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Age of acquisition and word frequency in written picture naming

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This study investigates age of acquisition (AoA) and word frequency effects in both spoken and written picture naming. In the first two experiments, reliable AoA effects on object naming speed, with objective word frequency controlled for, were found in both spoken (Experiment 1) and written picture naming (Experiment 2). In contrast, no reliable objective word frequency effects were observed on naming speed, with AoA controlled for, in either spoken (Experiment 3) or written (Experiment 4) picture naming. The implications of the findings for written picture naming are briefly discussed.

Words that are acquired early in life (referred to as EA words) are retrieved more rapidly from memory than words acquired later (LA words). This effect, referred to as the age-of-acquisition (hereafter AoA) effect, is now a well-established finding in psycholinguistics. It is robustly found in "output" tasks such as spoken picture naming (Barry, Morrison, & Ellis, 1997; Carroll & White, 1973b; Hodgson & Ellis, 1998; Lachman, 1973; Lachman, Schaffer, & Henrikus, 1974; Morrison, Chappell, & Ellis, 1997; Morrison, Ellis, & Quinlan, 1992), face naming (Moore & Valentine, 1998), category instance naming (Loftus & Suppes, 1972), word completion (Gilhooly & Gilhooly, 1979), and word naming (Brown & Watson, 1987; Coltheart, Laxon, & Keating, 1988; Gerhand & Barry, 1998; Gilhooly & Logie, 1981; Yamazaki, Ellis, Morrison, & Lambon Ralph, 1997). AoA effects have also been observed in "input tasks" such as visual lexical decision (Brysbaert, 1996; Gerhand & Barry, 1999; Turner, Valentine, & Ellis, 1998), perceptual identification (Lyons, Teer, & Rubenstein, 1978), and auditory lexical decision (Cirrin, 1984; Turner et al., 1998). AoA also affects the performance of brain-damaged patients (Hirsh & Ellis, 1994; Hirsh & Funnell, 1995). Of interest here is the fact that Hirsh and Ellis found an AoA effect on the written picture-naming error rate of a brain-damaged patient, NP. Surprisingly, however, no AoA effect has, to the best of our knowledge, ever been reported in written picture-naming tasks involving normal subjects.

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Thus, an important empirical issue is to determine whether an AoA effect can be observed in written picture naming in normals, as written picture naming is obviously an output task. Hence, it is clear that the main aim of our study was empirical.

Why should we address the issue of AoA effects in written picture naming? The reason is that is has often been claimed that written production is similar to spoken production, as it obviously appears to involve similar processes and representations (Ellis, 1988), although there is little or no evidence to support this claim. Our assumption is that it is necessary to gather empirical data if we wish to propose views on lexical access in writing or to constrain the few existing ones. Thus, given the growing importance of AoA effects in the spoken picture-naming literature, it is a logical step to determine whether an AoA effect can be observed in written picture naming. It is also worth noting that most reports of AoA effects relate to the English language and that, to our knowledge, there has not as yet been any published report of AoA effects in French.

Most AoA effects in spoken picture naming have been observed on the basis of adult estimates of the age at which words are first learned. Although the validity of such ratings has been questioned (Brysbaert, 1996), they nevertheless appear to be valid (Carroll & White, 1973a; Gilhooly & Gilhooly, 1980; Lyons et al., 1978; Morrison et al., 1997). For example, Carroll and White found a correlation higher than .80 between rated AoA scores and estimates of objective AoA taken from studies of the frequency of word use in children's reading and writing. Also, Gilhooly and Gilhooly reported a correlation of .84 between AoA ratings of words and the ability of children and young adults, aged from 5 to 21 years, to give acceptable definitions of those words. Although objective AoA scores would appear to be preferable to subjective AoA scores when available (Ellis & Morrison, 1998), in view of the fact that no objective AoA counts were available for French, and given the established validity of estimated AoA scores, we used estimated values of AoA provided by Alario and Ferrand (1999) for a set of 400 pictures standardized for French.

How are AoA effects accounted for?

Although AoA effects are clearly established at an empirical level, a straightforward explanation of these effects is lacking. Morrison (1993) showed that AoA effects are not merely cumulative frequency effects—that is, the total number of experiences of a word across one's lifetime—and Gilhooly (1984) has provided evidence that AoA effects do not reflect residence time in lexical memory. Regarding this latter explanation of AoA effects, Gilhooly examined the relative effects of AoA and residence time in a group of participants ranging in age from 20 to 58 years by using words introduced much earlier versus newly introduced words and showed that AoA was a better predictor of word-naming latencies than was either residence time or participant age. Concerning the cumulative frequency hypothesis of AoA effects, Morrison (1993) tested it in a word-naming study involving young and old adult participants. According to this hypothesis, the AoA effect should be smaller in older adults than in younger adults. However, she found that older and younger participants showed clear effects of AoA on spoken naming speed, which were almost identical in size.

Most accounts of AoA effects localize them at a phonological level, and more precisely, at a phonological lexeme level. The rationale for proposing the phonological lexeme level as the candidate locus of AoA effects in spoken picture naming is as follows. Morrison et al. (1992)

found no AoA effect in a semantic categorization task, thus ruling out the conceptual/semantic level as the locus of this effect, as it is generally assumed that semantic categorization indexes conceptual representations. Also, Morrison and Ellis (1995) found no effect of AoA in a delayed naming paradigm, where the word was followed by an unpredictable delay, and naming was prompted by a visual cue. Given that this paradigm is assumed to index the post-lexemic level, the absence of an AoA effect in delayed naming made it possible to rule out a post-lexemic locus of AoA effects. By a process of elimination, the effect of AoA on spoken picture naming would appear to be lexical. According to the commonly held view that lexicalization involves lemma access and lexeme retrieval (Bock & Levelt, 1994; Levelt, 1989; Levelt, Roelofs, & Meyer, 1999; Schriefers, Meyer, & Levelt, 1990; Roelofs, 1992; Roelofs, Meyer, & Levelt, 1998; but see Caramazza, 1997; Caramazza & Miozzo, 1998), there remain two potential candidates for the locus of AoA effects: the lemma level or the phonological lexeme level. Morrison and Ellis (1995) reasoned that if word naming involves direct mappings between visual and phonological lexemes, and if the same locus is proposed for AoA effects in both spoken picture naming and word naming, then the best candidate would be the phonological lexeme level. However, the issue of whether word naming actually involves a direct mapping between visual and phonological lexemes is far from being resolved. It has recently been claimed that word reading involves lemma access (Roelofs, Meyer, & Levelt, 1996). In an attempt to explain the interference effects of written words on spoken picture naming, Roelofs et al. (1996) have argued that orthographic lexemes in perception converge on the same lemmas as those used in speaking. Finally, a different account of AoA effects in language production tasks has been put forward by Hirsh and Funnell (1995). These authors have suggested that AoA effects might be the result of differentially effective links between semantics and phonology. However, this latter explanation as yet lacks an empirical foundation.

If the phonological lexeme level is assumed to be the genuine locus of AoA effects, the question of how AoA effects come about must be answered. Gilhooly and Watson (1981) have put forward an explanation within the framework of the revised logogen model (Morton, 1979). According to this, AoA effects arise at the speech output logogen level and are the consequence of EA words having lower activation thresholds than LA words. However, Gilhooly and Watson (1981) and Brown and Watson (1987) have proposed that the most plausible explanation for AoA effects is that EA words have more complete phonological representations than LA words (the completeness hypothesis). Thus, when subjects have to produce a target word as spoken output, EA words would benefit from more rapid phonological assembly than do LA words. Yet, compelling evidence for this explanation is lacking (Barry et al., 1997).

