acquisition, number of orthographic neighbours, orthographic uniqueness point; and the *semantic variables* of conceptual familiarity, imageability, image variability, concreteness, and emotional valence. The statistical characteristics of the words are provided in Table 2.

Procedure

The participants were tested individually in a quiet room. They were randomly assigned to one of the two encoding conditions: mental imaging versus animacy rating. The instructions for the animacy rating condition were the same as those used in Study 2.

The specific instructions used in the mental imaging condition were:

> I am going to present you with a list of words. For each word, I am going to ask you to imagine a mental image of the object, animal, or person which the word refers to. In addition, I want you to rate each word on a scale to indicate whether the task of imagining this mental image of the object, animal or person was easy or very difficult. In order to do this, you will have a 5 point-scale, with 1 indicating "very difficult to imagine this object, animal, or person" and 5 indicating "very easy to imagine this object, animal, or person".

Table 2. Statistical characteristics (mean, standard deviations, range, minimum-maximum, *t*-tests of the means) of the control variables for animate and inanimate stimuli used in Studies 3 and 4.

	Animate				Inanimate				*t*-test
	Mean	SD	Range	Min-max	Mean	SD	Range	Min-max	
Number of letters[a]	6.14	1.81	7	3–10	6	1.77	6	4–10	$p = .84$
Bigram frequency (per million words)[a]	8823.21	2898.64	9396	4058–13454	9358.14	3124.96	11616	2360–13976	$p = .65$
Book frequency[a]	22.29	46.64	186.35	0.61–186.96	20.63	43.96	175.13	0.07–175.2	$p = .93$
Subtitle frequency[a]	31.94	61.30	188.2	0.21–188.2	17.38	39.27	154.07	0.06–154.13	$p = .48$
Age-of-acquisition (1–5)[b]	2.44	0.75	2.6	1.15–3.75	2.81	0.91	2.97	1.23–4.2	$p = .26$
Number of orthographic neighbours[a]	3.43	3.92	13	0–13	3	3.93	10	0–10	$p = .78$
Orthographic uniqueness point[a]	5	2.20	10	0–10	4.07	2.02	8	0–8	$p = .27$
Conceptual familiarity (1–5)[b]	2.39	0.79	2.83	1.07–3.90	2.74	0.84	3.34	1.63–4.97	$p = .29$
Imageability (1–5)[c]	4.28	0.38	1.28	3.64–4.92	4.05	0.51	1.56	3.24–4.8	$p = .20$
Concreteness (1–5)[c]	4.59	0.28	0.77	4.09–4.86	4.57	0.46	1.81	3.05–4.86	$p = .93$
Emotional valence (1–5)[c]	3.33	0.55	1.96	2.48–4.44	3.04	0.60	1.92	2.2–4.12	$p = .21$

[a]Values taken from Lexique (www.lexique.org; New et al., 2004).
[b]All the scales are 5-point scales. The values were obtained from Bonin, Peereman, et al. (2003) and from Alario and Ferrand (1999).
[c]All the scales are 5-point scales. The values were obtained from Bonin, Méot, et al. (2003).

After all the words had been encoded, the participants performed the same two interference tasks as used in the previous study. Then, after 5 min had elapsed, a surprise free-recall task was given. The participants recalled in writing as many of the words as they could remember for 5 min.

Results

Animate words were not categorised or rated reliably faster ($m = 1479$ ms, $sd = 500$) than inanimate words ($m = 1517$ ms, $sd = 531$), $F(1, 58) = 2.02$, $p = .16$, $\eta_p^2 = .03$. The words in the animacy categorisation condition were rated reliably faster ($m = 1040$ ms, $sd = 286$) than the words in the mental imagery condition ($m = 1956$ ms, $sd = 727$), $F(1, 58) = 41.15$, $p < .001$, $\eta_p^2 = .42$. The interaction between the two factors was not significant, $F(1, 58) = .24$, $p = .63$, $\eta_p^2 = .004$. As far as the ratings in the mental imagery condition are concerned, inanimates were not given lower scores ($m = 3.95$, $sd = .53$) than animates ($m = 4.11$, $sd = .66$), $t(29) = 1.97$, $p = .06$.

The recall rate in the mental imagery condition did not differ significantly from that in the animacy categorising condition, $F(1, 58) = 1.55$, $p = .22$, $\eta_p^2 = .03$. More animate words than inanimate words were recalled correctly, $F(1, 58) = 35.00$, $p < .001$, $\eta_p^2 = .38$. Importantly, the interaction between Encoding condition and Type of words was significant, $F(1, 58) = 10.09$, $p < .01$, $\eta_p^2 = .15$. Post-hoc Tukey tests revealed a significant difference between animates and inanimates in the animacy categorisation condition, $p < .001$, but not in the mental imagery condition, $p = .22$ (see Figure 3). Also, the recall rate of animate words was not significantly different between the mental imagery and the animacy categorisation conditions, $p = .91$, whereas more inanimate words were correctly recalled in the imagery condition than in the animacy categorising condition, $p < .05$.

The analysis performed on the number of intrusions revealed no reliable difference between the “animacy” group and “mental imagery” group, $F(1, 58) = 1.78$, $p = .18$, $\eta_p^2 = .03$. (The numbers of intrusions were $m = 1.1$, $sd = 1.49$ and $m = .67$, $sd = .91$, respectively.) Also, the effect of Type of words was not significant, $F(1, 58) = .46$, $p = .50$, $\eta_p^2 = .01$. Finally, the interaction between Type of words and Condition was also not significant, $F(1, 58) = .46$, $p = .50$, $\eta_p^2 = .01$.

