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ARTICLE

“It is alive!” Evidence for animacy effects in semantic categorization and lexical decision

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ABSTRACT
Animacy is one of the basic semantic features of word meaning and influences perceptual and episodic memory processes. However, evidence that this variable also influences lexicosemantic processing is mixed. As animacy is a semantic variable thought to have evolutionary roots, we first examined its influence in a semantic categorization task that did not make the animacy dimension salient, namely, concrete-abstract categorization. Animates were categorized faster (and more accurately) than inanimates. We then assessed the influence of animacy in two lexical decision experiments. In Experiment 2, we mostly used legal nonwords, whereas in Experiment 3, we varied the context of the nonwords across participants in such a way that the discriminability between words and nonwords was either high or low. Animates yielded faster decision times than inanimates when legal nonwords were used (Experiment 2) and when the discriminability between words and nonwords was low (i.e., “difficult nonwords” in Experiment 3), but the difference between the two types of words was not reliable when discriminability was high (e.g., illegal strings of letters, i.e., “easy nonwords” in Experiment 3). The findings suggest that animacy is a core meaning-related dimension that influences a large number of processes involved in perception, episodic memory, and semantic memory.

Animacy can be defined as the traits that help us distinguish living from nonliving things (Popp & Serra, 2018) and one of the most important of these is self-propulsion (Di Giorgio, Lunghi, Simion, & Vallortigara, 2017).[1] In the present study, we adopted this definition of animacy, which therefore excludes many things than can move, but are not living, such as robots, vehicles, or rivers. Recently, the influence of animacy has been investigated in episodic memory tasks such as free recall (Bonin, Geli Bugaiska, 2014; Nairne, VanArsdall, Pandeirada, Cogdill, & LeBreton, 2013), cued recall (Popp & Serra, 2016; VanArsdall, Nairne, Pandeirada, & Cogdill, 2015), or recognition (Bonin et al., 2014). Moreover, a number of studies have shown that animacy effects are found in visual–attentional tasks (e.g., Guerrero & Calvillo, 2016; Jackson & Calvillo, 2013; New, Cosmides, &

Tooby, 2007). These findings suggest that the animacy dimension is an "intrinsic" property of concepts that is taken into account at encoding. At an ontological level, the distinction between animates and inanimates is thought to be a core organizing principle of children's experiences (e.g., Rostad, Yott, & Poulin-Dubois, 2012).

According to certain views of the organization of semantic memory, semantic knowledge is organized around broad categories such as living/animate versus non-living/inanimate things (Caramazza & Shelton, 1998; for a review, see Capitani, Laiacona, Mahon, & Caramazza, 2003), or more refined categories such as animals, plants, and artifacts (Caramazza & Mahon, 2003). For example, the domain-specific category-based model (Caramazza & Shelton, 1998) assumes that, due to evolutionary pressures, humans have dedicated neural mechanisms that permit the recognition of a few categories that are of greatest relevance for survival and/or reproduction (see also Mahon & Caramazza, 2009). Evidence for the hypothesis that the animacy dimension is relevant for conceptual organization in memory comes from analyses of the performance of brain-damaged patients who, for instance, have a deficit restricted to the category of animate items (e.g., Caramazza & Shelton, 1998).

According to a current dominant view of semantic memory (i.e., sensorimotor-based models, also referred to as embodied models) semantic knowledge of concepts consists of sensory and motor attributes (e.g., shape, smell, and potential interactions), which are distributed across neural regions that underlie sensory and motor processing. For instance, according to Barsalou's (1999) perceptual symbol systems theory, sensory experiences of a given concept become organized and are stored as a simulator. To give an example, the concept of APPLE corresponds to the sensorimotor experiences of touching, smelling, or cutting an apple, and this information is stored as part of the APPLE concept in the form of perceptual symbols. It is possible to simulate an APPLE by calling on its constituent perceptual symbols to re-create the perceptual experience of this fruit. Following this view, variations in the amount of simulation elicited by a word (e.g., *apple*) may lead to differences in processing. A great quantity of simulations associated with words (semantically richer words) leads to a processing advantage compared to fewer simulations (Pexman, Hargreaves, Siakaluk, Bodner, & Pope, 2008). Following this view, "information gained through sensorimotor or bodily experience is important to the representation of word meaning" (Sidhu & Pexman, 2016), and thus, it is possible to hypothesize that animates have a processing advantage because they are semantically "richer" than inanimate words, for instance due to a greater overlap in terms of semantic features (Davis, Xue, Love, Preston, & Poldrack, 2014; Xiao, Dong, Chen, & Xue, 2016), or because animates are richer than inanimates in terms of sensorimotoric features (Bonin et al., 2014 but see Gelin, Bugaiska, Méot, Vinter, & Bonin, 2019; Heard et al. 2019).

As claimed by Radanović, Westbury, and Milin (2016), animacy is one of the basic semantic features of word meaning, and as briefly reviewed above, different views of semantic organization and processing attribute a processing advantage to animates over inanimates. In addition, because a processing advantage has been reported in the domains of perception, attention, and episodic memory, it is therefore of great importance to examine how this feature is activated in tasks indexing access to lexicosemantic knowledge. In the present study, we addressed the impact of animacy in accessing lexicosemantic knowledge in semantic categorization and lexical decision tasks, an issue that has not as yet been investigated thoroughly. Although the visual lexical decision task relies primarily on orthographic codes (Balota, Ferraro, & Connor, 1991; Izura & Hernández-Muñoz, 2017), it has often been used successfully to investigate semantic codes (e.g., Yap, Lim, & Pexman, 2015; Yap, Tan, Pexman, & Hargreaves, 2011). However, evidence for animacy effects in lexical decision is inconclusive (Radanović et al., 2016). According to Radanović et al. (2016), the inconsistency of the findings concerning the impact of animacy in lexicosemantic tasks is thought to be due to the selection by researchers of specific categories of animate versus inanimate items (i.e., "the language-as-fixed-effect fallacy"; Clark, 1973).