At first sight, finding an AoA effect in written picture naming would not come as a surprise given that, as it has often been claimed that writing is entirely dependent upon speech processes and representations (Luria, 1970), written picture naming would necessarily involve phonological codes from which the orthographic codes are derived. However, this traditional view, referred to as the obligatory phonological mediation hypothesis (Luria, 1970), has been challenged by several findings in brain-damaged patients (e.g., Assal, Buttet, & Jollivet, 1981; Hanley & McDonnell, 1997; Hier & Mohr, 1977; Lhermitte & Derouesné, 1974) as well as in normals (Bonin, Fayol, & Gombert, 1997, 1998; Bonin, Fayol, & Peereman, 1998; for a brief review, see Bonin, 1997). To account for the neuropsychological data, the orthographic autonomy hypothesis was proposed (Miceli, Benvegnu, Capasso, & Caramazza, 1997; Rapp, Benzing, & Caramazza, 1997; Rapp & Caramazza, 1997). According to this hypothesis, the retrieval of orthographic codes does not obligatorily require prior access to phonology. It is thus assumed that activation from semantic codes propagates in parallel to their connected orthographic lexemes and phonological lexemes. Nevertheless, this hypothesis does not preclude the possibility that phonology plays a role in the determination of orthographic codes. In fact, Miceli et al. (1997) have distinguished between two versions of the orthographic autonomy hypothesis. According to the "weak" version, orthographic lexemes and phonological lexemes are directly linked to each other by means of lexical connections. The "strong" version holds that orthographic lexemes and phonological lexemes are not directly connected to each other, but that they can interact through sublexical conversions between phonological and orthographic units. As far as AoA effects are concerned, if we accept the idea that they are located at a phonological lexeme level, then the phonological mediation hypothesis in writing, which states that phonological codes are obligatorily accessed in order to access orthographic codes, clearly leads us to expect an AoA effect in written picture naming. An AoA effect is also predicted by the orthographic autonomy hypothesis given that it attributes a role to phonology by means of either lexical or sublexical links between phonological and orthographic lexemes.

In the first two experiments, some participants had to say aloud (Experiment 1), whereas some others had to write down (Experiment 2), the names of pictures that varied on estimated AoA scores. Thus, Experiment 1 is a mere replication of an AoA effect in spoken picture naming using French items. Written and spoken latencies as well as errors were measured. As in most experiments on AoA, the stimuli were controlled on a number of relevant variables, including objective word frequency (see the Procedure section for selection details).

EXPERIMENT 1

Method

Participants

Thirty psychology students from Blaise Pascal University were recruited. In this experiment, as well as in the following experiments, they received course credits for their participation, were all native speakers of French, and had normal or corrected-to-normal vision.

Stimuli

A total of 46 drawings of common objects were selected from the Cycowicz, Friedman, Rothstein, and Snodgrass (1997) database. The experimental pictures consisted of two sets of 18 pictures names: one set corresponding to EA picture names and one set to LA picture names. The AoA scores were based on the adult ratings provided by Alario and Ferrand (1999). It is worth noting that to collect AoA scores, Alario and Ferrand (1999) altered the scale used by Morrison et al. (1997) from 7 points to 5 points where 1 = learned at 0–3 years and 5 = learned at age 12+, with 3-year age bands in between. EA and LA words were matched on the following: name agreement; image agreement; visual complexity; log frequency; number of letters, phonemes, and syllables; log bigram frequency; and phoneme-to-grapheme consistency (see Appendix A for the detailed statistical characteristics of the stimuli). However, with this set of controlled factors taken into account, it was not possible to control for conceptual familiarity and image variability while at the same time maintaining a sufficient number of EA and LA items. As a result, these factors were included as covariates in the by-item analyses of variance (ANOVAs). In addition, 10 pictures were used as warm-ups.

The measures of name agreement, image agreement, visual complexity, familiarity, and image variability were taken from Alario and Ferrand (1999). Name agreement refers to the degree to which participants agree on the name of the picture, and is measured by the number of different names given to a particular picture across participants. In Appendix A, the mean percentage of participants producing the picture name is reported. Image agreement refers to the degree (evaluated using a 5-point scale) to which images generated by participants in response to a picture name match with the picture's appearance: A rating of 1 indicates low agreement—that is, the picture provides a poor match for the image—and a rating of 5 indicates high agreement. Familiarity refers to the familiarity of the concept depicted. It was also measured from a 5-point scale (1 = a very unfamiliar object, 5 = a very familiar object). Visual complexity corresponds to the number of lines and details in the drawing. In Alario and Ferrand (1999), the visual complexity task required the participants to rate the complexity of each drawing on a 5-point scale (1 = drawing very simple, 5 = drawing very complex) rather than the complexity of the object it represented. Image variability was again rated on a 5-point scale, and this measure indicates whether the name of an object evokes few or many different images for that particular object (1 = few images, 5 = many images). Frequency refers to objective word frequency. The frequency counts were taken from the Brulex database (Content, Mousty, & Radeau, 1990). Bigram frequency values (by type) were taken from Content and Radeau (1988). Finally, phoneme-to-grapheme consistency was taken from Véronis (1988).

Apparatus

The experiment was performed with PsyScope Version 1.2 (Cohen, MacWhinney, Flatt, & Provost, 1993) and run on a PowerMacintosh computer. The computer controlled the presentation of the pictures and recorded the latencies. The spoken latencies were recorded with the Button-Box connected to the computer and an AIWA CM-T6 small tie-pin microphone connected to the Button-Box.

Procedure

The participants were tested individually. During the first phase, they had to learn the name associated with each picture. To this end, each picture was presented on the screen with its name both written below it and auditorily presented via headphones (Sennheiser HD 25 SP). The picture remained on the screen until the participant pressed the "space bar". The participants were told to look carefully at each picture, to learn its name, and then, when they felt they knew its name, to press the key to proceed to the next picture. A learning trial had the following structure: A ready signal ("*") was presented for 1,000 ms and followed 200 ms later by the picture. The written name of the picture and its spoken name were presented 50 ms after picture onset. When the participant pressed the key, the next trial began after a delay of 1,000 ms. To ensure that the participants had correctly learned the names associated with the pictures, the experimenter tested them on several randomly selected pictures.

The rationale for conducting this learning phase was that our production experiments required the selection of specific measurable responses, and in production there is often no easy way to get specific responses (Bock, 1996). In cases where the name corresponding to each picture is not stipulated, the problem is that something other than the target is very often produced, with the consequence that many of the responses must be discarded because of their uncertain bearing on the questions of interest. Thus, "specified elicitation" is frequently used in spoken picture-naming studies in order to reduce variability in the names used to refer to the pictures (e.g., Jescheniak & Levelt, 1994; Schriefers et al., 1990; Starreveld & La Heij, 1995). The assumption is that the same lexical mechanisms are exercised regardless of whether the desired response is spontaneous or specified in advance (Bock, 1996).

The second phase was the experimental phase. The participants were told that they would see a picture (presented on the screen at a viewing distance of about 60 cm) and quickly had to say aloud the name of the picture. The experimenter monitored the participants' responses and scored them for correctness. The entire session lasted about half an hour.

