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Mixed evidence for a richness-of-encoding account of animacy effects in memory from the generation-of-ideas paradigm

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Abstract
Animacy effects in memory correspond to the observation that animates (e.g., *cow*) are remembered better than inanimates (e.g., *pencil*). Although the ultimate explanation of these effects seems to be well-documented, clear evidence that would support one or other of the proximate explanations of animacy effects has proven difficult to obtain. Here, we focused on the richness-of-encoding account of animacy effects in memory, which assumes that animates are recalled better than inanimates because the former are encoded with many more distinct associations with other items (i.e., richer memory traces) than the latter. Our goal was to provide further evidence for this account by replicating and extending the analyses of Meinhardt, Bell, Buchner, and Röer (2020) showing that more ideas are generated in response to animate than inanimate words and, importantly, that this generation process mediates the better recall of animates over inanimates. In line with the richness-of-encoding account, we successfully replicated the finding that more ideas were produced in response to animates than inanimates. Even though there is some evidence that the generation of ideas mediates animacy effects in memory, we also report findings from reanalyses of previous studies (Bonin et al., *Experimental Psychology, 62,* 371–384, Bonin et al., 2015; Gelin et al., *Memory, 25,* 2–18, Gelin et al., 2017; Gelin et al., *Memory, 27,* 209–223, Gelin et al., 2019) which—although supporting mediation—show that the number of ideas generated in response to animate and inanimate words cannot reliably predict memory of these words when they are learned in different encoding contexts.

Keywords animacy · richness-of-encoding · adaptive memory · episodic memory

Introduction

Animacy effects in memory correspond to the observation that animates (e.g., *rabbit*) are remembered better than inanimates (e.g., *cup*). These effects—also known as the animacy advantage—are now well-documented since they have been found in free-recall (e.g., Bonin et al., 2014, 2015; Félix et al., 2019; Gelin et al., 2017; Nairne et al., 2013; Popp & Serra, 2016, 2018; VanArsdall et al., 2017), cued-recall (e.g., Kazanas et al., 2020; Popp & Serra, 2016), and recognition (e.g., Leding, 2020; VanArsdall et al., 2013). The animacy advantage has been obtained with words (e.g., Bonin et al., 2014, 2015; Nairne et al., 2013), with nonwords linked to animate versus inanimate properties (VanArsdall et al., 2013), and with pictures (Bonin et al., 2014). Not only are animates remembered better than inanimates, but so too is the contextual information linked to the former type of item, that is to say animacy effects extend to source memory (Gelin et al., 2018).

The ultimate explanation of these effects is that animates are of greater fitness value than inanimates (Nairne et al., 2017a, b). Indeed, animates can be dangerous animals or enemies, prey, potential romantic or cooperation partners. In the distant past, it was important for our ancestors to pay more attention to animates than to inanimates (New et al., 2007), and also to remember animates better than inanimates (e.g., paying attention to dangerous animals; remembering where and when big game drink water). Importantly, the fact that animacy effects have been obtained in a survival context (Gelin et al., 2017) is in line with this ultimate explanation of them.

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As is often the case when a new effect is found, the researchers who discovered animacy effects in memory had to struggle to provide compelling evidence that this effect was truly related to the animacy dimension and not attributable to some other uncontrolled variables. Indeed, the animacy advantage in memory has passed many empirical tests. To mention only a few, animacy effects are not confounded with other well-known lexical psycholinguistic variables such as word frequency, age-of-acquisition, or length, and they have also persisted despite the methodological control of important semantic variables such as imageability, concreteness, or emotional valence. For instance, Bonin et al. (2014) found animacy effects in memory when controlling for more than twelve psycholinguistic variables. Other important factors that might be responsible for these memory effects have been ruled out: Animates are not remembered better than inanimates because they require more effortful encoding (e.g., Bonin et al., 2015), because they produce greater arousal (Meinhardt et al., 2018; Popp & Serra, 2018), are more threatening (Leding, 2019), are more easily chunked than the latter (Gelin et al., 2017; VanArsdall et al., 2017), or because of differences in mental image qualities (Gelin et al., 2019).

