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BRIEF REPORT

# Age-of-acquisition effects in delayed picture-naming tasks

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**Abstract** We report two experiments that explored the linguistic locus of age-of-acquisition effects in picture naming by using a delayed naming task that involved only a low proportion of trials (25 %) while, for the large majority of the trials (75 %), participants performed another task—that is, the prevalent task. The prevalent tasks were semantic categorization in Experiment 1a and grammatical-gender decision in Experiments 1b and 2. In Experiment 1a, in which participants were biased to retrieve semantic information in order to perform the semantic categorization task, delayed naming times were affected by age of acquisition, reflecting a postsemantic locus of the effect. In Experiments 1b and 2, in which participants were biased to retrieve lexical information in order to perform the grammatical gender decision task, there was also an age-of-acquisition effect. These results suggest that part of the age-of-acquisition effect in picture naming occurs at the level at which the phonological properties of words are retrieved.

**Keywords** Speech production · Psycholinguistics · Age-of-acquisition · Picture naming

It has been demonstrated that pictures whose names were acquired early in life are named faster and more accurately than pictures whose names were acquired later (e.g., Brysbaert & Ghyselinck, 2006). The issue of age-of-acquisition (hereafter, AoA) effects in speech production has a rich tradition of empirical research. Picture naming entails several cognitive stages of processing, such as perceptual processing, semantic access, lexical selection, and phonological encoding. Empirical research into AoA effects at the first two stages of processing has already been provided. The fact that AoA interacts with the visual degradation of the stimulus, but not with name frequency, suggests that part of the phenomenon arises at the perceptual level (Catling, Dent, & Williamson, 2008). Evidence for a semantic locus of the phenomenon has come, for instance, from semantic categorization tasks, in which participants were required to classify pictures on the basis of semantic information. The results showed faster reaction times (RTs) for early-acquired than for late-acquired items (e.g., Johnston & Barry, 2005). Beyond these prelexical sources of the phenomenon, in the present research we focused on AoA effects ascribed at linguistic stages—that is, lexical selection and phonological encoding.

In order to search for a lexical source of the AoA phenomenon, Belke, Brysbaert, Meyer, and Ghyselinck (2005) exploited the semantic cyclic cost in picture naming, which refers to the observation that naming latencies are slower when pictures are presented in blocks containing other semantic-coordinate pictures than when they are presented in blocks containing non-semantic-coordinate pictures. Under the assumption that the semantic cyclic cost reflects lexical selection difficulties, if part of the AoA phenomenon has a lexical localization, an interaction should occur between the cyclic cost and AoA. This prediction was confirmed, in that late-acquired target words showed larger cyclic costs than did early-acquired words, suggesting that lexical selection (i.e., lemma selection) is AoA-sensitive. Likewise, evidence for a phonological locus has come from the AoA effect in word reading reported by Gerhand and Barry (1998). These authors interpreted the effect as emerging at the phonological level, in line with the *phonological completeness hypothesis.* This hypothesis supports the notion that the first words a child

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acquires are stored in whole-word form in the phonological lexicon, but then, as vocabulary increases, a more economical form of storage must be adopted. Late-acquired words would be stored in segmented forms, since the same segments can be used to store different words that all contain such segments (Brown & Watson, 1987). Due to this difference in the forms of the stored representations, early-acquired words would be accessed more rapidly, resulting in shorter naming latencies (see, however, Monaghan & Ellis, 2002, for incongruent evidence).

To date, evidence for AoA effects at the lexical and phonological levels of processing in speech production has been reported by using different tasks (for a review and theoretical implications, see Brysbaert & Ghyselinck, 2006). Our aim here was to provide further evidence for AoA effects ascribed at linguistic stages of processing without recourse to different tasks. In the first experiment, we isolated AoA effects at post-semantic levels; then, in subsequent experiments, we focused on AoA effects at the level of phonological representations. For these purposes, we took advantage of the experimental paradigm devised by Almeida, Knobel, Finkbeiner, and Caramazza (2007). In order to isolate the stage of lexical access from the previous ones involved in picture processing, these authors used a delayed naming task. Their rationale was straightforward: Interposing a delay between target presentation and response execution allowed for input recognition processes to be completed before the naming response could be delivered. In order to preclude the possibility that participants would retrieve the name of the picture during the delay (as in "standard" delayed naming tasks), response uncertainty was introduced: A visual cue was presented at the end of the delay indicating whether a naming task or a semantic categorization task (animal vs. artifact) had to be performed. To further reduce the likelihood of name retrieval during the delay, the relative occurrences of the two tasks were unbalanced: 75 % of the trials required semantic categorization (the prevalent task), and the remaining 25 % picture naming. In this way, during the delay, participants were biased to gather the information needed to perform the most likely task—that is, semantic information. Hence, any variable affecting delayed naming times would have to be located at either the lexical or the phonological stage, and not (or not only) at previous stages.

