

## Differential Effects of Age of Acquisition on Spoken Naming of Object and Action Pictures: An ERP Study

**Authors:** Lou Hao, Li Cong, Zhang Qingfang, Zhang Qingfang

**Date:** 2019-01-09T00:00:00+00:00

### Abstract

Age of Acquisition refers to the age at which people first understand word meanings. Previous studies have found that words acquired earlier exhibit shorter reading reaction times than words acquired later, and researchers have debated the cognitive mechanisms underlying the Age of Acquisition effect. The present study employed Event-Related Potential technology to investigate the influence of Age of Acquisition (early vs. late) on the naming of object pictures and action pictures. A picture naming task was used, requiring participants to quickly and accurately name the pictures upon presentation. The results revealed that naming of early-acquired nouns was faster than that of late-acquired nouns, whereas naming of early-acquired verbs was slower than that of late-acquired verbs. The effect of Age of Acquisition on noun production occurred between 250-300 ms after picture presentation, manifested as smaller amplitudes for early-acquired nouns compared to late-acquired nouns, while the effect of Age of Acquisition on verb production occurred between 200-600 ms after picture presentation, manifested as larger amplitudes for early-acquired verbs compared to late-acquired verbs. This indicates that the Age of Acquisition effect in noun production occurs at the lexical selection stage, supporting the semantic hypothesis viewpoint; the Age of Acquisition effect in verb production appears across multiple processing stages, including lexical selection, phonological encoding, and phonetic encoding stages, which is related to the multiplicity of verb semantics and its associated motor-related brain region activation, supporting the network plasticity hypothesis viewpoint.

## Full Text

### Preamble

*Acta Psychologica Sinica* 2019, Vol. 51, No. 2, 143–153

DOI: 10.3724/SP.J.1041.2019.00143

### Distinct Effects of Age of Acquisition on Object and Action Picture Naming: An ERP Study

LOU Hao, LI Cong, ZHANG Qingfang

(Department of Psychology, Renmin University of China, Beijing 100872, China)

### Abstract

Age of Acquisition (AoA) refers to the age at which a word's meaning is first understood. Previous research has shown that early-acquired words are processed faster than late-acquired words in reading tasks, though the cognitive mechanisms underlying the AoA effect remain debated. This study employed event-related potential (ERP) technology to investigate how AoA (early vs. late) influences the naming of object and action pictures. Using a picture naming task, participants were asked to name pictures quickly and accurately upon presentation. The results revealed that early-acquired nouns were named faster than late-acquired nouns, whereas early-acquired verbs were named slower than late-acquired verbs. The AoA effect for nouns emerged between 250–300 ms after picture onset, with early-acquired nouns showing smaller amplitudes than late-acquired nouns. In contrast, the AoA effect for verbs appeared between 200–600 ms after picture onset, with early-acquired verbs showing larger amplitudes than late-acquired verbs. These findings suggest that the AoA effect in noun production occurs at the lexical selection stage, supporting the semantic hypothesis. The AoA effect in verb production, however, appears across multiple processing stages, including lexical selection, phonological encoding, and phonetic encoding, which may be related to the semantic multiplicity of verbs and activation of motor-related brain regions. This pattern supports the network plasticity hypothesis.

**Keywords:** spoken word production; picture naming; object picture; action picture; age of acquisition effect

**Classification Code:** B842

---

## Introduction

Age of Acquisition (AoA) refers to the age at which an individual first encounters and understands a word in spoken or written form [?, ?]. Carroll and White [?] first identified AoA as a critical factor affecting lexical access and production speed, demonstrating that early-acquired words are processed more easily than late-acquired words—a phenomenon known as the AoA effect. Research on AoA

effects is theoretically and practically significant, as it addresses whether early language acquisition influences adult language processing [?].

Studies examining AoA effects have employed both words and pictures as stimuli. Word-based tasks include lexical decision [?], word naming [?], and semantic categorization [?]. When using pictures as stimuli, AoA refers to the age at which the picture's name was acquired, with tasks including picture semantic classification [?], picture identification [?], object picture naming [?, ?, ?], and action picture naming [?, ?]. AoA effects have been observed in both types of materials, though the underlying processing mechanisms differ. Word processing involves lexical recognition—a process from orthography to semantics—whereas picture processing involves word production, encompassing conceptual preparation, lexical-semantic selection (selecting the appropriate lexical item based on conceptual activation, including syntactic and semantic specification), phonological encoding (retrieving segmental and prosodic information), phonetic encoding (programming articulatory motor commands), and articulation [?].

### 1.1 Mechanisms of AoA Effects

Researchers have debated the locus of AoA effects, proposing several theoretical accounts, most notably the phonological completeness hypothesis and the semantic hypothesis. The phonological completeness hypothesis posits that AoA effects arise during phonological retrieval, with early-acquired words stored as holistic phonological units and late-acquired words stored in a decomposed, non-holistic format comprising individual phonological segments and prosodic information. During phonological retrieval, early-acquired words can be accessed as whole units, whereas late-acquired words require integration of components before whole-word retrieval, resulting in faster processing for early-acquired words [?]. Supporting this view, Gerhand and Barry [?] found that AoA effects diminished when phonological processing was reduced, such as in lexical decision tasks with phonological suppression or when judging non-words that violate phonological rules, leading them to conclude that AoA effects occur during phonological retrieval.

