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Age-of-acquisition effects in semantic processing tasks

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Abstract

In two experiments, we examined whether word age-of-acquisition (AoA) is a reliable predictor of processing times in semantic tasks. In the first task, participants were asked to say the first associate that came to mind when they saw a stimulus word; the second task involved a semantic categorisation between words with a definable meaning and first names. In both tasks, there were significantly faster responses to earlier-acquired than to later-acquired words. On the basis of these results, we argue that age-of-acquisition effects do not originate solely from the speech output system, but from the semantic system as well.

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1. Introduction

Age-of-acquisition (AoA) is cited increasingly as an important variable in verbal tasks, largely due to the work of Ellis and his co-workers (e.g., Morrison, Ellis & Quinlan, 1992; Morrison & Ellis, 1995; Barry, Morrison & Ellis, 1997; Lambon Ralph, Graham, Ellis & Hodges, 1998; Turner, Valentine & Ellis, 1998). The notion that words learned earlier in life are faster to name than later-acquired words was

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first addressed experimentally by Carroll and White (1973), who examined picture-naming latencies. For a long time, however, the interest in AoA was limited to a few researchers, predominantly from the United Kingdom. The vast majority of researchers did not take the variable into account, and considered it as a confound of word frequency (in that earlier-acquired words tend to occur more frequently in adulthood). In a provocative article, Morrison and Ellis (1995) reopened the issue and reported that word frequency no longer affected word naming times when AoA was controlled for, whereas AoA kept on having a strong impact when word frequency was controlled for. On the basis of these findings, Morrison and Ellis concluded that all reported effects of frequency in lexical tasks may be AoA effects in disguise. Although subsequent studies have shown that Morrison and Ellis's claim was too strong because combined effects of frequency and AoA on word naming latencies have been obtained (Brysbaert, 1996; Brysbaert, Lange & Van Wijnendaele, 2000; Gerhand & Barry, 1998), a growing number of researchers become convinced that AoA plays a basic role in lexical tasks.

The consensus that seems to have emerged from recent studies is that AoA is the critical variable in word production; this is the so-called phonological completeness hypothesis (see Gerhand & Barry, 1998; Lambon Ralph et al., 1998). In general, reference is made to Brown and Watson's (1987) idea that early-acquired words are stored in their entirety within the phonological output lexicon, but that the representations of late-acquired words may be more fragmented. The extra time required to assemble the dispersed representation of late-acquired words would account for their slower naming speed. Two reasons are given for situating the AoA effect at the speech output stage. First, AoA is a significant variable in all tasks that require the production of a word to describe the presented stimulus (i.e., visual word naming, picture naming, word finding problems in aphasia), but is not always a significant variable in binary, manual decision tasks (e.g., object classification; see the following). Second, Gerhand and Barry (1998) found a strong effect of AoA on pronunciation duration, with a smaller and less reliable effect of frequency. In this task, participants were presented with spoken words, one at a time, and were requested to repeat each word 10 times as fast as they could while still pronouncing each word correctly and clearly. The time taken to repeat each word 10 times was measured by the experimenter.

Van Loon-Vervoorn (1989), however, suggested another possible origin of the AoA effect. According to her, the order of acquisition is the most important organisational principle of the semantic system, with the meanings of later-acquired concepts being built on those of earlier-acquired concepts. Empirical evidence for her position was provided by van Loon-Vervoorn (1989, Chapter 10). She used a discrete word-associate generation task to tap into the semantic system. In this task, participants are asked to say the first word that comes to their mind when seeing a stimulus word. The task has also been used by Chumbley and Balota (1984) and de Groot (1989) to assess the nature of the semantic system. Van Loon-Vervoorn presented 60 one-syllable words that allowed her to assess the independent effects of AoA, word frequency and imageability (IMA). She obtained a reliable effect of AoA (earlier-acquired words: RT = 1440 ms; later-acquired words: RT = 1681 ms), IMA (high = 1445 ms; low = 1677 ms), and no effect of frequency (high = 1539 ms; low = 1583 ms). On the basis of her findings, van Loon-Vervoorn (1989) concluded that AoA is a semantic variable rather than a lexical variable.