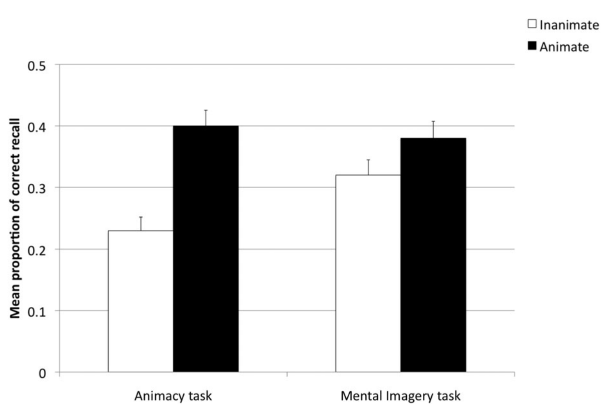

Figure 3. Mean proportions and standard errors of correct recall as a function of encoding condition (Animacy task versus Mental Imagery task) and type of words (animate versus inanimate words) in Study 3.

Discussion of study 3

The findings of Study 3 are clear-cut. We again found that animates are remembered better than inanimates in the animacy categorisation task. However, when adults had to encode words by creating mental images for both animates and inanimates, the difference in the recall rates of the two types of words was no longer reliable because of a memory boost in the recall rate of inanimates. This outcome is consistent with our reasoning that instructions directing participants to create mental images for both types of words should have the effect of placing inanimates and animates on an equal footing.

There is one potential issue concerning the findings of Studies 2 and 3 that imagery reduces animacy effects compared to a situation where words are categorised on the animate-inanimate dimension. We have assumed that an animate-inanimate categorisation task is a reliable control condition making it possible to evaluate animacy effects in memory relative to encoding conditions that entail the use of mental imagery. And importantly, we have also assumed that the use of mental imagery truly reduces animacy effects because inanimates, more than animates, benefit from this encoding strategy. What, therefore, is the effect of using a categorisation task to evaluate animacy effects in memory? We think that the choice of an animate-inanimate categorisation task is not a serious concern for the following reasons. First of all, as described in the Procedure section of Study 2, before performing the categorisation task, a brief definition of what is meant by animate *and* inanimate words was given to the participants and animates were not stressed more than inanimates. Second, Gelin et al. (2017) have shown that animacy effects in memory are independent of encoding instructions.[3] Thus, it is not necessary to focus on the animacy dimension in order to obtain animacy effects in memory (see also VanArsdall, Nairne, Pandeirada, & Cogdill, 2017). Finally, to further develop the finding that animacy effects are reduced when mental imagery is used as an encoding strategy, we took into account the sizes of the animacy effects that were found in certain of our previous studies.

Figure 4 shows the cat's-eye confidence intervals (e.g., Cumming, 2012) of the by-participants differences between animates and inanimates obtained in different studies involving imagery, intentional learning, or categorisation. As shown by Figure 4, animacy effects were the lowest in the three studies involving imagery, whereas the reverse was true for the studies in which words had to be categorised. Finally, there were medium animacy effects when intentional learning was used. Contrast analyses revealed that the mean for the imagery conditions ($m = .0349$) was lower than that obtained with intentional learning instructions ($m = .1101$), $t(139.7) = 3.59$, $p < .001$.[4] Also, we found that the difference in the effects of animacy between categorisation ($m = .1423$) and intentional learning was not significant, $t(157.9) = 1.57$, $p > .1$.

Overall, the findings of Study 3, together with the above supplementary analyses, fit with the hypothesis that imagery processes are more readily involved in the processing of animates than of inanimates or, conversely, that inanimates rely less on these processes. However, the findings from Studies 1 to 2 cast some doubt on this interpretation because both vividness and BOI – which are proxies for certain qualities of imaging – did not differ between animates and inanimates. Moreover, it could be argued that the findings on animacy effects in tasks involving imagery do not necessarily tell us anything about the proximate mechanisms involved in animacy

