Journal of Memory and Language 97 (2017) 103–120

Contents lists available at ScienceDirect

Journal of Memory and Language

journal homepage: www.elsevier.com/locate/jml

The first- and second-language age of acquisition effect in first- and second-language book reading

Nicolas Dirix *, Wouter Duyck

Department of Experimental Psychology, Ghent University, Ghent, Belgium

ARTICLE INFO

Article history:
Received 3 August 2016
Revision received 14 July 2017

Keywords:
Age of acquisition
Bilingualism
Eye tracking
Visual word recognition
Corpus study

ABSTRACT

The age of acquisition (AoA) effect in first/monolingual language processing has received much attention in psycholinguistic research. However, AoA effects in second language processing were only investigated rarely. In the current study, we investigated first (L1) and second language (L2) AoA effects in a combined eye tracking and mega study approach. We analyzed data of a corpus of eye movements to assess the time course of AoA effects on bilingual reading. We found an effect of L2 AoA in both early and late measures of L2 reading: fixation times were faster for words that were learned earlier in L2. This suggests that the L2 AoA effect has an influence throughout the entire L2 reading process, analogous to the L1 AoA effect. However, we are also the first to find an early effect of L1 AoA on L2 processing: if the L1 translation of the L2 word was learned earlier, the L2 word was also read faster. We discuss the implications of these findings for two important hypotheses that offer an explanation for the AoA effect: the mapping and semantic hypothesis. We propose that the current results suggest an integration between these accounts.

Introduction

Through our lifetime, we continuously encounter and learn new words. The age of acquisition (AoA) of words has been identified as an important factor in language processing. A well-established finding, at least in first-language (L1) processing, is that words with an earlier AoA are processed faster than words with a late AoA. This effect has a long history of replications in a multitude of experiments, including different paradigms and techniques.

L1 age of acquisition

In the very first study that revealed an influence of word-level AoA, Carroll and White (1973) found that pictures were named faster when their name was learned at an earlier age. This AoA effect in picture naming has been replicated with different sets of stimuli and in different languages (Belke, Brysbaert, Meyer, & Ghyselinck, 2005; Morrison, Ellis, & Quinlan, 1992; Pérez, 2007) and was also found in word naming studies (Brysbaert, Lange, & Van Wijnendaele, 2000; Gerhand & Barry, 1999b; Morrison & Ellis, 1995).

AoA also influences word recognition: in lexical decision, reaction times (RTs) are faster for earlier acquired words (e.g., Bonin, Chalard, Méot, & Fayol, 2001; Brysbaert, Lange et al., 2000; Butler & Hains, 1979; Gerhand & Barry, 1999a; Wilson, Cuetos, Davies, & Burani, 2013). Interestingly, in several of these studies (Bonin et al., 2001; Gerhand & Barry, 1999a; Wilson et al., 2013) an interaction was found between AoA and word frequency, with larger the AoA effects for low frequency words.

In two investigations of the English Lexicon Project (ELP; Balota et al., 2007), which consists of lexical decision data for 40,481 English words, the role of word-level AoA was investigated in combination with a large set of other linguistic variables (for example word frequency, length, ...; Cortese & Khanna, 2007; Cortese & Schock, 2012). Both studies found an AoA effect, with shorter RTs for earlier learned words. The above interaction between word frequency and AoA also showed up in Cortese and Schock (2012).

Finally, a few studies investigated the AoA effect by means of eye tracking. In this paradigm, the eye movements of participants are recorded while they read pieces of natural text or sentences, without performing an artificial task like lexical decision. In two eye tracking studies, Juhasz and Rayner (2003), Juhasz and Rayner (2006) investigated AoA effects in sentence reading. In the 2003 study, AoA and other predictors were included as continuous variables, whereas in the 2006 study an orthogonal design was applied (early vs late AoA). In both studies, early and late

* Corresponding author at: Henri Dunantlaan 2, 9000 Ghent, Belgium.
E-mail address: nicolas.dirix@ugent.be (N. Dirix).

http://dx.doi.org/10.1016/j.jml.2017.07.012
0749-596X/

timed measures were analyzed, and both yielded significant AoA effects (i.e., shorter fixations for early AoA words). In the 2006 study, an AoA effect was found for all eye tracking measures, whereas the 2003 study only found the AoA effect in early measures (single fixation duration and gaze duration). Juhasz and Rayner argue that the orthogonal design with extreme AoA values was more sensitive to detect AoA effects in late word processing. These L1 AoA effects in eye tracking were recently replicated in a corpus study by Dirix and Duyck (2017), in which eye movement data of monolinguals reading an entire novel was investigated. L1 AoA effects on 7158 nouns were found in all timed measures (single, first fixation and gaze duration and total reading time), as well as an interaction between AoA and word frequency in total reading times (cf. the lexical decision studies discussed above). Finally, Juhasz, Gullick, and Shesler (2011) investigated the AoA effect with ambiguous words that had an early and late learned meaning (e.g., *straw*, *volume*). The sentence context disambiguated the meaning of the target word, and target words received shorter fixations (both in early and late measures) when the early learned meaning of the ambiguous word was relevant.