Van Loon-Vervoorn's work has not been incorporated in the recent discussion on the importance of AoA, partly because it was published in Dutch but also because Morrison et al. (1992) had failed to obtain an AoA effect in a semantic task in which participants classified pictures of objects as naturally-occurring (e.g., apple) or man-made (e.g., anchor).

On the other hand, the possibility of a semantic origin of the AoA effect is appealing, because it would explain a number of findings. First, though there is an important, negative correlation between AoA and frequency, nearly all studies have reported a more pronounced correlation between AoA and other semantic variables. Rubin (1980), for instance, reported a correlation of −0.40 between AoA and frequency, together with a correlation of −0.59 between AoA and IMA. The same was true for Whaley (1978) who reported correlations of, respectively, −0.52 and −0.69. In both studies, factor analysis indicated that AoA loaded most on a semantic factor that included variables such as imagery, concreteness and number of meanings. Using a more objective AoA-measure (obtained by asking children of different ages to name line drawings), Morrison, Chappell & Ellis (1997) obtained a correlation of −0.47 between their real AoA measure and the logarithm of the Cobuild frequency, compared to a correlation of −0.55 between AoA and imageability.

A second finding that is in line with a semantic interpretation of the AoA effect is the robust AoA effect in object naming latencies, as picture naming requires not only the correct name to be produced but also semantic activation to connect the pictorial input with the verbal output (e.g., Snodgrass, 1984; Theios & Amrhein, 1989). Third, a semantic interpretation of the AoA effect may explain why the AoA effect in oral reading of visually presented words seems to be particularly strong when naming latencies are long (as was the case in Morrison & Ellis's (1995) study; see Gerhand & Barry (1998) for a discussion), because there has been some speculation that semantic variables may affect word naming times when these are long enough (e.g., Plaut, McClelland, Seidenberg & Patterson, 1996). Finally, AoA has a strong effect on lexical decisions times (see Table 1) and since the work of Chumbley and Balota (1984) it is known that lexical decisions involve semantics. Morrison and Ellis (1995) and Gerhand and Barry (1998) provided a phonological explanation of this AoA effect by assuming that lexical phonology contributes to the word/non-word decision, but further research (Gerhand & Barry, 1999) has shown that the AoA effect in the lexical decision task remains significant when efforts are made to interfere with the phonological processing (such as using only pseudo-homophone non-words or using articulatory suppression).

On the basis of these considerations, it occurred to us that researchers may have rejected van Loon-Vervoorn's semantic interpretation of AoA too rapidly. At least, it seemed worthwhile to investigate the importance of AoA for a number of semantic tasks, and see how these findings relate to more "lexical" tasks, such as word naming and lexical decision. To do so, we made use of a set of six lists of 24 words recently assembled by Brysbaert et al. (2000) and validated in a naming and a lexical decision

Table 1
Characteristics of the six Brysbaert et al.'s (2000) lists of 24 words[a]

	AoA (%)	log(freq)	IMA	Naming latency	Lexical decision
List 1	8	2.3	4.9	498	646
List 2	93	2.4	5.9	487	594
				11	52
List 3	65	1.7	5.0	490	639
List 4	66	4.0	4.7	478	554
				12	85
List 5	54	2.9	2.9	486	609
List 6	55	2.8	6.3	485	609
				1	0

[a] AoA: percentage of teachers indicating 6-yr olds should know the word; log(freq): logarithm (base 10) of frequency counts (on a total of 42 380 000); IMA: imageability rating on a scale from 1 to 7.

experiment. These lists consist of three pairs of lists that differ in AoA, frequency or IMA, and are matched on the other variables. We used these stimuli in two semantic tasks: a discrete word-associate generation task (Experiment 1) and a "word with a definable meaning" vs. "given-name" classification task (Experiment 2). The former is a replication of van Loon-Vervoorn (1989); the latter has been inspired by Taft and van Graan (1998).

2. Experiment 1

Experiment 1 was designed to find out whether we could replicate the findings of van Loon-Vervoorn (1989) with a new set of stimuli that had been validated in a series of naming and lexical decision tasks (Brysbaert et al., 2000).