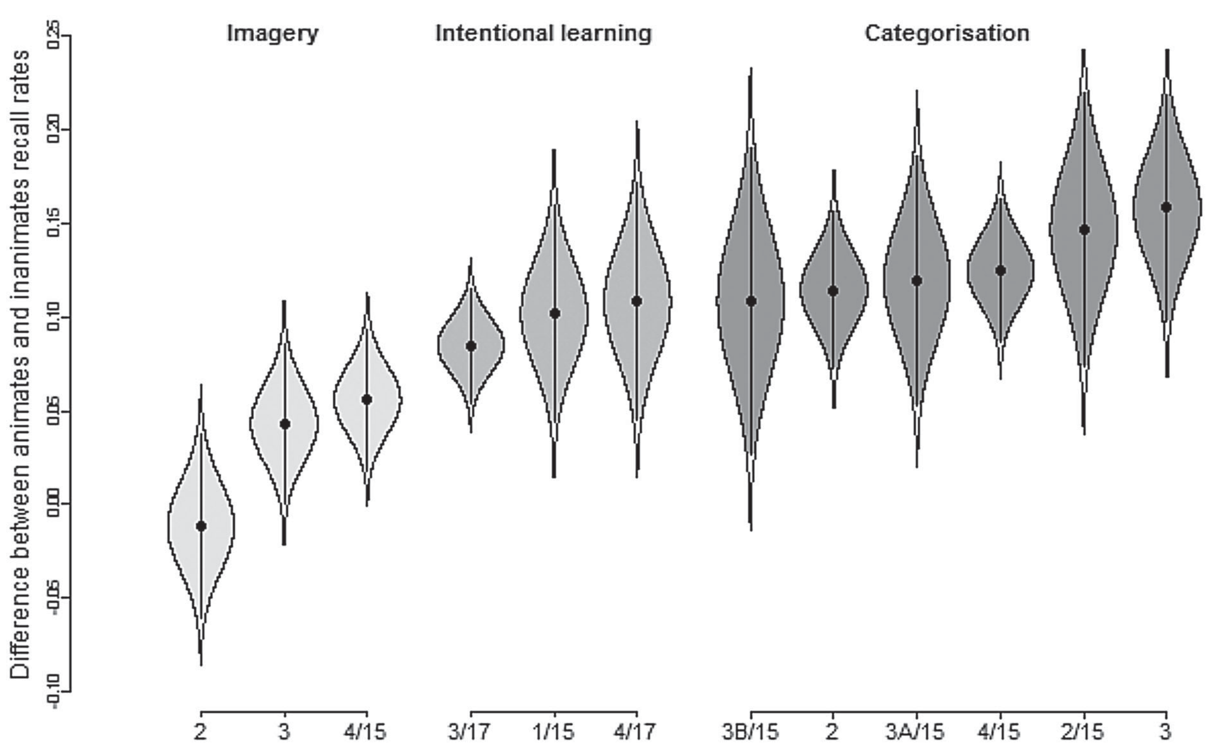

Figure 4. 95% cat's-eye confidence intervals of the by-participants differences between animates and inanimates obtained in the encoding conditions involving imagery, intentional learning and categorisation. On the abscissa, the numbers 2 and 3 correspond to Study 2 and Study 3, respectively, of the current paper. The other studies are published studies with their corresponding reference number and their year of publication (e.g., 3A/15 = Study 3A in Bonin et al.'s [2015] paper; 4/17 = Study 4 in Gelin et al.'s [2017] paper).

effects obtained in categorisation or explicit memory tasks. To address more directly the involvement of imagery processes in implicit or explicit memory tasks that do not explicitly required the use of imagery, we designed a fourth and final study in which participants were subjected to a concurrent visual-spatial memory load when encoding words.

Study 4. Animacy categorisation with a concurrent visual-spatial memory load

In this fourth and final study, we used a concurrent visual-spatial memory load paradigm to test more directly the hypothesis that imagery processes are involved more when encoding animates compared to inanimates. In Study 4, the participants had to perform two tasks. One task required them to categorise words as animates vs. inanimates, whereas the other task was a visual-spatial memory task. As illustrated in Figure 5 (see Procedure section), in one condition there was a very easily memorised visual pattern (the same set of regular black squares in a matrix) whereas in the other condition, there were complex patterns of black squares in a matrix that had to be memorised. The successful use of a concurrent visual-spatial memory task has been reported in the literature on moral dilemmas when testing for the involvement of imagery processes (Amit & Greene, 2012). If imagery processes play a role in the animacy effect in memory, because (1) it is assumed that animates generally rely more heavily on these processes than inanimates, and (2) these processes are able to boost memory (e.g., Elliott, 1973; Lupiani, 1977; Oliver et al., 2016; Winnick & Brody, 1984), then a concurrent visual-spatial memory load should be more detrimental to animates than to inanimates when categorising words. As a result, animates should be remembered less well in the memory load condition than in the no-memory load condition, and the difference in recall rates between animates and inanimates should be smaller in the load than in the no-load condition.

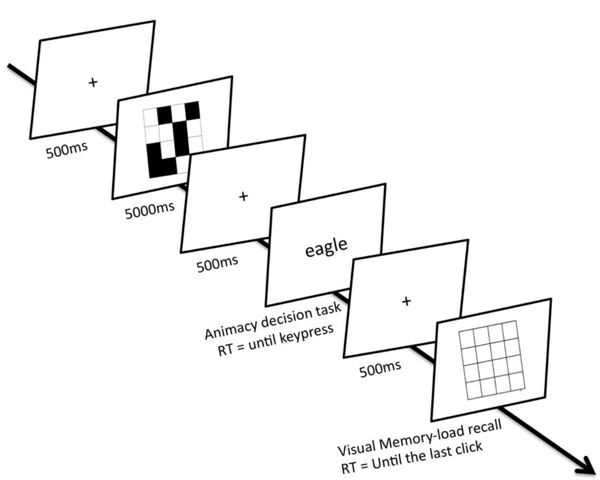

Figure 5. Structure of an experimental trial in Study 4.

Method

Participants

Thirty-four French-speaking students (29 women, mean age: 19.91 years) were involved. As in the previous study, they were all students from the University of Bourgogne and were rewarded with course credits. None were taking any medication known to affect the central nervous system. The number of participants was chosen in order to be comparable with that employed in the categorisation tasks used in Bonin et al.'s (2015) Experiments 2, 3A and 3B, in which a verbal memory load was used. If imagery processes do not play a role in animacy effects in memory, the same results as those found in these experiments should emerge in the present study, that is to say main effects of memory load and of animacy but no interaction between the two factors. It is important to note that in Bonin et al.'s (2015) Experiments 2, 3A and 3B, post hoc power for the main effects was above .90 with about thirty participants.

Stimuli

We used exactly the same stimuli as used in the previous study (Study 3), namely 28 words, half of which referred to animate entities and half to inanimate entities (see Table 2 for their characteristics).

