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German in childhood and Latin in adolescence: On the bidialectal nature of lexical access in English

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The nature of word etymology, long a topic of interest in linguistics, has been considered to a much lesser extent in the word recognition literature. The present study created a database of overlapping words from the English Lexicon Project (ELP) and a database with the age of acquisition (AoA) norms which were categorized as either Germanic or Latin-based. Results revealed that Germanic words were learned earlier than Latin-based words. Germanic words also showed slower reaction times and higher accuracy relative to Latin-based words even when controlling for AoA, word frequency, and length. Additionally, analyses were conducted using a publicly available database that used the English Crowdsourcing Project (ECP) data with native and second language (L2) English speakers. The results with native speakers were similar to those collected with the ELP. However, nonnative speakers showed better accuracy and faster reaction times for Latin-based words compared to Germanic words. The findings support a bidialectal view of English in that Germanic words serve as the base of lexical processing during childhood, whereas Latin-based words fill in the lexical space across adolescence and into early adulthood. Furthermore, L2 speakers appear to acquire English via more advanced Latin-based vocabulary relative to native speakers. These results carry implications for theories of word recognition and the processing of lexical items in populations that come from linguistically diverse backgrounds.

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Introduction

At the lexical level, English could be thought of as two languages and English speakers with advanced vocabulary as bilingual. Whereas early learned words are mostly of Germanic origin, late learned words become progressively derived from Latin, having been imported directly or indirectly into English. Despite the widespread study of Latin vs. Germanic origin of English in linguistic literature, this distinction has received very little attention in the word recognition literature. In the current paper, words from the English Lexicon Project (ELP; Balota et al., 2007) were combined with the age of acquisition norms (Kuperman et al., 2012) and word etymology (https://www.etymonline.com) for a set of over 20,000 words. In addition, two databases were added that used the English Crowdsourcing Project (ECP) data with English native (Mandera et al., 2020) and L2 speakers (Brysbaert, 2020, May 18).

Based on previous studies, we hypothesized that early learned words should typically have Germanic roots and later learned words be derived from Latin. This effect should be most observable in the proportion of words that are from each etymological category depending on age. In the second set of analyses, the effect of etymology will be assessed even when taking into consideration other factors such as lexical age of acquisition, lexical frequency, and length. The presence of an effect would reveal that adult users are sensitive to the etymology of a word when performing common word recognition tasks. The results of crowdsourcing with native speakers will verify whether results from the ELP generalize to newer methods with a more recently collected set of data. Recently, work by Brysbaert (2020, May 18) has shown a larger proportion of advanced words in L2 English speakers. Analyses conducted with etymology should help to elucidate the extent to which these advanced words are in fact Latin-based. The paper will end by discussing the implications of etymology for models of word recognition and for the nature of lexical access in linguistically diverse populations.

Age of acquisition (AoA). The effects of age of acquisition on word recognition have now been documented in a number of studies (see Barry et al., 2006; Juhasz, 2005 for a review) across a number of experimental tasks including reading (Gilhooly, 1984; Zevin and Seidenberg, 2002, 2004), lexical decision (Juhasz et al., 2019), picture naming (Barry et al., 2006; Carroll and White, 1973a, 1973b; Juhasz, 2005; Meschyan and Hernandez, 2002) and eye-tracking (Dirix and Duyck, 2017; Juhasz and Rayner, 2006). The results from these studies show unequivocally that AoA explains behavioral data in experiments even when controlling for other relevant variables such as frequency, length, and number of syllables. The network plasticity hypothesis argues that AoA effects originate because early learned words are connected to core concepts and thus receive a privileged place within a broad semantic network (Lambon Ralph, 2006).

This view is compatible with Hernandez and Li (2007) who propose that learning early in life is based more on sensory and motor brain systems whereas learning later in life is based on higher-level cognitive brain systems that develop later in life. In this view, AoA effects appear because stimuli learned early in life occupy a preferential place in the representational network and are more closely linked to sensory and motor systems. Furthermore, it has been argued that AoA effects appear to a greater extent when people are asked to produce the name of a picture rather than reading a written word (Zevin and Seidenberg, 2002, 2004). Finally, differences in reaction times are larger when the relationship between the visual stimulus does not bear any systematic relationship to its response. Thus, in principle, there should be very small AoA effects for written words according to the plasticity hypothesis, a finding that is not borne out in studies.

More recently, integrated views of AoA draw from multiple frameworks to account for behavioral AoA effects on word recognition and acknowledge that these effects are likely the result of multiple factors. The mapping theory (Zevin and Seidenberg, 2002) posits that neuroplasticity decreases over time, resulting in early-learned words that are richly represented in the network and late-learned words that find places in a system that is already made of early learned words. On the other hand, Brysbaert and colleagues (2000) argue that richer semantic representations and more connections for early-learned words are the basis for AoA effects. Recent frameworks take into account both of these views (Brysbaert and Ellis, 2016; Chang and Lee, 2020; Dirix and Duyck, 2017). For instance, in Chinese orthography the connections between lexical items and their print forms are arbitrary and exhibit strong AoA effects. In other words, later-learned words that map abstractly onto their written form face a processing cost. Thus, AoA effects should not be deduced down to the timing of learning alone but also reflect other characteristics that distinguish early and late learning (Chang and Lee, 2020). Brysbaert and Ellis (2016) demonstrate this concept using results from aphasia patients. They theorize that words that are less semantically rooted and with less weight in a network are more susceptible to loss following injury.

The relative dominance of words of Germanic origin in early English lexical and morphological systems versus the shift to more Latin-based items as English speakers advance through the education system poses a unique challenge. Specifically, core concepts learned early in life are linked to orthographic forms, leading to a link between meaning and sound and then later with the written form once schooling begins. This extends beyond single words leading to the process of word-formation which takes on an increasingly Latin-based form in English. For example, for a monolingual English speaker, words like *antepenultimate* or *antediluvian* may represent a monolithic entity lacking generalizability and transparency that would be more easily accessible and decodable to someone speaking a Romance language such as Spanish or Italian. Both the morphology and etymology of a considerable portion of academic English needed to succeed in today's society may pose unique challenges to monolingual English speakers. It also highlights the discontinuity between early and later learned forms and has implications for the network plasticity hypothesis that has been used to argue for the presence of AoA effects.