However, subsequent studies have found evidence inconsistent with the phonological completeness hypothesis. Monaghan and Ellis [?] conducted a phonological segmentation task requiring participants to segment and pronounce word sounds, finding no advantage for late-acquired words in segmentation—contrary to the hypothesis's prediction that decomposed representations should facilitate segmentation. Chinese researchers have reported similar findings. Zhang, Ding, and Chen [?] employed three phonological matching tasks (holistic phonological processing, onset matching, and rime matching) and found faster processing for early-acquired words in both holistic and partial phonological tasks, contradicting the phonological completeness hypothesis's expectation of faster partial processing for late-acquired words. Zhang et al. [?] tested deaf college students, who have weaker phonological awareness and use sign language, thereby

reducing phonological involvement. According to the phonological completeness hypothesis, deaf participants should not show AoA effects in picture naming, Chinese character semantic classification, or picture semantic classification tasks. However, significant AoA effects were observed across all three tasks, again contradicting the phonological hypothesis.

The semantic hypothesis, in contrast, proposes that the order of vocabulary acquisition represents the most fundamental organizational principle of the semantic system, with late-acquired word meanings built upon the foundation of early-acquired word meanings. Consequently, AoA effects occur during semantic processing. Brysbaert et al. [?] observed typical AoA effects in both semantic association tasks (where participants produced the first word that came to mind in response to a target) and semantic categorization tasks, indicating that AoA effects emerge during semantic processing. Significant AoA effects have also been found in various semantic judgment tasks, such as animacy decisions [?] and artifact judgments [?]. Chinese research on AoA effects in Chinese word processing tends to support the semantic hypothesis. Chen et al. [?] compared word naming (reading aloud presented words) and picture naming, finding no AoA effect in Chinese character naming. They then employed word semantic categorization and picture semantic classification tasks, both of which revealed AoA effects. These three experiments suggest that AoA effects occur during semantic processing, independent of phonological retrieval. Chen, Lin, and Zhang [?] replicated these findings using similar tasks. The researchers suggested that the absence of AoA effects in Chinese character naming might be due to Chinese being a logographic script where orthography is not directly linked to phonology, making semantic processing more salient than phonological processing.

Some researchers have proposed that AoA effects may occur across multiple processing stages [?, ?]. The network plasticity hypothesis, derived from connectionist computer modeling, suggests that patterns trained earlier are represented better than those trained later, mirroring AoA effects. Within the network structure, early-acquired words play a more important role in shaping the lexical network than late-acquired words, and the network's plasticity decreases for later acquisitions. According to this hypothesis, AoA effects can appear at any stage involving retrieval of existing information—namely, conceptual, semantic, and phonological processing. Holmes and Ellis [?] found AoA effects in both phonological suppression and non-suppression conditions during picture categorization, though the effect was reduced under phonological suppression. This suggests that while AoA effects may partially originate from phonological encoding, they are not limited to this stage, as the effect did not disappear entirely under suppression. Catling and Johnston [?] examined AoA effects across four tasks: picture-picture matching (determining whether two sequentially presented pictures were identical), object reality decision, picture-word matching (determining whether a word matched a previously presented picture), and picture naming. They compared effect sizes (Cohen's  $d$ ) across tasks, finding AoA effects in all four. The effect size was largest in picture naming, significantly greater than in the other tasks. Picture-picture matching

and object reality decision tasks, which primarily involve conceptual processing, showed similar effect sizes. The picture-word matching task, which involves both conceptual and lexical-semantic processing, showed a larger effect size than the first two tasks, though the difference was not significant. The researchers concluded that AoA effects occur at the conceptual level (evidenced by effects in picture-picture matching and reality decision tasks), possibly at the semantic level (evidenced by picture-word matching), and most strongly at the phonological encoding stage (evidenced by the largest effect in picture naming). The finding that picture naming, which involves more processing stages than the other tasks, produced the largest AoA effect aligns with the network plasticity hypothesis. Chen et al. [?] investigated AoA effects at early orthographic processing stages using a visual threshold identification task with blurred characters, finding that early-acquired characters were identified more quickly and accurately, with lower recognition thresholds—suggesting that AoA effects can also occur at perceptual processing stages (see also [?]).

In summary, first, the phonological completeness hypothesis is primarily based on findings from lexical comprehension tasks (word naming), whereas the semantic and network plasticity hypotheses are mainly derived from word production tasks (picture naming, picture classification). The network plasticity hypothesis is more flexible than the phonological and semantic hypotheses, as it can account for AoA effects observed in both lexical comprehension and production. Second, although both lexical comprehension and production involve semantic and phonological processing, the specific processes may differ. In picture naming, a word production task, conceptual activation occurs first, followed by lexical-semantic selection, phonological encoding, phonetic encoding, and articulation. Picture-picture matching and picture categorization tasks generally involve only conceptual-level retrieval, whereas picture-word matching involves both conceptual and lexical-semantic retrieval. In contrast, lexical comprehension does not necessarily require semantic processing, meaning that AoA effects are more closely tied to activation at conceptual and lexical-semantic levels.