Procedure

The participants were tested individually in a quiet room. The procedure was identical to that used in Bonin et al.'s (2015) Study 2. The animacy categorisation task and the memory-load condition were within-participants. At the start of the experiment, the participants were given a brief definition of what is meant by "animate" versus "inanimate".

Each experimental trial had the following structure (see Figure 5). A ready signal (+) lasting 500 ms was displayed in the centre of the screen. In the memory-load condition, a matrix comprising 4×4 squares (2.5×2.5 cm) was presented for 5000 ms and half of the cells were randomly colorised in black. The participants were asked to remember the visual display until they were told to redraw the matrix using mouse clicks (to this end, an empty matrix was displayed on the screen). In the no-load condition, the same procedure was used except that the 8 left-hand cells of the matrix were colorised in black (in the visual domain this condition is equivalent to Bonin et al.'s (2015) no memory-load condition in which the word WHITE was presented on the screen). They were also told that they would have to recall this visual display. After the matrix presentation, an "+" was presented for 500 ms followed by a word displayed until the participant's response. The participants had to categorise as quickly as possible whether the word presented in the middle of the screen referred to an animate or an inanimate item by pressing a key. An "+" was again presented for 500 ms followed by an empty matrix and the participant had to redraw the visual display they had just seen (they could not correct any errors they made when clicking the mouse).

The two memory-load conditions were blocked with the result that half of the participants began with the memory-load condition and the other half with the no-load memory condition. Moreover, for each type of word (animates vs. inanimates), half were accompanied by a memory load whereas the other half were not.

After all the words had been categorised, the participants performed the same two interference tasks as used in the previous studies. After 5 min had elapsed, a surprise free-recall task was given and the participants recalled in writing as many of the words as they could remember for 5 min.

Results and discussion of study 4

Memory load scores and categorisation times

As strongly expected, the matrices comprising sequences of random black squares were recalled less well ($m =$ 90.57%, $sd = .07$) than the (easy) matrices comprising identical sequences of black squares ($m =$ 99.97%, $sd = .0015$), $F(1, 33) = 61.81$, $p < .001$, $\eta_p^2 = .652$. The main effect of animacy and the interaction between animacy and memory-load conditions were not reliable (both Fs < 1).

As far as categorisation times are concerned, no effects turned out to be significant: Memory load: $F(1, 33) = 2.02$, $p = .165$, $\eta_p^2 = .052$; Animacy: $F(1, 33) = 1.38$, $p = .249$, $\eta_p^2 = .04$; Animacy × Memory load: $F(1, 33) = 1.23$, $p = .275$, $\eta_p^2 = .036$.

Recall rates

The correct recall proportions for animates versus inanimates as a function of the visual-spatial memory load are presented in Figure 6.

A higher proportion of words was recalled in the no-load condition than in the load condition, $F(1, 33) =$ 35.72, $p < .001$, $\eta_p^2 = .52$. Also, a greater proportion of animate words than inanimate words was recalled, $F(1, 33) = 29.75$, $p < .001$, $\eta_p^2 = .474$. The interaction between Encoding condition and Type of words was not significant, $F < 1$, $\eta_p^2 = .025$.

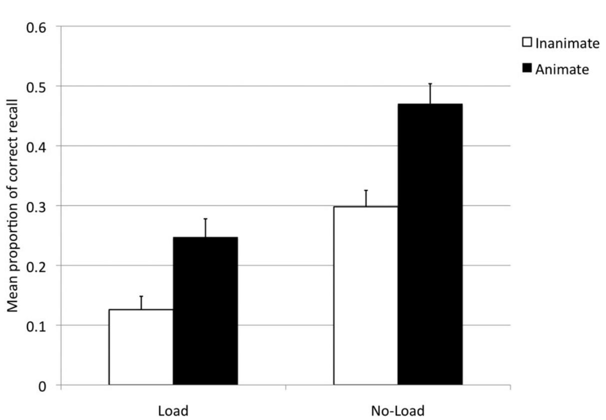

Figure 6. Mean proportions and standard errors of correct recall as a function of Memory load (load versus no load) and Type of words (animates versus inanimates).

As far as the number of extralist words is concerned, there was no significant difference between inanimates ($m = .62$, $sd = 1.13$) and animates ($m = .32$, $sd = .94$), $t(33) = -1.38$, $p = .177$.

Adding a visual-spatial memory load during the categorisation of animate and inanimate words did not diminish the animacy effect in memory. Indeed, once again animates were memorised better than inanimates. At the same time, the cognitive load manipulation was successful: The memory load had a negative effect on the overall level of recall compared to the no-load condition. The findings argue against the idea that animacy effects are underpinned by imagery processes, especially because animates rely more on these processes than inanimates. In effect, if this hypothesis were correct, we should have found that animates were more impeded by a visual-spatial memory load than inanimates, and thus less well-remembered in this encoding condition. However, contrary to any such expectation, the animacy effect remained the same in the memory-load condition as compared to the no-load condition, a pattern of findings which, critically, is very difficult to reconcile with the hypothesis that imagery processes are involved in animacy effects in episodic memory.