As claimed by Meinhardt et al. (2020), the precise way in which animacy effects are produced, that is to say the proximate mechanisms that are involved, nevertheless remains something of a mystery. Although a number of proximate explanations have been put forward in the literature to account for animacy effects in memory, evidence that would unambiguously favor one of these explanations is so far unfortunately lacking. In the present study, we focused on one specific account of animacy effects in memory: *the richness-of-encoding account*. According to the richness-of-encoding hypothesis, animates are remembered better than inanimates because the former are encoded in a more elaborate (richer) way than the latter: In comparison to inanimate words, animate words stimulate the creation of *more* distinct associations with other stored items, which then act as retrieval cues at recall, thus leading to better retention scores for the latter than the former. As reported by Meinhardt et al. (2020), this account has received mixed support in the literature. Recently, Meinhardt et al. (2020) tested a central prediction of the richness-of-encoding account of animacy effects, namely that animate words stimulate the generation of more ideas than inanimate words. They asked adults to report the ideas that spontaneously came to mind when processing animate and inanimate words, respectively. In line with this prediction, they found that more ideas were produced in response to animate words than to inanimate words. In addition, positive correlations were found between the mean number of ideas generated at encoding and successful recall and the number of ideas turned out to mediate the relationship between the animacy dimension and recall performance.

Our goal in the present study was to provide further evidence for the richness-of-encoding account of animacy effects. This is an important endeavor because, firstly, Meinhardt et al.'s (2020) findings have important theoretical implications as they support the richness-of-encoding hypothesis of animacy effects in memory—a promising candidate mechanism for explaining these effects in memory. Secondly, in the light of the replication crisis (Open Science Collaboration, 2015; Pashler & Wagenmakers, 2012), it is unwise to rely on the findings of a single study conducted by a single research group; independent replications are necessary to test the robustness of the findings. Thus, we sought to replicate and extend Meinhardt et al.'s analyses (Meinhardt et al., 2020) using French words that had successfully led to the observation of animacy effects in memory in previous studies (Bonin et al., 2015; Gelin et al., 2017, 2019).

Method

Participants

The research was carried out between September 2019 and February 2021 at the University of Bourgogne. The participants were 131 adults (105 females and 26 males) aged 17– 39 years (M = 20.30 years; SD = 2.62). Most of them were psychology students and received course credits for their participation. The remaining participants were volunteers recruited through an acquaintance network. None of them were taking medication that could affect their memory. Five subjects were excluded from the analyses: four because they were not native speakers of French, and one because he did not understand the instructions. Written informed consent was obtained from all the participants. After the research was completed, the participants were debriefed regarding the research goals. The general procedure used in this study was approved by the Statutory Ethics Committee of the University Clermont-Auvergne.

Stimuli

We used exactly the same 28 French nouns that were used in Bonin et al. (2015) and Gelin et al. (2017, 2019) (see Table 1A in the Supplemental Material for the list of the words). The words were divided into two lists of 14 items each (animates versus inanimates) matched on the lexical variables of book and subtitle frequency, age-of-acquisition, number of orthographic neighbors and orthographic uniqueness point; the surface variables of number of letters and bigram frequency; and the semantic variables of conceptual familiarity, imageability, concreteness and emotional valence. The statistical characteristics of the words can be seen in Gelin et al.'s (2017) Table 1.

Procedure

The participants were tested individually while seated comfortably in a quiet room. After informed consent had been provided, demographic information was collected (age, gender, native language, education level, use of neuroleptics). The participants were then instructed that they would be presented with words presented centered on the screen. For each word, they would have to produce whatever ideas came to mind and to separate each idea with a comma. When the participant felt that s/he had no more ideas to write down, s/he had to press "enter" on the keyboard to move to the next word. There was no time limit for producing ideas in response to the words. Animate and inanimate words were randomly presented. OpenSesame software was used to run the experiment. After the generation-of-ideas task, the participants were given filler tasks that lasted about three minutes before a final surprise free-recall test. The filler tasks were the "X– O" letter-comparison task (Salthouse et al., 1997), and the "plus–minus" task (from Jersild, 1927, and Spector & Biederman, 1976). In the free-recall task, the participants were asked to type in all the nouns they could remember from the encoding phase. They were given five minutes to complete this last task.

Statistical Analyses

In order to investigate whether the results reported by Meinhardt et al. (2020) could be replicated, we closely followed their procedure when analyzing the new set of data collected in French. The mediation of animacy effects through richness-of-encoding was tested using recall rates and number of ideas, which were computed at the level of participants. Montoya and Hayes's (2017) procedure was used to analyze two conditions of within-participant mediation. Reasoning at the level of participants only, however, has the drawback that it ignores item variability, which has been shown to inflate Type-I error rates (e.g., Baayen et al., 2008). Thus, the by-trial recall rates were analyzed using logistic regression mixed models with participants and words included as random factors. To our knowledge, the statistical tools available to test indirect effects in this type of statistical model are poorly developed. Therefore, the putative mediation of animacy effects through richness-of-encoding was analyzed using the causal step approach popularized by Baron and Kenny (1986). Even though this approach suffers from various drawbacks (e.g., Montoya & Hayes, 2017), we decided to use it in order to provide further evidence for the mediation of animacy effects through richness-of-encoding. Finally, in order to check that mediation could be observed in tasks that did not require participants to explicitly generate ideas during the encoding of animate and inanimate words, by-items analyses were performed on the recall data taken from three previous studies which had used exactly the same words as in the present study (Bonin et al., 2015; Gelin et al., 2017, 2019). Given that the predictions about the relationship between animacy effects and the number of ideas generated from animates versus inanimates were all one-tailed, each test on these aspects was considered as significant whenever its bilateral p-value was lower than .10 and 90% confidence intervals were considered for the indirect effects.[1]