In sum, the AoA effect seems to be quite robust in the literature on monolingual/L1 language processing. Faster processing of earlier learned words has been found in a large variety of paradigms and in different modalities (see Johnston and Barry (2006) or Juhasz (2005) for reviews). Recent monolingual/L1 mega studies of lexical decision (e.g., Cortese & Schock, 2012) and eye movements (Dirix & Duyck, 2017) validated the pioneer findings of smaller scale experiments.

Second language age of acquisition

Although the monolingual/L1 domain now approaches 45 years of AoA research, it has only been 15 years since word-level AoA has been investigated in the field of bilingualism, and studies are very rare. This is remarkable, because there is much more interindividual variability in the age at which words are learned for a second language (L2), so that the variable is possibly of greater relevance than for L1 processing. The majority of the words that we learn in L2 will also be known already in our L1, which creates an interesting situation: L2 words have an L2 AoA (the age at which the word was learned in L2), but also an L1 AoA (the age at which the L1 translation of the L2 word was learned). These L1 and L2 AoAs do not necessarily correspond: words that were learned early in L1 can be learned late in L2 and vice versa. Two main questions were addressed in the few L2 AoA studies that have been carried out. First, researchers investigated whether a word-level AoA effect may indeed be found in L2 processing. Second, it was investigated what mainly drives this AoA effect: the order at which the words were learned in the L1 or L2?

Izura and Ellis (2002) first addressed these questions. In their Experiment 1 (picture naming) and 2 (lexical decision), they found shorter RTs for earlier acquired words in L1 and L2, thus confirming the existence of a L2 AoA effect. To further assess whether it was the L1 or L2 AoA of the words that caused the AoA effect in L2, Izura and Ellis orthogonally manipulated the L1 and L2 AoA of their stimuli in Experiment 4 (lexical decision). Results showed only within-language AoA effects: in L1, RTs were faster for words learned early in L1, irrespective of when the words were learned in L2. Similarly, L2 reading was only influenced by order of acquisition in L2, not L1. The AoA seems to only have an impact within each language. Izura and Ellis (2004) later replicated these findings in both translation judgments and lexical decision. To date, these are the only two visual word recognition studies that investigated both the roles of L1 and L2 AoA in a full orthogonal design. For production, similar within-language AoA effects were also obtained in a bilingual picture naming task (Hirsh, Morrison, Gaset, & Carnicer,2003).

In a spin-off of AoA research, the order of acquisition (OoA) effect of newly acquired stimuli is investigated. These "laboratory studies of AoA" allow researchers to study the impact of learning new stimuli at different points in time, while characteristics such as frequency can be controlled. Typically, a part of the stimuli set is introduced at the beginning of the study phase ("early acquired"); another part is presented at a later time ("late acquired"). This generally results in processing advantages for earlier learned items. For example, participants were faster to categorize "early" learned abstract checkerboard stimuli than a "later" learned set (Stewart & Ellis, 2008). In studies that involved linguistic material, similar results were obtained. Izura et al. (2011) found that early learned novel words for existing objects were processed faster in a series of behavioral tasks up to 35 days after the learning phase. Joseph, Wonnacott, Forbes, and Nation (2014) found OoA effects on eye movements: total reading times decreased for novel words between the training and testing phase both for early and late learned items, but this effect was significantly larger for the early trained set.

These OoA studies support the robustness of acquisition effects, as OoA effects emerge even with a minimal delay between the presentation of the early and late stimuli set. Second, Izura et al. (2011) claim that these effects mirror real-life AoA effects, as the advantage for the early learned set can persist for weeks after training. Finally, studies involving linguistic materials could be interpreted as learning vocabulary of a novel language, mapping new lexical forms onto existing semantics, analogous to real life L2 learning.

To summarize, in the previous parts we have shown that L1 AoA is a well-established effect in psycholinguistic research. For L2 processing, some rare studies have confirmed L2 AoA effects, independent of L1 AoA, but the number of studies and stimuli is limited. Also, only isolated L2 word reading was investigated, and AoA eye tracking research for L2 sentence reading is completely lacking, until the present study. Our study will shed light on the specific time-course of AoA effects. Further, we will also argue that this approach may clarify the etiology of the (L1) AoA effect, about which two hypotheses exist.

The origin of the age of acquisition effect

The first hypothesis about the mechanism behind the AoA effect is the *semantic hypothesis*. According to this hypothesis, AoA effects originate from the organization of the semantic representational network of words (Brysbaert, Van Wijnendaele, & De Deyne, 2000; Steyvers & Tenenbaum, 2005). As we learn new words or concepts, they are linked to semantic representations we already know. Early learned words take up a more central place in the semantic network, so that they are more easily accessible than later learned words. In a study of semantic networks, Steyvers and Tenenbaum (2005) indeed found that most nodes in the network have few connections, but they are joined through a few nodes with many connections, so-called "hubs" (cf. the early learned words).

There are a few sources of empirical evidence for a semantic locus of the AoA effect. First, earlier learned words were categorized faster in semantic categorization tasks (Brysbaert, Van Wijnendaele et al., 2000; Menenti & Burani, 2007), In a more complex design, Ghyselinck, Custers, and Brysbaert (2004) presented names of living and non-living stimuli, which were either printed in upper- or lowercase. Participants were instructed to judge the letter case of targets words by responding verbally, using the labels "living" and "non-living", so that responses were either congruent