Etymology and advancing AoA. Speakers of English have a clear sensitivity to the etymology of words, but the lack of transparency of some of the later learned academic lexicon may pose challenges in secondary and post-secondary education. Although this effect has been observed in a wide range of domains, the most relevant areas for the current study have been found in the production of language and in reading (Bar-Ilan and Berman Ruth, 2007; Treiman et al., 2018). In a seminal study, investigators looked at the extent to which the origin of a word varied across modality, spoken or written, and register, narrative vs. expository text (Bar-Ilan and Berman Ruth, 2007). Across all ages, expository writing led to a higher use of Latin-based words relative to narrative writing. Furthermore, adults used higher numbers of Latin-based words in general with a percentage that approximated 100% of the words chosen for the most formal registers. Thus, early learned words that occur in more informal contexts are more likely to be of Germanic origin. Late learned words used in formal contexts are more likely to be Latin-based words.

The influence of Latin and Germanic affixes (both prefixes and suffixes) can also be seen in the reading literature (as illustrated in

our previous *antepenultimate* or *antediluvian* examples). Treiman and colleagues asked a group of undergraduates to rate which of two nonwords were more word-like (Treiman et al., 2018). In three experiments, monolingual English speakers showed sensitivity to Latin status. Participants were more likely to rate an item as more word-like if the origin of the offset matched the origin of the onset. For example, words that have an ending that originates from Latin such as -ic, are more likely to have a single consonant before them. Thus, *Arabic* is a word whereas *arabbic* is not. Germanic endings such as -est, however, are more likely to be preceded by a double consonant. Thus, *bossiest* is a word whereas *bosiest* is not. The results from Treiman et al's study confirmed these findings. For nonwords, (e.g., chabic vs. chabbic), participants were more likely to rate the item with single consonants as word-like when the ending had a Latin-like appearance. When participants were shown items that were Germanic in their ending (e.g., chabest vs. chabbest), they were more likely to rate the item with a double consonant as more word-like. Treiman and colleagues conclude that skilled readers of English, even ones that are monolingual, are to some extent like bilinguals. They are exposed to two orthographic systems and are able to detect whether the internal rules used in each of these are being followed or not. We will test this hypothesis in the present study by looking at the extent to which word etymology (Germanic vs. Latin) determines accuracy and speed of response in word recognition.

Work by Reilly and colleagues has looked at the nature of word etymology in relationship to other lexically important variables (Reilly et al., 2007; Reilly and Kean, 2007). A first study found that Latin-based items are less imageable than those from Germanic origin (Reilly and Kean, 2007). In a second study, the relationship of word etymology and lexical age of acquisition was significant on its own (Reilly et al., 2007). However, the variance seen in word etymology was captured by other variables including stress pattern, length, etc. Both studies by Reilly and colleagues were based on word corpora that were around 2000 words. In addition, neither of them considered AoA across later ages but rather truncated them at 13. Hence, both studies leave open the question of whether word etymology does show an effect with a larger number of words that extend across a longer set of AoA's.

The present study was designed to extend previous work by investigating whether etymological status and AoA contribute to word recognition. In our study, we gathered a list of ~20,000 words and coded each of them according to their etymology (Germanic versus Latin-based). We hypothesize that our results will parallel those seen in the previously cited sources: Germanic words in English will have earlier AoAs, while the words of Latin origin will be rated as having later AoAs. In addition, etymological origin will influence reaction times and accuracy even when accounting for AoA and other relevant factors such as word frequency and length. Specifically, reaction times should be faster for words from Germanic origin than those of Latin origin for native English speakers. Secondly, L2 English speakers should show a different pattern with more advanced, Latin-based words, having proportionally higher accuracy and faster reaction times relative to Germanic words. Results along this direction would confirm our hypothesis that word etymology is related to the age at which words are first learned in both native and L2 English speakers.

Methods

A relatively large set of words, 20,339, were compiled from two different sources in order to create a database that contained information about the variables such as word frequency, length, number of syllables, and AoA that were central to the current study. These combined databases were then used to produce the lexical items on which etymology was retrieved as detailed below. The base set of items were part of the ELP from Washington University in St. Louis (Balota et al., 2007). The database is comprised of 40,481 words and 40,481 non-words used by several universities for experimental research. Briefly, the ELP database was collected using a between-subjects design, in which participants were asked to make lexical decisions (is this a word or not?) and read the words aloud. Balota and colleagues collected both reaction times and percent correct for two dependent variables, lexical decision and word reading times. Because AoA ratings were not part of the original ELP data, these were derived from an additional database which also included frequency of word use, number of letters per word, and number of phonemes and syllables in each word (Kuperman et al., 2012). An additional two databases from the ECPs with English native (Mandera et al., 2020) and L2 speakers (Brysbaert, 2020, May 18) were also added. The combined final set of lexical items included lexical variables such as AoA, word frequency, log frequency, length, number of letters per word, number of phonemes and syllables as well as reaction times and percent correct for native and L2 English speakers. The datasets generated during the current study are available in the Open Science Framework repository at the following web address: https://osf.io/fkr2j/?view_only=b8fedcffd19a4327ae5780412fd77163.