## 1.2 Different Roles of AoA in Object and Action Naming

Nouns and verbs represent two fundamental word classes that differ at multiple linguistic levels, including semantic, syntactic, and pragmatic dimensions. For instance, verbs serve functional roles in sentence processing, whereas nouns function as arguments. Verb production is also more complex than noun production: nouns typically refer to specific objects, while verbs involve associated concepts [?]. Previous research has demonstrated significant differences between nouns and verbs in comprehension and production.

AoA is an important factor influencing object picture naming. Regression analyses of object picture naming in various alphabetic languages have consistently identified AoA as a significant predictor of naming speed [?, ?, ?, ?]. In action picture naming, Cuetos and Alija [?] found AoA to be a significant predictor of naming latency in Spanish, a result replicated in French by Schwitter, Boyer,

Méot, Bonin, and colleagues [?]. However, research on action picture naming in Chinese has not found significant AoA effects. Chen and Zhu [?] investigated predictors of action picture naming latency in Mandarin and found effects of H-value (a measure of naming consistency), familiarity, and visual complexity. Although correlational analysis revealed a positive correlation of 0.137 between AoA and naming latency ( $p < 0.05$ ), AoA did not emerge as a significant predictor in regression analyses when other factors were included. Li, Zhang, and Huang [?] examined AoA effects in both object and action picture naming, finding a classic AoA effect for object pictures but a reversed AoA effect for action pictures, where early-acquired verbs were named slower than late-acquired verbs.

Previous AoA research has relied on behavioral reaction times as the primary measure. The present study employed high-temporal-resolution ERP technology to examine how AoA affects object and action picture naming, the time course of these effects, and to test the phonological completeness, semantic, and network plasticity hypotheses by identifying the specific stages of noun and verb production affected by AoA. Picture naming is a classic task in speech production research that includes all stages of spoken word production: conceptual preparation, lexical selection, phonological encoding, phonetic encoding, and articulation, typically completed within 600–700 ms [?]. Meta-analytic results indicate that lemma selection occurs between 200–275 ms after picture onset, phonological encoding between 275–450 ms, and phonetic encoding between 455–600 ms [?, ?]. By comparing the time course of AoA effects with these meta-analytic results, we can identify the specific stages of spoken word production affected.

Laganaro and Perret [?] investigated AoA effects in French spoken word production using immediate and delayed picture naming tasks, finding AoA effects only in immediate naming. These effects appeared in two time windows: 220–250 ms and 330–350 ms, corresponding to lexical selection and phonological encoding stages, respectively. Using topographic ERP microstate segmentation, they found that AoA effects consistently emerged around 350 ms, during phonological encoding (see also [?, ?]). Thus, the researchers concluded that in French spoken production, AoA effects occur at the phonological encoding stage and are limited to a single stage rather than multiple stages. Previous ERP research on AoA effects in Chinese has focused on lexical recognition processes [?, ?], with no ERP studies examining AoA effects in Chinese spoken word production or considering how word class differences might affect picture naming processes.

Therefore, the present study used high-temporal-resolution ERP technology to examine whether AoA differentially affects object and action picture naming, whether the time courses of these effects differ, and to further test the phonological completeness, semantic, and network plasticity hypotheses by identifying the stages at which AoA affects noun and verb production. Participants performed a picture naming task with object and action pictures whose names varied in AoA (early vs. late). This task engages all stages of spoken word

production, including conceptual preparation, lexical selection, phonological encoding, phonetic encoding, and articulation, allowing observation of how AoA affects the production of object and action words at specific stages. Based on the phonological completeness hypothesis, we predicted that AoA effects would occur during phonological and phonetic encoding stages of spoken naming. According to the semantic hypothesis, AoA effects should appear during semantic processing, including conceptual preparation and lexical selection. Given the differences between object and action words—action words involve more linguistic factors (thematic relations, etc.) and more complex processing than object words—the differences between early- and late-acquired verbs should be greater than those between early- and late-acquired nouns. Consequently, we expected AoA effects to be more pronounced in action naming than in object naming.

---

## Method

### Participants

Twenty-eight participants (9 male, mean age = 22.18 years, SD = 2.56 years) were recruited from universities in Beijing. All were native Mandarin speakers with standard pronunciation, normal or corrected-to-normal vision, and no history of brain disease. Participants provided informed consent and received monetary compensation after the experiment.

### Materials

The experimental materials consisted of 94 object pictures (selected from [?]) and 94 action pictures (27 selected from [?] and 67 from [?, ?]), with 4 object pictures and 4 action pictures used for practice. AoA ratings for object pictures were obtained from the database established by Liu et al. [?], while AoA ratings for action pictures were obtained from the database developed in Li's [?] master's thesis. Object and action pictures were each divided into early- and late-acquired sets of 45 pictures each. The early- and late-acquired object pictures, as well as the early- and late-acquired action pictures, were matched on naming consistency, familiarity, concreteness, visual complexity, image variability, and word frequency (see Table 1). *t*-tests confirmed significant differences in AoA between early- and late-acquired object pictures,  $t(44) = -13.19$ ,  $p < 0.01$ , and between early- and late-acquired action pictures,  $t(44) = -14.15$ ,  $p < 0.01$ , with no significant differences on other variables ( $t_s < 2$ ,  $p_s > 0.05$ ).

