Age of acquisition affects early orthographic processing during Chinese character recognition

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ABSTRACT

Three experiments investigated age of acquisition (AoA) effects on early orthographic processing during Chinese character recognition. In Experiment 1, we measured the accuracy of identification of brief masked characters, accuracy was higher for early compared to late acquired characters. In Experiment 2, the visual duration threshold (VDT) was measured for both early and late acquired Chinese characters. The results showed that early acquired characters were successfully identified at shorter display durations than late acquired characters. Significant AoA effects were also found in Experiment 3, using a lexical decision task requiring mainly orthographic processing (discriminating real Chinese characters from orthographically illegal and unpronounceable characters). In summary, three experiments provide converging empirical evidence, for AoA effects on the early orthographic processing stages of Chinese character recognition. These results suggest that AoA effects during word identification go beyond the phonological or semantic processing stages. These results aslo provide cross-linguistic evidence for an AoA effect on early perceptual processing during identification.

1. Introduction

Age of acquisition (AoA) refers to the age at which a word is first learnt. In the last three decades, a large number of studies have found that words acquired earlier in life are processed more efficiently than words acquired later in life. AoA affects processing in many languages: English (e.g., Gerhand & Barry, 1998; Lambon Ralph & Ehsan, 2006; Morrison & Ellis, 1995, 2000; Morrison, Hirsh, Chappell, & Ellis, 2002), French (Bonin, Fayol, & Chalard, 2001; Bonin, Barry, Meot, & Chalard, 2004), Italian (Barca, Burani, & Arduino, 2002; Bates, Burani, D'Amico, & Barca, 2001; Menenti & Burani, 2007), Dutch (Ghyselinck, Custers, & Brysbaert, 2004; Menenti & Burani, 2007), Turkish (Raman, 2006), Japanese (Havelka & Tomita, 2006; Yamazaki, Ellis, Morrison, & Lambon Ralph, 1997) and Chinese (Chen, You, & Zhou, 2007; Chen, Zhou, Dunlap, & Perfetti, 2007). AoA has also been shown to influence a range of different tasks (see Johnston and Barry (2006) and Juhasz (2005) for comprehensive reviews). Despite considerable research effort, exactly how AoA increases the efficiency of cognitive processing is still a matter of considerable debate.
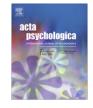
Early research into AoA effects emphasized the importance of lexical and especially phonological levels of representation. One early account of AoA effects, the phonological completeness hypothesis, proposed that AoA effects arise at the level of the speech output lexicon (Brown & Watson, 1987). While early-acquired words are stored as whole units at the phonological level, late acquired words are stored as segments that must be assembled before output, inducing a delay for these late words.

Although some earlier studies were consistent with the phonological completeness hypothesis (Gerhand & Barry, 1999; Gilhooly & Gilhooly, 1979; Gilhooly & Logie, 1981), more recent experiments have provided evidence against a phonological locus for the AoA effect. Monaghan and Ellis (2002a) found no AoA effect in a phonological segmentation task, in which participants took away the initial sounds of a word in order to produce the remaining segment, providing evidence against the phonological completeness hypothesis. Additionally a phonological locus would seem to predict reduced AoA effects when phonological assembly is facilitated, yet when Catling and Johnston (2006) facilitated phonological assembly by priming they found no change in the magnitude of the AoA effect.

Although there may be good reason to doubt AoA effects on phonological processing, there is evidence to support AoA effects at the level of lexical selection for word production. On the basis

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of a review of the literature Brysbaert and Ghyselinck (2006) point out that the AoA effect in picture naming is larger than the corresponding effect in word naming, and larger than the word frequency effect in either task. Brysbaert and Ghyselinck (2006) interpret this pattern of findings as suggesting a strong source of AoA effects at the level of lexical retrieval. Further evidence for this view comes from recent work by Catling and Johnston (2008) who showed using the same stimuli across tasks, that when lexical access was required AoA effects increased in size. Well known effects thought to be localized to lexical levels of processing, e.g. long-term repetition priming (Barry, Hirsh, Johnston, & Williams, 2001), and the semantic homogeneity effect in object naming (Belke, Brysbaert, Meyer, & Ghyselinck, 2005), also interact with AoA, consistent with AoA effects on lexical levels of processing.

Other researchers have provided positive evidence for AoA effects on earlier semantic levels of processing. For example, Brysbaert, Van Wijnendaele, and De Deyne (2000) found AoA effects, when participants categorized words as person or object names. Subsequently other researchers have also found AoA effects in semantic decision tasks with pictures (Holmes & Ellis, 2006; Johnston & Barry, 2006). AoA effects have also been found to modulate the magnitude of semantic interference effects in simple binary classification tasks (Ghyselinck et al., 2004). Additionally Brysbaert et al. (2000) have demonstrated AoA effects on a semantic association task.