We used Almeida et al.'s (2007) delayed naming paradigm and manipulated the prevalent task. In Experiment 1, the prevalent task was either an animal/artifact semantic categorization or a grammatical gender decision. In the first case, during the delay participants were biased to process pictures up to the semantic level. In contrast, when the prevalent task was gender decision, grammatical-gender information stored with the lexical representation of the target pictures had to be accessed (e.g., Navarrete, Basagni, Alario, & Costa, 2006), and therefore, during the delay participants were biased to process pictures up to that level. Finally, in order to test whether the materials were sensitive to AoA effects, an immediate naming condition with no delay between the presentation of the target picture and the visual cue was also included.

We made the following predictions. First, if AoA impacts postsemantic stages of processing, we should find an effect in the delayed naming condition when the prevalent task was semantic categorization (see Almeida et al., 2007). Second, if AoA impacts even subsequent stages—that is, phonological encoding—we should also find an effect in the delayed naming condition when the prevalent task was grammatical gender decision. And third, if gender decision entails "deeper processing" (i.e., the retrieval of grammatical information) than semantic categorization, we expected a main effect of type of bias in the delayed conditions, so that naming latencies should be faster when the prevalent task was gender decision than when it was semantic categorization.

## Experiment 1a

Participants were instructed to complete a semantic categorization task or a naming task on pictures, depending on a visual cue.

### Method

*Participants* A group of 40 students from the University of Padua took part in the experiment (half performed the immediate naming condition and the other half the delayed naming condition).

*Materials* A set of 160 pictures were evenly selected from two semantic categories (animals and artifacts). From each category, 20 pictures were chosen as experimental targets (i.e., pictures to be named), whereas the remaining 60 were fillers (i.e., pictures to be categorized) in the categorization trials. From each semantic category, 10 target pictures representing early-acquired Italian words were selected, and 10 others representing late-acquired Italian words (the early and late groups were matched according to several variables; see Table 1). Filler pictures were evenly selected from the semantic categories of animals and artifacts. Ten lists of stimuli were created in which the presentation of the experimental trials and the filler trials was pseudorandomized according to the following constraints: Two experimental trials (i.e., naming) were never presented one after the other (at least one semantic categorization filler trial separated them), and no more than five items from the same semantic category were presented in a row. In order to control for the order of presentation of early- and late-acquired words between subjects, 10 other lists were created maintaining

**Table 1** Properties of the experimental items used in Experiments 1 and 2

| | Experiment 1 | | Experiment 2 | |
|---|---|---|---|---|
| | Early Acquired | Late Acquired | Early Acquired | Late Acquired |
| AoA (1–7) | 2.24 | 3.16* | 2.26 | 3.15* |
| Imageability (1–7) | 6.21 | 6.04 | 6.17 | 6.05 |
| Concreteness (1–7) | 6.18 | 6.03 | 6.32 | 5.94 |
| Familiarity (1–7) | 6.69 | 6.35* | 6.72 | 6.5* |
| Spoken frequency | 2.90 | 1.75 | 5.75 | 5.25 |
| Written frequency | 27.3 | 19.1 | 43.3 | 32 |
| Neighborhood size | 1.05 | 0.8 | 1.15 | 1.3 |
| Bigram frequency | 10.86 | 10.75 | 10.96 | 10.86 |
| Syllables | 2.6 | 2.7 | 2.6 | 2.8 |
| Phonemes | 6 | 6.4 | 5.95 | 6.4 |

AoA = age of acquisition. The values for each variable are retrieved from Barca, Burani, and Arduino (2002). For all comparisons, $p > .13$, except $^{*}p < .01$

exactly the same pseudorandomized sequence of target and filler trials. However, the trials with early-acquired targets were replaced with trials with late-acquired words, and vice versa.

*Procedure* Three colored circles were created (blue, yellow, and gray). The trials in the immediate condition consisted of the following events: a fixation point (+) for 600 ms, replaced by a picture superimposed either on the blue circle (75 % of the trials) or on the yellow circle (25 % of the trials). When the circle surrounding the picture was blue, participants were instructed to vocally categorize the picture as an animal or object; when the circle was yellow, they were instructed to name the picture. The pictures remained on screen for 3,000 ms or until response. After a blank screen of 1,259 ms, the next trial started. For the delayed condition, the procedure was identical, except for the fact that pictures were first presented superimposed on a gray circle. After 1,000 ms, the gray circle turned from gray to either blue or yellow, and the participants were required to categorize or name the picture.