A trial consisted of the following sequence of events: A ready signal ("*") was presented for 1,000 ms followed by a picture. The picture remained on the screen until the participants initiated the spoken response. The next trial began 5,000 ms after the participants had initiated their response. This intertrial delay was established on the basis of studies similar to our own (Bonin & Fayol, 2000; Bonin, Fayol, & Gombert, 1997, 1998). For both output modes, latencies were measured from picture onset to the initiation of the response.

Results

In Experiment 1, as well as in the following experiments, observations were discarded from the latency analyses for both spoken and written picture naming in the following cases: (1) the participant did not remember the picture name; (2) a technical problem occurred; (3) an item other than the expected one was produced. Specifically, for the spoken responses, observations were also scored as errors when participants stuttered or produced nonlinguistic sounds (such as mouth clicks) or repaired the utterance after a dysfluency. For all experiments, we performed two types of analyses on the latency data: one without excluding outlying, though correct, reaction times (RTs), and one in which latencies exceeding two standard deviations above the participant and item means were excluded (but not counted as errors). Both analyses yielded the same results across experiments. For the sake of conciseness, only the latter analysis is reported for all experiments.

Latencies exceeding two standard deviations above the participant and item means accounted for 2.41% of the data. Overall, 6.57% of the observations were excluded.

Latencies and errors were subjected to ANOVAs with AoA as an experimental factor. To generalize over both participants and items (Clark, 1973), in all the experiments, ANOVAS were carried out on the participant means (F_1) and on the item means (F_2). In Experiments 1 and 2, conceptual familiarity and image variability were included as covariates in the analyses by items. Throughout the analyses, the conventional level of .05 for statistical significance was adopted.

The mean spoken latencies, their standard deviations, and the error rates appear in Table 1. EA labels were produced faster than LA labels, $F_1(1, 29) = 124.25$, $MSE = 2593.8$; $F_2(1,$

TABLE 1
Mean spoken latencies (SL)[a], standard deviations of these means (SD), and error rates (E)[b] from Experiment 1 as a function of AoA

Spoken picture naming					
EA			*LA*		
SL	*SD*	*E*	*SL*	*SD*	*E*
753	63.8	1.8	900	113.5	6.4

Note: EA = early acquired words; LA = late acquired words.
[a] In ms.
[b] In percentages.

32) = 37.86, MSE = 4639.7, and the former were less prone to errors than the latter, $F_1(1, 29) = 17.68$, MSE = .0018181; $F_2(1, 32) = 7.30$, MSE = .0032277.

EXPERIMENT 2

Method

Participants

Thirty psychology students taken from the same pool as that in Experiment 1 participated in this experiment. None had participated in Experiment 1.

Stimuli

The stimuli were the same as those in Experiment 1.

Apparatus

A graphic tablet (WACOM UltraPad A5) and a contact pen (UP 401) were used to record the graphic latencies.

Procedure

The procedure was the same as that in Experiment 1, except that the participants produced the picture names by writing them down. The written responses were timed as follows: The participants sat with the stylus right above the tablet so that the latency was the time taken to make contact after picture onset. The timing was accurate to the nearest millisecond. In order to avoid any variability in the positioning of the stylus before each word was written, a line was drawn, and the participant was obliged to position the stylus at the very start of the line at a height from the tablet that just touched the edge of the line. The experimenter systematically ensured that the instructions were adhered to and always corrected the participants if they failed to observe them.

TABLE 2
Mean written latencies (WL)[a], standard deviations of these means (SD), and error rates (E)[b] from Experiment 2 as a function of AoA

Written picture naming					
EA			*LA*		
WL	*SD*	*E*	*WL*	*SD*	*E*
1043	115.8	1.6	1124	123.5	3.5

Note: EA = early acquired words; LA = late acquired words.
[a] In ms.
[b] In percentages.

Results

The criteria defined in Experiment 1 were applied in order to exclude some of the data. Latencies exceeding two standard deviations above the participant and item means were discarded (2.31%). Overall, 4.90% of the observations were excluded. Specifically for the written responses, observations were discarded when a word was misspelled, or the participant wrote down a letter or two and then paused—that is, waited for more than one second without moving the stylus. Pause durations were measured electronically. However, this latter case occurred very "rarely" (less than 0.5% of the data) as the instructions strongly stressed that words had to be produced clearly and quickly.

The mean written latencies, their standard deviations, and the error rates are presented in Table 2. EA labels yielded faster latencies than LA labels, $F_1(1, 29) = 60.24$, $MSE = 1614.2$; $F_2(1, 32) = 22.56$, $MSE = 2160.2$. More errors were observed on LA than on EA words, but the AoA effect was marginally significant on participants, $F_1(1, 29) = 3.152174$, $MSE = .0016319$, $p = .086$, and not significant on items, $F_2(1, 32) = 2.28$, $MSE = .0013828$.

Discussion of Experiments 1 and 2

Experiment 1 clearly replicated the effect of AoA on onset latencies and on errors in spoken picture naming using French material. Experiment 2 revealed an effect of AoA on onset latencies in written picture naming even though this effect was not significant on errors (we observed only a trend in the by-participant analysis). Given the two hypotheses stated in the Introduction regarding access to written name representations—the obligatory mediation hypothesis and the orthographic autonomy hypothesis—such an effect was expected because (1) both hypotheses claim that phonological representations contribute to access to orthographic representations—namely, the obligatory mediation hypothesis states that phonology is obligatorily involved, and the orthographic autonomy hypothesis holds that phonology plays a role in the determination of orthographic codes by means of lexical or sublexical links—and (2) most accounts of AoA effects have located them at a phonological level. However, the possibility that the AoA in written picture naming has an effect at a level other than that of phonological lexemes cannot be discarded. Before considering this point further (we return to it in the General Discussion), Experiments 3 and 4 were conducted in order to examine the issue of whether true objective word frequency effects could be observed in spoken and written picture naming when AoA was controlled for. This issue is a very important one as it has often been claimed that frequency effects are actually AoA effects in disguise.

EXPERIMENTS 3 AND 4

The word frequency effect is one of the most famous effects in psycholinguistics. As far as spoken picture naming is concerned, numerous studies have reported a frequency effect on spoken object-naming speed. The classic study by Oldfield and Wingfield (1965) showed a linear relationship between spoken picture-naming latency and log frequency. More recently, Jescheniak and Levelt (1994) have reported an extensive study of frequency effects in spoken picture naming and concluded in favour of a phonological lexeme basis for these effects. However, the status of the frequency effect in spoken picture naming has been called into question. Morrison et al. (1992), in a re-analysis of the data reported by Oldfield and Wingfield, showed that, when AoA scores were taken into account in multiple regression analyses, only AoA was a significant independent determinant of naming latency. Also, Morrison et al., using multiple regression analyses, have shown that in spoken picture naming, only AoA (and length) had significant effects on naming speed (for similar findings, see Carroll & White, 1973b; Gilhooly & Gilhooly, 1979; but see Barry et al., 1997; Snodgrass & Yuditsky, 1996). These studies thus suggest that objective frequency does not appear to make any independent contribution. According to Barry et al. (1997), the Jescheniak and Levelt (1994) study of frequency effects also suffers from a confound of frequency with AoA. It is worth noting that Levelt et al. (1999) recently acknowledged that the frequency effects reported in the spoken picture-naming study of Jescheniak and Levelt could be AoA effects.