Word etymology procedure. In order to determine the etymology of the target words, groups of 2000 words were assigned to 10 different undergraduate raters. Raters were instructed to analyze each word in a systematic fashion. The first step was to identify whether the word had one root or two roots (compound words commonly consisted of two roots, such as *homework*). Once the root was identified, the students were tasked with classifying the root (or roots) under three different categories: Germanic origin, Latin origin, or neither origin. Roots that could be traced back to Germanic, Old English, Norse, and Proto-Germanic origins were labeled as "Germanic" while roots that could be traced from Latin and Romance Languages that derive from Latin (e.g., Anglo-French, French, Spanish, Italian, and Latin via German) were labeled as "Latin." The roots that had neither Germanic nor Latin origin were labeled as "0" for neither. Words marked as 0 included acronyms, words with other origins such as Hindi, Native American languages, proper names, onomatopoeias, and slang. In addition to identifying the roots of the words, the raters were also tasked with classifying the prefixes and suffixes attached to each root. If a student found that a word root had a prefix and/or a suffix, they would have to determine whether the prefix and/or suffix was of Germanic origin, Latin origin, or neither origin. For instance, a student would divide the word "going" into two parts when analyzing the word. The word would be split into "go", as the root, and "-ing" as the suffix. Etymology was determined by the *Online Etymology Dictionary* (https://www.etymonline.com). Once all the words were categorized, each resulting list of words was cross-rated by another rater. Words that raters were unsure of labeling were highlighted for feedback on how to proceed from the authors of this paper. The final database was checked by three of the authors for accuracy.

Statistical analyses. The analyses were conducted in three steps. In a first step, we looked at the distribution of words from the ELP data and the different mean (self-rated) ages of acquisition for both Germanic and Latin-based words using a regression analysis and a chi-square test in order to look at the distribution of items. This test was used to help establish whether the age of having learned the word as rated by participants differs across

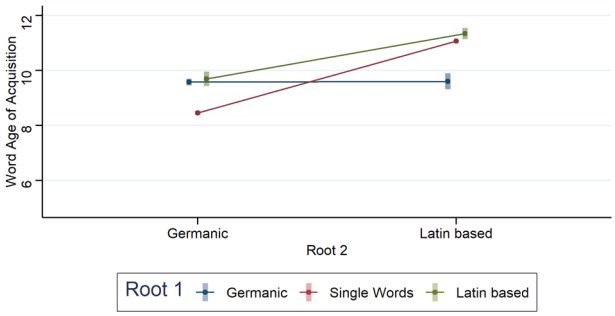

Fig. 1 Interaction between root 1 (first word) and root 2 (second word) in terms of origin. Single Germanic words are learned earlier than Latin-based words (red line). The same appears for compounds that start with a Latin-based item (green line). For compounds that start with a Germanic item, the AoA of the word does not change if the second word is Germanic or Latin-based.

Table 1 Sample stimuli for the word etymology experiment.

	Root 1	Root 2
Germanic	0	night
Latin	0	flower
Germanic–Germanic	bath	room
Germanic–Latin	sun	flower
Latin–Germanic	river	bank
Latin–Latin	air	plane

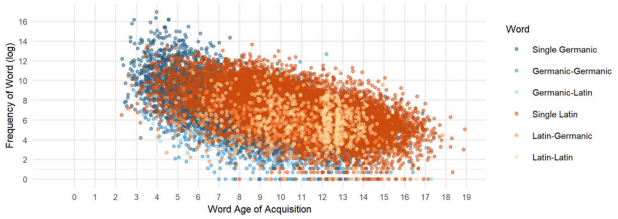

Fig. 2 Items that begin with a Germanic item or are single Germanic words are represented in blue. Items that begin with a Latin item or single Latin items are represented in orange. Germanic words indicated in blue are learned earlier in life and have higher word frequency in adult language than Latin-based items in orange.

Latin and Germanic-based words. The second step used a set of linear regressions that sought to establish whether there was an effect of word etymology on reaction times and accuracy during word reading tasks (lexical decision and naming tasks). We ran different regression models for the different data sets we had English monolingual participants in the ELP naming task, English monolinguals in the ELP and ECP lexical decision task, and finally, L2 speakers in the ECP lexical decision task. These regression models used AoA, log word frequency, and length as covariates. This would help to establish the extent to which word etymology continued to speed or slow word reading even when accounting for other variables that are known to play a role in word recognition. The final step for each of these data sets was to conduct planned comparisons contrast analyses to establish what etymology combination(s) have higher/lower accuracy or faster/slower reaction times based on the data set (monolingual ELP and ECP and L2 ECP) and task (naming vs. lexical decision).

Results

Word etymology and age of acquisition in English native speakers. In the ELP data set for English monolingual participants, the final list of words consisting of a set of items that had either a single root (such as *cat*) or were formed with two roots and hence was compounded (such as *homework*). To test the effect of age of acquisition, we ran a linear regression analysis to examine the relationship of the etymology of single words (Root 1 = 0) and compound words using the first and second roots (i.e., Root 1: *home* + Root 2: *work* = *homework*). Figure 1 shows the graph for the regression model results which indicates a clear relationship between AoA and etymology ($F(5, 20{,}292) = 722.6$, $p < 0.001$, Adj.$R^2 = 0.151$). We can see that on average Germanic single words ($M = 8.45$ years old) are the earliest to be acquired and Latin–Latin compound words ($M = 11.34$ years old) the latest. For single words, Germanic words are acquired much earlier than Latin-based single words ($b = -2.61$, $p < 0.001$). Compound words with Germanic Root 1 are acquired around the same age regardless of the etymology of Root 2 ($b = -0.03$, $p = 0.84$). For Latin-based Root 1 compound words, Latin–Germanic are learned earlier than Latin–Latin ($b = -1.65$, $p < 0.001$). The regression results also show that there is a significant effect of Root 1 ($p < 0.001$) and a significant interaction effect between Root 1 and Root 2 ($p < 0.001$) which we further investigated with a contrast analysis confirming these results.