Before the experiment, each picture was presented in a familiarization phase with its corresponding written name, and participants were instructed to name the picture. After familiarization, the participants performed 20 practice trials with a set of pictures not included in the experimental phase.

### Results and discussion

Separate analyses of variance (ANOVAs) were carried out treating Subjects and Items as random factors, yielding $F_1$ and $F_2$ statistics, respectively. These analyses were performed on the experimental pictures only. Trials in which an error or a voice-key failure occurred were removed. In addition, naming latencies less than 250 ms, greater than 2,000 ms, or greater than 3.5 *SD*s from a given participant's mean were also excluded from the analysis. The analyses were conducted on 87 % of the data (see Table 2).

The analysis of naming latencies showed a main effect of AoA [$F_1(1, 38) = 43.32$, $p < .001$, $\eta^2 = .53$; $F_2(1, 38) = 17.73$, $p < .001$, $\eta^2 = .31$]. The main effect of naming condition was also significant [$F_1(1, 38) = 46.36$, $p < .001$, $\eta^2 = .55$; $F_2(1, 38) = 643.9$, $p < .001$, $\eta^2 = .94$], but the interaction between the two factors was not significant [$F_1 < 1$; $F_2(1, 38) = 1.37$, $p = .24$, $\eta^2 = .03$]. In the error analysis, the main effect of AoA was significant [$F_1(1, 38) = 31.43$, $p < .001$, $\eta^2 = .45$; $F_2(1, 38) = 8.81$, $p < .01$, $\eta^2 = .18$], while the main effect of naming condition and the interaction between the two factors were not significant (*F*s < 1).

A significant AoA effect was reported independently of the delay between the presentation of the picture and the presentation of the response cue. Since participants had the time, during the delay, to process the target picture up to the semantic level, the AoA effect in the delayed condition must be ascribed to stages occurring after semantic processing (i.e., lexical selection and/or phonological encoding). In the next experiment, we explored the phonological locus of the AoA effect by using a grammatical gender decision as the prevalent task.

## Experiment 1b

The same procedure was used as in the delayed naming condition of Experiment 1a, with the only difference being that participants performed a gender decision on the filler trials by uttering "masculine" or "feminine," the two grammatical genders of the Italian language. The items were the same as in Experiment 1a.

### Results and discussion

Following the same criteria as in Experiment 1a, analyses were performed on 93 % of the data points. In the naming latencies analysis, paired *t* tests revealed faster RTs for early-acquired words than for late-acquired words [$t_1(19) = -3.66$; $p < .01$; $t_2(38) = -2.83$; $p < .01$]. The effect of AoA was also significant in the error analysis [$t_1(19) = 4.27$; $p < .001$; $t_2(38) = 2.05$; $p < .05$] (see Table 2).

The ANOVA with Experiment (delayed condition of Exp. 1a vs. Exp. 1b) and AoA as main factors revealed that naming latencies were faster in Experiment 1b than in Experiment 1a, $F_1(1, 38) = 4.38$, $p < .05$, $\eta^2 = .1$;

**Table 2** Mean naming latencies and standard deviations (*SD*s), in milliseconds, and error percentages (*E*) in the age-of-acquisition and naming conditions of Experiment 1

| | Semantic Categorization (Exp. 1a) | | | | | | Gender Decision (Exp. 1b) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Immediate Condition | | | Delayed Condition | | | Delayed Condition | | |
| AoA | Mean | SD | E | Mean | SD | E | Mean | SD | E |
| Early acquired | 968 | 133 | 9 | 711 | 97 | 7.5 | 658 | 86 | 3.5 |
| Late acquired | 1,077 | 158 | 17.3 | 793 | 140 | 17.8 | 721 | 81 | 10.5 |
| Difference | −109 | | −8.3 | −82 | | −8.8 | −63 | | −7 |

$F_2(1, 38) = 21.77, p < .001, \eta^2 = .36$. The interaction between AoA and experiment was not significant ($F$s < 1).[1]

As can be seen in Table 1, the early- and late-acquired items were not matched for familiarity. In order to control for the effect of this variable, a multiple regression analysis was performed on naming latencies. Familiarity was entered in the first step of the model, and entering AoA as a predictor in the second step resulted in a significant increase of the explained variance [$R^2$ change = .004, $F(1, 2102) = 7.81$, $p < .01$]. In fact, AoA proved to be a significant predictor for naming latencies even when familiarity was partialed out in the first step ($\beta$ =.083, $t$ = 2.79, $p < .01$). Further multiple regression analyses were conducted in which the other variables listed in Table 1 were included in the first step of the model. Entering AoA as a predictor in the second step improved the amount of explained variance [$\beta$ = .110, $t$ =3.41, $p < .01$; $R^2$ change = .005, $F(1, 2094) = 11.63$, $p < .01$].