### Design

The experiment employed a 2 (word class: object picture, action picture)  $\times$  2 (AoA: early-acquired, late-acquired) within-participants design. Participants named both action and object pictures, with the order counterbalanced across participants: half completed object naming first, followed by action naming,

while the other half completed the tasks in reverse order. During each naming task, pictures were presented pseudorandomly at the center of the screen, with no consecutive presentations of pictures whose names shared the same initial phoneme.

### Apparatus

The experiment was controlled by E-prime 2.0 software. Pictures were displayed on a PIII-667 computer screen, and responses were recorded via a microphone connected to a PET-SRBOX response box. All stimulus presentation, timing, and response time collection were computer-controlled.

### Procedure

Participants sat approximately 70 cm from the computer screen. The experiment consisted of three phases: (1) **Learning phase**: Participants studied the pictures and their corresponding names, being told that these pictures would appear in the subsequent formal experiment and that they should memorize each picture's name. After studying, their learning was tested. If participants named a picture incorrectly, the experimenter corrected them and instructed them to remember the name provided by the program. This continued until participants could name all pictures correctly. (2) **Practice phase**: Participants named 4 practice pictures to familiarize themselves with the experimental procedure. (3) **Formal experiment**: Participants were instructed to name each action or object picture as quickly and accurately as possible.

The trial procedure was identical for practice and formal phases. Each trial began with a fixation cross "+" presented for 500 ms at the center of the screen, followed by a picture (object or action) presented centrally. Participants named the picture as quickly and accurately as possible. The picture disappeared when participants began their response, followed by a 1000 ms blank screen before the next trial. If participants did not respond within 2000 ms, the picture disappeared automatically, a 1000 ms blank screen appeared, and the next trial began. Participants were instructed to avoid filler sounds such as "um" or "ah." The computer recorded response times, and the experimenter recorded naming accuracy. Participants took three 1-minute breaks during the experiment, which lasted approximately 30 minutes.

### EEG Recording and Analysis

EEG was recorded using a NeuroScan ESI-64 system with a reference electrode at the right mastoid. A ground electrode was placed 1 cm below the frontal hairline. Vertical and horizontal electrooculograms (VEOG and HEOG) were recorded bipolarly. VEOG electrodes were placed above and below the left eye, and HEOG electrodes were placed 1 cm lateral to the outer canthi of both eyes. Impedance at all electrode sites was maintained below 5 k $\Omega$ . Continuous EEG was recorded with a bandpass of 0.05–100 Hz and a sampling rate of 500 Hz per

channel. Offline analysis epochs ranged from 200 ms pre-stimulus to 600 ms post-stimulus, with a 200 ms pre-stimulus baseline. A 0.1-30 Hz bandpass filter was applied during analysis. Only trials with correct responses were included in the averaging. Epochs contaminated by eye movements, muscle artifacts, or drift were rejected, and trials with amplitudes exceeding  $\pm 100$  V were automatically excluded. EEG data were averaged separately for each condition, yielding four conditions: early-acquired nouns, late-acquired nouns, early-acquired verbs, and late-acquired verbs.

Nine regions of interest (ROIs) were selected, with amplitude values for lateral ROIs averaged across two electrode sites: left anterior (F3, F5), midline anterior (FZ), right anterior (F4, F6), left central (C3, C5), midline central (CZ), right central (C4, C6), left posterior (P3, P5), midline posterior (PZ), and right posterior (P4, P6). Mean amplitudes for each time window were submitted to repeated-measures ANOVAs with word class (noun, verb), AoA (early, late), region (anterior, central, posterior), and hemisphere (left, midline, right) as factors. When sphericity assumptions were violated, Greenhouse-Geisser corrections were applied.

Based on waveform inspection and previous findings, we analyzed ERP amplitudes from 200 ms post-stimulus onward, dividing the epoch into 50 ms windows: 200-250 ms, 250-300 ms, 300-350 ms, 350-400 ms, 400-450 ms, 450-500 ms, 500-550 ms, and 550-600 ms.

---

## Results

### Behavioral Results

Data from seven participants were excluded: five due to insufficient trial counts after artifact rejection and two due to excessive EEG artifacts. The final analysis included data from 21 participants, with each condition containing over 40 valid trials per participant.

Error trials were excluded from analysis. Error rates for the four conditions were: early-acquired nouns = 3.6%, late-acquired nouns = 3.2%, early-acquired verbs = 5.4%, and late-acquired verbs = 4.5%. Items with error rates exceeding 10% were removed (3 items total: 1 late-acquired noun, 2 early-acquired verbs). Response times shorter than 300 ms or longer than 2000 ms were excluded, as were data points exceeding three standard deviations from the mean.