General discussion

The study of the mnemonic influence of animacy is new in the episodic memory literature. To date, only a few studies have investigated the impact of this dimension (Nairne et al., 2017). However, an increasing number of findings suggest that animacy effects in memory are robust. As set out in the Introduction, memory for animates has been consistently found to be better than for inanimates in both intentional and incidental learning as well as in a variety of memory tasks: free recall (Bonin et al., 2014; Nairne et al., 2013), recognition (Bonin et al., 2014), and cued recall (VanArsdall, Nairne, Pandeirada, & Cogdill, 2015; but see Popp & Serra, 2016 and below). It is important to keep in mind that animacy effects in memory were discovered because of the adoption of an evolutionary framework championed by James Nairne and his research team (Nairne, 2010, 2015). The major assumption of evolutionary psychology is that our cognitive mechanisms evolved through natural selection because they provided benefits for fitness. Nairne assumes that our memory systems were sculpted by a range of selection pressures faced by our ancestors in the distant past (Nairne, 2010, 2015; Nairne & Pandeirada, 2010, 2016) and that our memory systems evolved to solve adaptive problems. Therefore, memory processes should be tuned to encode and retrieve information related to survival and reproduction issues, including finding food and water, protecting ourselves against predators or enemies, or finding a mate. The impact of animacy in memory was therefore predicted by an evolutionary account of memory. Stated differently, this novel finding was acquired through forward engineering (Nairne, 2015), and, therefore, studies of animacy effects in memory were first focused on ultimate explanations. Exactly how animacy effects are produced and the nature of the mechanisms underpinning these effects are issues that have been investigated more recently (Bonin et al., 2015; Popp & Serra, 2016, 2018; VanArsdall et al., 2017). However, ultimate and proximate explanations should not be thought of as rival explanations. On the contrary, they are complementary (Nairne & Pandeirada, 2016). In the present research, we focused on proximate explanations of animacy effects in episodic memory and aimed to provide further evidence for the hypothesis that imagery processes are involved in animacy effects. At the end of the discussion, we will address the link between proximate and ultimate explanations.

Let us summarise the main findings of our studies. First of all, we explored the role of the vividness of animates versus inanimates. Contrary to our expectations, vividness ratings were not found to be a relevant dimension that could partially account for animacy effects in memory. This finding does not fit well with the idea that imagery processes are involved in animacy effects in memory since vividness is a quality of mental images. In a second study, we tested a hypothesis that derived directly from a previous work of our own (Bonin et al., 2015), namely that animates would be represented mentally in a more dynamic manner than inanimates. However, the findings of Study 2 were not consistent with this account because "freezing" the mental representations of animates and inanimates had the same effects as imagining interacting with their referents. Given that freezing the mental representations makes animates more like inanimates, it should have had a detrimental effect on the memorability of animates if, indeed, their dynamic/motoric nature were the key factor underpinning animacy effects. Since motoric information is a property of mental images, these findings together with the BOI ratings, which did not differ between animates and inanimates, could be taken to argue that imagery and animacy are unrelated.

The findings from Study 2 also rule out the idea that animacy effects in memory are due to the fact that animates give rise to representations in which one is more personally involved (by imagining touching the animate objects, e.g., touching the *baby*), because when the participants were oriented to freeze their mental representations, they were explicitly told to imagine the objects as if they were taking a photograph of them. Such a situation introduces a distance between oneself and the objects with no direct contact with the body except for visual contact.

Given that in both Bonin et al.'s (2015) Study 4 and the current Study 2, the participants had to create mental images from words, we put forward the hypothesis that animates may have been remembered better than inanimates because animates more readily (or more strongly) mobilise imagery processes than inanimates. As a result, inanimates receive a memory boost when individuals are directed to encode them using imagery because this is a well-known procedure that improves memory (Elliott, 1973; Lupiani, 1977; Oliver et al., 2016; Winnick & Brody, 1984). Indeed, in Study 3, when adults were led to encode words by creating mental images for both animate or inanimate words, rather than categorising them as animates or inanimates, the animacy effect on memory performance vanished. This was due to the presence of a memory boost for inanimates only. As a matter of fact, animates were not recalled better when participants had to imagine them than when they had to categorise them. In Study 4, a memory load procedure was used. The participants had to encode animate vs. inanimate words while at the same time remembering a very easy (= no memory load) or a more difficult visual-spatial configuration. Contrary to the hypothesis that a visual-spatial memory load should impede the encoding of animates more than inanimates, because the former words rely more on imagery processes than the latter, we found that the animacy effect was left unchanged in the visual-spatial load condition compared to the no-load condition.

Where do the findings from the present studies leave us? We started our paper with an ultimate explanation of animacy effects in memory, namely the assumption that animates are remembered better than inanimates because they are more important for fitness purposes (Nairne et al., 2017). In addition to this ultimate explanation, we put forward a proximate explanation of these effects, namely that imagery could be one key proximate mechanism of animacy effects in memory (even though we acknowledge that this proximate mechanism is certainly not the only one). At best, the evidence from the current studies in favour of this hypothesis is mixed. In effect, on the one hand, the recall of animate items was not affected by intentional imagery processing whereas that of inanimate items was (Study 3), and in such a way that the levels of recall were comparable (Figure 4). We take these findings to suggest that imagery processes are involved in animacy effects. At the same time, however, there are several aspects of our data which do not fit well with – and some others which more clearly run against – the imagery account of animacy effects. First of all, certain dimensions of imagery (vividness, BOI) are not correlated with the animacy dimension, and do not seem to be related to animacy effects. Second, both Nairne et al. (2013) and Gelin et al. (2017) showed that imagery and animacy were each independent predictors of recall in a regression analysis (it is also worth noting that Bonin et al. [2014] found animacy effects with pictures matched on visual complexity and image agreement and with picture names matched on imageability). To go a step further in this direction, we reanalysed the recall data of Gelin et al.'s (2017) Study 2 in which several predictors of recall rates were included, among of them animacy and imageability, and we included the interaction between imageability and animacy in the regression model. We found the same significant effects as those found in Gelin et al. (2017) and, importantly, an interaction between animacy and imageability which was not significant, $F < 1$. The lack of a reliable interaction between animacy and imageability runs against the idea that imagery processes are responsible for the superior recall of animates over inanimates in incidental or intentional encoding tasks. If this were indeed the case, the difference between animates and inanimates should have been reduced with increasing imageability values. Third, the findings of the present Study 4 are even more damaging for the imagery account of animacy effects. In effect, adding a memory load – more precisely, a visual-spatial load – during the processing of animate and inanimate words caused animates to be remembered better than inanimates, in spite of the fact that the load manipulation was successful since the overall level of recall was less in the load compared to the no-load condition. The findings from Study 4 make it difficult to argue that animates are supported more by mental imagery than are inanimate concepts. As a result, and contrary to what we suggested earlier, it is possible that animacy effects in categorisation tasks are not due to imagery (or are only to a small extent), but to another mechanism whose influence is superseded by the requirement to use imagery processes, thereby eliminating the animacy effect. Taken overall, it is already clear that to provide a full account of animacy effects, it will be necessary to consider other proximate mechanisms in future studies.