Several studies have investigated the influence of animacy in semantic categorization and in lexical decision. Radanović and Milin (2011) used an animacy categorization task with Serbian nouns that could be classified on the basis of a morphonological marker (i.e., linguistic animacy marking), and did not find a reliable effect of animacy in lexical decision times. However, this task is not strictly speaking a semantic task as linguistic features are also involved in animacy decisions. In a subsequent study, Radanović et al. (2016) did not find reliable effects of animacy in lexical decision times in either Serbian or English. However, in both languages, reliable effects of animacy were found in a semantic categorization task: animacy decision.

According to Radanović et al. (2016), the findings suggest that animacy does not play a role in word recognition. However, as acknowledged by these authors, such a conclusion is based on null results for lexical decision times. In the lexical decision literature, it is well known that the wordlikeness of nonwords modulates the effect of different lexical properties on lexical processing (e.g., Stone & Van Orden, 1993). It has been assumed that the depth of processing increases when the nonwords used are more wordlike, such as legal nonwords or pseudohomophones (i.e., nonwords that sound like real words, e.g., *brane*). Conversely, when nonwords consist of sequences of letters that are illegal in the orthographic system in question, such as unpronounceable nonwords, less time is needed to make word–nonword decisions (Evans, Lambon Ralph, & Woollams, 2012).

In the studies by Radanović and Milin (2011) and Radanović et al. (2016), the nonwords that were used followed Serbian or English orthographic and phonotactic rules. However, it is still possible that the word–nonword contrast gave rise to a shallow level of processing that resulted in nondetectable animacy effects on lexical decision times. Radanović et al.'s (2016) conclusion is therefore premature, and we think that the extent to which animacy information is consulted when recognizing words must be reexamined. To that end, the foremost goal of the present work was to shed further light on this issue by examining whether animacy reliably influences lexical decision. Furthermore, one potential shortcoming of the semantic categorization task used by Radanović et al.'s (2016; viz. animacy categorization) is that the participants were forced to use information relating to animacy. As a result, we cannot be sure that such information would be activated and used in other semantic tasks in which the animacy dimension is not made salient. In the first experiment, we therefore investigated whether animacy would be observed in semantic categorization when the task does not make animacy information salient.

A concrete-abstract categorization task was used. In this task, participants have to decide as quickly as possible whether words are "abstract" or "concrete" (Pexman, Heard, Llyod, & Yap, 2017). If animacy is one basic semantic feature of word meaning, we anticipate that animate concrete words (e.g., *baby*) should be categorized faster than inanimate concrete words (e.g., *mountain*). In two further experiments, we used lexical decision to assess animacy effects. More precisely, we hypothesized that animacy would be a critical semantic dimension used by the cognitive system, especially if the word–nonword classification is somehow more difficult, and the task therefore requires more sources of information, including semantic information on which to base lexical decisions. In Experiment 2, the nonwords were mostly legal (see Procedure section for details). In Experiment 3, we varied the types of nonwords used. The target words were intermixed with either difficult or easy nonwords. We expected to find reliable animacy effects on lexical decision performance, especially when the discrimination between words and nonwords was made more difficult and when the semantic information provided a useful supplementary source of information for word–nonword classification. Thus, the prediction was that animacy effects should emerge and be stronger when nonwords used as filler items are more wordlike (e.g., pseudohomophones) but that these effects should not be observable in lexical decision times when the nonwords are easy to classify because they do not look like French words (e.g., illegal strings of letters in French).

Experiment 1. semantic categorization

In the following experiment, the participants had to decide as quickly as possible whether words were "abstract" (e.g., *freedom* or *curse*) or "concrete" (e.g., *baby* or *duck*). A concrete word was defined as any word whose referent can be experienced by the senses (Bonin, Méot, & Bugaiska, 2018). Among the concrete words, half referred to animate entities whereas the other half referred to inanimate entities. Because classifying words as concrete versus abstract requires access to semantic information, animate words should be categorized more quickly (and more accurately) than inanimate words.

Method

Participants

Sixty-nine adults (6 males, mean age 19.37 years, range 17–28) from the University of Bourgogne took part. They received academic credits for their participation. All were native speakers of French, and they had either normal or corrected-to-normal vision.

Stimuli

Experimental stimuli consisted of 128 nouns that were selected from the Snodgrass and Vanderwart (1980) and Bonin, Peereman, Malardier, Méot, and Chalard (2003) databases. Half referred to animate things and the other half to inanimate things and constituted the set of concrete words (C). This set was matched with 128 abstract words (A) taken from Ferrand (2001), for the surface variables of number of letters (C: *M* = 6.57, *SD* = 2.04, *min–max* = 3–15; A: *M* = 6.98, *SD* = 1.92, *min–max* = 3–12) and number of syllables (C: *M* = 2.5, *SD* = 0.90, *min–max* = 1–5; A: *M* = 2.32, *SD* = 1.05, *min–max* = 1–7). The list of animate and inanimate concrete words and the abstract words used in Experiment 1 is provided in the online-only Supplemental Materials A.

As far as the concrete words are concerned, animate and inanimate words were matched on a large number of surface variables (i.e., number of letters and of syllables, first syllable frequency, and bigram frequency), lexical variables ([book and subtitle] frequency, age of acquisition, number of orthographic neighbors, and orthographic uniqueness point), and semantic variables (imageability, image variability, and emotional valence). The full statistical details of the experimental words are shown in Table 1.

Procedure

The participants were tested collectively (in small groups, eight participants maximum) in a sound-attenuated room under standard lighting conditions. They sat about 60 cm from the computer screen. The participants were instructed that they would be presented with a long list of words and that they would have to categorize any given word presented on the screen as concrete or abstract. A brief definition of what is meant by concrete and abstract was provided at the beginning of the experiment. More precisely, a concrete word was defined as a word whose concept refers to perceptible entities such as objects, persons, or places (Bonin et al., 2018). Computers running the Eprime software (Psychology Software Tools, Pittsburgh, PA) controlled the presentation of the stimuli and recorded response times (RTs). Each trial had the following structure: a ready signal "> <" was presented for 200 ms in the center of the screen followed by a word that remained visible until the participant's response. The stimuli were displayed in lowercase in 12-point Trebuchet MS. The participants had to decide as quickly as possible, and without making errors, if the word referred to a concrete or to an abstract word by pressing two different keys using their two hands (the "ALT" and "CTRL" keys located at opposite ends of the keyboard were used for the concrete and abstract responses, respectively, for half of the participants and the reverse for the other half). The intertrial interval was set to 400 ms. The words were presented randomly and in a different order for each participant. Whenever a wrong response was given, a visual feedback was provided. The participants had to press a key to continue the experiment. Warm-up trials (six) were included before the experiment proper.