2.1. Method

Participants: Twenty first-year students from the Katholieke Universiteit Leuven participated for course credits. All were native Dutch speakers.

Stimulus materials: The stimuli were 144 words selected by Brysbaert et al. (2000). AoA measures were based on teachers' ratings collected by Kohnstamm, Schaerlaekens, de Vries, Akkerhuis and Froonincksx (1981). Kohnstamm et al. asked a representative sample of teachers from last-year Kindergarten and first-year primary school to indicate for each of 6785 Dutch words whether a 6-yr old should understand it. The same AoA measures were used by van Loon-Vervoorn (1989), who showed that they have a high correlation with the retrospective student ratings used by most English speaking researchers (see Morrison et al., 1997, for a discussion of the validity of these AoA measures). The frequency measures were based on the Celex database (Baayen, Piepenbrock & Van Rijn, 1993), and the IMA values were taken from van Loon-Vervoorn (1985) who had all words of Kohnstamm et al. (1981) rated on a 7-point scale for imageability.

The properties of Brysbaert et al.'s (2000) stimulus lists are displayed in Table 1 (see also their appendix). The first pair of lists differed on AoA (8% vs. 93%, meaning that for the latter-acquired words, only 8% of the teachers indicated that these words should be known by 6-yr olds, whereas for the earlier-acquired words, 93% of the teachers expected their pupils to know them). The lists were matched for frequency and as much as possible for IMA. Due to the high correlation between AoA and IMA, a complete matching of the latter was not possible without seriously reducing the AoA range. The second pair of lists differed on frequency and was matched for AoA and IMA. The third pair differed on IMA and was matched for AoA and frequency. It should be remarked that the range of IMA was not the largest possible (2.9/7 vs. 6.3/7) due to the priority given to AoA. This means that the IMA effect may be underestimated in the studies reported in the following. Brysbaert et al. (2000) presented their stimuli in a naming and a lexical decision task, the data of which are also included in Table 1. In both experiments there were reliable effects of AoA (naming: 11 ms; LD: 52 ms) and frequency (naming: 12 ms; LD: 85 ms). Similar results have been reported for English (Gerhand & Barry, 1998).

Procedure: On each trial, a warning signal appeared 500 ms prior to the stimulus word. The task of the participant was to say as fast as possible the first word (associate) that came to mind when seeing the stimulus word. The word remained on the screen until the participant said the associate or for a maximum of 5 s. Voice onset times were registered to the nearest millisecond, using Bovens and Brysbaert's (1990) software. After the participant had said the associate, the experimenter typed in the response. The next trial started 1 s after the response had been entered. Each participant got a different randomisation of the stimuli. At the beginning of the experiment, there was a practice block of 20 trials.

2.2. Results

Table 2 lists the response latencies, the percentage of no responses, and the mean number of different responses given as a function of AoA, frequency and IMA. In 3% of the trials, no precise time registration was made due to coughs or other extraneous noise. These trials were discarded from the RT analyses.

There was a significant effect of all three variables on response latencies. (AoA: $F1(1,19) = 35.9$, $MSe = 21\,611$, $P < 0.01$; $F2(1,46) = 16.0$, $MSe = 57\,221$, $P < 0.01$. Frequency: $F1(1,19) = 28.0$, $MSe = 16\,994$, $P < 0.01$; $F2(1,46) = 8.4$, $MSe = 94\,105$, $P < 0.01$. IMA: $F1(1,19) = 47.8$, $MSe = 16\,141$, $P < 0.01$; $F2(1,46) = 9.6$, $MSe = 112\,478$, $P < 0.01$.) It should be noted, however, that the effect of frequency was opposite to the one usually reported (i.e., responses were faster to low-frequency words than to high-frequency words). The percentage of no responses followed the same pattern as that of the RTs (i.e., more no responses in conditions with a long

Table 2
Results of Experiment 1 (discrete associate generation; words from Brysbaert et al.'s (2000) lists)

	Late/low	Early/high	Difference
Response latency and percentage of no response			
AoA	1781 (3)	1502 (2)	279 (1)
Frequency	1584 (3)	1802 (4)	−218 (−1)
IMA	1941 (7)	1663 (3)	278 (4)
Number of different associates (max = 20)			
AoA	10.8	8.7	2.1
Frequency	9.5	11.2	−1.7
IMA	12.1	10.1	2.0

RT). Finally, there were more different associates generated in the conditions that gave rise to the longest response latencies. (AoA: $F2(1,46) = 7.1$, $MSe = 7.3$, $P < 0.02$. Frequency: $F2(1,46) = 4.3$, $MSc = 8.2$, $P < 0.05$. IMA: $F2(1,46) = 3.6$, $MSe = 12.8$, $P < 0.07$.)