A 2 (word class: noun, verb)  $\times$  2 (AoA: early, late) ANOVA on response times revealed a significant main effect of word class, with noun naming ( $806 \pm 63$  ms) faster than verb naming ( $873 \pm 62$  ms),  $F(1, 20) = 68.16$ ,  $p = 0.01$ ,  $p^2 = 0.77$ ;  $F(1, 173) = 52.90$ ,  $p = 0.01$ ,  $p^2 = 0.23$ . The main effect of AoA was not significant,  $F(1, 20) = 0.03$ ,  $p = 0.88$ ,  $p^2 = 0.01$ ;  $F(1, 173) = 0.01$ ,  $p = 0.96$ ,  $p^2 = 0.01$ . Importantly, the interaction between word class and AoA was significant,  $F(1, 20) = 40.68$ ,  $p = 0.01$ ,  $p^2 = 0.67$ ;  $F(1, 173) = 6.07$ ,

$p = 0.02$ ,  $p^2 = 0.03$ . Follow-up analyses revealed that early-acquired nouns ( $794 \pm 66$  ms) were named faster than late-acquired nouns ( $818 \pm 60$  ms), a difference significant in participant analysis,  $F(1, 20) = 17.62$ ,  $p = 0.01$ ,  $p^2 = 0.47$ , and marginally significant in item analysis,  $F(1, 87) = 3.45$ ,  $p = 0.07$ ,  $p^2 = 0.04$ . Conversely, early-acquired verbs ( $885 \pm 60$  ms) were named slower than late-acquired verbs ( $862 \pm 63$  ms), a difference significant in participant analysis,  $F(1, 20) = 28.14$ ,  $p = 0.01$ ,  $p^2 = 0.59$ , and marginally significant in item analysis,  $F(1, 86) = 2.69$ ,  $p = 0.10$ ,  $p^2 = 0.03$ .

### ERP Results

Trials with incorrect responses or response times shorter than 500 ms or longer than 2000 ms were excluded. Previous research indicates that 175 ms post-stimulus represents the visual processing stage [?], and no AoA effects have been reported within 200 ms post-stimulus [?]. Therefore, we analyzed ERP amplitudes from 200 ms onward, using 50 ms time windows.

Repeated-measures ANOVAs with word class (noun, verb), AoA (early, late), region (anterior, central, posterior), and hemisphere (left, midline, right) conducted on mean amplitudes for each time window revealed significant interactions among word class, AoA, region, and hemisphere across all time windows (see Table 2 ).

Figure 1 [Figure 1: see original paper] shows the AoA effect (early minus late) for nouns and verbs across time windows in ROIs where significant differences were observed. Figure 2 [Figure 2: see original paper] displays waveforms at electrode F5 for object and action pictures under early and late AoA conditions, along with topographic maps of the AoA effect in the corresponding time windows.

---

### Discussion

Using a picture naming task and ERP technology, we investigated differential effects of AoA on Chinese noun and verb production. We observed a classic AoA effect in object picture naming, with early-acquired object pictures named faster than late-acquired ones. In contrast, we found a reversed AoA effect in action picture naming, with early-acquired action pictures named slower than late-acquired ones. ERP results showed that the AoA effect for object picture names emerged between 250–300 ms after picture onset, with early-acquired nouns eliciting smaller amplitudes than late-acquired nouns. For action picture names, the AoA effect appeared across three time windows: 200–250 ms, 300–400 ms, and 450–600 ms, with early-acquired verbs producing larger, more positive amplitudes than late-acquired verbs. The ERP amplitude analyses revealed different patterns of AoA effects for nouns and verbs, suggesting distinct underlying cognitive mechanisms.

The mean naming latencies in our study (806 ms for nouns, 873 ms for verbs)

were substantially longer than the 600–700 ms reported in meta-analyses. Could this extended latency cause corresponding delays in all processing stages? Some researchers argue that longer response times reflect proportional increases across all stages [?]. Others suggest that only certain stages are prolonged. Laganaro et al. [?] compared three groups of participants with different mean response latencies (fast: 714 ms, medium: 815 ms, slow: 926 ms) and found that while the duration of lexical selection varied (74–85 ms in the two faster groups vs. 151 ms in the slowest group), not all processes showed equivalent prolongation. The extended time course in our study likely corresponds to an extended lexical selection process rather than delays across all stages.

The AoA effect in object picture naming occurred between 250–300 ms. In spoken word production, 200–275 ms corresponds to the lexical selection stage [?]. Given our longer behavioral response times and previous findings [?, ?], we propose that this time window corresponds to lexical selection, indicating that the AoA effect in object picture naming occurs at this stage, consistent with findings from French object picture naming studies [?, ?]. Early-acquired nouns facilitate semantic selection, reflected in smaller amplitudes compared to late-acquired nouns. In contrast, the AoA effect in action picture naming persisted across a longer time course, appearing in windows corresponding to lexical selection (200–250 ms), phonological encoding (300–400 ms), and phonetic encoding (450–600 ms) [?, ?]. These results demonstrate that AoA effects manifest differently in object and action picture naming: a single-stage pattern for objects versus a multi-stage pattern for actions.

Our findings indicate that AoA differentially affects noun and verb production. Based on the time course of noun AoA effects (250–300 ms), early- and late-acquired nouns did not differ in phonological or phonetic encoding stages, contradicting the phonological completeness hypothesis. This time window corresponds to lexical selection in spoken production [?], supporting the semantic hypothesis. Our results align with previous Chinese picture naming studies [?], suggesting that late-acquired word meanings are built upon early-acquired word meanings, resulting in faster semantic activation and retrieval for early-acquired words. The verb AoA effect, however, spanned multiple time windows corresponding to lexical selection, phonological encoding, and phonetic encoding, indicating that AoA effects in verb production occur across multiple stages, consistent with the network plasticity hypothesis.

