Exploring the multiple-level hypothesis of AoA effects in spoken and written object naming using a topographic ERP analysis

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ABSTRACT

Here we tested the multiple-loci hypothesis of age-of-acquisition effects in both spoken and handwritten object naming using Event-Related Potentials (ERPs) and spatiotemporal segmentation analysis. Participants had to say aloud or write down picture names that varied on frequency trajectory (age-of-acquisition). Early-acquired words yielded shorter naming times than late-acquired words in both spoken and written naming. More importantly, AoA modulated ERPs only during a later time-window in both output modalities: waveforms started to diverge around 400 ms, which corresponded to the end of a period of topographic stability starting at around 260 ms in both conditions. These stable electrophysiological maps lasted longer in the late than in the early-acquired condition and shifted the onset of the following periods of stable electrophysiological activity. Taken together, the findings are at odds with the multiple loci hypothesis, but support the hypothesis that AoA affects a single encoding level, namely the word-form encoding process.

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1. Introduction

Identifying the factors that affect the speed and the accuracy of lexical processing has long been a critical issue in psycholinguistics, cognitive neuropsychology and cognitive neurosciences. As far as object naming, which is the focus of the current study, is concerned a number of variables have been investigated as potential determinants of the naming performance in the spoken (e.g., Alario et al., 2004), and, also to a lesser extent, in the written modality (Bonin, Chalard, Méot, & Fayol, 2002). Among these factors is the age at which words are learned (henceforth AoA). Indeed, AoA effects have been found in a wide variety of lexical tasks in the performance of both healthy (see Johnston & Barry, 2006; Juhasz, 2005 for reviews). AoA is also one of the most influential factor affecting the performance of patients with Alzheimer's disease (Herrera, Rodriguez-Ferreiro, & Cuetos, 2012), with semantic dementia (Woollams, 2012) and of aphasic patients (e.g., Catling, South, & Dent, 2013; Cuetos, Aguado, Izura, & Ellis, 2002; Kittredge, Dell, Verkuilen, & Schwartz, 2008). However, even

though the existence of AoA effects is well-established at an empirical level, the locus and the functional dynamics of AoA effects in object naming are far from being fully understood (Juhasz & Yap, 2013). As we shall argue, this situation is due to the fact that a strategy of logical elimination of the different levels at which AoA effect takes place has been used. The aim of this study was to address the issue of which mental operation is affected by AoA in object naming. To this aim we analyzed AoA effects in both spoken and written modalities using Event-Related Potentials (ERPs) covering the entire encoding period, from picture onset to articulation and spatiotemporal segmentation analyses (Brunet, Murray, & Michel, 2011; Michel, Koenig, Gianotti, & Wackermann, 2009; Murray, Brunet, & Michel, 2008). In the following, we shall first briefly address the issue of the measurement of the AoA of the words. Then we will review the issue of the locus(i) of AoA effects in object naming and spell out the approach we have pursued to address this issue.

The best way of evaluating and conceptualizing the AoA of words has long been, and remains, a subject of debate (see Bonin, Méot, Mermillod, Ferrand, & Barry, 2009; Mermillod, Bonin, Méot, Ferrand, & Paindavoine, 2012). The most frequently used measures of word AoA are subjective estimations. Adults are given a list of words and are required to provide an estimation of the age at which they think they learned each of the words using

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Likert scales with different age-bands (e.g., Alario & Ferrand, 1999; Barry, Morrison, & Ellis, 1997; Bonin, Peereman, Malardier, Méot, & Chalard, 2003; Marques, Fonseca, Morais, & Pinto, 2007). Zevin and Seidenberg (2002) adopted a different perspective to account for AoA effects, using *frequency trajectory (FT)*. FT is operationally defined as by the difference between the "adult" frequency and the "child" frequency. Among other things, this measure is less highly correlated with other lexical variables than the standard AoA measures (Bonin, Barry, Méot, & Chalard, 2004; Bonin et al., 2009). Although, certain aspects of frequency trajectory can be criticized (e.g., the fact that only two points in time are generally taken into account, e.g., Bonin et al., 2004), we believe that this measure is certainly a reliable alternative to investigate AoA effects (Mermillod et al., 2012).[1] We then have opted for these measures in the present study which have not as yet been used to explore the locus of AoA effects.

1.1. Locus(i) of AoA effects in object naming

In the literature, several potential loci of AoA effects have been proposed in object naming. Fig. 1 provides a theoretical framework for understanding the processes and the representations underpinning spoken and written object naming and the potential loci of AoA effects. It is generally assumed that object naming involves four main processing levels (e.g., Humphreys, Riddoch, & Quinlan, 1988; Levelt, Roelofs, & Meyer, 1999). First, a visual representation of the object is generated from the visual image, leading to the retrieval of structural representations (i.e., visual object recognition). The associative and functional properties of the to-be-named object (i.e., conceptual/semantic activation) are then accessed. The third processing level is lexical access, which involves the retrieval of a lexical entry specifying the word's gender and grammatical category (lemma retrieval in Fig. 1, but see Caramazza, 1997) and the access to the word-form (L-level in Fig. 1). Finally, the abstract (individual phonemes in speaking or individual graphemes in writing) codes are passed on to a set of processing stages, which lead to the planning of motor movements.