In addition, the distribution of each word type varied across specific AoA ranges. To analyze this, a truncated variant of the AoA measure, which aggregated average AoA ratings into a single year, was analyzed using a contingency table that included the etymology of words for both roots. The results of this analysis yielded an overall statistically significant effect across both compound and single words, X^2 (15, 20,338) = 2679.95, $p < 0.001$. The results showed an increase in the number of words across the AoA ranges. Further, the results showed that there was a change in the number of Germanic words relative to Latin-based words across development. Germanic words were more prevalent in early childhood and became less predominant for AoAs in late childhood and adolescence. In adolescence, there was a larger proportion of Latin-based words relative to Germanic words. These results were further broken down to consider the nature of compounds leading to four different conditions, Germanic–Germanic, Germanic–Latin, Latin–Germanic, and Latin–Latin. Sample stimuli for all conditions can be seen in Table 1 and can be visually seen in Fig. 2.

The proportion of Germanic–Germanic compounds (e.g., bathroom, birdbath) remained larger than Germanic–Latin compounds (e.g., sunflower, platform) across the entire range of development (X^2 (15, 2335) = 27.55, $p < 0.025$). Compounds beginning with a Latin word showed the same pattern. There were relatively more Latin–Germanic (e.g., riverbank, machine-gun) compounds than there were Latin–Latin (e.g., airplane, counteroffer) compounds across all ages (X^2 (15, 1070) = 199.59, $p < .001$). For single words, there was a general increase in the absolute number of words across age. However, the ratio of Germanic-to-Latin words changed across development. The proportion of Germanic words was much larger in early childhood relative to Latin (Germanic vs. Latin, X^2 (16,933) = 2762.98, $p < 0.001$). The number of Latin words also increased with age. However, the increase in the number of words was steeper leading to a much larger proportion of Latin words in the later AoAs. In summary, the number of words from both etymological backgrounds increased with age in native speakers of English. Furthermore, Germanic words outweighed Latin-based words in earliest AoAs with Latin-based words increasingly predominating in later AoAs. These results match previous studies with native English speakers.

Table 2 English Lexicon Project: regression model results for naming task (accuracy and reaction time).

	Accuracy (%)		Reaction time (ms)	
	B	SE	*B*	SE
Word frequency (log)	−12.739***	0.278	0.010***	<0.001
Age of acquisition	11.331***	0.231	−0.014***	<0.001
Length	13.584***	0.238	0.003***	<0.001
Root 1 (single word/Germanic)	29.080***	2.048	−0.033***	0.003
Root 1 (Latin-based/Germanic)	11.377**	3.966	−0.002	0.005
Root 2 (Latin-based/Germanic)	3.562	4.342	−0.004	0.006
Root1 (single word/Germanic)*Root 2	15.515***	4.554	−0.007	0.006
Root1 (Latin-based/ Germanic)*Root 2	45.911***	6.350	−0.036***	0.008
Adjusted R^2	0.273***		0.540***	

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

Table 3 English lexical project: simple effect/contrast analysis for naming tasks.

	Accuracy (%)		Reaction time (ms)	
	B	SE	*B*	SE
Germanic Root 2				
Germanic–Germanic/ Germanic Single	0.033***	0.003	−29.1***	2.05
Germanic–Germanic/ Latin–Germanic	0.002	0.005	−11.4*	3.97
Germanic Single/ Latin–Germanic	−0.032***	0.005	17.7***	3.84
Latin-based Root 2				
Germanic–Latin/Latin Single	0.040***	0.005	−44.6***	4.14
Germanic–Latin/Latin–Latin	0.037***	0.006	−57.3***	4.96
Latin Single/Latin–Latin	−0.003	0.004	−12.7***	2.95
Germanic–Germanic/ Germanic–Latin	0.004	0.006	−3.56	4.34
Germanic Single/Latin Single	0.011***	0.002	−19.08***	1.40
Latin–Germanic/Latin–Latin	0.040***	0.006	−49.47***	4.63

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

Word naming task in English native speakers. The ELP data contained *accuracy* and *reaction time* data for English native speakers in word naming tasks. An initial analysis was run using linear regression based on methodology proposed by Hayes (2017). The linear regression investigated the effect of etymology (Root 1 and Root 2 being either Germanic, Latin, or 'empty' for single words) on naming accuracy and reaction time as two separate outcomes of interest. For each outcome of interest, the following covariates were entered in the models: word frequency (log), word length, and rated age of acquisition. As expected, these covariates were all significant in the regression models for naming accuracy and reaction time for the ELP data ($p < 0.001$). Further, we found significant effects of Root 1 ($p < 0.001$) and significant interaction effects of Root 1 and Root 2 ($p < 0.001$) for the model predicting naming accuracy and for the model predicting reaction time. These results suggest that accuracy and reaction time was differentially affected by compounding depending on the etymology of the second root for both naming accuracy and reaction times. The complete results of the regression models predicting naming accuracy and reaction time for the ELP participants can be seen in Table 2.

To more easily interpret the regression coefficients and interactions for the etymology factors, we used simple effect/contrast analyses per methodology in Fox and Weisberg (2018). In all comparisons, the base root (Root 2) is the one that defines the word's origin. The full set of contrast analysis results for ELP naming accuracy and reaction time are shown in Table 3. These interactions are best seen in Fig. 3a for ELP naming accuracy and Fig. 3b for naming reaction time.

For words that had a second root that was Germanic, there were significant differences in naming accuracy for the ELP data between Germanic–Germanic and Germanic single words ($b = 0.033$, $p < 0.0001$) and between Germanic single words and Latin–Germanic ($b = -0.032$, $p < 0.0001$) but not between Germanic–Germanic and Latin–Germanic ($b = .002$, $p = 0.94$; naming accuracy means for Germanic–Germanic: $M = 97.3\%$; Germanic single words: $M = 94.0\%$; Latin–Germanic compounds: $M = 97.2\%$). For words that had a second root that was Latin-based, there were significant differences between Germanic–Latin and Latin single words ($b = 0.04$, $p < 0.0001$) and between Germanic–Latin and Latin–Latin words ($b = 0.04$, $p < 0.0001$). Germanic–Latin compounds had the highest average accuracy ($M = 96.9\%$), followed by Latin–Latin compounds ($M = 93.2\%$) and single-root Latin words ($M = 92.9\%$). The results from accuracy in the ELP data support the notion that Germanic words form the basis of English lexical processing in adults.