Analyses

In all of the experiments, errors were analyzed using a mixed-effect logistic model (MLogM) with random intercepts by participants and words and, whenever possible (see below), participants' random slopes for the animacy factor. The computations were done with the glmer function included in the lme4 package of R. After some trials had been removed (see below for the criteria), correct RTs were submitted to a mixed-effect linear model (MLM) with random intercepts and slopes by participants and random intercepts by words using the lmer function of lme4. The tests

Table 1. Statistical characteristics of the animate and inanimate words used in Experiments 1 and 3

	Animate				Inanimate				
	Mean	*SD*	Range	Min–max	Mean	*SD*	Range	Min–max	*t* test
Number of letters[a]	6.36	1.93	8	3–11	6.78	2.14	12	3–15	$t(126) = -1.16$, $p = .25$
Number of syllables[a]	2.38	0.86	4	1–5	2.61	0.96	5	0–5	$t(126) = -1.44$, $p = .15$
First syllable frequency[a]	1098.13	3396.88	26168.79	0.21–26169	1055.22	3418.57	26169	0–26169	$t(126) = 0.07$, $p = .94$
Bigram frequency (per million words)[a]	9019.02	3209.63	17119	2963–20082	9820.98	2727.31	13429	2360–15789	$t(126) = -1.51$, $p = .13$
Book frequency[a]	13.81	27.25	186.89	0.07–186.96	27.80	56.14	315.67	0.07–315.74	$t(126) = -1.78$, $p = .08$
Subtitle frequency[a]	16.39	33.43	188.29	0.12–188.41	17.07	32.58	176.04	0.06–176.1	$t(126) = -0.11$, $p = .91$
Age of acquisition[b]	2.54	0.74	3.47	1.15–4.62	2.69	0.78	3.37	1.23–4.6	$t(126) = -1.10$, $p = .27$
Number of orthographic neighbors[a]	2.95	4.68	24	0–24	2.47	3.97	19	0–19	$t(126) = 0.63$, $p = .53$
Orthographic uniqueness point[a]	5.38	1.97	11	0–11	5.23	2.45	9	0–9	$t(126) = 0.36$, $p = .72$
Imageability[c]	4.33	0.54	2.88	2.08–4.96	4.31	0.48	1.96	3.04–5	$t(126) = 0.30$, $p = .77$
Image variability[b]	2.23	0.66	3	1–4	2.13	0.74	4	0–4	$t(126) = 0.88$, $p = .38$
Emotional valence[c]	3.17	0.74	3.24	1.32–4.56	3.04	0.73	3.16	1.2–4.36	$t(126) = 0.98$, $p = .33$

Note: [a]Values taken from Lexique (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).

were run using the lmerTest package and Sattertwhaite approximations for the degrees of freedom.

Results and discussion of Experiment 1

In order to assess whether (a) there were more errors on inanimate than on animate words and (b) there were less errors on concrete (= inanimate + animate words) than on abstract words, two dummy independent variables coding the conditions were included in the mixed-effect logistic model and the reference category was alternated to enable the comparison of all pairs. Using this model, the percentages of incorrect responses were estimated at 3.3%, 5.0% and 10.9% for animate, inanimate, and abstract words, respectively. The error rate was significantly higher for abstract words than for concrete words (animates: $z = 8.52$, $p < .001$ and inanimates: $z = 5.88$, $p < .001$). There were reliably more errors for inanimate than for animate words, $z = 2.47$, $p = .0134$. It is worth noting that because the model with participants' random slopes did not converge, the results that are reported relate to the model with random intercepts only.

As far as the analysis of RTs is concerned, scores 3 *SD* above or below the mean RT per participant and per condition (1.99% of the remaining trials) were considered as outliers and therefore removed. We used the same procedure to remove outliers in Experiments 2 and 3.

In the MLM including the factor type of words, a significant effect of this factor was found, F (2, 215.62) = 39.29, $p < .001$, with mean RTs being faster for animate ($M = 681.75$ ms, $SE = 15.5$) than for inanimate words ($M = 728.42$ ms, $SE = 15.92$), $t(223.18) = -4.15$, $p < .001$. In addition, abstract words ($M = 782.42$ ms, $SE = 16.33$) took longer to classify than concrete words, and the difference was reliable for both animates, $t(203.54) = 8.86$, $p < .001$, and inanimates, $t(194.59) = 4.59$, $p < .001$. (It is important to note that the same results were found without the elimination of outliers.)

In sum, as we predicted, animate words were categorized faster (and more accurately) as concrete words than inanimate words. As the concrete-abstract categorization task did not make the animacy dimension salient to the participants, the findings therefore suggest that animacy is a core semantic feature of word meaning. However, as pointed out by an anonymous reviewer, it may be asked whether animates were faster to categorize as concrete items than inanimates because the former words were also more concrete than the latter and concrete words are generally processed faster than abstract words (e.g., Schwanenflugel, Harnishfeger, & Stowe, 1988; see also Bonin et al., 2018). Concreteness ratings were obtained for our experimental words from the Bonin, Méot, et al. (2003) normative study. Fortunately, it turned out that animates were less concrete ($M = 4.56$, $SD = 0.50$) than inanimates ($M = 4.72$, $SD = 0.27$), $p = .024$, a result that runs contrary to the finding that animate words are responded to faster than inanimate words because they are more concrete.[2] In the same vein, it is possible that the concrete words were faster to categorize because they were more frequent than the abstract words. This was, however, not the case because the abstract words were significantly more frequent ($M = 1.21$, $SD = 0.64$) than both the animates ($M = 0.87$, $SD = 0.53$), $t(253) = 3.75$, $p < .001$, and inanimates ($M = 0.86$, $SD = 0.56$), $t(253) = 3.81$,

$p < .001$ (the results are reported with a log+1 transformation of the *subtitle* frequencies but they were similar when raw frequencies and/or *book* frequencies were used).