Given the central role of frequency in most theoretical accounts of word retrieval, and because some studies have suggested a possible role for word frequency in spoken picture naming (Barry et al., 1997; Snodgrass & Yuditsky, 1996), we sought to determine whether true objective word frequency effects could be observed in spoken (Experiment 3) and written (Experiment 4) picture naming when AoA is controlled for. To the best of our knowledge, no study has explicitly dealt with the issue of frequency effects in written picture-naming experiments involving normal participants, except for the Bonin, Fayol, and Gombert (1998) study. In that study, Bonin et al. reported frequency effects in written as well as in spoken picture naming. Unfortunately, the authors did not control for AoA. In Experiments 3 and 4, the same design as that in Experiments 1 and 2 was used.

EXPERIMENT 3

Method

Participants

Thirty adults from the same pool as that of Experiments 1 and 2 were recruited but none had participated in any of the previous experiments.

Stimuli

A total of 44 drawings of objects were selected from the Cycowicz et al. (1997) database. One set of 17 pictures corresponded to high-frequency picture names and one set of 17 to low-frequency picture names. The frequency counts were taken from the Brulex database (Content et al., 1990). In addition, 10 pictures were used as practice trials. High- and low-frequency picture names were matched on the following: age of acquisition; name agreement; image agreement; visual complexity; conceptual familiarity; number of letters, phonemes, and syllables; log bigram frequency; and phoneme-to-grapheme consistency. However, with this set of factors taken into account, it was not possible to control for image variability while at the same time retaining a sufficient number of high- and low-frequency words. As a result, this factor was included as a covariate factor in the ANOVAs with items as a random factor. The list of the experimental stimuli and their statistical characteristics are provided in Appendix B.

Apparatus and procedure

These were the same as those in Experiment 1.

TABLE 3
Mean spoken latencies (SL)[a], standard deviations of these means (SD), and error rates (E)[b] from Experiment 3 as a function of frequency

Spoken picture naming					
HF			*LF*		
SL	*SD*	*E*	*SL*	*SD*	*E*
745	78.8	2.5	755	89.4	5.1

Note: HF = high-frequency words; LF = low-frequency words.
[a] In ms.
[b] In percentages.

Results

As in the previous experiments, latencies exceeding two standard deviations above the participant and item means were excluded (1.96%). Overall, 5.78% of the observations were excluded.

Latencies and errors were subjected to ANOVAs with frequency (high frequency: HF, low frequency: LF) entered as a factor. In both Experiments 3 and 4, image variability was introduced as a covariate factor in the item analyses.

The mean spoken latencies, their standard deviations and the error rates are presented in Table 3.

HF words were not produced significantly faster than LF words, $F_1(1, 29) = 2.15$, $MSE = 716.7$; $F_2 < 1$. There were more errors on LF words than on HF words but this effect was only significant for participants, $F_1(1, 29) = 5.21$, $MSE = .0018713$; $F_2(1, 31) = 1.45$.

EXPERIMENT 4

Method

Participants

Thirty adults from the same pool as that of Experiments 1–3 were recruited but none had participated in any of the previous experiments.

Stimuli

These were the same as those in Experiment 3.

Apparatus and procedure

These were the same as those in Experiment 2.

TABLE 4
Mean written latencies (WL)[a], standard deviations of these means (SD), and error rates (E)[b] from Experiment 4 as a function of frequency

Written picture naming					
HF			*LF*		
WL	*SD*	*E*	*WL*	*SD*	*E*
1085	170.9	2.3	1100	189.5	3.9

Note: HF = high-frequency words; LF = low-frequency words.
[a] In ms.
[b] In percentages.

Results

As in the previous experiments, latencies exceeding two standard deviations above the participant and item means were excluded (1.96%). Overall, 5.88% of the observations were excluded.

The mean written latencies, their standard deviations, and the error rates are presented in Table 4.

HF words did not yield significantly faster latencies than LF words, $F_1(1, 29) = 1.26$; $F_2(1, 31) = 2.84$, $MSE = 4225.9$. Also, there were not significantly more errors on LF words than on HF words, $F_1(1, 29) = 1.55$; $F_2(1, 31) = 2.76$, $MSE = .0016534$.

Discussion of Experiments 3 and 4

The findings resulting from Experiments 3 and 4 are straightforward: No reliable objective word frequency effects were observed on written and spoken picture-naming latencies with AoA controlled for. As far as the errors are concerned, the effect of frequency was significant only in spoken picture naming in the by-participants analysis. These findings cast some doubt on the status of the frequency effects reported in written and spoken picture naming by Bonin, Fayol, and Gombert (1998). It should be recalled that in this study AoA was not controlled for. Thus, it is possible that the frequency effects reported in the study were in fact genuine AoA effects. The findings from Experiment 3 replicate those of a number of earlier studies. The absence of frequency effects with words matched on AoA scores is an important one because it adds to the growing body of evidence that suggests that AoA is one of the major determinants of picture-naming latencies. However, it must be stressed that these findings do not preclude the observation of frequency effects in either spoken or written picture naming. Indeed, word frequency effects in spoken picture naming are found in some studies (e.g., Barry et al., 1997; Snodgrass & Yuditsky, 1996) but not in others (e.g., Gilhooly & Gilhooly, 1979; Morrison et al., 1992; Vitkovitch & Tyrrell, 1995). It is worth noting that the studies in which frequency effects were found used large numbers of items, and that in Experiments 3 and 4 we used only 17 items per condition. It could also be the case that frequency and AoA interact, so that frequency effects are found with LA words but not with EA words. Remember that in Experiments 3 and 4, both HF and LF words were EA words. In fact, a recent study conducted by

Barry et al. (1997) has shown that in spoken picture naming, objective spoken frequency interacted with estimated AoA. More precisely, they observed that the frequency effect was significant with LA words but not significant on EA words, or in other words, that the AoA effect was stronger for low-frequency than for high-frequency words. Given the findings of Barry et al., we cannot exclude the possibility that frequency effects might have been found had we used LA words. Thus, future research should be directed at determining whether the critical interaction between word frequency and AoA can be replicated in picture naming. Nevertheless, what is clear is that controlling for AoA greatly reduces the magnitude of the "frequency effects" reported when AoA is not controlled[1].

Finally, one might ask whether the lack of a significant word frequency effect on naming speed might be related to the fact that the names were practised during the learning phase just before the experiments proper. In the Jescheniak and Levelt (1994) study, the size of the "frequency" effect did not reliably vary with the repetition of the picture names. However, it is worth noting that (1) in the Jescheniak and Levelt study, the initial presentation of the pictures and their names occurred prior to the production experiment as in our study and (2) AoA was not controlled for. As pointed out by Griffin and Bock (1998), the benefit of repetition in naming latencies is usually revealed by comparing the first and second presentations of the pictures. Because in both the Jescheniak and Levelt study and ours, the participants were trained on the pictures before the picture-naming experiments, this component of the repetition effect is missing from both studies. Consequently, we are unable, on the basis of Jescheniak and Levelt's (1994) study, to state whether larger frequency effects (or AoA effects given that these two factors were confound) would have been observed if the participants had not practised the names of the pictures before the naming experiment proper. The same comment applies to our Experiments 1 and 2: We cannot tell from these experiments whether AoA effects would have been larger if the names had not been retrieved until the spoken or written picture-naming task itself. The studies that have investigated frequency effects in relation to repetition have often shown that frequency effects are attenuated with repetition (e.g., Bartram, 1973; Monsell, Matthews, & Miller, 1992; Wheeldon & Monsell, 1992). As suggested by Griffin and Bock (1998), those studies in which persistent frequency effects are found after only a few presentations could indeed be attributable not to frequency but to disparities between HF and LF words on name uncertainty and phonological variables such as length (Bartram, 1974; Oldfield & Wingfield, 1965). As none of the previously mentioned studies that have investigated frequency effects in relation to picture repetition controlled for AoA, we are unable to state whether the factor that truly interacted with repetition was word frequency or AoA. Pending more evidence on repetition effects in picture naming, it is also conceivable that frequency effects but not AoA effects are wiped out by repetition.