The results for naming response times were slightly different than those for naming accuracy. For Germanic words, naming reaction times were significantly faster for Germanic–Germanic words ($M = 679.5$ ms) compared to either Germanic single words ($M = 708.6$ ms; $b = -29.1$, $p < 0.001$) or compound Germanic–Latin ($M = 690$ ms; $b = -11.4$, $p = 0.012$). Latin–Germanic compounds were significantly slower than Germanic single words ($b = 17.7$, $p < 0.0001$). Moreover, for words with a Latin-based root (Root 2), Germanic–Latin compounds had the fastest reaction times ($M = 683.1$ ms), followed by single-root Latin words ($M = 727.7$ ms; $b = -44.6$, $p < 0.0001$), and Latin–Latin compounds ($M = 740.4$ ms; $b = -57.3$, $p < 0.0001$).

Taken together, these results show that Germanic words are faster than Latin-based words. However, Latin single words tend to be slower than Germanic–Latin compounds but faster than Latin–Latin compounds. These results show that for English monolingual speakers, the presence of a Latin root either as the first or second word in a compound is associated with slower reaction times. The presence of a Germanic root either in the first or second position tends to speed up reaction times. These results are consistent with the view that the processing of English words

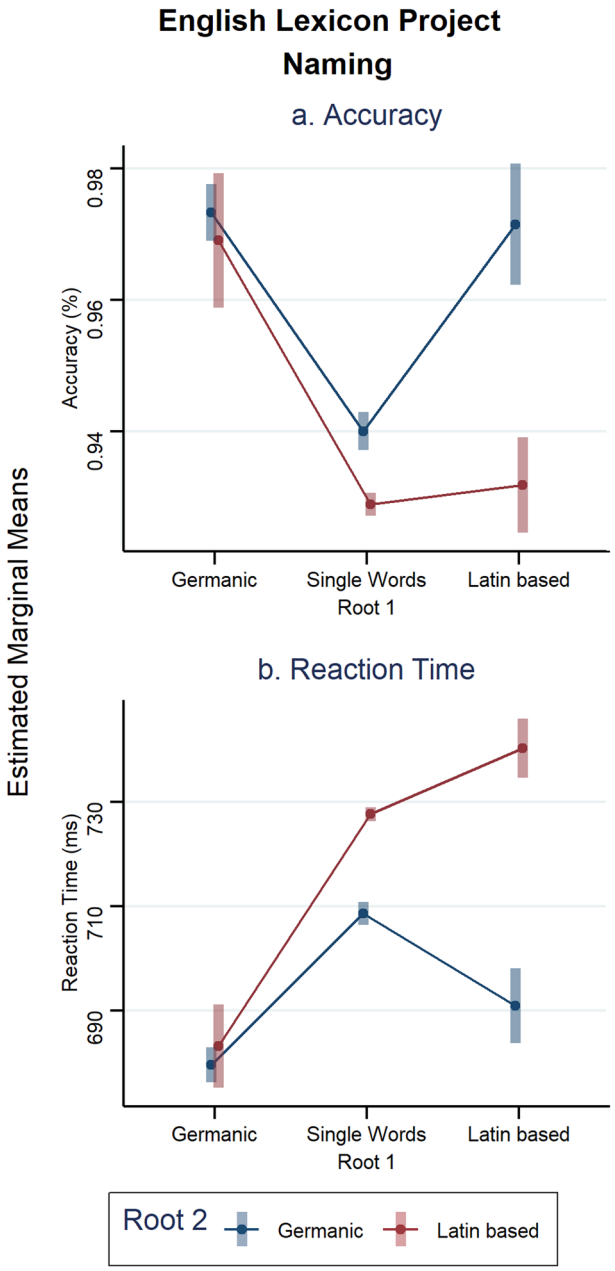

Fig. 3 English monolinguals are least accurate and slowest for Latin-Latin based compounds.

is built around a Germanic lexical base with Latin words slowing processing down.

Lexical decision task in English native speakers. For the lexical decision task, we had two large data sets to contrast as we had data for both the ELP and ECP participants for accuracy and reaction times. Again, we started with an initial linear regression analysis (Hayes, 2017) investigating the effect of etymology (Root 1 and Root 2) on lexical decision accuracy and reaction time as two separate outcomes of interest for each data set (ELP and ECP). In each model, we added word frequency (log), word length, and rated age of acquisition as covariates. Again, as expected, these covariates were all significant in all the regression models for lexical decision accuracy and reaction time for the ELP and ECP data. We also found that for ELP lexical decision accuracy there was a significant effect of Root 1 ($p < 0.001$) and a significant interaction effect of Root 1 and Root 2 ($p < 0.001$). For ELP lexical decision reaction times and ECP reaction times, we also found significant effects for Root 1 ($p < 0.001$) and for the interaction effect of Root 1 and Root 2 ($p < 0.001$). Interestingly, we did not find any significant effects of etymology in the regression model results for ECP lexical decision accuracy. The complete results of the regression models predicting lexical decision accuracy and reaction time for the ELP and ECP participants can be seen in Table 4.

Once again we ran simple effect/contrast analyses (Fox and Weisberg, 2018) to more easily interpret the regression coefficients and interactions for the etymology factors. In all comparisons, the base root (Root 2) is the one that defines the word's origin. The full set of contrasts analyses results for ELP and ECP lexical decision accuracy and reaction time are shown in Table 5. These interactions are best seen in Fig. 4a for ELP lexical decision accuracy, Fig. 4b for ELP lexical decision reaction time, Fig. 4c for ECP lexical decision accuracy, and Fig. 4d for ECP lexical decision reaction time.