Experiment 2. lexical decision with legal nonwords

In the studies by Radanović and Milin (2011) and Radanović et al. (2016), a lexical decision task was designed with nonwords that followed Serbian or English orthographic and phonotactic rules. No reliable effects of animacy were found on lexical decision times. In the following experiment, we also used legal French nonwords (there were only three illegal nonwords). In the literature in lexical decision, legal nonwords that are not pseudohomophones are the most frequently used type of nonwords. Because effects of semantic variables have been reported in lexical decision with the use of this type of nonwords, and because animacy is a semantic variable, we should find animacy effects in the lexical decision performance.

Method

Participants

Fifty-four adults (14 males, mean age 21.84 years old, range 19–44) from the University of Bourgogne took part. Although the experiment was part of a course requirement, all the participants were free to decline to participate in the experiment. They were all native speakers of French and had either normal or corrected-to-normal vision.

Materials

The word list was the same as the one used in the Bonin et al. (2014) studies, and all the words used here were also used in Experiment 1 (see online-only Supplemental Materials A for the words used in Experiment 2). There were 56 nouns divided into two lists of animate versus inanimate words. As described in Bonin et al. (2014), animates and inanimates were matched on several psycholinguistic variables, namely, surface variables (number of letters and syllables, first syllable frequency, and bigram frequency), lexical variables ([book and subtitle] frequency, age of acquisition, number of orthographic neighbors, and orthographic uniqueness point) and semantic variables (imageability, image variability, conceptual familiarity and emotional valence). The full details of the experimental words are shown in Table 2.

The nonwords were created from the words by changing one or two letters using a dedicated toolbox available on Lexique.org. Among the nonwords, three were illegal nonwords, but all the remaining nonwords were legal strings of letters in French. The statistical characteristics corresponding to the nonwords are provided in Table 3. The list of the nonwords used in Experiment 2 is provided in the online-only Supplemental Materials B.

Procedure

The participants completed a lexical decision task collectively in a sound-attenuated room under standard lighting conditions. The room was equiped with

Table 2. Statistical characteristics of the animate and inanimate words used in Experiment 2

	Animate				Inanimate				
	Mean	*SD*	Range	Min–max	Mean	*SD*	Range	Min–max	*t* test
Number of letters[a]	6.5	1.9	7	3–10	6.61	1.91	7	3–10	$t(54) = -0.21$, $p = .83$
Number of syllables[a]	2	2.71	2	1–3	1.96	0.78	3	1–4	$t(54) = 0.18$, $p = .86$
First syllable frequency[a]	738.35	1270.07	6265.59	0.21–6265.8	703.79	1637.13	8654.78	1.22–8656	$t(54) = 0.09$, $p = .93$
Bigram frequency (per million words)[a]	8220.43	3193.09	12024	1430–13454	9447.93	2675.39	11616	2360–13976	$t(54) = 1.53$, $p = .13$
Book frequency[a]	16	36	186.89	0.07–186.96	22	45	175.13	0.07–175.2	$t(54) = -0.53$, $p = .60$
Subtitle frequency[a]	20	47	188.26	0.15–188.41	13	30	154.07	0.06–154.13	$t(54) = 0.70$, $p = .48$
Age of acquisition (1–5)[b]	2.52	0.65	2.6	1.15–3.75	2.75	0.8	2.97	1.23–4.2	$t(54) = -1.23$, $p = .22$
Number of orthographic neighbors[a]	2.14	3.4	13	0–13	2.5	3.7	11	0–11	$t(54) = -0.38$, $p = .71$
Orthographic uniqueness point[a]	4.78	2.27	10	0–10	5	2.74	9	0–9	$t(54) = 0.90$, $p = .37$
Conceptual familiarity (1–5)[b]	2.14	0.79	2.83	1.07–3.9	2.49	0.85	3.79	1.18–4.97	$t(54) = -1.62$, $p = .11$
Imageability (1–5)[c]	4.42	0.37	1.32	3.64–4.96	4.2	0.49	1.6	3.24–4.84	$t(54) = 1.92$, $p = .06$
Image variability (1–5)[b]	2.72	0.67	2.45	1.85–4.3	2.5	0.57	2.42	1.6–4.07	$t(54) = 1.30$, $p = .20$
Emotional valence (1–5)[c]	3.29	0.68	3.24	1.32–4.56	2.99	0.64	2.6	1.52–4.12	$t(54) = 1.71$, $p = .09$

Note: [a]Values taken from Lexique (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).

Table 3. Statistical characteristics of the nonwords used in Experiments 2 and 3

	Nonwords used in Exp. 2		Nonwords used in Exp. 3 (difficult nonwords)		Nonwords used in Exp. 3 (easy nonwords)	
	Mean	*SD*	Mean	*SD*	Mean	*SD*
Number of letters[a]	6.55	1.89	6.70	2.09	6.63	2.07
Number of orthographic neighbors[a]	1.36	2.14	2.39	3.21	0.80	2.00
Bigram frequency (per million words)[a]	8056.38	3504.76	8975.50	2826.56	7122.41	2852.07
Trigram frequency (per million words)[a]	880.30	774.37	1004.37	737.27	733.05	616.65

Notes: *SD*, standard deviation. [a]Values taken from Lexique (New et al. 2004).