GENERAL DISCUSSION

Written picture naming has largely been ignored in the discussions of psycholinguists studying lexical access in language production (e.g., Roelofs et al., 1998). Thus, it is not surprising that, until now, no study had investigated the issue of AoA effects in written picture naming in

[1]We thank Andrew Ellis for pointing this out.

normal adults. Our study attempted to fill this gap. As emphasized in the Introduction, the purpose of our study was empirical as it was designed to collect evidence about the influence of AoA in written picture naming. The main findings can be easily summarized. In Experiments 1 and 2, robust AoA effects were found in both spoken (Experiment 1) and written picture naming (Experiment 2). It is worth noting that the replication of an AoA effect in spoken picture naming had never previously been established in a French language study. From an empirical point of view, this is the first report of an AoA effect in written picture naming obtained from normals that we are aware of. Finally, Experiments 3 and 4 showed that no reliable objective word frequency effect was found in either written or spoken picture naming when high- and low-frequency words were matched on AoA scores (only an effect on errors in spoken picture naming was reliably observed in the by-participants analysis).

As stressed in the Introduction, the finding of an AoA effect in written picture naming is not surprising given that robust AoA effects have been found with output tasks and that written picture naming is obviously one such task. Now that we have established that AoA affects written picture-naming performance in normal participants, it remains to determine the locus of the AoA effect and the mechanisms by which it emerges. Because our study was not designed to test hypotheses concerning the locus of AoA effects, we can only offer some general speculations.

The two hypotheses relating to access to written form representations presented in the Introduction—that is, the obligatory phonological mediation hypothesis and the orthographic autonomy hypothesis—are able to account for the AoA effect found in onset written picture-naming latencies, as both of them state that phonology plays a role in the access to orthographic codes, and most accounts of AoA effects localize them at a phonological level. Nevertheless, the present findings do not allow us to disentangle these two hypotheses. It might therefore be tempting to conclude from our findings that the AoA effect observed in written picture naming is phonologically based, as Hirsh and Ellis (1994) have suggested in order to account for the effect of AoA on the written picture-naming error rate of their brain-damaged patient, NP. This explanation is highly plausible and can be easily embraced given that there is no firm evidence that AoA effects emerge in a task that does not require phonological retrieval (Gerhand & Barry, 1999). But in a sense, one might argue that our written picture-naming task has done this, because the task clearly does not require phonological retrieval, even if such retrieval does occur in practice. Therefore, we cannot rule out the possibility that the AoA effect in written picture naming is located at a level other than that of phonological lexemes. In the Introduction we have presented the arguments that have been put forward in support of a phonological lexeme locus of AoA effects, but there is no conclusive evidence to indicate that this level is the sole locus of AoA effects—that is to say, AoA effects could also be located at the lemma level or in the links between semantic and lexical codes. As far as the latter hypothesis of AoA effects is concerned, it is important to note that the same hypothesis has been put forward to explain objective word frequency effects in spoken picture naming (Barry et al., 1997; Vitkovitch & Humphreys, 1991). This latter explanation of objective frequency effects is often framed within connectionist models of word reading, according to which frequency affects the strength of the connections between different representations (e.g., Seidenberg & McClelland, 1989). More specifically, to account for the interaction between frequency and AoA in spoken picture naming, Barry et al. (1997) have suggested that the frequency effect is localized in the connections between lemmas and lexemes, whereas the AoA effect is localized at the level of the phonological representations. An object's name will be retrieved faster if the connection between the lemma and lexeme representations of that word is strong (i.e., it is a high-frequency word), and it will be retrieved faster if the lexeme is unitary rather than fragmented (i.e., an EA word). These two factors can be combined, with the result that the fastest retrieval will be for high-frequency and EA words, whereas the slowest retrieval will be for low-frequency and LA words.

Finally, AoA effects might be very widespread in the lexical system and not simply rooted in a phonological level. Therefore, AoA might also affect performance in tasks that do not require the activation of phonology (Gerhand & Barry, 1998). In contrast, if it is assumed that the phonological level is the *sole* locus of AoA effects, the implication is that all the tasks where AoA effects are found necessarily involve phonology. For instance, because AoA effects are found in visual lexical decision (a task frequently used to study visual word recognition), this would imply that phonology is involved in that task (Gerhand & Barry, 1999). But after more than two decades of intensive research into visual word recognition, the issue of whether phonology obligatorily mediates lexical access is still a topic of much dispute (Coltheart & Coltheart, 1997; Van Orden, Pennington, & Stone, 1990). Therefore, AoA might have an effect not only on phonological lexemes but also on orthographic lexemes. Such a suggestion has already been put forward by Yamazaki et al. (1997) in a study of Japanese word naming in which they found independent contributions of age of spoken and written acquisition in the prediction of the speed of naming Japanese Kanji. Accordingly, the AoA effect that we observed in written onset latencies might be orthographically based. If this suggestion is correct, a study in which written AoA and spoken AoA scores are considered using a large set of items should reveal that written picture-naming performance is predicted by the former and spoken picture-naming performance by the latter. However, no study of this kind can be conducted given that no separate written and spoken AoA scores are available for French. In effect, in our Experiments 1 and 2, the AoA scores (taken from Alario & Ferrand, 1999) were based on adults' estimations of the age at which they thought they had learned the words in either their spoken or their written form. From a general standpoint, it is clear that future research is crucial in order to test the different explanations that relate to the questions of the locus of AoA and objective word frequency effects and the mechanisms underlying these effects. To date, a compelling explanation of these effects is unfortunately lacking (Lewis, 1999).

To conclude, our study makes a valuable empirical contribution by showing that (1) AoA effects on naming speed are reliably observed in both spoken and written picture naming using the French language, and (2) in experiments of comparable power, an objective word frequency effect is not reliably observed on naming speed (written or spoken) when high- and low-frequency words are matched on AoA scores (at least on EA words).

REFERENCES

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

Assal, G., Buttet, J., & Jolivet, R. (1981). Dissociations in aphasia: A case report. *Brain and Language*, *13*, 223–240.

Barry, C., Morrison, C.M., & Ellis, A.W. (1997). Naming the Snodgrass and Vanderwart pictures: Effects of age of acquisition, frequency, and name agreement. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, *50A*, 560–585.

Bartram, D.J. (1973). The effects of familiarity and practice on naming pictures of objects. *Memory & Cognition*, *1*, 101–105.

Bartram, D.J. (1974). The role of visual and semantic codes in object naming. *Cognitive Psychology*, *6*, 325–356.

Bock, J.K. (1996). Language production: Methods and methodologies. *Psychonomic Bulletin & Review*, *3*, 395–421.

Bock, J.K., & Levelt, W.J.M. (1994). Language production: Grammatical encoding. In M.A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 945–984). New York: Academic Press.