Results

For each item, we considered "one idea" to be each "word" or "group of words" that was delineated by a comma. This procedure has the advantage of being somewhat "objective". In effect, since nothing is rejected when counting for the number of ideas, animates are not advantaged over inanimates. The coding procedure was first performed by a Master's student. The number of ideas was then coded again by the last author of the paper (see below for the different categorization criteria used). The correlation between the obtained numbers of ideas generated by items was .995 between the two raters.

Analyses at Participant Level

The mean number of ideas generated in response to words was higher for animates ($m = 6.08$, $sd = 2.85$) than for inanimates ($m = 5.15$, $sd = 2.51$), $t(124) = 11.27$, $p < .0001$, $d_z = 1.01$. As expected, the proportion of correctly recalled animate words ($m = .66$, $sd = .17$) was higher than that of inanimate words ($m = .51$, $sd = .13$), $t(124) = 8.34$, $p < .0001$, $d_z = .75$. The analysis on the number of intrusions showed no significant difference between animate ($m = .12$, $sd = .35$) and inanimate words ($m = .18$, $sd = .46$), $t(124) = -1.07$, $p = .2876$, $d_z = -.10$. In addition, the recall rates were positively correlated with the number of ideas generated in response to words, $r(123) = .28$, $n = 125$, $p = .0017$. Even though the correlation was also positive at the level of items,[2] it failed to reach significance, $r(26) = .24$, $n = 28$, $p = .2203$.

[1] A common practice is to base the decision on p-values obtained in bilateral tests. When parameter estimations agree with unilateral hypotheses, the associated unilateral p-values are equal to bilateral ones divided by two. Reasoning on the basis of unilateral tests makes it possible to get more powerful tests.

[2] The number of ideas given by the participants was used as a proxy for the number of ideas per item.

Following Meinhardt et al. (2020), the SPSS macro MEMORE (Version 2.1; Montoya & Hayes, 2017) was run with 10,000 bootstrapped samples and 90% confidence intervals (CI) of the effects in order to test whether the number of ideas mediates the relationship between animacy and recall rates. In line with this prediction, the indirect effect of animacy on recall performance was significant, $b = 0.03$, CI [0.005, 0.062]. Also, and importantly, the direct effect of animacy was significant, $b = 0.11$, CI [0.07, 0.15]. In addition, the differences between the numbers of ideas provided in response to animates and inanimates when the mean numbers of ideas was controlled for had a positive significant effect[3] on the differences in recall rates, $b = .03$, CI [.002, .07].

Logistic Mixed Model

For a given participant and a given word, recall was coded "0" whenever the word was not recalled and "1" otherwise. These two binary codes constitute the outcome variable. The mediator variable was the number of ideas generated by both the participant and the word in question. Animacy was defined as a dummy coding variable with 0 corresponding to inanimates and 1 to animates. The computations were run with the *glmer* and *lmer* functions included in the lme4 package of R. As mentioned above, because we are not aware of tools comparable to the PROCESS SPSS macro (Hayes, 2013) available to test mediation in the case of mixed models, we followed the causal steps approach originally advocated by Baron and Kenny (1986). In a first step, the animacy effect on the mediator variable was tested using a linear mixed-effects model (LMEM, *lmer* function). In a second step, the total effect of animacy on recall rate was tested using a mixed effects logistic regression (MELR, g*lmer* function). Finally, the associated direct effect was investigated by including the mediator variable in the MELR. Random intercepts of items and participants were included in all models. *P*-values of the effects were computed using Wald *t*-statistics and the *z* distribution in LMEM or Satterthwaite's method for denominator degrees of freedom in MELR (*lmerTest* package). Given that *p*-values are debatable for these models (e.g. Luke, 2017), the results were complemented by computing the 90% confidence intervals of the effects obtained by repeating the above steps over 5000 bootstrapped samples.