12 computers. Each participant was seated at a fixed distance of 60 cm in front of the screen running E-Prime software (2016; Psychology Software Tools, Pittsburgh, PA). The software displayed the stimuli and recorded the responses. The participants were instructed to decide, for each presented string of letters on the screen, whether it was a French word or not. The stimuli were displayed in lowercase in 12-point Trebuchet font. The participants had to press the “yes” button of a keypad with the preferred hand (“ALT” on the keyboard if they were right-handed or “CTRL” if they were left-handed) when the string of letters was a word, and to press the “no” button of the keypad with the nonpreferred hand when it was not a word (i.e., it was a nonword). The participants were instructed to respond as quickly as possible, while avoiding errors. However, if an error occurred, feedback was provided to the participants. They had to press one of the two response keys to continue the experiment. The stimuli were presented randomly and in a different random order to each participant. Before the experiment proper, there were 20 warm-up trials.

Each trial consisted of the following order of events. At the beginning of each trial, the participant was first instructed to look at a fixation point (“> <”) that was displayed for 200 ms in the center of the screen. The fixation point was then replaced by a target (word or nonword) centered on the screen. The target remained on the screen until the participant responded by selecting either the word-response or the nonword-response. The interval between trials was 400 ms.

Results and discussion of Experiment 2

Four words were removed: two (*koala* [koala], *locomotive* [locomotive]) because of technical problems and two others (*lionceau* [lion cub], *cymbales* [cymbals]) because the accuracy scores were below 50%. For the remaining words, incorrect decisions amounted to 3.58% and 4.22% for animates and inanimates, respectively.

The difference in MLogM was not significant when animacy was included as an independent variable, $z = -.78$, $p > .1$.

A total of 1.53% of the trials with correct RTs were considered as outliers and were therefore removed (see Experiment 1 for the procedure used to exclude data). The MLM with animacy included as an independent variable revealed that the mean lexical decision time for animate words was significantly faster ($M = 591.89$, $SE = 12.84$) than for inanimate words ($M = 620.1$, $SE = 14.83$), $t(59.8) = -2.6$, $p < .05$.

Using nonwords that were all legal except for three, we found animacy effects in lexical decision times. This finding in French is clearly at odds with the lack of animacy effects in lexical decision in English and in Serbian reported by Radanović et al. (2016). Might the structure of the different orthographic systems be responsible for the lack of animacy effects in lexical decision in Serbian and English? Certain researchers have assumed that word recognition decisions can be made without the involvement of central components of the semantic system in certain linguistic systems (e.g., Spanish; Izura & Hernández-Muñoz, 2017) on the basis of findings showing that certain semantic variables, for example imageability, have an effect in English but no reliable effects in a more transparent language such as Spanish (Izura & Hernández-Muñoz, 2017). As far as English is concerned, we do not think that differences between the French and English orthographic systems can account for Radanović et al.'s (2016) failure to find animacy effects in lexical decision because English is more opaque than French in the orthography → phonology direction (e.g., Ziegler, Jacobs, & Stone, 1996) and a large number of studies have found effects of semantic variables such as imageability in English (e.g., Strain, Patterson, & Seidenberg, 1995). We are therefore left with no explanation for the lack of animacy effects in both Serbian and English reported by Radanović et al. (2016) except that, perhaps, the nonwords they used were easy to discriminate from the words.

In the third and final experiment, we wanted to study more difficult nonwords than those used in Eperiment 2 and to contrast them with easy nonwords. We thought that the inclusion of pseudohomophones would render the word–nonword categorization more difficult. In the word recognition literature, pseudohomophones are thought to be difficult nonwords because they sound like words. Therefore, in order to categorize them quickly and accurately, a deep level of processing is required. Likewise, we varied the types of nonwords used: difficult versus easy nonwords. We should find animacy effects on lexical decision performance when the discrimination between words and nonwords is made more difficult, that is to say with nonwords corresponding to pseudohomophones and to non-pseudohomophones having word neighbors. In the latter case, semantic information can be used as a supplementary source of information to perform the word–nonword decisions. However, we did not expect to find a reliable effect of animacy with the easy nonwords.

Experiment 3. lexical decision with easy versus difficult nonwords

Method

Participants

Seventy adults (11 males, mean age 20.98 years old, range 19–24) from the University of Bourgogne were involved. Thirty-three were included in the easy nonword condition and 37 were included in the difficult nonword condition. As for Experiment 2, although the experiment was part of a course requirement, all the participants were free to decline to participate in the experiment. They were all native speakers of French and had either normal or corrected-to-normal vision.

Materials

The words were the same as those used in Experiment 1 (see online-only Supplemental Materials A). The 256 nonwords were created from the words using the dedicated toolbox from Lexique.org in order to create easy (128) nonwords and difficult (128) nonwords. As far as the easy nonwords are concerned, half were nonwords with strings of letters that are illegal in French (e.g., *aoapa*) and the remaining half were legal nonwords that were obtained by changing two letters from the words (e.g., *outrucre* for the French word *autruche* meaning *ostrich*). The difficult nonwords were more wordlike nonwords. To this end, the difficult nonwords were either pseudohomophones (e.g., *eigle* is a pseudohomophone of the French word *aigle*, meaning eagle; *baiquilles* is a pseudohomophone of the French word *béquilles*, meaning crutches) or nonwords that were not pseudohomophones but that had orthographic (word) neighbors as defined by the orthographic N metric (Coltheart, Davelaar, Jonasson, & Besner, 1977), that is, the number of words derivable from the nonword by changing one letter while preserving the identity and position of the other letters. For example, *canord* is a nonword that has *canard* (duck) as an orthographic word neighbor. The difficult nonword list consisted of half pseudohomophones and half "N-nonwords." Nonwords having many word neighbors are responded to more slowly than nonwords having fewer neighbors (Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004). As can be seen in Table 3, there were more N-words for the difficult nonwords than for the easy nonwords. The difficult nonwords had significantly more neighbors and higher bigram and trigram frequencies than the easy nonwords (all $p < .001$; see Table 3 for means and standard deviations). No reliable differences were observed on the number of letters. Likewise, there were two levels of difficulty in word/nonword discriminability: easy or difficult. The list of the nonwords used in Experiment 3 is provided in the online-only Supplemental Materials B.

Apparatus and procedure

The apparatus used in Experiment 2 was also used here. The procedure was the same as in Experiment 2 except that the participants were randomly assigned to one of the two nonword conditions.