Bonin, P. (1997). Produire des mots isolés oralement et par écrit. *Revue de Neuropsychologie*, *7*, 29–70.

Bonin, P., & Fayol, M. (2000). Writing words from pictures: What representations are activated and when? *Memory & Cognition*, *28*, 677–689.

Bonin, P., Fayol, M., & Gombert, J.E. (1997). Role of phonological and orthographic codes in picture naming and writing: An interference paradigm study. *Current Psychology of Cognition*, *16*, 299–320.

Bonin, P., Fayol, M., & Gombert, J.E. (1998). An experimental study of lexical access in the writing and naming of isolated words. *International Journal of Psychology*, *33*, 269–286.

Bonin, P., Fayol, M., & Peereman, R. (1998). Masked form priming in writing words from pictures: Evidence for direct retrieval of orthographic codes. *Acta Psychologica*, *99*, 311–328.

Brown, G.A.A., & Watson, F.L. (1987). First in, first out: Word learning age and spoken word frequency as predictors of word familiarity and word naming latency. *Memory & Cognition*, *15*, 208–216.

Brysbaert, M. (1996). Word frequency affects naming latency in Dutch when age of acquisition is controlled. *European Journal of Cognitive Psychology*, *8*, 185–193.

Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cognitive Neuropsychology*, *14*, 177–208.

Caramazza, A., & Miozzo, M. (1998). More is not always better: A response to Roelofs, Meyer, and Levelt. *Cognition*, *69*, 231–241.

Carroll, J.B., & White, M.N. (1973a). Age-of-acquisition norms for 220 pictureable nouns. *Journal of Verbal Learning and Verbal Behavior*, *12*, 563–576.

Carroll, J.B., & White, M.N. (1973b). Word frequency and age of acquisition as determiners of picture naming latency. *Quarterly Journal of Experimental Psychology*, *12*, 85–95.

Cirrin, F.M. (1984). Lexical search in children and adults. *Journal of Experimental Child Psychology*, *37*, 158–175.

Clark, H.H. (1973). The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. *Journal of Verbal Learning and Verbal Behavior*, *12*, 335–359.

Cohen, J., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavior Research Methods, Instruments, & Computers*, *25*, 257–271.

Coltheart, M., & Coltheart, V. (1997). Reading comprehension is not exclusively reliant upon phonological representation. *Cognitive Neuropsychology*, *14*, 167–175.

Coltheart, V., Laxon, V.J., & Keating, C. (1988). Effects of imageability and age of acquisition on children's reading. *British Journal of Psychology*, *79*, 1–12.

Content, A., Mousty, P., & Radeau, M. (1990). Brulex: Une base de données informatisée pour le français écrit et parlé. *L'Année Psychologique*, *90*, 551–566.

Content, A., & Radeau, M. (1988). Données statistiques sur la structure orthographique du français. *C.P.C.: Cahiers de Psychologie Cognitive. European Bulletin of Cognitive Psychology*, *8*, 399–404.

Cycowicz, Y.M., Friedman, D., Rothstein, M., & Snodgrass, J.G. (1997). Picture naming by young children: Norms for name agreement, familiarity, and visual complexity. *Journal of Experimental Child Psychology*, *65*, 171–237.

Ellis, A.W. (1988). Normal writing processes and peripherical acquired dysgraphia. *Language and Cognitive Processes*, *3*, 99–127.

Ellis, A.W., & Morrison, CM. (1998). Real age-of-acquisition effects in lexical retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *24*, 515–523.

Gerhand, S., & Barry, C. (1998). Word frequency effects in oral reading are not merely age-of-acquisition effects in disguise. *Journal of Experimental Psychology*, *24*, 267–283.

Gerhand, S., & Barry, C. (1999). Age of acquisition, word frequency, and the role of phonology in the lexical decision task. *Memory & Cognition*, *27*, 592–602.

Gilhooly, K.J. (1984). Word age-of-acquisition and residence time in lexical memory as factors in word naming. *Current Psychological Research and Reviews*, *3*, 24–31.

Gilhooly, K.J., & Gilhooly, M.L. (1979). Age of acquisition effects in lexical and episodic memory tasks. *Memory & Cognition*, *7*, 214–223.

Gilhooly, K.J., & Gilhooly, M.L. (1980). The validity of age-of-acquisition ratings. *British Journal of Psychology*, *71*, 105–110.

Gilhooly, K.J., & Logie, R.H. (1981). Word age-of-acquisition, reading latencies and auditory recognition. *Current Psychological Research*, *1*, 251–262.

Gilhooly, K.J., & Watson, F.L. (1981). Word age-of-acquisition effects: A review. *Current Psychological Research*, *1*, 269–286.

Griffin, Z.M., & Bock, K. (1998). Constraint, word frequency, and the relationship between lexical processing levels in spoken word production. *Journal of Memory and Language*, *38*, 313–338.

Hanley, J.R., & McDonnell, V. (1997). Are reading and spelling phonologically mediated? Evidence from a patient with a speech production impairment. *Cognitive Neuropsychology*, *14*, 3–33.

Hier, D.B., & Mohr, J.P. (1977). Incongruous oral and written naming. *Brain and Language*, *4*, 115–126.

Hirsh, K.W., & Ellis, A.W. (1994). Age of acquisition and lexical processing in aphasia: A case study. *Cognitive Neuropsychology*, *11*, 435–458.

Hirsh, K.W., & Funnell, E. (1995). Those old, familiar things: Age of acquisition, familiarity and lexical access in progressive aphasia. *Journal of Neurolinguistics*, *9*, 23–32.

Hodgson, C., & Ellis, A.W. (1998). Last in, first to go: Age of acquisition and naming in the elderly. *Brain and Language*, *64*, 146–163.

Jescheniak, J.D., & Levelt, W.J.M. (1994). Word frequency effects in speech production: Retrieval of syntactic information and phonological forms. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*, 824–843.

Lachman, R. (1973). Uncertainty effects on time to access the internal lexicon. *Journal of Experimental Psychology*, *99*, 199–208.

Lachman, R., Schaffer, J.P., & Henrikus, D. (1974). Language and cognition: Effects of stimulus codability, name-word frequency, and age-of-acquisition on lexical reaction time. *Journal of Verbal Learning and Verbal Behavior*, *13*, 613–625.

Levelt, W.J.M. (1989). *Speaking: From intention to articulation*. Cambridge: MIT Press.

Levelt, W.J.M., Roelofs, A., & Meyer, A.S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, *22*, 1–75.

Lewis, M.B. (1999). Age of acquisition in face categorisation: Is there an instance-based account? *Cognition*, *71*, B23–B39.

Lhermitte, F., & Derouesné, J. (1974). Paraphasies et jargon-aphasie dans le langage oral avec conservation du langage écrit. [Paraphasia and jargon-aphasia in oral language with conservation of written language.] *Revue Neurologique*, *130*, 21–38.

Loftus, E.F., & Suppes, P. (1972). Structural variables that determine the speed of retrieving words from long term memory. *Journal of Verbal Learning and Verbal Behaviour, 11,* 770–777.

Luria, A.R. (1970). *Traumatic aphasia*. The Hague: Mouton.

Lyons, A.W., Teer, P., & Rubenstein, H. (1978). Age-at-acquisition and word recognition. *Journal of Psycholinguistic Research*, *7*, 179–187.