More ideas were generated in response to animates than inanimates, $b = .94$, $t(26) = 2.35$, $p = .0266$, CI [0.82, 1.06], and the recall rate was higher for animates than for inanimates, total effect: $b = .59$, CI [0.48, 0.73], OR (= Odds Ratio) = 1.81, $z = 1.96$, $p = .0496$. The indirect effect of the number of generated ideas was also significant, mean over all bootstrapped samples = .07, CI [.05, .09]. In addition, the (direct) effect of animacy on recall turned out to be reduced but still significant at the .1 level, $b = .53$, CI [0.41, 0.66], OR = 1.7, $z = 1.75$, $p = .0803$ as was the effect of the number of generated ideas on recall when controlling for animacy at the .001 level, $b = .08$, CI [0.06, 0.10], $z = 5.84$, $p < .0001$, suggesting that the more ideas were generated, the better recall was.

In sum, using a less liberal procedure to analyze the data, we obtained the same kind of results as found by Meinhardt et al. (2020).

Reanalyses of Previous Data on Animacy Effects in Memory

In their General Discussion, Meinhardt et al. (2020) pointed out that the animacy effect in memory seemed to be enhanced in their studies involving the generation of ideas compared to previous studies in which there was no explicit generation of ideas prior to recall. The same pattern was observed when the results reported above were compared with those obtained in Bonin et al.'s (2015) Study 1 in which an intentional learning task was employed with the same set of words as used here (m(A) – m(I) = .11, $d_z = .70$ versus m(A) – m(I) = .14, $d_z = .75$). This pattern suggests the possibility that the mediation effect obtained with the generation-of-ideas task is, at least in part, attributable to the use of such a task during encoding. In order to test for this possibility, we decided to reanalyze the data obtained in three previous studies of our own that used the same set of words: The above-mentioned Bonin et al. Study 1 (Bonin et al., 2015), which made use of intentional learning, and two other studies that employed incidental recall after the words had been categorized as animates or inanimates (=Gelin et al.'s (2019) Study 3, referred to as "C" for categorization below) or rated for their survival relevance in a grassland scenario (=Gelin et al.'s (2017) Study 1, referred to as "S" for survival below). In the latter task, the participants had to imagine they were stranded in the grasslands of a foreign land and had to survive with no basic supplies (the instructions were taken from Nairne et al., 2007).

Animacy effects were significant in one-tailed tests in all of these tasks when analyzed both by participants (I: m(A) – m(I) = .11, $d_z = .70$; C: m(A) – m(I) = .17, $d_z = 1.02$; S: m(A) – m(I) = .13, $d_z = .98$ – all ps < .001) and by items

[3] Testing this aspect is equivalent to testing an effect of the mediator when controlling for the two conditions of the independent variable. This is necessary in order to evaluate the validity of step 3 of the mediation procedure originally proposed by Judd et al. (2001) (see Montoya & Hayes, 2017).

(same differences in the means I: $d = .76$, $p = .0536$; C: $d = 1.15$, $p = .0052$; S: $d = .65$, $p = .0995$).[4]

In the present study, the richness of encoding was measured at the level of items using the ideas generated by participants in response to words. Indeed, there are two easy original ways to operationalize this construct. One can consider the number of different ideas (NDI) given for the words. It is also possible to consider that the ideas were cited by different numbers of participants and use the total number of ideas generated by all participants in response to a word[5] (NDItot). However, as far as the by-items analyses are concerned, one issue is how to deal with idiosyncratic responses, that is to say the ideas that are generated by only one participant for a given word. In fact, idiosyncrasies were in the majority for all words: They constituted between 59% (*verre*) and 74% (*garçon*) of the number of the different generated ideas. To address this issue, the original measures described above were considered both with and without idiosyncrasies (NDI_I and NDItot_I).

By-items recall rates were taken as the dependent variable in a mediation model including each of the richness-of-encoding measures in turn and the animacy dimension as the effect to be mediated. The PROCESS SPSS macro (Hayes, 2013) was used to run the analyses. The (total) effect of animacy on recall rates was significant in unilateral tests in all the studies (I: $b = .11$, $t(26) = 2.02$, $p = .0536$, $d = .76$; C: $b = .17$, $t(26) = 3.06$, $p = .0052$, $d = 1.15$, S: $b = .13$, $t(26) = 1.71$, $p = .0995$, $d = .65$; current study: $b = .14$, $t(26) = 2.21$, $p = .0361$, $d = .84$). Except in the case of the NDI_I measure, $b = 8.64$, $t(26) = 1.28$, $p = .2106$, $d = .49$, it was the same for the number of generated ideas, NDI: $b = 29.64$, $t(26) = 1.71$, $p = .0989$, $d = .65$; NDItot: $b = 117.36$, $t(26) = 2.35$, $p = .0267$, $d = .89$; NDItot_I: $b = 96.36$, $t(26) = 2.23$, $p = .0344$, $d = .84$.