In the literature, several hypotheses have been forward to account for animacy effects in memory. Popp and Serra (2016) identified two general accounts of the animacy memory advantage. The first account is that the relationship between the animacy status of items and memory is direct, that is to say animacy is a feature of a concept that is directly associated with better memory. The second account is that a proximate mechanism mediates the relationship between animacy and memory: animacy captures attention or produces mental arousal. The direct account is clearly at odds with the finding of Popp and Serra (2016) that "object-object" pairs are remembered better than "animal-animal" pairs in cued recall. As far as the mental arousal account is concerned, Popp and Serra (2018) recently found animacy effects in memory when arousal rating scores were controlled for, thus ruling out the hypothesis that animates are remembered better than inanimates due to the former referring to items that elicit greater mental arousal than the latter.

Indeed the hypothesis that animacy effects are in part due to attentional capture had already been proposed by Bonin et al. (2014), VanArsdall et al. (2013), and more recently by Bugaiska et al. (in press). Popp and Serra assume that animates capture more attention than inanimates. In line with this hypothesis, when pairs of words are presented for learning, if attention is drawn to one word in a pair (an animate word) rather than focused on the association itself, then pairs comprising animate stimuli should be less well remembered than pairs comprising only object stimuli. However, attentional capture cannot be the sole process responsible for animacy effects in memory because even though animates are detected faster than inanimates (e.g., Altman, Khislavsky, Coverdale, & Gilger, 2016; New, Cosmides, & Tooby, 2007), once detected, they do not appear to be more attentionally demanding, as shown by Bonin et al. (2015) in a dual-task paradigm. Bonin et al. (2015) did not find that animacy effects in free recall were modulated by the addition of a concurrent memory load consisting of letters and digits. Finally, one account of animacy effects in free recall that has often been put forward is that they are due to organisational processes. The idea is that animates are easier to chunk and to retrieve (e.g., they belong to the category of animals or humans) than inanimates, which generally come from more diverse categories (e.g., tools, furniture). However, this hypothesis has been ruled out in recent studies (Gelin et al., 2017; VanArsdall et al., 2017).

Before concluding, one important issue to address concerns the boundary conditions of animacy (and survival processing) effects and how these can sometimes be misinterpreted at the level of ultimate explanations. We would like to make clear that the observation that survival processing benefits or animacy effects in memory are not observed under certain conditions, or even that they can be reversed (Popp & Serra, 2016), should not be taken to argue against ultimate explanations of these memory effects. Indeed, Popp and Serra (2016) were able to provide evidence of reversed animacy effects in cued recall. More precisely, in one experiment (Experiment 1), they showed that whereas animals were recalled better than objects in free recall, object-object pairs were recalled better than animal-animal pairs (e.g., *bottle, clock* recalled better than *bear, camel*). In another experiment (Experiment 3), they compared adults' cued recall for different pairs of words: animal-animal, object-object but also animal-object and object-animal and found that object-object pairs were recalled better than the other types of pairs, all of which included an animal stimulus. Thus, these reversed animacy effects are important because they provide boundary conditions for the observation of animacy effect in memory. However, these latter findings should not be interpreted as invalidating the ultimate account of animacy effects, namely that animates are remembered better than inanimates because animate entities are more important than inanimates for both survival and reproduction. On the contrary, an ultimate explanation does not imply the strong assumption that animacy effects in memory should *always* be reliably observed, with animates being remembered better than inanimates in all contexts and tasks. More generally, evolutionary psychologists do not assume that evolved mechanisms are rigid (Kenrick & Griskevicius, 2013). For example, as explained by Nairne and Pandeirada (2016), observing that birds cannot fly under certain conditions (e.g., because their feathers are covered with oil) does not rule out the idea that flying has an ultimate function. The reversal of animacy effects in cued recall can be easily accounted for if one assumes that animates attract more attention than inanimates (Popp & Serra, 2016): Because attention is drawn to animates in pairs of words, the memory of word pairs will be impaired by the presence of animates in the pairs.

To conclude, the present studies represent a significant effort to test one putative proximate mechanism of animacy effects in memory, namely imagery processes. Unfortunately, we were not able to provide unambiguous evidence concerning their involvement and, therefore, the precise mechanisms underpinning animacy effects remain to be identified. Of course, this represents a genuine challenge for future studies.