Overall, the results obtained in Experiment 1 met our predictions. First, AoA affected naming latencies in the delayed condition when the prevalent task was semantic categorization (Exp. 1a), suggesting that AoA also impacts postsemantic stages of processing. Second, AoA affected naming latencies in the delayed condition when the prevalent task was gender decision (Exp. 1b), suggesting that phonological representations are also AoA-sensitive. Third, a significant difference between the delayed conditions of Experiments 1a and 1b was obtained, indicating that, during the delay, gender decision entails "deeper processing" of the picture stimuli than does semantic categorization. In other words, the use of a grammatical-gender decision as the prevalent task biased participants to select the lexical representation of the pictures in Experiment 1b, but not in Experiment 1a, in which participants were biased to select semantic information. We are not arguing here that pictures are *only* processed up to the level required to perform the prevalent task (i.e., the semantic or the grammatical–lexical level). Indeed, compelling evidence exists that supports the notion that activation spreads in a cascaded fashion from perceptual up to phonological levels of processing (Navarrete & Costa, 2009). Rather, we argue that during the delay, participants are more likely to select and prepare the representations for the prevalent response (Almeida et al., 2007).

However, before definitive conclusions could be drawn, further controls were required. Indeed, in Experiment 1b grammatical-gender values (masculine/feminine) were not equally distributed within the two AoA conditions (see the Supplemental Materials). In addition, since some studies have reported an interaction between natural gender and grammatical gender (e.g., Vigliocco & Franck, 1999), pictures depicting animals needed to be excluded from the gender decision task. We addressed these issues in Experiment 2.

## Experiment 2

The same procedure was used as in Experiment 1b, with the difference that pictures depicting animals were not included. In order to test the materials for AoA effects, an immediate naming condition was included.

### Method

*Participants* A group of 44 participants took part in the experiment (half performed the immediate naming condition, and the other half the delayed naming condition).

*Materials and procedure* A set of 160 pictures were evenly selected, representing Italian words with masculine and feminine genders. For each gender, 20 pictures representing early-acquired words and 20 pictures representing late-acquired words were selected (see Table 1 for details).

[1] The ANOVA with Experiment (immediate condition of Exp. 1a vs. Exp. 1b) and AoA as main factors again revealed that naming latencies were faster in Experiment 1b than in Experiment 1a [$F_1(1, 38) = 89.47$, $p < .001$, $\eta^2 = .7$; $F_2(1, 38) = 896.91$, $p < .001$, $\eta^2 = .95$]; the interaction between AoA and experiment here was marginally significant [$F_1(1, 38) = 3.14$, $p = .08$, $\eta^2 = .07$; $F_2(1, 38) = 2.8$, $p = .1$, $\eta^2 = .06$].

### Results

Following the same criteria used in Experiment 1, analyses were conducted on 88.7 % of the data (see Table 3). The analysis of naming latencies showed main effects of AoA [$F_1(1, 42) = 26.84$, $p < .001$, $\eta^2 = .39$; $F_2(1, 38) = 7.75$, $p < .01$, $\eta^2 = .16$] and of naming condition [$F_1(1, 42) = 61.92$, $p < .001$, $\eta^2 = .59$; $F_2(1, 38) = 363.49$, $p < .001$, $\eta^2 = .9$]. The interaction between the two factors was significant in the subject analysis [$F_1(1, 42) = 4.29$, $p < .05$, $\eta^2 = .09$; $F_2(1, 38) = 2.08$, $p = .15$, $\eta^2 = .05$]. Critically, the AoA effect was significant in both naming conditions, as revealed by paired *t* tests [delayed, $t_1(21) = -2.45$, $p < .03$; $t_2(38) = -1.86$, $p = .07$; immediate, $t_1(21) = -4.68$, $p < .001$; $t_2(38) = -2.57$, $p < .02$]. In the error analysis, no significant effects were reported (all *p*s > .16).