The most often cited locus for AoA effects in spoken object naming is still the word-form level (e.g., Morrison, Ellis, & Quinlam, 1992; Navarrete, Scaltritti, Mulatti, & Peressotti, 2012) albeit not within the framework of the phonological completeness hypothesis.[2] As far as written naming is concerned, the locus of AoA effects has also been ascribed to the word-form level (the L-level in Fig. 1). Nevertheless, the hypothesis that the phonological level is the sole locus of AoA effects in object naming and in other lexical tasks has been criticized mainly because it cannot account for the fact that AoA effects are found in tasks in which lexical representations do not seem to be required such as face recognition/face familiarity decision tasks, (e.g., Lewis, 1999; Moore & Valentine, 1999; Valentine, Hollis, & Moore, 1998).

One hypothesis is that AoA effects in object naming do not originate solely at the word-form level but can potentially take place at other processing levels (i.e., the multiple loci hypothesis of AoA
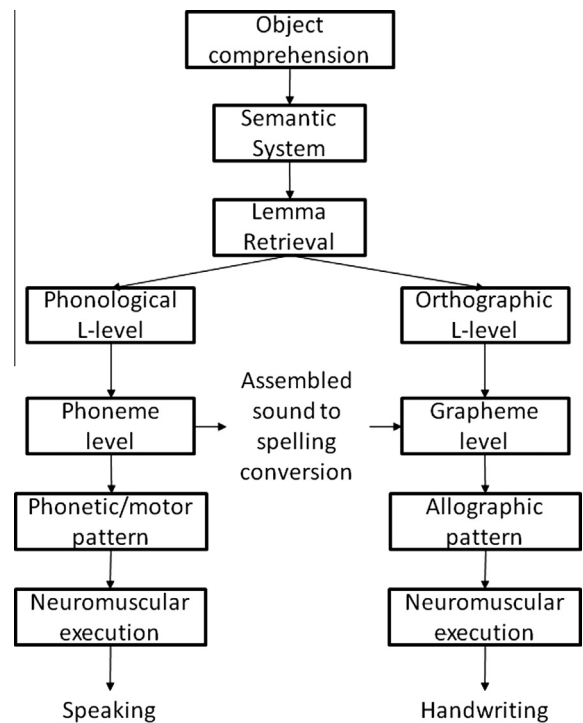

Fig. 1. Processing levels of spoken and handwritten object naming.

effects). More precisely, two other loci have been put forward: the object recognition level (e.g., Catling, Dent, & Williamson, 2008; Dent, Calting, & Johnston, 2007) and the semantic/conceptual level (e.g., Belke, Brysbaert, Meyer, & Ghyselinck, 2005; Johnston & Barry, 2005; Morrison & Gibbons, 2006). The object recognition level has been proposed as a candidate locus for AoA effects in object naming for two reasons. The first reason is methodological (Levelt, 2002). Levelt (2002) claimed that in certain object naming studies reporting AoA effects (e.g., Barry et al., 1997; Bonin, Fayol, & Chalard, 2001; Bonin, Peereman, & Fayol, 2001), the speed of object recognition was not controlled for. However, strong AoA effects in object naming latencies have been found when the ease of the perceptual processing of the objects was controlled for Bonin, Chalard, Méot, and Barry (2006). The second reason is that AoA effects have been observed in object recognition tasks (e.g., Catling et al., 2008; Dent et al., 2007). Since object naming involves object recognition (Bonin, Roux, Barry, & Canell, 2012), a logical consequence would seem to be that AoA effects in object naming can arise at this level.

Another plausible locus for AoA effects in object naming is the semantic level. According to Brysbaert, van Wijnendaele, and de Deyne (2000), AoA effects arise as a result of the organization of the semantic information in the mental lexicon. The order of acquisition is thought to be an important organizational principle of the semantic system (Steyvers & Tenenbaum, 2005), with the result that late-acquired concepts are built on earlier-acquired concepts. Indeed, AoA effects have been found in semantic tasks such as categorization (e.g., Brysbaert et al., 2000; Johnston & Barry, 2005; Morrison & Gibbons, 2006 but see Morrison et al., 1992). In object naming, it is assumed that access to semantic codes is obligatory for the retrieval of object names (e.g., Bonin et al., 2012) and this assumption is consistent with the findings that AoA effects are stronger in picture naming than in word reading since it is sometimes thought that word reading does not require (or requires less) semantic code activation (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). Although the hypothesis that AoA effects have a semantic locus is still discussed in the literature, there is also

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[1] It is worth noting that the issue of the best AoA measures to use is unsettled. Actually, Pérez (2007) has shown for instance that there was no reliable effect of frequency trajectory beyond AoA ratings in his regression analyses of naming times. As far as object or face naming is concerned, maybe both rated AoA and frequency trajectory variables will contribute to research by providing complementary

[2] In accordance with a phonological locus of AoA effects, Brown and Watson (1987) put forward an account of AoA effects referred to as the phonological completeness hypothesis. According to this hypothesis, phonological representations of Early Acquired words are holistic in nature, whereas those of Late Acquired words are more fragmented. Therefore, the former are quicker to retrieve than the latter. Often cited in the past, the phonological completeness hypothesis of AoA effects has been since discarded by Monaghan and Ellis (2002) who reported strong evidence against it.