On Language and Age of Acquisition

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Abstract

Age of acquistion (AoA) effects have been found to have strong effects in the syntactic domain. The current paper reviews this literature and newer work which suggests that syntactic effects may be present in certain syntactic functions. In addition, work which suggests that AoA also shows effects during semantic processing is presented. It is concluded that AoA effects are pervasive across a wide range of tasks and domains. Theoretical accounts of these effects are discussed.

1. Introduction

A distinguished colleague tells the story of her father, who immigrated to the U.S. from Holland at age 32 and functioned well in English for three decades at home and in his business as an insurance broker. Despite these years of fluency in two languages, he lost the ability to communicate in English (but not Dutch) during hospitalization for a stroke at the age of 63. Reports like the one above are quite dramatic and have led some to propose that each language is represented in different parts of the brain [1]. However, others see this as evidence that each language is differentially sensitive to damage [2, 3]. The variables that modulate neural activity, age of acquisition (AoA) and proficiency (PR), have been discussed for over 100 years [2, 3]. These two variables are also reflected in recent work using functional Magnetic Resonance Imaging (fMRI), a technique which allows researchers to look at the oxygenation level of blood and thereby measure which neural areas are firing more extensively during a particular task. Recent studies using fMRI have found mixed effects with some suggesting that AoA is the primary determinant of neural activity whereas others suggest that proficiency is the primary determinant. AoA has been found to modulate neural activity during sentence comprehension [4] but only when proficiency is NOT taken into account. When early and late bilinguals were equated on proficiency, the differences between these groups disappeared [5]. The importance of proficiency has been supported by studies which find considerable individual differences in the level of proficiency in second language learners, in both early and late learners [6]. Proficiency has also been found to play a role in semantic tasks [7]. Evidence for the importance of proficiency can be found in recent work with populations that are immersed and educated in a second language relatively early in life. Work with Koreans adopted by French families reveal no neural or behavioral trace of the first language even when it was learned as late as age 8 [8]. Second, behavioral work by Hernandez and colleagues suggests that proficiency and not AoA determine naming latencies when L2 acquisition occurs early in life [9-12]. In short, to date there is mixed evidence that AoA is the primary determinant of behavioral and neural asymmetries while performing language tasks.

The fact that AoA seems to play a reduced role in some bilingual research is counterintuitive. AoA is known to be an important factor in a number of domains, especially in phonological processing and production of a second language [13-15]. More importantly, research which has investigated the effects of AoA on language processing has found that tasks involving syntax show larger AoA effects than semantic tasks [16, 17]. In a seminal study, Weber-Fox and Neville [16] asked a group of Chinese-English participants to look at sentences which contained three different types of syntactic violations (phrase structure, specificity constraint, and subjacency constraint) as well as semantic violations. This experiment used event-related potentials (ERP's) a method which provides the means for measuring the brain's electrical activity to a number of linguistic and non-linguistic factors. In the language domain, ERP's have been found to be sensitive to semantic violations [18, 19] and syntactic violations [20]. Results revealed differences in the timing and distribution of the ERP's to syntactic violations in participants who learned English as early as 2. However, differences in the ERP's to semantic violatioins only appeared in participants who learned English after 11. These results are consistent with the view that AoA plays a role in the neural activity associated with grammatical violations.

More recently, Wartenburger et al. [7] asked Italian-German bilinguals to monitor for syntactic violations (number, gender or case) or semantic violations.while being scanned with fMRI. Three groups were tested,

early bilinguals with high proficiency in L2 (EAHP in a second language), and late bilinguals with either high (LAHP) or low proficiency (LALP) in L2. Increased brain activity in L2 relative to L1 was seen in all three groups for both semantic and syntactic violations. Furthermore, direct comparisons between groups in L2 yielded an interesting pattern of results. For grammaticality judgements, LAHP subjects showed increased activity in BA 44/6 and BA 44 relative to the EAHP group. BA 44 has been found to be associated with morphosyntactic processing [21] whereas superior BA 44 (near BA 6) is associated with phonological retrieval [22]. Taken together these results suggest that processing of grammatical violations in late learners results in increased motor planning and articulatory effort even when these subjects are matched in proficiency with early learners. Whereas there were also differences between the LAHP and LALP subjects, these were restricted to areas in the temporal-parietal juncture, the inferior parietal lobule and the lingual gyrus. However, there was no increased activity for the LALP subjects relative to the LAHP subjects.