We propose that the different AoA patterns in object and action picture naming stem from two sources. First, nouns have relatively clear, stable semantics, whereas verbs possess multiple meanings. Second, early-acquired action words may be connected to more concepts than late-acquired action words, which have fewer conceptual connections [?]. When word frequency is controlled, verb naming often activates various related concepts (e.g., “making a phone call,” “playing ball,” “fetching water”). Therefore, late-acquired action words, with fewer associated concepts, produce less interference and are named faster than early-acquired action words. The activation of multiple semantic representations and

related concepts may cause verb AoA effects to appear across multiple stages, including lexical selection, phonological encoding, and phonetic encoding (200–600 ms). In contrast, nouns have more specific semantics, and when word frequency is matched, their AoA effects are limited to the lexical selection stage (250–300 ms). The AoA effects we observed were primarily localized to left-hemisphere and midline brain regions (Figure 2 [Figure 2: see original paper]), consistent with previous ERP findings [?].

Differences between nouns and verbs have long existed in human language acquisition. Tardif [?] found that nouns and verbs constitute the largest proportion of early vocabulary, yet verbs are more difficult to learn and are acquired later than nouns. This may relate to functional differences between word classes: verbs serve functional roles in sentences while nouns serve as arguments, and verb expression is more complex than noun expression. Nouns simply refer to objects, whereas verbs involve concepts associated with specific actions [?]. Neuropsychological research has also revealed different patterns for nouns and verbs in picture naming. Arévalo et al. [?] found that brain-damaged speakers of Chinese made more verb production errors than noun production errors regardless of speech fluency. Similarly, we found higher error rates for verbs (4.95%) than nouns (3.4%).

Research on noun AoA effects in Indo-European languages has identified effects at lexical selection and phonological encoding stages [?, ?]. Laganaro and Perret [?] found AoA effects around 350 ms post-stimulus, lasting approximately 32 ms, suggesting a locus at phonological encoding. The discrepancy between Chinese and Indo-European languages may relate to linguistic characteristics and production processes. Most studies of Indo-European languages have found bidirectional connections between lexical selection and phonological encoding [?, ?, ?], with near-simultaneous activation of semantic and phonological information [?]. Chinese spoken word production, however, appears to involve independent, non-interactive stages, with temporally separable activation of semantic and phonological information [?, ?].

Why might action picture naming show AoA effects at the phonetic encoding stage? Research indicates that nouns and verbs have distinct neural substrates: verb processing activates frontal regions, while noun processing activates temporo-occipital regions. Verb meanings are associated with motor pathways, with frontal regions near motor areas involved in verb processing, whereas concrete noun meanings are associated with visual pathways, linking noun processing to temporo-occipital regions near visual centers [?, ?]. Consequently, corresponding brain regions are activated during action picture naming.

Zevin and Seidenberg [?] proposed that AoA effects in word production may reflect the influence of cumulative word frequency and frequency distribution patterns. For nouns, early-acquired items may maintain high usage frequency long after acquisition, resulting in faster naming. As individuals age, the proportion of complex and abstract late-acquired verbs in their vocabulary increases. Although early-acquired verbs are learned earlier, their cumulative frequency

may be lower than that of late-acquired verbs, resulting in longer reaction times for early-acquired verbs and producing the reversed AoA pattern. Whether this factor applies to Chinese requires further investigation.

In summary, this study is the first to examine AoA effects in Chinese spoken word production for object and action picture naming. We found distinct AoA patterns for object and action pictures: early-acquired nouns were named faster than late-acquired nouns, while early-acquired verbs were named slower than late-acquired verbs, demonstrating a reversed AoA effect. ERP results revealed that noun AoA effects occurred at the lexical selection stage (250–300 ms), with smaller amplitudes for early-acquired nouns. Verb AoA effects appeared across multiple stages, including lexical selection, phonological encoding, and phonetic encoding (200–600 ms), with larger amplitudes for early-acquired verbs. Both noun and verb AoA effects were primarily localized to the left hemisphere. The noun AoA effect supports the semantic hypothesis, whereas the verb AoA effect across multiple stages provides evidence for the network plasticity hypothesis. The distinct cognitive mechanisms underlying AoA effects in noun and verb production likely relate to functional differences between word classes in sentence communication and differences in their semantic connection networks.

---

## References

- Akinina, Y. L., Malyutina, S., Ivanova, M., Iskra, E., Mannova, E., & Dragoy, O. (2015). Russian normative data for 375 action pictures and verbs. *Behavior Research Methods*, 47(3), 691–707.
- Alario, F. X., Ferrand, L., Laganaro, M., New, B., Frauenfelder, U. H., & Segui, J. (2004). Predictors of picture naming speed. *Behavior Research Methods, Instruments, and Computers*, 36(1), 140–155.
- Arévalo, A. L., Lu, C. C., Huang, L. B. Y., Bates, E. A., & Dronkers, N. F. (2011). Action and object processing in brain-injured speakers of Chinese. *Neuropsychology*, 25(6), 755–765.
- Bai, X. J., Wang, L. H., Lv, Y., & Hu, W. (2010). An ERP study on age of acquisition effect. *Psychological Exploration*, 30(1), 21–26.
- Bakhtiar, M., Su, I. F., Lee, H. K., & Weekes, B. S. (2016). Neural correlates of age of acquisition on visual word recognition in Persian. *Journal of Neurolinguistics*, 39, 1–11.
- Barry, C., Johnston, R. A., & Wood, R. F. (2006). Effects of age of acquisition, age, and repetition priming on object naming. *Visual Cognition*, 13(7-8), 911–927.
- Bates, E., D' Amico, S., Jacobsen, T., Székely, A., Andonova, E., & Devescovi, A., ...Tzeng, O. (2003). Timed picture naming in seven languages. *Psychonomic Bulletin & Review*, 10(2), 344–380.