A supplementary analysis showed that with the exception of the recall data in the survival rating task, the correlations between the recall rates observed in the other three studies and the different measures of generated ideas were all positive and above .19. However, none of these correlations was significant, except for those with the number of different generated ideas in the experiment involving a categorization task, NDI: $r = .53$, $p = .0036$; NDI_I: $r = .45$, $p = .0153$; NDItot: $r = .43$, $p = .0224$; NDItot_I: $r = .36$, $p = .058$. The

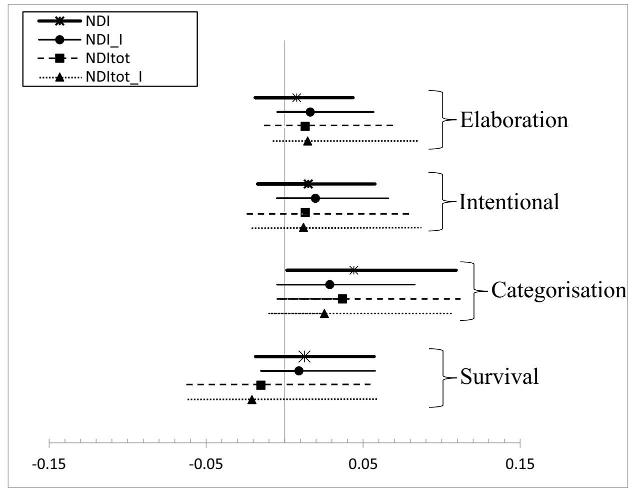

Fig. 1. 90% confidence intervals of the indirect effects

correlations were generally higher when the numbers of different ideas were used rather than the total numbers of generated ideas (with idiosyncrasies included or not). The correlations between the recall rates and the number of generated ideas obtained in the survival rating task were lower than those obtained in the other tasks (NDI: $r = .19$; NDI_I: $r = .16$; NDItot: $r = .06$; NDItot_I: $r = .02$; all $ps > .1$).

Again with the exception of the recall scores from the survival rating task, the direct effects of animacy on recall rates observed in the mediation analyses were always lower than the corresponding total effects and remained significant when a categorization task (all $ps < .05$) was used during encoding as well as in the current study ($ps < .1$ with all measures of generated ideas). They just failed to reach unilateral significance in the intentional learning task (ps between .1109 and .1222). In the task involving survival ratings, direct effects were a little reduced when NDI and NDI_I measures were used, but were—at least descriptively—enhanced when NDItot and NDItot_I scores were used. Except for the survival rating task, the point estimations of the indirect effects were all positive and their confidence intervals were mostly positive (see Fig. 1). However, they failed to reach significance, except in the categorization task when the number of different generated ideas was used. Finally, the results obtained in the study involving survival relevance ratings were more mixed, with positive point estimations of indirect effects being obtained with the NDI measures but negative ones with the NDItot measures.

A last aspect worth noting concerns the effects of the idea generation measures on recall rates when controlling for the animacy dimension. They were all not significant, except those concerning the NDI measures in the experiment involving a categorization task (NDI: $b = .0015$, $p = .0176$ and NDI_I: $b = .0033$, $p = .0417$).

[4] For the current experiment, the animacy effect was also significant at .05 in the by-items analysis ($p = 0361$; $d = .84$).

[5] To this end, we also explored another possibility through the information statistic H, which has been largely employed when measuring agreement between the names given to a specific picture of an object (e.g. Snodgrass & Vanderwart, 1980). However, the results obtained with the use of H generally outperformed those obtained with the variables described for the purpose of mediation (there were, however, no contradictions between them).

To summarize, if we except the study involving survival ratings, the point estimations of the indirect effects are all positive and the reduction of the direct effects of animacy is in line with the mediation elaboration account of animacy effects in memory. The effects are often not reliable, probably because of the low number of items used and perhaps also because of the rather "raw" measures of the richness of encoding that were used. However, even if richness of encoding is a construct that remains difficult to operationalize, the observations that (1) The direct effects are not reduced to a greater extent and (2) The indirect effects are not very strong suggest that the richness-of-encoding account of animacy effects in memory is only one part of the story as far as proximate mechanisms are concerned.