In the lexical decision accuracy contrast analysis results, we see very different effects of etymology in the ELP data compared to the ECP data. For the ELP participants, lexical decisions are most accurate on average for Germanic–Germanic compound words ($M = 88.0\%$) and least accurate on average for Latin–Latin words ($M = 82.6\%$). For Germanic words, there are significant differences in lexical decision accuracy between Germanic–Germanic words and Germanic single words ($M = 84.0\%$; $b = 0.04$, $p < 0.0001$), as well as Germanic single words and Germanic–Latin compound words ($M = 87.7\%$; $b = -0.04$, $p < 0.0001$) for ELP participants. For Latin words, there are significant differences between Germanic–Latin and Latin single words (Germanic–Latin: $M = 87.6\%$; Latin single words: $M = 84.7\%$; $b = 0.03$, $p = .0017$), Germanic–Latin and Latin–Latin ($b = 0.05$, $p < 0.0001$), and Latin single words and Latin–Latin words ($b = 0.02$, $p = 0.0012$) for ELP participants. In contrast, the ECP accuracy data show no significant differences between the different etymology in words, the mean accuracy levels for all word root combinations are between $M = 94.0\%$ (for Latin–Germanic) and $M = 94.7\%$ (for Latin single words). These effects can be seen in Fig. 4a for ELP lexical decision accuracy and Fig. 4c for ECP lexical decision accuracy.

In the lexical decision reaction time contrast analysis results, we see similar effects of etymology in the ELP data and the ECP data, although the reaction times are higher on average for the ECP participants. ELP participants in the lexical decision are on average the fastest with Germanic–Germanic compound words ($M = 752.3$ ms) and slowest with Latin–Latin compound words ($M = 794.2$ ms). For Germanic words (Root 2 = Germanic), there are significant differences between Germanic–Germanic and Germanic single words ($M = 778.9$ ms; $b = -26.62$, $p < 0.0001$) and between Germanic single words and Germanic–Latin words ($M = 759.4$ ms; $b = 19.53$, $p < 0.0001$). For Latin words (Root 2 = Latin), there are significant differences between Latin–Latin and Germanic–Latin ($M = 769.8$ ms; $b = -24.41$, $p = 0.0001$), as well as Latin–Latin and Latin single words ($M = 776.1$ ms; $b = -18.11$, $p < 0.0001$). ECP participants in the lexical decision are also fastest on average with Germanic–Germanic compound words ($M = 974.0$ ms) and but slowest with Germanic single words ($M = 1031.1$ ms). Similar to what we found in the ELP data, for Germanic words (Root 2 = Germanic) reaction times in the ECP data, there are significant differences between Germanic–Germanic and Germanic single words ($b = -57.11$, $p < 0.0001$), and between Germanic single words and Latin–Germanic words ($M = 975.4$ ms; $b = 55.70$, $p < 0.0001$). For Latin words (Root 2 = Latin), there are significant

Table 4 English Lexicon Project and English Crowdsourcing Project: regression model results for lexical decision task (accuracy and reaction time).

	Monolingual lexical decision			
	ELP		ECP	
	B	SE	*B*	SE
Accuracy (%)				
Word frequency (log)	0.031***	0.001	0.016***	<0.001
Age of acquisition	−0.030***	<0.001	−0.011***	<0.001
Length	0.025***	<0.001	0.009***	<0.001
Root 1 (Single word/Germanic)	−0.040***	0.004	0.003	0.002
Root 1 (Latin-based/Germanic)	−0.003	0.008	−0.003	0.004
Root 2 (Latin-based/Germanic)	−0.005	0.009	0.004	0.004
Root1 (Single word/Germanic)*Root 2	0.011	0.009	−0.002	0.004
Root1 (Latin-based/Germanic)*Root 2	−0.047***	0.013	−0.001	0.006
Adjusted R^2	0.419***		0.371***	
Reaction time (ms)				
Word frequency (log)	−21.045***	0.326	−37.133***	0.454
Age of acquisition	12.556***	0.271	18.031***	0.378
Length	17.875***	0.280	11.210***	0.390
Root 1 (Single word/Germanic)	26.621***	2.401	57.113***	3.348
Root 1 (Latin-based/Germanic)	7.087	4.655	1.410	6.485
Root 2 (Latin-based/Germanic)	17.471***	5.097	2.269	7.098
Root1 (Single word/Germanic)*Root 2	−20.322***	5.346	−9.132	7.446
Root1 (Latin-based/Germanic)*Root 2	17.322*	7.453	45.000***	10.383
Adjusted R^2	0.553***		0.553***	

ELP English Lexicon Project, *ECP* English Crowdsourcing Project.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

Table 5 English Lexical Project and English Crowdsourcing Project: simple effect/contrast analysis for lexical decision tasks.

	Monolingual lexical decision			
	ELP		ECP	
	B	SE	*B*	SE
Accuracy (%)				
Germanic Root 2				
Germanic-Germanic/Germanic Single	0.040***	0.004	−0.003	0.002
Germanic-Germanic/Latin-Germanic	0.003	0.008	0.003	0.003
Germanic Single/Latin-Germanic	−0.037***	0.008	0.005	0.004
Latin-based Root 2				
Germanic-Latin/Latin Single	0.029**	0.008	−0.0002	0.004
Germanic-Latin/Latin-Latin	0.050***	0.010	0.004	0.004
Latin Single/Latin-Latin	0.021**	0.006	0.004	0.003
Germanic-Germanic/Germanic-Latin	0.005	0.009	−0.004	0.004
Germanic Single/Latin Single	−0.006*	0.003	−0.002	0.001
Latin-Germanic/Latin-Latin	0.052***	0.009	−0.003	0.005
Reaction time (ms)				
Germanic Root 2				
Germanic-Germanic/Germanic single	−26.62***	2.40	−57.11***	3.35
Germanic-Germanic/Latin-Germanic	−7.09	4.65	−1.41	6.48
Germanic Single/Latin-Germanic	19.53***	4.51	55.70***	6.28
Latin-based Root 2				
Germanic-Latin/Latin single	−6.30	4.86	−47.98***	6.76
Germanic-Latin/Latin-Latin	−24.41***	5.82	−46.41***	8.11
Latin Single/Latin-Latin	−18.11***	3.46	1.57	4.82
Germanic-Germanic/Germanic-Latin	−17.47***	5.10	−2.27	7.10
Germanic Single/Latin Single	2.85	1.64	6.86**	2.28
Latin-Germanic/Latin-Latin	−34.79***	5.43	−47.27***	7.57