Micelli, G., Benvegnu, B., Capasso, R., & Caramazza, A. (1997). The independence of phonological and orthographic forms: Evidence from aphasia. *Cognitive Neuropsychology*, *14*, 35–69.

Monsell, S., Matthews, G.H., & Miller, D.C. (1992). Repetition of lexicalization across languages: A further test of the locus of priming. *Quarterly Journal of Experimental Psychology*, *44*, 763–783.

Moore, V., & Valentine, T. (1998). The effect of age of acquisition on speed and accuracy of naming famous faces. *The Quarterly Journal of Experimental Psychology*, *51A*, 485–513.

Morrison, C.M. (1993). *The loci and roles of word age of acquisition and word frequency in lexical processing*. Unpublished DPhil thesis, University of York.

Morrison, C.M., Chappell, T.D., & Ellis, A.W. (1997). Age of acquisition norms for a large set of object names and their relation to adult estimates and other variables. *The Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, *50A*, 528–559.

Morrison, C.M., & Ellis, A.W. (1995). The role of word frequency and age of acquisition in word naming and lexical decision. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*, 116–133.

Morrison, C.M., Ellis, A.W., & Quinlan, P.T. (1992). Age of acquisition, not word frequency, affects object naming, not object recognition. *Memory & Cognition*, *20*, 705–714.

Morton, J. (1979). Facilitation in word recognition: Experiments causing change in the logogen model. In P.A. Kolers, M. Vrolstad, & H. Bouma (Eds.), *Processing of visible language* (Vol. 1, pp. 259–268). New York: Plenum.

Oldfield, R.C., & Wingfield, A. (1965). Response latencies in naming objects. *The Quarterly Journal of Experimental Psychology*, *17*, 273–281.

Rapp, B., Benzing, L., & Caramazza, A. (1997). The autonomy of lexical orthography. *Cognitive Neuropsychology*, *14*, 71–104.

Rapp, B., & Caramazza, A. (1997). The modality specific organization of grammatical categories: Evidence from impaired spoken and written sentence production. *Brain and Language*, *56*, 248–286.

Roelofs, A. (1992). A spreading-activation theory of lemma retrieval in speaking. *Cognition*, *42*, 107–142.

Roelofs, A., Meyer, A.S., & Levelt, W.J.M. (1996). Interaction between semantic and orthographic factors in conceptually driven naming: Comment on Starreveld and La Heij (1995). *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*, 246–251.

Roelofs, A., Meyer, A.S., & Levelt, W.J.M. (1998). A case for the lemma/lexeme distinction in models of speaking: Comment on Caramazza and Miozzo (1997). *Cognition*, *69*, 219–230.

Schriefers, H., Meyer, A.S., & Levelt, W.J.M. (1990). Exploring the time course of lexical access in language production: Picture-word interference studies. *Journal of Memory and Language*, *29*, 86–102.

Seidenberg, M.S., & McClelland, J.L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review*, *96*, 523–568.

Snodgrass, J.G., & Yuditsky, T. (1996). Naming times for the Snodgrass and Vanderwart pictures. *Behavior Research Methods, Instruments, and Computers*, *28*, 516–536.

Starreveld, P.A., & La Heij, W. (1995). Semantic interference, orthographic facilitation and their interaction in naming tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*, 686–698.

Turner, J.E., Valentine, T., & Ellis, A.W. (1998). Contrasting effects of age of acquisition and word frequency on auditory and visual lexical decision. *Memory & Cognition*, *26*, 1282–1291.

Van Orden, G.C., Pennington, B.F., & Stone, G.O. (1990). Word identification in reading and the promise of subsymbolic psycholinguistics. *Psychological Review, 97,* 488–522.

Véronis, J. (1988). From sound to spelling in French: Simulation on a computer. *Cahiers de Psychologie Cognitive*, *8*, 315–335.

Vitkovitch, M., & Humphreys, G.W. (1991). Perseverative responding in speeded naming to pictures: It's in the links. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *17*, 664–680.

Vitkovitch, M., & Tyrrell, L. (1995). Sources of disagreement in object naming. *The Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, *21A*, 1155–1168.

Wheeldon, L.R., & Monsell, S. (1992). The locus of repetition priming of spoken word production. *The Quarterly Journal of Experimental Psychology*, *44A*, 723–761.

Yamazaki, M., Ellis, A.W., Morrison, C.M., & Lambon Ralph, M.A. (1997). Two age of acquisition effects in the reading of Japanese Kanji. *British Journal of Psychology*, *88*, 407–421.

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APPENDIX A

List of the stimuli and their statistical characteristics used in Experiments 1 and 2

Stimuli	Translation	Na[a]	IA[a]	Fa[a]	VC[a]	IV[a]	AoA[a]	Fr[b]	Nl	Np	Ns	Bfr[c]	PGc[d]
Early acquired words													
Lion	Lion	100	3.53	1.50	4.17	2.33	1.69	17	4	3	1	2716	82.33
Canard	Duck	93	3.47	2.50	2.97	2.83	1.85	13	6	5	2	1312	71.94
Vache	Cow	100	3.40	2.67	3.59	2.73	1.60	35	5	3	1	649	73.21
Lapin	Rabbit	100	4.07	2.67	3.14	2.90	1.65	20	5	4	2	714	81.62
Montagne	Mountain	93	2.83	2.67	2.93	3.70	1.88	101	8	5	3	1160	77.44
Ballon	Ball	100	2.57	2.87	2.45	3.07	1.27	38	6	4	2	2000	70.49
Poisson	Fish	100	3.00	3.33	3.48	4.13	1.62	36	7	5	2	1881	51.89
Parapluie	Umbrella	82	3.23	3.43	3.24	3.07	1.88	10	9	8	3	1085	83.86
Chat	Cat	100	3.50	3.63	3.59	4.17	1.35	43	4	2	1	872	70.34
Gâteau	Cake	100	2.87	3.67	2.34	4.10	1.27	11	6	4	2	422	65.06
Chien	Dog	100	2.23	3.80	2.76	4.33	1.19	121	5	3	1	888	58.92
Carotte	Carrot	100	4.47	3.90	3.07	2.30	1.58	3	7	5	2	1693	61.82
Pomme	Apple	100	4.00	4.40	1.55	3.23	1.46	30	5	3	1	1147	51.95
Manteau	Coat	93	3.23	4.53	2.9	3.73	1.76	48	7	4	2	1161	60.95
Arbre	Tree	96	3.37	4.60	4.31	4.50	1.38	206	5	5	1	1789	96.15
Doigt	Finger	79	4.10	4.90	2.52	2.87	1.31	167	5	3	1	347	33.45
Cuiller	Spoon	100	3.83	4.93	2.38	2.97	1.35	9	7	6	2	3113	55.53
Chaise	Chair	100	3.13	4.93	2.24	3.43	1.38	82	8	6	1	1299	51.93
Mean		96.5	3.40	3.60	3.00	3.40	1.50	55.1	6.1	4.3	1.7	1347	66.60
Late acquired words													
Lampe	Lamp	100	2.73	4.80	2.00	3.73	2.04	72	5	3	1	527	48.83
Chemise	Shirt	100	3.80	4.37	3.10	3.70	2.04	47	7	5	2	1370	79.68
Chèvre	Goat	79	4.13	1.80	3.48	2.33	2.12	15	6	5	1	1598	81.55
Tambour	Drum	100	3.77	1.57	2.79	2.27	2.15	15	7	5	2	1065	77.73
Marteau	Hammer	96	2.33	2.10	2.90	2.17	2.19	12	7	5	2	943	78.46
Couronne	Crown	100	3.33	1.40	4.10	2.77	2.20	28	8	5	2	1760	64.88
Cactus	Cactus	100	3.76	1.47	1.90	3.00	2.35	2	5	6	2	827	78.80
Cigarette	Cigarette	93	3.93	4.10	2.17	2.87	2.38	45	9	7	3	1076	57.15
Pipe	Pipe	100	3.90	1.93	1.93	2.73	2.46	27	4	3	1	476	72.69