Discussion

Adopting an evolutionary perspective, Nairne and colleagues were the first to report an animacy advantage in memory, namely the observation that animates are remembered better than inanimates (Nairne et al., 2013; VanArsdall et al., 2013). It is important to stress that this memory effect was discovered only recently. As shown by DeYoung and Serra (in press), the animacy advantage in memory is not an effect that adults who are involved in memory experiments are aware of and familiar with. These authors rightly pointed out that if this were the case "*why has it taken over 100 years of empirical cognitive psychological research for researchers in the field to begin studying and controlling for animacy effects in research?*". Recently, Madan (2021) examined the influence of a large number of different word properties on free recall performance and found that animacy was an important dimension and, in fact, the dimension that was most highly correlated with recall rates, in line with Nairne et al.'s (2013) previous findings.

Animacy effects are considered to constitute strong empirical evidence for the adaptive memory view, according to which memory was sculpted in the distant past to solve fitness-relevant problems such as finding food and water, protection from predators, or a partner with whom to reproduce (Nairne, 2010; Nairne et al., 2017a, b; Nairne & Coverdale, 2021; Nairne & Pandeirada, 2008, 2010, 2016). The ultimate explanation of animacy effects in memory is that animates have a special relevance for an individual's fitness because they can be potential enemies, represent mating partners, or be dangerous animals or prey (Nairne et al., 2017a, b). Such ultimate explanations of animacy effects have to be complemented by proximate explanations (Nairne & Pandeirada, 2016).

The animacy advantage has generated a lot of research aimed at investigating the factors that could be responsible for it. However, many of the factors thought to be involved in animacy effects have been ruled out. As set out in the Introduction, ideas suggesting, for example, that the animacy advantage is due to animates being more threatening (Leding, 2019), generating more mental arousal (Meinhardt et al., 2018; Popp & Serra, 2018), having more sensory features (Bonin et al., 2014), etc. than inanimates have all been discarded. Many studies have attempted to identify the proximate mechanisms underpinning animacy effects. At present, animacy effects do not seem to be due to the involvement of an effortful encoding process (Bonin et al., 2015), to the fact that animates have a more organized nature than inanimate items (Bonin et al., 2015; VanArsdall et al., 2017), or to imagery processes (Gelin et al., 2019). However, the hypothesis that the animacy advantage arises as a result of attentional processes is supported by evidence showing that animates are detected faster than inanimates (e.g., Bugaiska et al., 2019; Guerrero & Calvillo, 2016; Jackson & Calvillo, 2013; New et al., 2007; and see also Leding, 2020).

Recently, Meinhardt et al. (2020) proposed the interesting hypothesis that the animacy advantage could be attributable to animates being encoded in a more elaborate (richer) way than inanimates. More precisely, animate words would stimulate the creation of a larger number of distinct associations with other items in long-term memory than inanimate words. These associations would subsequently act as more efficient retrieval cues, leading to better memory performance for animates than for inanimates. The aim of our study was to provide further evidence of the richness-of-encoding account of animacy effects in memory.

Our findings can be easily summarized. First of all, and in the same way as reported by Meinhardt et al. (2020), we found that the number of ideas in response to animate words was higher than that in response to inanimate words. This finding is clearly in line with the richness-of-encoding account. Second, we found that the number of ideas generated at encoding was positively correlated with correct recall rates. Third, the number of ideas was found to mediate the relationship between the animacy dimension and recall performance. The findings obtained from the reanalyses of previous memory studies are also consistent with this mediation. In the reanalysis of both Bonin et al.'s (2015) Study 1 involving intentional learning and Gelin et al.'s (2019) Study 3 based on incidental recall after performing an animacy categorization task, we found that the direct effects of animacy were lower than the total effects, with estimations of indirect effects being in the predicted direction. Even though the indirect effect was significant only with one of the number of ideas measures in the categorization task, the rather small number of items used in these reanalyses and the difficulty of operationalizing a straightforward "by-items richness-of-encoding" measure mean that these properties are, overall, in line with the hypothesized mediation. Finally, the results obtained from the reanalyses of Gelin et al.'s (2017) Study

1 were mixed, and did not make it possible to provide evidence for or against the richness-of-encoding hypothesis of animacy effects.