Results and discussion of Experiment 3

One word that was incorrectly spelled on the screen (*esquimau* [inuit]) and two other words with accuracies below 50% (*fourmilier* [anteater], *banjo* [banjo]) were removed. Error decision rates varied between 5.3% (inanimates, difficult nonwords) and 6.4% (inanimates, easy nonwords). In the MLogM analysis, none of the animacy or pseudoword effects or their interaction turned out to be significant (all $p > .1$). Once again, as was the case in Experiment 1, the model including random slopes failed to converge, which led us to include only random intercepts.

A total of 1.95% of the correct RTs were outliers, and were therefore set apart following the same exclusion procedure as that described in Experiment 1. Animacy and type of nonwords were included as independent variables in the MLM. The effect of animacy was marginally significant, F (1, 127.74) = 3.58, $p = .061$, whereas the effect of type of nonwords was significant, F (1, 67.96) = 8.17, $p < .01$: RTs with easy nonwords ($M = 570.1$, $SE = 9.83$) were responded to faster than with difficult nonwords ($M = 605.94$, $SE = 9.36$). The interaction effect between animacy and type of nonwords was reliable, F (1, 67.40) = 4.31, $p < .05$. The simple effect of animacy was significant in the difficult nonword condition, $t(145.97) = –2.48$, $p < .05$, with RTs being faster for animate words ($M = 595.78$, $SE = 9.99$) than for inanimates words ($M = 616.11$, $SE = 10.44$), whereas no reliable difference was found in the easy nonword condition, $t(150.07) = –1.11$, $p > .1$ (animates $M = 565.49$, $SE = 10.42$; inanimates $M = 574.71$, $SE = 10.91$). For the sake of completeness, it should be noted that RTs were significantly faster in the easy nonwords condition than in the difficult nonwords condition both for animates, $t(67.93) = –2.44$, $p < .05$, and inanimates, $t(67.93) = –3.13$, $p < .01$.

As we anticipated, when the discrimination between words and nonwords was made more difficult (using pseudohomophones and nonwords that are not pseudohomophones but that are wordlike because they have many word neighbors) and thus when semantics provided a supplementary source of information to categorize words and nonwords, lexical decision times were faster for animate words than for inanimate words. Although we anticipated larger animacy effects with the difficult nonwords, the animacy effect on lexical decision times was not larger in this latter condition than in Experiment 2, in which legal nonwords were used (I-A RT difference = 20.33 ms vs. 28.21 ms).

In addition, and to our surprise, the overall reaction times were not slower for the words intermixed with half pseudohomophones (605.94 ms) than when the words were intermixed with virtually only legal nonwords in Experiment 2 (605.5 ms). This pattern of findings suggests that the two sets of nonwords (legal nonwords in Experiment 2 and difficult nonwords in Experiment 3) yielded a similar level of word–nonword discriminability. For the 56 words common to the two lexical decision experiments,[3] repeated t tests comparing the level of difficulty ("difficult" and "easy" in Experiment 3 vs. "legal" nonwords in Experiment 2) revealed that the difficult nonwords had significantly more neighbors and higher bigram frequencies than the nonwords used in Experiment 2, $t(55) = 3.43$, $p < .01$ and $t(55) = 2.37$, $p < .05$. Despite the presence of comparable differences, these two types of nonwords did not differ significantly on number of letters or trigram frequency (both $ps > .1$). In addition, the nonwords used in Experiment 2 had significantly more neighbors, $t(55) = 3.68$, $p < .001$, and higher bigram, $t(55) = 2.59$, $p < .05$, and trigram frequencies, $t(55) = 2.09$, $p < .05$, than the easy nonwords used in Experiment 3. If we compare the level of difficulty of the remaining nonwords used in Experiment 3 to that of the nonwords used in Experiment 2, we find the same pattern of results; that is to say, the difficult nonwords (and the nonwords in Experiment 2) had more neighbors and higher bigram and trigram frequencies than the nonwords in Experiment 2 (and the easy nonwords in Experiment 3).

However, the differences were not significant (it should be noted that the differences between the difficult and the easy nonwords of Experiment 3 were, however, still significant for the 72 considered nonwords, but marginal for trigram frequencies). Taken overall, these findings suggest that the differences between the difficult nonwords in Experiment 3 and the nonwords in Experiment 2 were too tenuous to bring about any differences in the animacy effect on lexical decision times.

General discussion

Animacy is an important semantic trait that has been found to influence many perceptual-attentional (Bugaiska et al., 2019; Guerrero & Calvillo, 2016; Jackson & Calvillo, 2013; New et al., 2007) and episodic memory tasks (Bonin et al., 2014; for a review, see Nairne, VanArsdall, & Cogdill, 2017). According to certain views of the organization of semantic memory, semantic knowledge is thought to be organized around categories such as living/animate versus nonliving/inanimate things (Capitani et al., 2003; Caramazza & Mahon, 2003; Caramazza & Shelton, 1998). Moreover, in line with embodied models of semantic memory (Barsalou, 1999; Pulvermüller, 2013), the processing advantage over inanimates in a semantic categorization task (e.g., Radanović et al.'s, 2016, animacy categorization task) could be due to the former items having more (sensorimotor) semantic features than the latter. However, the influence of this dimension in tasks involving lexicosemantic code activation remains unclear. Thus, precisely how animacy is activated and used in different lexicosemantic processing tasks is an issue that needs to be addressed empirically. The present research was designed to shed light on this issue. In a series of three experiments, we tested the influence of animacy in adults. We designed one semantic task, concrete-abstract categorization, and two lexical decision tasks. A key aspect of the lexical decision tasks was that the nonwords were manipulated in order to render lexical decisions more or less difficult. The rationale was that if nonwords are more wordlike (e.g., pseudohomophones), more sources of information would have to be used in order to decide whether presented strings of letters are words or nonwords than when words are less or not wordlike (e.g., unpronounceable nonwords). As a result, semantic information should be more activated and used more in a context of difficult nonwords than in a context of easy nonwords. We therefore expected that animacy effects would be reliable in lexical decision when the nonwords were more wordlike, and not reliable when nonwords that are easy to discriminate from words (e.g., illegal letter strings) were used. Our findings successfully confirmed this prediction. It is interesting to note that a context of legal nonwords was sufficient for animacy effects to reliably surface in lexical decision, and that it is therefore not necessary to create a nonword context in which familiarity is not a viable dimension for word–nonword discrimination (i.e., by using pseudohomophones).