Notes

1. We are aware of the fact that plants are also living things that barely move, and might therefore be included in the category of animates. However, in our studies, we considered only animals and humans as animates, setting aside the issue of the status of plants in episodic memory. We acknowledge that plants should be the focus of future studies on animacy effects in memory. Also, the definition of animacy used here (and which is the standard definition used in the literature on animacy effects in memory) excludes from the category of animates many things (e.g., robots, vehicles, weather phenomena, and bodies of water) that can move but are not living things.
2. However, it has to be acknowledged that it is also possible to find a number of inanimates that elicit high levels of motoric experience (e.g., *forks*, *screwdrivers*), because they were designed for motoric interaction with the human body, and it is also true that there are many cases of animates for which motoric interaction with a human body seems difficult if not impossible (e.g., interacting with a *shark*), or highly constrained (e.g., playing with a *tiger* is possible but only in specific circumstances such as with a tamer).
3. In effect, Gelin et al. (2017) found animacy effects not only when participants were instructed to encode words for their survival value but also when they encoded words in non-survival scenarios, such as planning a trip as a tour guide, or moving to a new house. Animates are also remembered better when words are rated for their pleasantness (Gelin et al., 2017) or even when they have to be explicitly learned (Bonin et al., 2015).
4. The difference was also significant ($p < .05$) when the imagery study from the current Study 2, for which the observed animacy effect was negative, was excluded, $t(122.1) = 2.39$.

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References

Alario, F.-X., & Ferrand, L. (1999). A set of 400 pictures standardized for French: Norms for name agreement, image agreement, familiarity, visual complexity, image variability, and age of acquisition. *Behavior Research Methods, Instruments, & Computers*, *31*, 531–552.

Altman, M. N., Khislavsky, A. L., Coverdale, M. E., & Gilger, J. W. (2016). Adaptive attention: How preference for animacy impacts change detection. *Evolution and Human Behavior*, *37*, 303–314.

Amit, E., & Greene, J. D. (2012). You see, the ends don't justify the means: Visual imagery and moral judgment. *Psychological Science*, *23*, 861–868.

Bonin, P., Gelin, M., & Bugaiska, A. (2014). Animates are better remembered than inanimates: Further evidence from word and picture stimuli. *Memory & Cognition*, *42*, 370–382.

Bonin, P., Gelin, M., Laroche, B., Méot, A., & Bugaiska, A. (2015). The "how" of animacy effects in episodic memory. *Experimental Psychology*, *62*, 371–384.

Bonin, P., Méot, A., Aubert, L. F., Malardier, N., Niedenthal, P. M., & Capelle-Toczek, M. C. (2003). Normes de concrétude, de valeur d'imagerie, de fréquence subjective et de valence émotionnelle pour 866 mots [Norms of concreteness, imagery, subjective frequency and emotional valence for 866 words]. *L'Année Psychologique*, *103*, 655–694.

Bonin, P., Peereman, R., Malardier, N., Méot, A., & Chalard, M. (2003). A new set of 299 pictures for psycholinguistic studies: French norms for name agreement, image agreement, conceptual familiarity, visual complexity, image variability, age of acquisition, and naming latencies. *Behavior Research Methods, Instruments, & Computers*, *35*, 158–167.

Bueno, S., & Megherbi, H. (2009). French categorization norms for 70 semantic categories and comparison with Van Overschelde et al.'s (2004) English norms. *Behavior Research Methods*, *41*, 1018–1028.

Bugaiska, A., Grégoire, L., Camblats, A. M., Gelin, M., Méot, A., & Bonin, P. (in press). Animacy and attentional processes: Evidence from the stroop task. *Quarterly Journal of Experimental Psychology*.

Collins, R. L., Taylor, S. E., Wood, J. V., & Thompson, S. C. (1988). The vividness effect: Elusive or illusory? *Journal of Experimental Social Psychology*, *24*, 1–18.

Conway, M. A. (2009). Episodic memories. *Neuropsychologia*, *47*, 2305–2313.

Cumming, G. (2012). *Understanding the new statistics: Effect sizes, confidence intervals, and meta-analysis*. New York, NY: Routledge.

D'Angiulli, A., Runge, M., Faulkner, A., Zakizadeh, J., Chan, A., & Morcos, S. (2013). Vividness of visual imagery and incidental recall of verbal cues, when phenomenological availability reflects long-term memory accessibility. *Frontiers in Psychology*, *4*, 1.

Di Giorgio, E., Lunghi, M., Simion, F., & Vallortigara, G. (2017). Visual cues of motion that trigger animacy perception at birth: The case of self-propulsion. *Developmental Science*, *20*, e12394.

Elliott, L. (1973). Imagery versus repetition encoding in short- and long-term memory. *Journal of Experimental Psychology*, *100*, 270–276.

Frey, K. P., & Eagly, A. H. (1993). Vividness can undermine the persuasiveness of messages. *Journal of Personality and Social Psychology*, *65*, 32–44.

Gardiner, J. M. (1988). Functional aspects of recollective experience. *Memory & Cognition*, *16*, 309–313.

Gelin, M., Bonin, P., Méot, A., & Bugaiska, A. (2018). Do animacy effects persist in memory for context? *Quarterly Journal of Experimental Psychology*, *71*, 965–974.

Gelin, M., Bugaiska, A., Méot, A., & Bonin, P. (2017). Are animacy effects in episodic memory independent of encoding instructions? *Memory*, *25*, 2–18.

Hargreaves, I. S., Pexman, P. M., Johnson, J. C., & Zdrazilova, L. (2012). Richer concepts are better remembered: Number of features effects in free recall. *Frontiers in Human Neuroscience*, *6*, 73.