As in Experiment 1, a multiple regression analysis was performed on naming latencies. Familiarity was entered in the first step of the model; entering AoA as a predictor in the second step resulted in a significant increase of the explained variance [$R^2$ change = .003, $F(1, 1558) = 5.37$, $p < .03$]. AoA proved to be a significant predictor for naming latencies even when familiarity was partialed out in the first step ($\beta = .089$, $t = 2.32$, $p < .03$). Furthermore, as in Experiment 1, a multiple regression analysis was conducted in which the other variables listed in Table 1 were included in the first step of the model: Still, the AoA effect remained significant [$\beta = .105$, $t = 2.44$, $p < .02$; $R^2$ change = .004, $F(1, 1550) = 5.95$, $p < .02$].

## General discussion

The main findings of the present study can be summarized as follows. The AoA effect reported in the delayed picture-naming trials of Experiment 1a, in which participants were biased to process picture stimuli up to the semantic level, reflected a postsemantic source of the AoA effect. The AoA effect reported in the delayed picture-naming trials of Experiments 1b and 2, in which participants were biased to process pictures up to the lexical level, reflected a phonological source of the AoA effect. Further evidence supporting the conclusion that the AoA effect in Experiments 1b and 2 arose during phonological encoding, and not during subsequent response execution processes, comes from the fact that under "standard" delayed naming conditions, the AoA effect disappears (e.g., Catling & Johnston, 2009).

**Table 3** Mean naming latencies and standard deviations (*SD*s), in milliseconds, and error percentages (*E*) in the age-of-acquisition and naming conditions of Experiment 2

| | Immediate Condition | | | Delayed Condition | | |
|---|---|---|---|---|---|---|
| AoA | Mean | SD | E | Mean | SD | E |
| Early acquired | 1,047 | 130 | 10.9 | 757 | 81 | 6.4 |
| Late acquired | 1,141 | 190 | 10.5 | 793 | 142 | 10.5 |
| Difference | −94 | | 0.5 | −36 | | −4.1 |

A general pattern observed in studies exploring AoA effects is that the effect tends to be greater for tasks involving overt naming than for tasks involving perceptual and/or semantic processing (e.g., Bonin, Chalard, Méot, & Barry, 2006). Catling and Johnston (2006) proposed that the size of the effect increases as a function of the number of stages affected by AoA involved in the task. Following this argument, one could expect that the AoA effect size in our experiments should be indirectly related to the number of stages required by the prevalent task and resolved during the delay. That is, when the delay allows for deeper processing of the stimulus, as in the gender decision task, a smaller AoA effect is expected. Indeed, the effect sizes obtained in Experiments 1 and 2 are congruent with this prediction. As can be seen in Tables 2 and 3, the smallest AoA effects were obtained in the delayed gender decision tasks (63 and 36 ms). In the delayed semantic categorization task, the effect was larger (82 ms). Finally, the largest AoA effects were obtained in the immediate naming conditions (109 and 94 ms). However, the statistical analyses only partially confirmed this pattern: The interaction between AoA and naming condition was significant only in Experiment 2 (see the Results sections). It could be that the failure to observe clear significant interactions was due to the fact that we were comparing effects emerging within the same task (overt naming), whereas previous studies that had reported such interaction compared different tasks (semantic categorization vs. overt naming; see Bonin et al., 2006; Catling & Johnston, 2009).

In relation to Experiment 1a (see also Almeida et al., 2007), it is plausible that semantic categorization and picture-naming tasks engage different semantic information: Indeed, while picture naming requires the selection of a specific concept, the responses in a semantic categorization might just rely on the activation of general semantic features shared by the exemplars of the category. Thus, it could be that, during the delay, participants access semantic information to perform the prevalent categorization task, and when a picture-naming trial is presented, further semantic information needs to be accessed in order to fully retrieve the unique concept corresponding to the picture. If this were the case, it could be that part of the AoA effect in the delayed condition of Experiment 1a could be ascribed to a semantic stage of processing.

In sum, our results suggest that part of the AoA effect reported in picture naming has a postsemantic origin (e.g., Belke et al., 2005; Catling & Johnston, 2009). More importantly, we presented evidence confirming that part of this postsemantic AoA effect occurs at the level at which the phonological properties of words are retrieved. We are not claiming, here, that previous stages of processing are insensitive to AoA effects, but that the AoA effects are not exclusively linked to picture recognition, semantic processing, or lexical access. The data reported here are in line with current neuropsychological (Kittredge, Dell, Verkuilen, & Schwartz, 2008) and magnetic resonance imaging (Hernandez & Fiebach, 2006) studies showing a phonological source for the AoA effect. To conclude, AoA is a highly reliable phenomenon that has multiple loci. Our results strongly suggest that the retrieval of phonological forms is AoA-sensitive. Furthermore, in the present study we have described a novel method for exploring AoA effects in picture-naming tasks.

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