Given that only a small part of the variance in lexical decision is explained by the semantic characteristics of the words (Pexman, 2012; Pexman et al., 2017), it is important to stress that we successfully found animacy effects in lexical decision in Experiments 2 and 3. We also assessed the influence of animacy in a semantic task: concrete versus abstract categorization. The reason why we tested the impact of animacy in a semantic task is because its influence had previously been observed in animacy categorization tasks, which may inflate the influence of this variable. In Experiment 1, participants were encouraged to rely on the concreteness dimension, and not on the animacy dimension. Thus, the observation that animacy plays a role in a task emphasizing the concreteness dimension suggests that this semantic dimension is activated even though it is not required to perform the task. The animacy dimension is thus an "intrinsic" property of concepts that is taken into account at encoding.

How can the influence of animacy in lexicosemantic tasks be accounted for?

One explanation, rooted in evolutionary psychology, for the mnemonic advantage of animates over inanimates, has been that animates are of higher fitness values (i.e., they can be dangerous animals, family members or friends, or sexual partners) than inanimates (Nairne, 2010, 2015; Nairne et al., 2017). Such an *ultimate explanation* of animacy effects has been complemented by *proximate explanations*. There are two main proximate explanations that have been proposed to account for animacy effects in semantic memory. According to one explanation, the animacy advantage arises as a result of attentional processes. This account is supported by the findings that animates are detected faster than inanimates (e.g., Guerrero & Calvillo, 2016; Jackson & Calvillo, 2013; New et al., 2007). Another explanation of animacy effects can be referred to as the semantic richness account. According to this account, animate words are semantically "richer" than inanimate words because the former have a greater overlap in terms of semantic features than the latter (Davis et al., 2014; Xiao et al., 2016). A feature-listing task performed by young adults on 64 concepts taken from living and nonliving semantic categories showed that semantic representations overlap more in the living than in the nonliving domain (Zannino, Perri, Pasqualetti, Caltagirone, & Carlesimo, 2006). In line with the semantic richness account, it could be that animates are richer than inanimates in terms of sensorimotoric features (Bonin et al., 2014, but see Gelin et al., 2019; Heard et al., 2019).

In episodic memory, the idea that animates have a more organized nature than inanimate items has been put forward to explain why animates are remembered better than inanimates. However, the studies that have tested this hypothesis have failed to find supporting evidence. In Bonin, Gelin, Laroche, Méot, and Bugaiska (2015), strong animacy effects were found on the recall performance of adults even though the items in the animate category were no more similar to one another than the items in the inanimate category. The semantic similarity of the items was assessed using the Normalized Google Distance (a measure computed from the number of hits for words returned by the Google search engine; Cilibrasi & Vitanyi, 2007; Hutson & Damian, 2014). Finally, in a recent study, Gelin, Bugaiska, Méot, and Bonin (2017, Experiment 4) found that animate words were recalled better than inanimate words when category size and cohesiveness of items across both animate and inanimate categories were controlled for (see also VanArsdall et al., 2015). However, evidence for the semantic richness account of animacy effects in lexical processing can be found in the findings obtained in certain neuroscientific studies. For example, Davis et al. (2014) found that neural global pattern similarity in the medial temporal lobe, which was taken as indicating an overlap with other studied items, was reliably correlated with word recognition confidence (see also LaRocque et al., 2013). Xiao et al. (2016) performed a functional magnetic resonance imaging study in which participants had to study living and nonliving words via an animacy categorization task and were then tested 30 min later for memory using a recognition test. More living than nonliving words were correctly recognized. In accordance with the overlapping semantic feature hypothesis, Xiao et al. found that, first, there was a greater semantic similarity for living words than for nonliving words as assessed by ratings. Second, greater neural global pattern similarity was observed for living words than for nonliving items in the posterior portion of the left parahippocampus. Third, the neural global pattern similarity in the left parahippocampus reflected the rated semantic similarity, and also mediated the memory differences between living and nonliving items. Fourth, greater activation was found in the left hippocampus for living words than for nonliving words, which, according to the researchers, might reflect greater semantic context binding.

Using the Normalized Google Distance to assess the semantic similarity of the items used in our experiments, we found that animates (A) were more closely related than inanimates (I), Experiment 1: $M(\mathrm{A}) = 0.71$, $M(\mathrm{I}) = 0.79$, $t(126) = -3.56$, $p < .001$; Experiment 2: $M(\mathrm{A}) = 0.71$, $M(\mathrm{I}) = 0.79$, $t(50) = -2.19$, $p < .05$; Experiment 3: $M(\mathrm{A}) = 0.73$, $M(\mathrm{I}) = 0.80$, $t(123) = -2.82$, $p < .01$. This finding is therefore in line with the hypothesis that animates are processed faster in lexicosemantic tasks because they have a greater semantic overlap than inanimates. Based on the above discussion, we suggest that different mechanisms are recruited in different tasks (e.g., episodic vs. semantic tasks) when processing animates versus inanimates and that there is no single account of animacy effects. Related to this, in the word recognition literature, a number of studies have shown that words with richer semantic representations are processed faster. However, different semantic variables (e.g., imageability, number of meanings, and number of semantic features) make differential qualitative or quantitative contributions depending on the tasks that are used to index these effects (Pexman et al., 2008). More generally, the magnitude of semantic richness effects is greater in semantic categorization than in lexical decision (Goh, Yap, Lau, Ng, & Tan, 2016). The influence of different semantic dimensions is selectively modulated by task-specific demands (Yap et al., 2011). More precisely, it is assumed that tasks involving lexical judgments (e.g., lexical decision) emphasize aspects related to wordform (Balota et al., 1991; Izura & Hernández-Muñoz, 2017) more than they do aspects related to semantics. In contrast, tasks involving semantic judgments require deeper semantic analyses, with the result that the semantic properties of words are more important and play a greater role (Pexman et al., 2008).[4]

Before concluding, there is one limitation to our work that deserves attention. The animacy dimension can be viewed as a continuous (graded) rather than a discrete dimension (Radanović et al., 2016). The fact that we did not use a graded measure of animacy can be seen as a limitation to our study as we were not able to detect nonlinear effects of animacy in lexical decision or semantic categorization. Radanović et al. (2016) found a nonlinear effect of animacy given that the subjects took less time to categorize obvious animate and inanimate items than more ambiguous items and, at the same time, that nonambiguous animate items were categorized faster than nonambiguous inanimate items.