Hayakawa, S., & Keysar, B. (2018). Using a foreign language reduces mental imagery. *Cognition*, *173*, 8–15.
Jersild, A. T. (1927). Mental set and shift. *Archives of Psychology*, *89*, 5–82.
Kenrick, D. T., & Griskevicius, V. (2013). *The rational animal: How evolution made us smarter than we think*. New York, NY: Basic Books.
Keppel, G., & Wickens, T. D. (2004). *Design and analysis. A researcher's handbook*. Upper Saddle River, NJ: Pearson Education, Inc.
Lupiani, D. A. (1977). The facilitative effects of imagery instructions and stimulus characteristics on immediate and long term free recall and clustering. *The Journal of General Psychology*, *97*, 73–87.
Madan, C. R., & Singhal, A. (2012). Encoding the world around us: Motor-related processing influences verbal memory. *Consciousness and Cognition*, *21*, 1563–1570.
Marks, D. F. (1973). Visual imagery differences in the recall of pictures. *British Journal of Psychology*, *64*, 17–24.
Nairne, J. S. (2010). Adaptive memory: Evolutionary constraints on remembering. In B. H. Ross (Ed.), *Psychology of learning and motivation* (vol. 53, pp. 1–32). Burlington: Academic Press.
Nairne, J. S. (2015). Adaptive memory: Novel findings acquired through forward engineering. In D. S. Lindsay, C. M. Kelley, A. P. Yonelinas, & H. L. Roediger (Eds.), *Remembering: Attributions, processes, and control in human memory* (pp. 3–14). New York, NY: Psychology Press.
Nairne, J. S., & Pandeirada, J. N. S. (2010). Adaptive memory: Ancestral priorities and the mnemonic value of survival processing. *Cognitive Psychology*, *61*, 1–22.
Nairne, J. S., & Pandeirada, J. N. S. (2016). Adaptive memory: The evolutionary significance of survival processing. *Perspectives on Psychological Science*, *11*, 496–511.
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.
New, J., Cosmides, L., & Tooby, J. (2007). Category-specific attention for animals reflects ancestral priorities, not expertise. *Proceedings of the National Academy of Sciences*, *104*, 16598–16603.
New, B., Pallier, C., Brysbaert, M., & Ferrand, L. (2004). Lexique 2: A new French lexical database. *Behavior Research Methods, Instruments, & Computers*, *36*, 516–524.
Oliver, M. C., Bays, R. B., & Zabrucky, K. M. (2016). False memories and the DRM paradigm: Effects of imagery, list, and test type. *The Journal of General Psychology*, *143*, 33–48.
Pexman, P. M., Hargreaves, I. S., Siakaluk, P. D., Bodner, G. E., & Pope, J. (2008). There are many ways to be rich: Effects of three measures of semantic richness on visual word recognition. *Psychonomic Bulletin & Review*, *15*, 161–167.
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.
Rubin, D. C., & Friendly, M. (1986). Predicting which words get recalled: Measures of free recall, availability, goodness, emotionality, and pronunciability for 925 nouns. *Memory & Cognition*, *14*, 79–94.
Salthouse, T. A., Toth, J. P., Hancock, H. E., & Woodard, J. L. (1997). Controlled and automatic forms of memory and attention: Process purity and the uniqueness of Age-related influences. *The Journals of Gerontology, Series B: Psychological Sciences & Social Sciences*, *52B*, P216–P228.
Santarpia, A., Blanchet, A., Poinsot, R., Lambert, J. F., Mininni, G., & Thizon-Vidal, S. (2008). Évaluer la vivacité des images mentales dans différentes populations françaises. *Pratiques Psychologiques*, *14*, 421–441.
Shedler, J., & Manis, M. (1986). Can the availability heuristic explain vividness effects? *Journal of Personality and Social Psychology*, *51*, 26–36.
Siakaluk, P. D., Pexman, P. M., Aguilera, L., Owen, W. J., & Sears, C. R. (2008). Evidence for the activation of sensorimotor information during visual word recognition: The body–object interaction effect. *Cognition*, *106*, 433–443.
Siakaluk, P. D., Pexman, P. M., Sears, C. R., Wilson, K., Locheed, K., & Owen, W. J. (2008). The benefits of sensorimotor knowledge: Body–object interaction facilitates semantic processing. *Cognitive Science: A Multidisciplinary Journal*, *32*, 591–605.
Sidhu, D. M., & Pexman, P. M. (2016). Is moving more memorable than proving? Effects of embodiment and imagined enactment on verb memory. *Frontiers in Psychology*, *7*, 1010.
Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, *6*, 174–215.
Spector, A., & Biederman, I. (1976). Mental set and mental shift revisited. *The American Journal of Psychology*, *89*, 669–679.
VanArsdall, J. E., Nairne, J. S., Pandeirada, J. N. S., & Blunt, J. R. (2013). Adaptive memory: Animacy processing produces mnemonic advantages. *Experimental Psychology*, *60*, 172–178.
VanArsdall, J. E., Nairne, J. S., Pandeirada, J. N., & 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., & Cogdill, M. (2017). A categorical recall strategy does not explain animacy effects in episodic memory. *Quarterly Journal of Experimental Psychology*, *70*, 761–771.
Winnick, W. A., & Brody, N. (1984). Auditory and visual imagery in free recall. *The Journal of Psychology*, *118*, 17–29.
Yap, M. J., Tan, S. E., Pexman, P. M., & Hargreaves, I. S. (2011). Is more always better? Effects of semantic richness on lexical decision, speeded pronunciation, and semantic classification. *Psychonomic Bulletin & Review*, *18*, 742–750.