ELP English Lexicon Project, *ECP* English Crowdsourcing Project.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

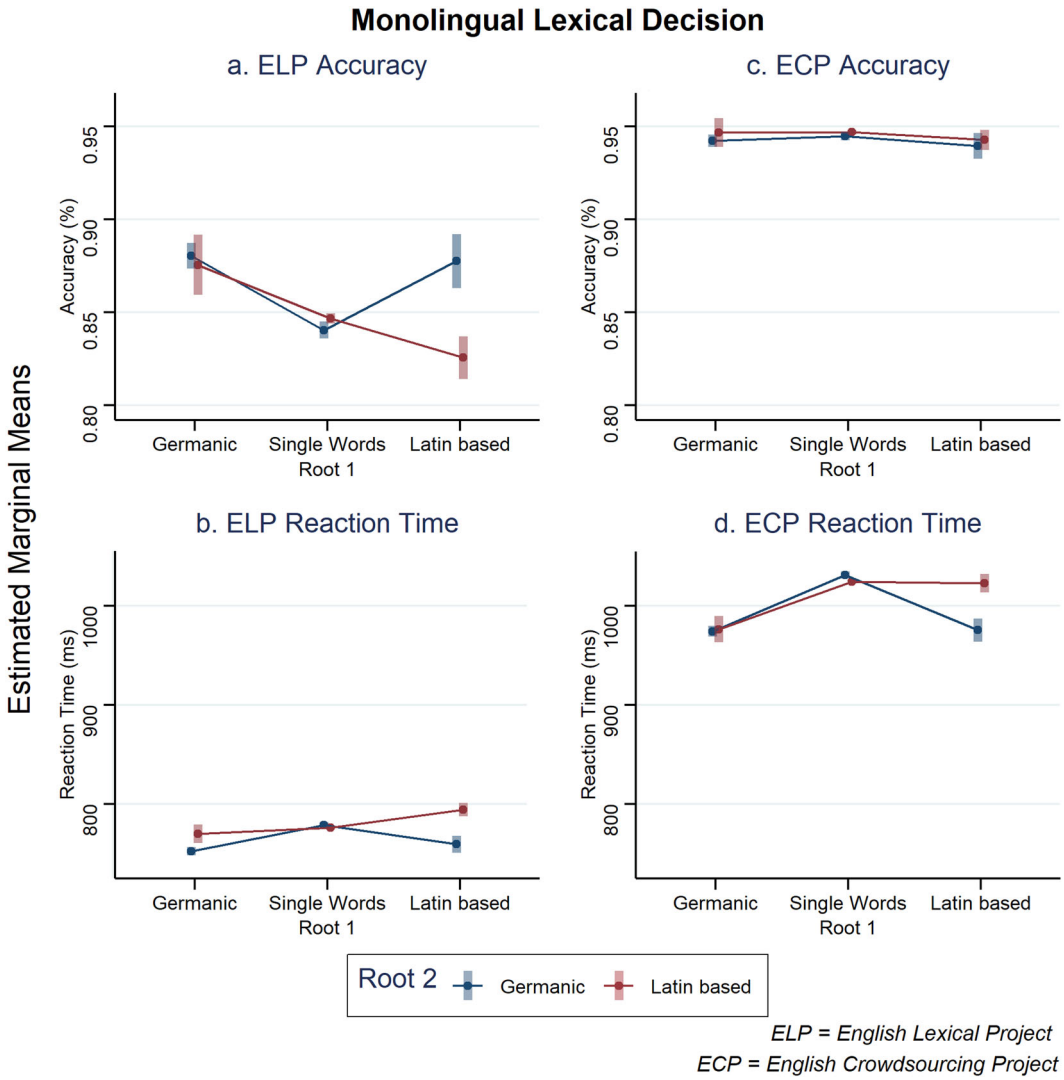

Fig. 4 English L2 learners are more accurate and faster for Latin-based items (red) relative to Germanic items (blue).

Table 6 English Crowdsourcing Project L2: regression model results for lexical decision task (accuracy and reaction time).

	Accuracy (%)		Reaction time (ms)	
	B	**SE**	***B***	**SE**
Word frequency (log)	0.050***	0.001	−64.089***	0.605
Age of acquisition	−0.030***	<0.001	18.667***	0.504
Length	0.031***	<0.001	15.953***	0.519
Root 1 (Single word/Germanic)	−0.031***	0.004	−5.717	4.458
Root 1 (Latin-based/Germanic)	0.007	0.008	14.711	8.634
Root 2 (Latin-based/Germanic)	0.011	0.008	−3.325	9.451
Root1 (Single word/Germanic) * Root 2	0.042***	0.009	−54.361***	9.913
Root1 (Latin-based/Germanic) * Root 2	0.008	0.012	−73.383***	13.824
Adjusted R^2	0.564***		0.613***	

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

differences between Latin–Latin and Germanic–Latin (Latin-Latin: $M = 1022.7$ ms; Latin-Germanic: $M = 976.3$ ms; $b = -46.41$, $p < 0.0001$) and Germanic-Latin and Latin single words ($M = 1024.3$ ms; $b = -47.98$, $p < 0.0001$). Taken together, these results show that Germanic words are generally faster than Latin-based words. However, single Germanic words tend to be slower most other types of words.

Lexical decision task in English L2 speakers. For the ECP data, lexical decision task information was available for English L2 speakers (ECP L2). This provided an interesting point of comparison to better contrast how English monolinguals and English L2 speakers process English in a lexical decision task.