- Belke, E., Brysbaert, M., Meyer, A. S., & Ghyselinck, M. (2005). Age of acquisition effects in picture naming: Evidence for a lexical-semantic competition hypothesis. *Cognition*, *96*(2), B45-B54.
- Bonin, P., Boyer, B., Méot, A., Fayol, M., & Droit, S. (2004). Psycholinguistic norms for action photographs in French and their relationships with spoken and written latencies. *Behavior Research Methods, Instruments, and Computers*, *36*(1), 127-139.
- Brown, G. D. 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*(3), 208-216.
- Brysbaert, M., Van, W. I., & De Deyne, S. (2000). Age-of-acquisition effects in semantic processing tasks. *Acta Psychologica*, *104*(2), 215-226.
- Carroll, J. B., & White, M. N. (1973). Age-of-acquisition norms for 220 picturable nouns. *Journal of Verbal Learning and Verbal Behavior*, *12*(5), 563-576.
- Catling, J. C., & Johnston, R. A. (2006). The effects of age of acquisition on an object classification task. *Visual Cognition*, *13*(7-8), 968-980.
- Catling, J. C., & Johnston, R. A. (2009). The varying effects of age of acquisition. *The Quarterly Journal of Experimental Psychology*, *62*(1), 50-62.
- Catling, J. C., Dent, K., Johnston, R. A., & Balding, R. (2010). Age of acquisition, word frequency, and picture-word interference. *Quarterly Journal of Experimental Psychology*, *63*(7), 1304-1317.
- Chalard, M., & Bonin, P. (2006). Age-of-acquisition effects in picture naming: Are they structural and/or semantic in nature? *Visual Cognition*, *13*(7-8), 864-883.
- Chen, B. G., Dent, K., You, W. P., & Wu, G. L. (2009). Age of acquisition affects early orthographic processing during Chinese character recognition. *Acta Psychologica*, *130*(3), 196-203.
- Chen, B. G., You, W. P., & Wang, L. X. (2006). The research development of the age-of-acquisition effect in lexical processing. *Psychological Science*, *29*(6), 1515-1517.
- Chen, B. G., You, W. P., & Zhou, H. X. (2007). Age of acquisition effects in reading Chinese: Evidence in favor of the semantic hypothesis. *Acta Psychologica Sinica*, *39*(1), 9-17.
- Chen, B. G., You, W. P., Zhang, Y. F., & Liu, W. H. (2010) Acquisition age of effects on the early orthographic processing stage of Chinese character recognition. *Psychological Science*, *33*(3), 726-728.
- Chen, B. G., Zhou, H. X., Dunlap, S., & Perfetti, C. A. (2007). Age of acquisition effects in reading Chinese: Evidence in favour of the arbitrary mapping

hypothesis. *British Journal of Psychology*, 98(3), 499-516.

Chen, J., Lin, S. H., & Zhang, J. J. (2011). The word AoA effects in Chaoshan-Putonghua bilinguals' experimental performance. *Acta Psychologica Sinica*, 43(2), 111-112.

Chen, Y. X., & Zhu, L. Q. (2015). Predictors of action picture naming in Mandarin Chinese. *Acta Psychologica Sinica*, 47(1), 11-18.

Cuetos, F., & Alija, M. (2003). Normative data and naming times for action pictures. *Behavior Research Methods, Instruments, and Computers*, 35(1), 168-177.

Damian, M. F., & Martin, R. C. (1999). Semantic and phonological codes interact in single word production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 25(2), 345-361.

Dell'Acqua, R., Sessa, P., Peressotti, F., Mulatti, C., Navarrete, E., & Grainger, J. (2010). ERP evidence for ultra-fast semantic processing in the picture-word interference paradigm. *Frontiers in Psychology*, 1, 177.

Druks, J., Masterson, J., Kopelman, M., Claire, L., Rose, A., & Ray, G. (2006). Is action naming better preserved (than object naming) in Alzheimer's disease and why should we ask? *Brain and Language*, 98(3), 332-340.

Ellis, A.W., & Lambon Ralph, M. A. (2000). Age of acquisition effects in adult lexical processing reflect loss of plasticity in maturing system: Insights from connectionist networks. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 26(5), 1103-1123.

Fang, J. M., & Zhang, Z. (1998). Comparative study on cognitive processing of Chinese characters between hearing-impaired and normal children. *Chinese Journal of Special Education*, (4), 19-21.

Gentner, D. (1982). Why nouns are learned before verbs: Linguistic relativity versus natural partitioning. *Language*, 2, 301-334.

Gerhand, S., & Barry, C. (1999). Age of acquisition, word frequency, and the role of phonology in the lexical decision task. *Memory & Cognition*, 27(4), 592-602.