Where does all this leave us? Taken as a whole, the present findings are in line with the richness-of-encoding account of animacy effects in memory. First of all, the fact that both in the present study and in the Meinhardt et al. (2020) study, animates generated more creative encoding than inanimates (at least when the number of ideas is taken as a gross index of creativity) fits well with the richness-of-encoding account of the animacy advantage in memory. As far as this type of finding is concerned, it is worthy of note that the idea that survival items or contexts (such as imagining being stranded in the grasslands of a foreign land) stimulate creative thinking had already been put forward by certain researchers to account for the survival processing advantage (Röer et al., 2013; Wilson, 2016 but see also Altarriba & Avery, 2021). For instance, Röer et al. (2013) found that participants generated more ideas in response to words that were presented in the context of a survival processing scenario than in the context of a control scenario.[6] Second, evidence has been reported that the number of ideas plays a mediating role in recall performance on animates versus inanimates. Third, even though our reanalyses of previous memory studies yielded mixed results regarding the role of a deep/richer encoding of animates in the animacy advantage, taken overall, the weight of evidence from these re-analyses was more in favor than against the richness account of animacy effects in memory. However, the observation that the mean of the percentages of indirect effects (taken as the point estimations) over total effects obtained across all analyses, except the one corresponding to the survival rating task, was approximately equal to 15% (21% in the by-participants analysis in the current experiment) suggests that the richness explanation tells only one part of the story about animacy effects. Relatedly, even though the ratios were higher in Experiment 2 (43%) and in Meinhardt et al.'s (2020) Experiment 4 (56%), the direct effects of animacy reported by these authors were significant (in Experiment 2) and "nearly" significant (in Experiment 4).

One aspect of the findings worth discussing is the role of the explicit generation task in animacy effects in memory. The animacy effect obtained during encoding in our study after the generation task seems larger than that obtained during encoding after an intentional learning task. One interpretation might be that the use of an explicit (and perhaps "effortful") generation-of-ideas task led to an even richer encoding of the words than is usually performed in studies investigating animacy effects in memory. However, we doubt the plausibility of this account. In effect, the indirect effect of animacy accounted for about 19% of the total effect in the reanalysis of Gelin et al.'s (2019) Study 3, which used an implicit learning task (animacy categorization), and this percentage turned out to be approximately the same as that obtained in the current study!

Some readers might wonder how richness of encoding is related to "meaningfulness", a variable which has also been taken into account in studies investigating word properties that influence recall performance (e.g., Aka et al., 2021; Nairne et al., 2013; Rubin & Friendly, 1986). Meaningfulness is an index of a word's semantic associations with other words (Balota et al., 2001). (Initially, Noble (1952) defined the meaningfulness (m) of an item as the number of strong associations that a given word has with other words.) To obtain meaningfulness measures for words, time-constrained free association tasks are generally used. For instance, in Paivio et al. (1968), meaningfulness values for words were the mean number of written associations provided in 30 s (see also Rubin & Friendly, 1986). In contrast, "richness of encoding measures" for words have been obtained (here and in Meinhardt et al.'s study) without time limitations. Meaningfulness and richness-of-encoding measures are collected in similar ways and the two dimensions are conceptually related since both attempt to quantify a word's semantic relatedness to other words. Certain studies have found meaningfulness to be an important variable that is able to account for a large proportion of explained variance in recall (e.g., Nairne et al., 2013; but see Aka et al., 2021; Christian et al., 1978; Rubin & Friendly, 1986). More generally, it has been shown that words associated with relatively more semantic information are responded to faster and/or more accurately across a variety of lexical processing tasks (Yap et al., 2011). However, animacy remains the best predictor of recall performance when other semantic variables are taken into account, whether (Nairne et al., 2013) or not (Madan, 2021) meaningfulness is considered. Because of the similarities between the two measures, it is possible to anticipate findings similar to those reported here for animacy effects if meaningfulness scores are substituted for richness-of-encoding scores in mediation analyses. Unfortunately, we are not able to test this prediction because meaningfulness

[6] As pointed out by an anonymous reviewer, it is possible that different encoding contexts (e.g., survival scenario, moving scenario) constrain the generation of ideas to different degrees—with animate words causing, on average, the production of more ideas than inanimate words—and that differences in the number of ideas generated in response to specific words may vary in different contexts. Apart from the observation that the interactions between animacy or tasks and the measures of generated ideas are never significant—which suggests that differences between animacy conditions and tasks are similar whatever the number of generated ideas—the current findings cannot be used directly to answer such a question. In the Gelin et al. (2017) studies, animacy effects did not differ across different encoding contexts (e.g., survival encoding, tour guide), suggesting that, perhaps, different contexts do not substantially modify the number of ideas produced in response to animate compared to inanimate words. However, this issue still has to be investigated in detail.

scores were not available for the words used in the current studies. Thus, this remains an interesting issue that should be addressed in depth in future studies.[7]