In order to test for nonlinear effects of animacy, we collected ratings of animacy from a sample of 33 independent participants who had to rate, on a 7-point scale, the animacy dimension of the 128 words used in our experiments (–3 = inanimates to +3 = animates). Reliabilities were high: Chronbach's $\alpha = 0.998$, animates = 0.90; inanimates = 0.80. Only three animates words had mean positive ratings below 2 (*sirène* [mermaid]: 0.94, *ange* [angel]: 1.15 and *druide* [druid]: 1.97) and one inanimate word had a mean negative rating above –2 (*locomotive* [locomotive]: –1.85). The difference in the ratings between animates (A) and inanimates (I) was significant, $t(126) = 95.81$, $p < .001$, $M(\mathrm{A}) = 2.79$, $M(\mathrm{I}) = -2.79$. In order to test the prediction that it takes less time to process both nonambiguous animate and inanimate items than ambiguous items in lexical decision or in semantic categorization, we introduced animacy ratings, type of words (animates vs. inanimates) and their interaction in the MLM for each task (lexical decision vs. semantic categorization).

Two words that had been classified a priori as animates but had ratings below 2, and were situated more than 4 *SD* above the grand mean, were considered as outliers and were therefore excluded from the analyses (the same patterns of results were obtained when these two words were included). In semantic categorization, the interaction effect was significant, $F\ (1, 122.56) = 9.62$, $p < .01$. The simple slope of the ratings was significantly negative for animates, $\beta = -135.32$, $t(123.84) = -4.4$, $p < .001$, but not for inanimates, $\beta = -1.64$, $t(121.24) = -.5$, $p > .1$. In the two lexical decision tasks, neither the interaction effect nor the simple slopes were significant (all $p > .1$). We performed additional analyses using MLMs that included as predictors only a restricted cubic splines with three knots of the rating scores. In the three experiments, we found the same descriptive pattern, that is to say, positive slopes for ratings between –3 and –2 and negative slopes for animacy ratings between 2 and 3. The animacy rating scores factor was significant in both semantic categorization and lexical decision in Experiment 2. The finding that unambiguous animate items were categorized faster than ambiguous items in semantic categorization is to some extent compatible with the findings reported by Radanović et al. (2016). Because we performed an a priori classification of our items, the range of the rating scores was highly restricted. The absence, in the case of inanimates, of the descriptive pattern found for animates is therefore difficult to interpret. In conclusion, animacy is a core dimension of meaning that influences the processes involved in perception, episodic memory, and as the present findings suggest, lexicosemantic memory.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/S0142716419000092

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Notes

1. Heard, Madan, Protzner, and Pexman (2019) recently collected animacy ratings for English words. In their instructions, they asked their participants to rate *how alive* and *capable of self-propelled motion* each word's referent was. Thus, this latter trait is often taken as one of the most important traits that distinguishes animates from inanimates. A more exhaustive definition of animacy is the one proposed by Gelman and Spelke (1981). According to these authors, there are fundamental differences between animates and inanimates, such as animates initiate actions whereas inanimates can act only when something/someone initiates the action; animates are made of biological structures that maintain life and allow reproduction; and animates have mental states such as perceiving, learning, and feeling.

2. Some readers might wonder whether the concern raised here about the possible confound between concreteness and animacy does apply to lexical decision as Kousta, Vigliocco, Vinson, Andrews, and Del Campo (2011) actually found evidence that abstract words are processed faster—not slower—in lexical decision than concrete words when extraneous variables (e.g., imageability) are controlled for. First of all, as claimed by Barber, Otten, Kousta, and Vigliocco (2013), concrete words are usually found to be processed faster in lexical decision than abstract words. Second, the animate and inanimate words included in our experiments were *all concrete* (on a 5-point scale, in all three experiments, the mean concreteness scores taken from Bonin, Méot, et al. (2003) were greater than 4.5, with 5 corresponding to "very concrete"). Third, and to anticipate the results, for the subset of words used in Experiment 2, animates were processed faster than inanimates in lexical decision in spite of the fact that concreteness scores were virtually identical for animates ($M = 4.61$; $SD = 0.31$) and inanimates ($M = 4.67$; $SD = 0.36$), $p = .50$. Last, but not least, when the concreteness variable was introduced as a covariate in the analyses, the patterns of findings remained the same as when this factor was not taken into account and this was true for all three experiments.

3. Because the 56 words of Experiment 2 were also included in Experiment 3, and the latter experiment included 72 additional words, it was necessary to perform two separate analyses: one analysis restricted to the words in common and another analysis in order to compare the characteristics of the remaining 72 words with those of the 56 words.

4. In line with this conceptual analysis, Yap, Pexman, Wellsby, Hargreaves, and Huff (2012) found larger effects of imageability in semantic categorization than in lexical decision. Cascaded interactive activation mechanisms have been put forward to account for richness effects in word recognition (Pexman, 2012; Yap, Lim, & Pexman, 2015), that is to say, processing mechanisms that include bidirectional feedback between semantic and lexical representations (Pexman, 2012). For example, to account for concreteness effects, it is assumed that lexical units corresponding to words that are more concrete receive more feedback activation from the semantic feature units and therefore cross the recognition threshold faster than words that are less concrete and that receive less feedback activation.

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