A different pattern emerged for between-group comparisons during semantic processing. In these paradigms, there was increased activity in BA 46 and the fusiform gyrus for the LAHP group. For the LALP group, there was increased acitivity in BA 46/9 and BA 44/6. These results are consistent with the view that the late low proficiency group is engaged in more effortful phonological retrieval (BA 44/6). Furthermore, this increase in phonological retrieval leads to increased activity in BA 46/9, an area that is known to be involved in executive function for both verbal and nonverbal tasks [23]. However, there were no differences between both high proficiency groups. Taken together these results are consistent with the view that syntactic processing is sensitive to differences in AoA whereas semantic processing is sensitive to differences in proficiency. Finally, it suggests that both semantic and syntactic group differences are associated with increased phonological retrieval (BA 44/6) whereas activity associated with brain areas involved in morphosyntactic processing, i.e. using the ends of words to determine their grammatical functions, (BA 44) distinguished between groups that show differences on syntactic tasks. In short, there is some aspect of syntactic processing that leads to activity of areas that are more tightly associated with syntactic processing.

Recent results from the literature open up a number of questions with regard to the finding that syntax is more sensitive to AoA than semantics. First, it is not clear what factors may play a role in the AoA effect. One possibility is that syntactic functions share less across languages than semantic functions (at least the ones tested to date). In addition, it is possible that there is some processing component of syntax which is more sensitive to AoA (a classic third variable problem). Second, it remains to be seen if AoA effects are present for semantic domains.

1.1 Which syntactic functions show AoA effects?

In a first study, a set of Spanish native speakers who had spent less than 2 years in the United States at the time of testing were asked to indicate via button press the grammatical gender of a set of words in Spanish [24]. The opacity of the mapping was varied such that half the items were transparent (a for feminine and o for masculine) and half the items were opaque (ending in d,e.n,l,r,s,t,z). The results revealed increased activity for the opaque items in the anterior insula, BA 44/45, and BA 44/6. BA 44/45 has been found to be active for studies which have looked at syntactic processing [21 , 25, 26 , 27] as well as in studies which have compared gender monitoring to semantic monitoring [28]. The anterior insula is known to be involved in articulation [29, 30] and BA 44/6 is known to be involved in phonological processing [22]. Furthermore, Heim et al. [31] found increased activity in BA 44/6 when German monolinguals were asked to generate the determiner (*der, die or das* gender marked *the* in German) for a picture compared to simply naming the picture. These results are consistent with the view that monolinguals generate the determiner in order to determine the gender of opaque items. BA 44/6 indicates the need for increased phonological retrieval demands, the anterior insula indicates the need for increased articulatory demands, and BA 44/45 shows increased activity because of the syntactic computation that occurs when checking determiner-noun agreement. In short, the neural data are consistent with the view that monolinguals covertly form a small syntactic phrase when retrieving the gender of opaque items. This strategy was confirmed in post-experimental interviews.

A subsequent unpublished study compared early Spanish-English bilinguals with late English-Spanish bilinguals using the gender decision described above. Early Spanish-English bilinguals are of interest because they are dominant in English but learn Spanish first [for further work with this population see 9, 11, 12, 32]. Participants were matched on proficiency in Spanish using tests of vocabulary, reading and syntax. Furthermore, participants were matched on performance in the gender decision task. Although both groups showed increased activity for the opaque items, each group showed a different pattern of activity. The late English-Spanish bilinguals showed a large area of increased activity which extended from the anterior insula into BA 47. The early Spanish-English bilinguals showed increased activity just superior to this in BA 44/45. Direct comparisons between the groups revealed increased activity in BA 47 for the late bilinguals. The results confirm that AoA modulates activity on grammatical tasks. Furthermore, it reveals that these differences are graded in nature. That is, for transparent items the group differences are very small. However, for

opaque items the results reveal much larger differences. In short, not all grammatical functions show large AoA effects.