It is already clear that in addition to the richness account of animacy effects, other proximate explanations will have to be envisioned. Indeed, the idea that "richness-of-encoding" only partially explains animacy effects in memory suggests that the proximate explanations of animacy effects are likely to be multifaceted. This suggestion finds support in the recent findings reported by Blunt and VanArsdall (2021) who found that the effect of the animacy dimension—whether a word refers to a living or a nonliving thing—is additive to that of imagery type (animate versus inanimate imagery). More precisely, according to these researchers: *"animacy" may be separable into component dimensions: featural/conceptual (static) indicators of animacy (e.g., faces, legs, the ability to experience the world) that are largely inherent in a concept, and perceptual (dynamic) cues of animacy (e.g., self-propelled movement, intentionality, contingent behavior), which may or may not exist in any given mental image of a concept."* (p. 1367). It is worth mentioning that one variable which could partially reflect the facets of imagery and richness of encoding is image variability. Image variability is a measure that indicates whether a word evokes few or many different mental images. If both imagery and richness of encoding are involved in the animacy effect, then this effect should also be mediated by image variability, and might possibly be so to a greater extent than with the richness-of-encoding measures used here and by Meinhardt et al. (2020). Given that ratings of image variability were available for all the words used here (by combining the Alario and Ferrand (1999) and the Bonin et al. (2003) databases), we decided to include image variability as the mediator variable for the animacy effect in the four tasks separately (a z-score transformation was performed within each database beforehand). The results were extremely similar to those reported above, that is to say that the direct effects of animacy on recall rates were still lower than the total effects, while still exhibiting the same pattern of significant/not significant effects; point estimations of the indirect effects were all positive but not significant, and their confidence intervals were mostly positive. Moreover, the lower bounds of the confidence intervals were closer to 0 than when the previous richness-of-encoding measures were used (except with NID_I and MID_I and in the categorization task with the NID variable).

Perhaps there is something in the nature of the semantic representations of animates compared to that of inanimates that makes them special and boosts their retrieval. Indeed, Nairne et al. (2013) put forward the hypothesis that the representations of animate items have more features or attributes than those of inanimate stimuli, and that this difference in the representations of the two types of item brings about richer encodings, a suggestion which would make sense given that certain studies have found better recall of items with more semantic features (e.g., Hargreaves et al., 2012). Bonin et al. (2014) did not find that animates had more *sensory features* than inanimates. Bonin et al. (2019) examined the influence of animacy in a concrete-abstract categorization task (a semantic categorization task) and found that animates were categorized faster (and more accurately) than inanimates. Moreover, using the Normalized Google Distance to assess the semantic similarity of the items used in their experiments, they found evidence that animates were more closely related than inanimates, a finding in line with the hypothesis that animates are processed faster in a semantic task because they have a greater semantic overlap than inanimates. More recently, Rawlinson and Kelley (2021) examined whether the semantic representations of animate and inanimate items differed on the number of semantic features by using existing recall data from an item-level megastudy reported by Lau et al. (2018) and found that animates had more semantic features than inanimates. Importantly, this difference partially mediated the relationship between animacy and recall performance (approximately one-third of the variance in recall due to animacy was mediated by measures of numbers of features).

To conclude, the animacy advantage is a new and robust finding in the memory literature and its ultimate explanation has at no point been greatly disputed. Indeed, there is a general agreement that the capacity to remember is the product of evolution guided by natural selection (Nairne & Coverdale, 2021). However, even though there have been many attempts to identify how this effect comes about, i.e., proximate explanations, evidence *unambiguously* favoring any particular proximate explanation has so far been lacking. Nevertheless, the present findings and those of Meinhardt et al.'s (2020) studies suggest that the richness-of-encoding account of animacy effects in memory remains an interesting potential candidate which goes some way to accounting for the animacy advantage in memory.

[7] Nevertheless, before ending our discussion of this issue, we would like to indicate the results of a complementary analysis in which we took the number of different associates given for words as an index of richness-of-encoding. The scores were taken from the Bonin et al. (2013), in which participants were instructed to name the first word that came to mind in response to any given word. (We had scores available for only 9 animates and 7 inanimates used in the present study.) We found that the correlations of the number of associates with recall rates were all significantly positive at .05, except in the intentional learning task (r = .41, p = .119), and that more associates were generated for animate words than for inanimate words, $t(14)$ = 3.05, p = .0087. While the results were descriptively in line with those previously reported, that is to say direct effects of animacy lower than total effects and confidence intervals of indirect effects mostly positive, they were still too widely distributed.

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Data Availability Statement The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing Interest Statement The authors declare no competing interests.

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