In order to more fully exploit the power of our design, we in addition ran a multiple regression analysis on the word-associate generation times for all 144 stimulus words. The predictor variables were the AoA, frequency and IMA values. The regression analysis was the one recommended by Lorch and Myers (1990) for repeated measures designs and consisted of first calculating the regression weights for each individual separately, and then running a group *t*-test to see whether the mean group values differed significantly from zero. This analysis enables generalisation across stimuli and participants. The resulting regression equation was:

$$RT_{\text{assoc. gen.}} = 2194 - 2.2\,\text{AoA} + 37.6\,\text{freq} - 89.0\,\text{IMA}.$$

All three regression weights were significant (respectively, $t = -4.0$, d.f. = 19, S.D. = 2.4, $P < 0.01$; $t = 2.5$, d.f. = 19, S.D. = 67.6, $P < 0.05$; $t = -10.1$, d.f. = 19, S.D. = 39.3, $P < 0.01$).

2.3. Discussion

Experiment 1 replicated van Loon-Vervoorn (1989) and showed that IMA and AoA are important predictors of the speed with which an associate of a target word can be generated. Participants were faster to produce associates to highly imageable words and words that have been acquired early. There is also more agreement among participants about the associates of these words (i.e., participants are more likely to report the same associate for words that are highly imageable and acquired early). de Groot (1989, p. 824) reported a similar effect of IMA and attributed this to the fact "that the concept nodes for high-imageability words contain more information than those of low-imageability words and that relatively strong links depart from the former type of nodes" (see Chumbley & Balota, 1984, for a similar interpretation).

The effect of word frequency was also significant, but in the opposite direction: high-frequency words gave rise to longer reaction latencies and more diverse responses than low-frequency words matched for AoA and IMA. This finding was not present in van Loon-Vervoorn (1989; see the Introduction), but has been reported by de Groot (1989, Experiment 7). When she used words controlled for IMA and with frequency classes at the extremes, she obtained a 72 ms penalty for high-frequency words compared to low-frequency words. Interestingly, the frequency effect was not present in de Groot (1989, Experiments 1 and 2) when the frequency classes were more restricted, which may provide an explanation for the discrepancy between our findings and those of van Loon-Vervoorn (1989). An inverse frequency effect (better performance on low than high-frequency words) has also been reported in memory tasks and has been attributed to the fact that the semantic representations of low-frequency words may be more distinctive than those of high-frequency words (e.g., Dewhurst, Hitch & Barry, 1998). Irrespective of the precise interpretation of the word frequency effect in the discrete word-associate generation task, it is clear that the AoA effect van Loon-Vervoorn reported is a genuine one and was not caused by the choice of her stimuli.

Although the discrete word-associate generation task is considered as one of the most interesting tasks to get access to the organisation of the semantic system (Chumbley & Balota, 1984; de Groot, 1989), a criticism against the task in the present context may be that it still requires the generation of a verbal response. Hence, one cannot exclude the possibility that the AoA effect was due to response generation and not to the time required to find an associate in the semantic system (though this interpretation requires the assumption that the AoAs of the produced associates are correlated with those of the presented stimulus words). To counter this criticism, we ran a second experiment in which participants had to make a binary, manual decision. As mentioned in the Introduction, Morrison et al. (1992) failed to obtain an AoA-effect in such a semantic classification task. However, this study may have been suboptimal, because Morrison et al. (1992) distributed their stimulus pictures across two different semantic classes (naturally occurring vs. man-made) but reported aggregated RTs (i.e., the average decision latency of all earlier-acquired words irrespective of the class they belonged to, and the average decision latency of all later-acquired words irrespective the class they belonged to). Such a practice may decrease the power of the design, because it is known that participants in a binary decision task tend to redefine the task as a yes–no decision, and stimuli in a "no"-category tend to be processed differently than stimuli in a "yes"-category (Casey, 1992; Larochelle & Pineau, 1994).