1.2 AoA effects during semantic processing

Work conducted both in my laboratory and in collaboration with others has begun to shed light on the central questions that will be addressed in the current proposal. First of all, work in my laboratory has confirmed the presence of AoA for non-grammatical processing. In a first study, I asked monolinguals to name a set of pictures in which AoA and word frequency were orthogonally manipulated [33]. A main effect of AoA remained even when controlling for word frequency and even when naming was delayed. More recent work in collaboration with colleagues at the Max Planck Institute of Cognitive Neuroscience has sought to uncover the neural correlates of word AoA in monolinguals performing an auditory and visual lexical decision task (Press right button if it is a word, press the left button if it is a pseudoword such as "mave") while being scanned with fMRI. Results revealed that the precuneus which is known to play a role in automatic retrieval from memory was activated for early learned words across auditory and visual presentation modalities. Additional activity in the auditory cortex was observed specifically for the reading of early acquired words. Late learned words revealed increased activity in BA 45/47 indicating more complex semantic retrieval. These results confirm that reaction time AoA effects are robust. Second, it appears that early lexical memories may be more automatic or auditory in nature whereas late learned lexical memory most likely involves complex retrieval. This latter result is consistent with findings from monolingual simulations of AoA [34]. This finding confirms that AoA effects appear in monolinguals for lexical tasks which do NOT involve grammatical processing. Furthermore, a number of studies have found that AoA effects appear in monolingual semantic tasks [35]. Hence, AoA effects are quite pervasive.

1.3 Overlap across languages

As noted earlier, work in the bilingual imaging literature has found that semantic effects were more sensitive to proficiency. A number of studies have confirmed this basic finding [7, 36]. Recent work in our laboratory Using fMRI late high proficient German-English second language learners were tested in L1 (German) and L2 (English) with concrete and abstract words that showed maximal overlap (cognates) in orthography or not (noncognates). All words were translation equivalents. Participants decided whether a visually presented word was abstract or concrete. Results revealed a graded language difference in neural activity with abstract non-cognates showing the most activation differences across languages and concrete cognates showing the fewest differences. Specifically, non-cognates showed more activity than cognates in superior BA 44 (near BA 6), BA 44/45 and in the insula extending into BA 47 in L2. There were no significant differences observed in L2 or for comparisons which looked for increased activity for cognates relative to noncognates. A second study using lexical decision yielded results which are consistent with those found in the first study. Taken together our results show that the amount of differential neural activity across languages depends on orthographic and semantic overlap. In short, a less proficient second language reveals a difference in items which overlap the least across languages (noncognates).

Recent work by Tokowicz and MacWhinney [37] sheds light on the nature of transfer in late second language learners. In that study, participants were asked to make grammaticality judgments to sentences which varied in the extent to which syntactic functions overlapped across languages. Participants brain activity was measured using ERP's. The first type of functions involved tense marking which is similar across languages. The second type of function involved determiner-noun agreement (las casas vs. la casas). Like Spanish number in English is marked on the noun (houses). However, unlike Spanish there is no need for the noun to agree with the determiner (the houses). Participants were also asked to make decisions about sentences which manipulated gender agreement, a function which is unique to Spanish (la casa vs. el casa). The results revealed increased activity for noun-verb agreement, a function which is similar across languages. However, participants did not show ERP differences for gender or number agreement in Spanish. Finally, results for determiner-noun gender agreement revealed ERP differences for this function. However, the distribution of the signal was diffuse. Taken together these results suggest that the nature of L1 influences brain responses to L2 during early learning. Furthermore, it confirms that functions which overlap across languages are easier to track in L2 than those which are not. These results suggest that in both semantic and syntactic tasks there is an effect of overlap. However, they leave open the question of whether AoA effects may interact with overlap. If syntactic function tend to rely on overlapping information, then AoA effects may be more dramatic in this domain. This would predict that AoA effects should be larger for semantic tasks for items with less conceptual overlap across languages.