Holmes, S. J., & Ellis, A. W. (2006). Age of acquisition and typicality effects in three object processing tasks. *Visual Cognition*, 13(7-8), 884-910.

Indefrey, P. (2011). The spatial and temporal signatures of word production components: A critical update. *Frontiers in Psychology*, 2, 255-275.

Indefrey, P., & Levelt, W. J. M. (2004). The spatial and temporal signatures of word production components. *Cognition*, 92(1-2), 101-144.

Johnston, R. A., & Barry, C. (2006). Age of acquisition effects in lexical processing. *Visual Cognition*, 13(7-8), 789-845.

- Laganaro, M., & Perret, C. (2011). Comparing electrophysiological correlates of word production in immediate and delayed naming through the analysis of word age of acquisition effects. *Brain Topography*, *24*(1), 1-12.
- Laganaro, M., Valente, A., & Perret, C. (2012). Time course of word production in fast and slow speakers: A high density ERP topographic study. *Neuroimage*, *59*(4), 3881-3888.
- Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, *22*(1), 1-75.
- Li, C., Zhang, Q. F., & Huang, R. (2017). The opposite effects of age of acquisition in object and action pictures naming. *Psychological Exploration*, *37*(3), 220-225.
- Liu, Y. Y., Hao, M. L., Li, P., & Shu, H. (2011). Timed picture naming norms for Mandarin Chinese. *Plos One*, *6*(1), e16505.
- Masterson, J., & Druks, J. (1998). Description of a set of 164 nouns and 102 verbs matched for printed word frequency, familiarity and age of acquisition. *Journal of Neurolinguistics*, *11*, 331-354.
- Mätzig, S., Druks, J., Masterson, J., & Vigliocco, G. (2009). Noun and verb differences in picture naming: Past studies and new evidence. *Cortex*, *45*(6), 738-758.
- Mobaghan, J., & Ellis, A. W. (2002). Age of acquisition and the completeness of phonological representations. *Reading and Writing*, *15*(7-8), 759-788.
- Morrison, C. M., & Gibbons, Z. C. (2006). Lexical determinants of semantic processing speed. *Visual Cognition*, *13*(7-8), 884-910.
- Perret, C., Bonin, P., & Laganaro, M. (2014). Exploring the multiple-level hypothesis of AoA effects in spoken and written object naming using a topographic ERP analysis. *Brain and Language*, *135*, 20-31.
- Pulvermüller, F. (1999). Words in the brain's language. *Behavioral and Brain Sciences*, *22*(2), 253-279.
- Schuhmann, T., Schiller, N. O., Goebel, R., & Sack, A. T. (2009). The temporal characteristics of functional activation in broca's area during overt picture naming. *Cortex*, *45*(9), 1111-1116.
- Schwitler, V., Boyer, B., Méot, A., Bonin, P., & Laganaro, M. (2004). French normative data and naming times for action pictures. *Behavior Research Methods, Instruments, and Computers*, *36*(3), 564-576.
- Shao, Z. S., Roelofs, A., & Meyer, A. S. (2013). Predicting naming latencies for action pictures: Dutch norms. *Behavior Research Methods*, *46*(1), 274-283.
- 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*(3), 686-698.

Starreveld, P. A., & La Heij, W. (1996). The locus of orthographic-phonological facilitation: Reply to Roelofs, Meyer, and Levelt (1996). *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*(1), 250-255.

Tardif, T. (1996). Nouns are not always learned before verbs: Evidence from Mandarin speakers' early vocabularies. *Developmental Psychology*, *32*(3), 492-504.

Warrington, E. K., & McCarthy, R. A. (1987). Categories of knowledge: Further fractionations and an attempted integration. *Brain*, *110*(5), 1273-1296.

Weekes, B. (2011). Age of acquisition effects on Chinese character recognition: Evidence from EEG. *Procedia Social and Behavioral Sciences*, *23*(23), 67-68.

Weekes, B. S., Shu, H., Hao, M. L., Liu, Y. Y., & Tan, L. H. (2007). Predictors of timed picture naming in Chinese. *Behavior Research Methods*, *39*(2), 335-342.

Zevin, J. D., & Seidenberg, M. S. (2002). Age of acquisition effects in word reading and other tasks. *Journal of Memory and Language*, *47*(1), 1-29.

Zhang, J. J., Chen, S. Q., Zhang, G. Y., & Dai, D. H. (2012). Age of acquisition effects in deaf college students. *Acta Psychologica Sinica*, *44*(11), 1421-1433.

Zhang, Z. J., You, W. P., & Chen, B. G. (2011). Age-of-acquisition effects of Chinese character: Test of phonological completeness hypothesis. *Psychological Development and Education*, *27*(6), 577-583.

Zhu, X. D., Damian, M. F., & Zhang, Q. F. (2015). Seriality of semantic and phonological processes during overt speech in Mandarin as revealed by event-related brain potentials. *Brain and Language*, *144*, 16-25.

Zhu, X. B., Zhang, Q. F., & Damian, M. F. (2016). Additivity of semantic and phonological effects: Evidence from speech production in Mandarin. *The Quarterly Journal of Experimental Psychology*, *69*(11), 2285-2304.

*Note: Figure translations are in progress. See original paper for figures.*

*Source: ChinaXiv – Machine translation. Verify with original.*