Ideally, to investigate the effects of AoA, frequency and IMA on semantic classification times, all stimulus words should be part of the same category, so that no unnecessary noise is introduced. A possible way to achieve this, has been suggested by Taft and van Graan (1998). To address the question of whether it is possible to read a word for meaning without phonological mediation, these authors asked their participants to decide whether or not each target word belonged to the category "words with definable meanings" (e.g., PLANK, PINT) or the category "given names" (e.g., TRENT, PAM). With this task Taft and van Graan (1998) found a reliable frequency effect but no effect of phonological regularity. Monsell, Doyle and Haggard (1989) used a somewhat similar task of classifying nouns as either denoting persons (e.g., father, woman, saint) or inanimate things (e.g., bullet, silence) and reported a clear frequency effect that was similar in magnitude to the frequency effect they found in a lexical decision task. Neither of the studies controlled for AoA. However, given that all the words of Experiment 1 are words with a definable meaning, Taft and van Graan's word/name task can easily be applied to the issue at hand.

3. Experiment 2

3.1. Method

Participants: Participants were 36 first-year psychology students from the Universiteit Gent. All were native Dutch speakers.

Procedure: The stimuli consisted of the 144 Brysbaert et al.'s (2000) words, and 144 first names with four or five letters. Half of these names had a high frequency according to the Celex database, half had a low frequency (log(frequencies) of 2.9 and 0.9, respectively). Examples of high-frequency names are "theo" and "nadia"; examples of low-frequency names are "clem" and "cecil". It can be expected that first-name frequency is highly confounded with first-name AoA, but we did not collect data on the last measure for our subject sample. All words were presented in lower-case letters and participants were instructed to indicate whether each stimulus was a word with a definable meaning or a first name. Each participant got a different randomisation of the stimulus list and started with a practice block of 20 trials.

4. Results

Table 3 shows the major findings of Experiment 2. RTs shorter than 200 ms and longer than 1500 ms were discarded from the RT analyses. This resulted in a loss of less than 1% of the data.

Table 3
Results of Experiment 2 (semantic classification task; words from Brysbaert et al.'s (2000) lists): response latencies and percentages of error

	Late/low	Early/high	Difference
AoA	632 (6.7)	569 (1.7)	63 (5.0)
Frequency	602 (4.0)	555 (1.3)	47 (2.7)
IMA	576 (1.4)	580 (4.1)	−4 (−2.7)

ANOVAs on the RTs indicated that both the 63 ms effect of AoA and the 47 ms effect of frequency were reliable. (AoA: $F1(1,35) = 104.30$, $Mse = 689$, $P < 0.01$; $F2(1,46) = 18.98$, $Mse = 2881$, $P < 0.01$. Frequency: $F1(1,35) = 43.97$, $Mse = 913$, $P < 0.01$; $F2(1,46) = 12.59$, $Mse = 2482$, $P < 0.01$.) The effect of IMA was not reliable ($F1(1,35) < 1$, $Mse = 828$, $F2(1,46) < 1$, $Mse = 4144$).

The AoA effect of 63 ms was not reliably larger than the AoA effect of 52 ms Brysbaert et al. (2000) reported for their lexical decision task (interaction between task and AoA: $F1(1,54) = 1.12$, $Mse = 760$). However, the frequency effect of 47 ms was reliably smaller than the frequency effect of 85 ms Brysbaert et al. obtained (interaction between task and frequency: $F1(1,54) = 8.70$, $Mse = 1061$, $P < 0.01$).

Again, to fully exploit the power of our design, we ran a multiple regression analysis on the semantic categorisation times with the three word variables as predictors. The resulting regression equation was:

$$RT_{\text{cat. time}} = 655 - 0.65\,\text{AoA} - 7.30\,\text{freq} + 1.93\,\text{IMA}.$$

The regression weights were significant for AoA ($t = -8.1$, d.f. = 35, S.D. = 0.48, $P < 0.01$) and frequency ($t = -7.30$, d.f. = 35, S.D. = 8.20, $P < 0.01$), but not for IMA ($t = 1.93$, d.f. = 35, S.D. = 10.8, $P > 0.25$).