1.4 FMRI studies of grammatical processing

Taken together the results reviewed are consistent with the view that both semantic and grammatical processing are graded in nature and that this continuity modulates differences at the neural level in early and late bilinguals. However, these results leave some questions unanswered. Unpublished work conducted by Hernandez et al. has looked at semantic processing in late German-English bilinguals. Cross-language differences could be due both to English being learned late and being the less dominant

language. Follow up studies comparing early bilinguals and late bilinguals would help to elucidate whether there is indeed an effect of cognate status and concreteness in both groups and whether the pattern of activity differs across groups. This would also help to clarify whether AoA effects appear in a task which is more effortful and whether less overlap (i.e. noncognates) yields larger cross-group differences. The notion of overlap is also be important when considering AoA differences in the neural activity associated with syntactic processing. Previous studies have found that overlap between languages affects the speed with which a syntactic function is learned in late L2 learners. Significant differences in the pattern of neural activity between early and late learners of Spanish have been found during gender decision for opaque items. That is, when grammatical functions have little overlap across languages, groups which differ on AoA show differences in neural activity. However, when these functions are easier then there are much smaller differences. Finally, future studies will test whether the effects of difficulty and overlap extend to other syntactic functions and conditions of syntactic violation Of particular interest, will be the comparison of violation conditions across groups. Violations are known to lead to increased activity in L2 relative to L1 [38].

1.5 Theoretical Accounts of AoA

Despite consistently finding maturational effects on syntactic processing, very few accounts have stipulated the underlying mechanism (aside from emphasizing a general maturational constraint) for this effect. More recently, Ullman and colleagues [39-41] have proposed that second language acquisition can be viewed as being constrained by declarative and procedural memory. In this model, lexical learning is reliant on memorized facts whereas grammatical processing is dependent on rules and routines. Work in the literature has firmly established a frontal-basal ganglia circuit which is involved in procedural learning and a medial temporal lobe system which is involved in declarative memory, i.e. learning new facts. Ullman and colleagues provide considerable evidence to bolster their claim that grammatical and lexical processing rely on different neural systems. This includes evidence from grammatical processing in aphasia as well as Alzheimer's and Parkinson's disease [39]. They also present evidence that procedural learning ability decreases with age whereas declarative learning ability may actually improve with age . This framework sheds light on AoA syntactic effects that the neural correlates of syntactic processing are more sensitive to AoA [42, 43] because of their reliance on procedural memory which is affected to a greater extent by maturational constraints. Within this model L2 learners must rely on declarative memory for grammatical processing. This, in turn, predicts that late L2 learners will show increased activity of areas involved in declarative memory during grammatical processing relative to L1 learners.

The procedural/declarative account for AoA effects, however, cannot account for results in the monolingual literature. For a long time, theorists have suggested that AoA was due to differences in phonological completeness [44]. In this view, early learned words are represented in a phonologically complete manner whereas late learned words have to be assembled around these phonological primitives. Whereas this hypothesis is consistent with some aspects of the data such as slower picture naming times [45-47] they are less compatible with other effects [48]. More recent work using connectionist simulations suggest that early learned items are favored because the network is biased to "recognize" these items. Recognizing late learned words, however, requires more effortful retrieval because a network is using connection weights that are optimized for early learned words. The most interesting aspect of this model is that it suggests that AoA effects are very general effects. As such second language acquisition, bilingualism and language processing in general serve as methods to investigate the general mechanisms that are involved in learning.

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