At a theoretical level these AoA effects on semantic processing have been accounted for by assuming that early acquired concepts provide the basis for constructing the meanings of late acquired concepts, and thus AoA has a lasting effect on the time needed to activate the meanings of words, (e.g. Brysbaert et al., 2000; Ghyselinck et al., 2004; Steyvers & Tenenbaum, 2005).

In general many of the effects of AoA on semantic tasks could arise from earlier influences of AoA on visual object recognition (see later). There is however additional evidence against AoA effects on semantics. Izura and Ellis (2004) demonstrated independent AoA effects in the first and second languages of bilinguals in a translation task. Since the translation task likely recruits a common semantic system, if AoA were primarily semantic, then first language AoA would be expected to dominate. Additionally in multitask investigations of AoA effects in picture (e.g. Catling & Johnston, 2009) and word processing (Menenti & Burani, 2007), AoA effects have been found to be no different when tasks additionally require semantic access.

Evidence is also now accumulating in favour of AoA effects on the earliest stages of visual object and word recognition. Moore, Smith-Spark, and Valentine (2004) asked participants to decide whether pictures of objects, presented at brief exposures, were real or not real. The results showed that early acquired objects were classified faster than late acquired objects. Moore et al. argued that because it is not necessary to access any phonological or semantic information to respond correctly in this perceptual classification task, the AoA effects in this task are likely to be the results of early visual object identification.

Dent, Catling, and Johnston (2007) explored AoA effects using the visual duration threshold (VDT) method; measuring the minimum exposure duration necessary for correct object identification. Since VDT measures the minimum exposure duration of the stimulus rather than total processing time, it provides a pure measurement of picture recognition time, not including the time of processing phonological and semantic information of the pictures. Dent et al. (2007) found that the visual duration threshold was significantly lower for pictures labeled with early-acquired names than for pictures labeled with late acquired names. This important result indicates that AoA affects the efficiency of visual objection recognition.

Ghyselinck, Lewis, and Brysbaert (2004) used the tachistoscopic presentation method to study the locus of AoA effects in the lexical processing. In their procedure, a word was briefly presented for 33 ms, followed by a pattern mask. Participants were required to identify the words. The results showed that the percentage of correct responses were higher for the early acquired words than that of the late acquired words. Again the primary limitation in this task is likely to be the speed or efficiency with which information can be acquired from the stimulus, thus this result is consistent with AoA affecting the efficiency of information uptake at the earliest stages. Furthermore, there is regression evidence for AoA effects on visual processing of Japanese characters (Yamazaki et al., 1997).

Comparison of AoA effects across different languages has been important in the development of AoA research. It is important to understand the similarities and differences in the effects of AoA on different languages. This enterprise will help to determine the generality of the AoA effect, and to define its boundary conditions.

In the present article, we report the results of three experiments carried out to explore AoA effects on early perceptual processing of Chinese characters. Our subjects were all native speakers of Chinese and our stimulus materials consisted of Chinese characters. AoA effects have been documented for Chinese character recognition in phonological and semantic processing tasks Chinese (Chen, You, et al., 2007; Chen, Zhou, et al., 2007; You, Chen, & Dunlap, 2009). Our present goal was to use several different methods to provide a set of converging evidence for AoA effects on visual processing of Chinese characters. The current study will provide a useful addition to the evidence base concerning AoA effects, generalizing perceptual AoA to processing of Chinese characters.

In Experiment 1, we employed a tachistoscopic presentation method, in which participants had to identify very briefly presented masked characters. In Experiment 2, the visual duration threshold method was used. In Experiment 3, a visual lexical decision task with orthographically illegal fillers was used to minimise semantic or phonological access.

2. Experiment 1

Concerning the tachistoscopic presentation method, it may tap all of the processes involved in character recognition, including phonological retrieval and semantic processing. However the accuracy of tachistoscopic recognition is likely to be primarily sensitive to the difficulty of perceptual processing. In their Dutch study, Ghyselinck et al. (2004) used tachistoscopic presentation to explore AoA effects and attributed the efffects to perceptual processing. A similar view was expressed by Dent et al. (2007), they argued that once activation in the perceptual processing system is stabilised after a certain processing duration, other aspects of semantic and lexical retrieval will unfold over time without the need for the continued presence of the stimulus. In the tachistoscopic identification task duration is fixed, and success or failure should depend on whether activation in the perceptual system is stabilised. Given that the chance of stable activation at a given duration depends on perceptual processing efficiency, if AoA affects this efficiency it should also affect accuracy, so long as an appropriately short duration is used.

In Chinese study, Perfetti and Tan (1998) used a primed-naming task to explore the time course of orthographical, phonological, and semantic activation in Chinese character identification. In this task, the target was preceded by a graphic, phonological or semantic prime and the participants were asked to name the target as quickly as possible. They found that the orthographical prime facilitated the target recognition within 43-ms SOA, phonological prime within 57-ms SOA, while semantic prime until 85-ms SOA.