Fusée	Rocket	100	3.50	1.67	4.21	2.73	2.46	10	5	4	2	560	62.54
Violon	Violin	96	4.27	2.03	4.28	2.36	2.54	14	6	5	2	1904	94.80
Drapeau	Flag	100	3.13	2.17	1.79	4.07	2.58	22	7	5	2	498	80.58
Bureau	Desk	100	3.20	4.60	2.97	3.67	2.65	105	6	4	2	556	79.53
Prise	Plug	96	1.83	3.60	2.55	2.23	2.92	47	5	4	1	2089	75.56
Canon	Cannon	93	3.43	1.07	4.62	2.03	3.08	45	5	4	2	2721	82.99
Cerveau	Brain	96	3.37	2.80	3.34	2.83	3.12	51	7	5	2	433	61.03
Enclume	Anvil	79	2.93	1.10	2.59	1.93	4.04	3	7	5	2	810	69.63
Poignée	Handle	75	1.87	4.07	3.10	1.93	4.15	24	7	5	2	665	50.70
Mean		94.2	3.30	2.60	3.00	2.70	2.60	32.4	6.3	4.7	1.8	1104	72.10

Notes: NA = name agreement (%); IA = image agreement; Fa = conceptual familiarity; VC = visual complexity; IV = image variability; AoA = estimated age of acquisition; Fr = word frequency (values per million); Nl = number of letters; Np = number of phonemes; Ns = number of syllables; Bfr = bigram frequency; PGc = phoneme-to-grapheme consistency. [a]From Alario and Ferrand (1999). [b]From Content, Mousty, and Radeau (1990). [c]From Content and Radeau (1988). [d]Using Véronis' (1988) procedure.

APPENDIX B

List of the stimuli and their statistical characteristics used in Experiments 3 and 4

Stimuli	Translation	Na[a]	IA[a]	Fa[a]	VC[a]	IV[a]	AoA[a]	Fr[b]	Nl	Np	Ns	Bfr[c]	PGc[d]
High-frequency words													
Oiseau	Bird	86	3.90	3.87	3.38	4.70	1.38	112	6	4	2	660.40	39.57
Maison	House	100	2.53	4.47	3.24	4.37	1.38	507	6	4	2	2248.40	70.32
Arbre	Tree	96	3.37	4.60	4.31	4.50	1.38	206	5	5	1	1789.25	96.1
Chaise	Chair	100	3.13	4.93	2.24	3.43	1.38	82	6	3	1	1503.20	51.93
Fleur	Flower	96	3.40	3.93	2.93	4.50	1.40	164	5	4	1	1591.50	89.21
Jambe	Leg	89	3.77	4.80	2.34	2.83	1.40	114	5	3	1	282.00	32.83
Soleil	Sun	100	3.53	4.37	1.14	3.30	1.42	257	6	5	2	681.80	61.227
Cheval	Horse	100	4.07	2.63	3.93	3.27	1.54	135	6	5	2	749.80	95.88
Chapeau	Hat	100	2.93	2.83	2.38	4.00	1.62	87	7	4	2	587.33	76.53
Boîte	Box	89	2.70	2.97	1.21	3.87	1.65	53	5	4	1	1470.50	49.47
Nuage	Cloud	89	2.90	3.87	2.45	3.47	1.68	64	5	4	2	894.75	70.17
Fenêtre	Window	96	1.77	3.67	3.48	3.57	1.69	196	7	7	2	1568.83	79.78
Etoile	Star	100	4.30	3.77	1.17	3.43	1.69	92	6	5	2	1350.80	48.66
Train	Train	61	2.87	3.97	4.69	3.43	1.73	168	5	3	1	1292.50	68.09
Lune	Moon	79	3.60	3.80	1.03	3.20	1.77	84	4	3	1	948.33	69.80
Cœur	Heart	100	3.73	3.50	1.00	3.07	1.81	605	5	3	1	2393.00	59.01
Montagne	Mountain	93	2.83	2.67	2.93	3.70	1.88	101	8	5	3	1160.29	77.44
Mean		92.6	3.30	3.80	2.60	3.70	1.60	178.1	5.7	4.2	1.6	1245.00	66.80
Low-frequency words													
Abeille	Bee	82	3.63	2.43	4.93	2.33	1.88	17	7	4	2	1168.00	40.01
Banane	Banana	100	4.60	3.87	1.21	2.23	1.58	3	6	5	2	1549.40	74.50
Bol	Bowl	93	3.30	4.47	1.62	3.47	1.38	8	3	3	1	649.00	97.16
Bouton	Button	100	4.80	4.43	2.03	3.77	1.85	29	6	4	2	1919.40	94.20
Brousse	Brush	96	2.67	4.23	2.69	3.17	1.77	9	6	4	1	1192.40	63.54
Carotte	Carrot	100	4.47	3.90	3.07	2.30	1.58	3	7	5	2	1693.17	61.88
Collier	Necklace	82	3.90	3.33	1.79	3.77	1.86	13	7	5	2	3835.50	58.81
Coq	Hen	100	4.43	2.40	3.76	2.43	1.85	18	3	3	1	2358.00	57.84
Fourchette	Fork	100	4.00	4.90	2.66	2.80	1.42	6	10	6	2	1082.11	73.85
Fraise	Strawberry	100	3.03	3.20	2.76	2.70	1.81	6	6	4	2	1522.60	57.08

Gâteau	Cake	100	2.87	3.67	2.34	4.10	1.27	11	6	4	2	422.40	65.06
Grenouille	Frog	61	4.17	1.87	3.69	2.67	1.92	9	10	6	2	1379.56	67.73
Parapluie	Umbrella	82	3.23	3.43	3.24	3.07	1.88	10	9	8	3	1085.13	83.85
Porte	Door	93	3.30	4.67	3.17	3.40	1.52	1	5	4	1	1887.25	77.77
Poubelle	Trashcan	100	4.07	4.37	3.38	3.03	1.81	3	8	5	2	1276.71	61.10
Poupée	Doll	54	2.00	3.07	4.31	3.83	1.23	11	6	4	2	873.60	67.24
Souris	Mousse	93	4.27	2.27	3.38	2.63	1.62	10	6	4	2	1132.80	68.83
Mean		90.3	3.70	3.60	3.00	3.00	1.70	9.9	6.5	4.6	1.8	1472.00	68.90

Notes: NA = name agreement (%); IA = image agreement; Fa = conceptual familiarity; VC = visual complexity; IV = image variability; AoA = estimated age of acquisition; Fr = word frequency (values per million); Nl = number of letters; Np = number of phonemes; Ns = number of syllables; Bfr = bigram frequency; PGc = phoneme-to-grapheme consistency. [a]From Alario and Ferrand (1999). [b]From Content, Mousty, and Radeau (1990). [c]From Content and Radeau (1988). [d]Using Véronis' (1988) procedure.