Finally, RTs were reliably faster to high-frequency first names (RT = 554 ms; PE = 4%) than to low-frequency first names (RT = 669 ms; PE = 9%; $F1(1,35) = 146.48$, $Mse = 1649$, $P < 0.01$; $F2(1142) = 85.64$, $Mse = 6198$, $P < 0.01$).

4.1. Discussion

In Experiment 2, we found that a semantic classification task in which participants have to decide whether a stimulus word refers to the category of words with a definable meaning or to the category of first names, produced effects of both AoA and word frequency, but no effect of IMA. The AoA effect was of the same magnitude as the effect found in a lexical decision task (compare Tables 1 and 3), whereas the frequency effect was reliably smaller. To explain the AoA effect in lexical decision times, Morrison and Ellis (1995, p. 128) hypothesised: "... Thus, an AOA effect in lexical decision could arise if lexically derived phonology contributed to the generation of a yes response to familiar words." The slightly larger AoA effect in our semantic task would therefore indicate that lexically derived phonology also contributes to the generation of a binary decision between words and first names, if one were to adopt the logic of Morrison and Ellis's argument. Although this is not a priori impossible, such a position is hard to defend given Taft and van Graan's (1998) finding that the word/first-name semantic categorisation task is insensitive to phonological effects. They reported that latencies to respond to regular definable words (e.g., PLANK) did not differ from latencies to irregular definable words (e.g., PINT), though both types of words showed a reliable difference in naming times. In our view, the findings of both Experiments 1 and 2 are much easier to explain within a framework that postulates AoA effects in the semantic system.

The semantic hypothesis would have been corroborated if in addition we had found an imageability effect for the semantic categorisation task. The lack of such an effect could be due to the rather restricted range of IMA values we had to use (but see Experiment 1), and/or to the fact that IMA effects are less clear once stimuli are controlled for AoA. Just like frequency effects have been called into question due to the confound between frequency and AoA, so is IMA. For instance, Coltheart, Laxon and Keating (1988) showed that the AoA effect on word naming remains significant when imageability is controlled for, but that imageability has no effect when AoA is controlled for (see also Table 1).

5. General discussion

In this article, we investigated the claim that AoA effects in lexical processing tasks arise solely from the speech production system. In two experiments, we found reliable AoA effects in tasks that have been proposed to address the semantic system, even though the characteristics of the tasks differed considerably (associate generation vs. semantic classification). This means that researchers may have been too hasty to reject van Loon-Vervoorn's (1989) semantic hypothesis.

The dependence of word meanings on previously acquired meanings and the highly interconnected nature of semantic concepts may be the main reason why the order of acquisition remains the most important organising factor of the semantic system throughout life and why frequency of encountering has relatively little effect on access time within the semantic system. One could imagine that the increase of availability of mental representations due to repeated encounters with the corresponding input works especially well for representations that are largely independent from one another, so that a change of one representation has little impact on the access to other representations or on the relationship between different representations. Such a loose organisation may very well correspond to that of the lexical system as it is conceived in most models of word recognition.

In conclusion, we agree with Ellis and his coworkers that AoA is an important variable in visual word recognition and has been neglected far too much. However, on the basis of the present evidence we suggest that the locus of AoA effects may have been interpreted too narrowly. Our results show that there is a clear AoA effect in semantic tasks (see also Lewis, 1999, for an effect of AoA in face categorisation). Whether there is a single, semantic locus of AoA effects or whether AoA has multiple loci must await future research (see, e.g., Forster, 1992, for a model that predicts both AoA and word frequency effects at the level of the input lexicon). Further experiments (both in English and other languages) are necessary to validate the semantic hypothesis, and to see, for instance, whether AoA is a more important factor in word naming for languages with highly inconsistent letter-sound correspondences than for languages with transparent letter-sound mappings, as it has been argued that the former require more semantic mediation in word naming than the latter (e.g., Plaut et al., 1996).

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