We started the analysis with the linear regression (Hayes, 2017) examining the effect of etymology (Root 1 and Root 2) on lexical

Table 7 English Crowdsourcing Project L2: simple effect/contrast analysis for lexical decision tasks.

	Accuracy (%)		Reaction time (ms)	
	B	SE	*B*	SE
Germanic Root 2				
Germanic-Germanic/Germanic Single	0.031***	0.004	5.72	4.46
Germanic-Germanic/Latin-Germanic	−0.007	0.008	−14.71	8.63
Germanic Single/Latin-Germanic	−0.038***	0.007	−20.43*	8.37
Latin-based Root 2				
Germanic-Latin/Latin Single	−0.011	0.008	60.08***	9.00
Germanic-Latin/Latin-Latin	−0.015	0.009	58.67***	10.80
Latin Single/Latin-Latin	−0.004	0.006	−1.41	6.42
Germanic-Germanic/Germanic-Latin	−0.011	0.008	3.33	9.45
Germanic Single/Latin Single	−0.053***	0.003	57.69***	3.04
Latin-Germanic/Latin-Latin	−0.019*	0.009	76.71***	10.08

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

decision accuracy and reaction times for L2 speakers. The outcomes of interest were again lexical decision accuracy and reaction time. For each outcome of interest, the covariates entered were word frequency (log), word length, and rated age of acquisition. Again, as expected, these covariates were all significant in models for accuracy and reaction times. The complete results of the regression models can be seen in Table 6 for ECP L2 lexical decision accuracy and reaction time. The results also revealed statistically significant interactions, such that accuracy for ECP L2 participants was differentially affected by compounding depending on the etymology of the first root and the interaction of Root 1 and Root 2. For reaction times in ECP L2 participants, we also saw a significant effect of the interaction of Root 1 and Root 2 but no significant effect of the etymology of the first root.

We then looked at the simple effect/contrast analyses per Fox and Weisberg (2018) to interpret these interactions. The full set of contrasts analysis results for ECP L2 lexical decision reaction times are shown in Table 7. This interaction is also best seen in Fig. 5a for ECP L2 lexical decision accuracy and in Fig. 5b for ECP L2 lexical decision reaction times.

Once again, in all comparisons, the base root (Root 2) is the one that defines the word's origin. For L2 speakers, Latin–Latin words were most accurate ($M = 77.3\%$) followed closely by Latin single words ($M = 77.0\%$), Germanic–Latin words ($M = 75.9\%$), Latin–Germanic ($M = 75.4\%$), Germanic–Germanic ($M = 74.7\%$), and lastly Germanic single words ($M = 71.6\%$). For Latin-based words, there were no statistically significant differences in lexical decision accuracy for L2 speakers. On the other hand, there were statistically significant differences between accuracy for Germanic–Germanic and Germanic single words ($b = 0.03$, $p < 0.0001$) and between Germanic single words and Latin–Germanic words ($b = -0.04$, $p < 0.0001$).

Reaction times patterns were somewhat consistent with accurate results. For L2 speakers, Latin single words were fastest ($M = 1258$ ms) followed closely by Latin–Latin words ($M = 1259$ ms). The other etymology combinations were much slower in comparison (Germanic single words: $M = 1315$ ms; Germanic–Latin: $M = 1318$ ms; Germanic–Germanic: $M = 1321$ ms; and Latin–Germanic: $M = 1336$ ms). For Germanic words, there was a significant difference between Germanic single words and Latin–Germanic words ($b = -20.43$, $p = 0.0389$). For Latin words, there was a significant difference between Germanic–Latin and Latin single words ($b = 60.08$, $p < 0.0001$) and between Germanic–Latin, and Latin–Latin-based words ($b = 58.67$, $p < 0.0001$).

These results show that L2 speakers are not only faster with Latin-based words but also more accurate and that the presence of a Latin base root (Root 2) is also associated with higher accuracy. Further, these results are consistent with the view that L2 speakers learning emphasizes learning of English words via a Latin lexical base resulting in a different pattern of language acquisition relative to English monolinguals. As noted above, English native speakers transition from Germanic words in childhood to Latin-based words in adolescence and adulthood.

Discussion

The analysis of words using AoA norms along with word etymology is consistent with the hypothesis that, in native speakers of English, early learned words are more likely to be of Germanic origin whereas late learned words are Latin-based. First, differences in word etymology were differentially associated with Germanic and Latin words even when controlling for other relevant variables including word frequency and length. Germanic words formed a larger proportion of early learned words, whereas Latin words increased both in absolute number as well as proportionally with increasing age. For simple lexical items consisting of one root word, Germanic words were generally learned significantly earlier than Latin-based words. For compound words, when the first root was Germanic, there was no significant difference in age of acquisition for the word regardless of the origin (Latin versus Germanic) of the second root. When the first root was Latin, if the second root was also Latin, it was learned significantly later than if the second was Germanic.

The results for reaction times were consistent with the findings for AoA. Although there were some subtle differences between data collected in the ELP and in the crowdsourcing data, for the most part, the results support the view that Germanic words are processed more easily than Latin-based words. For the English Lexicon data, reaction times for Germanic words were reduced relative to Latin based words for both single and compound words, in general. All compounds with Germanic words as either the first root, the second root, or both were faster than Latin–Latin compounds. Thus, the words with the slowest reaction times were Latin–Latin compounds. The results from accuracy were largely consistent with those observed for reaction time. Accuracy was equally high for any compound word- that had a Germanic root word. Germanic–Latin compounds were also read with very high accuracy. However, both Latin single words and Latin–Latin compounds displayed significantly lower accuracy than items with a Germanic root. The results for lexical decision data either in the ELP or in the crowdsourcing data did not yield such clear data. Nevertheless, Latin–Latin compounds continued to be the least accurate and slowest overall. The results from both AoA and naming with monolingual English-native speakers are consistent with the view that whereas Germanic is the basis of the lexicon and word

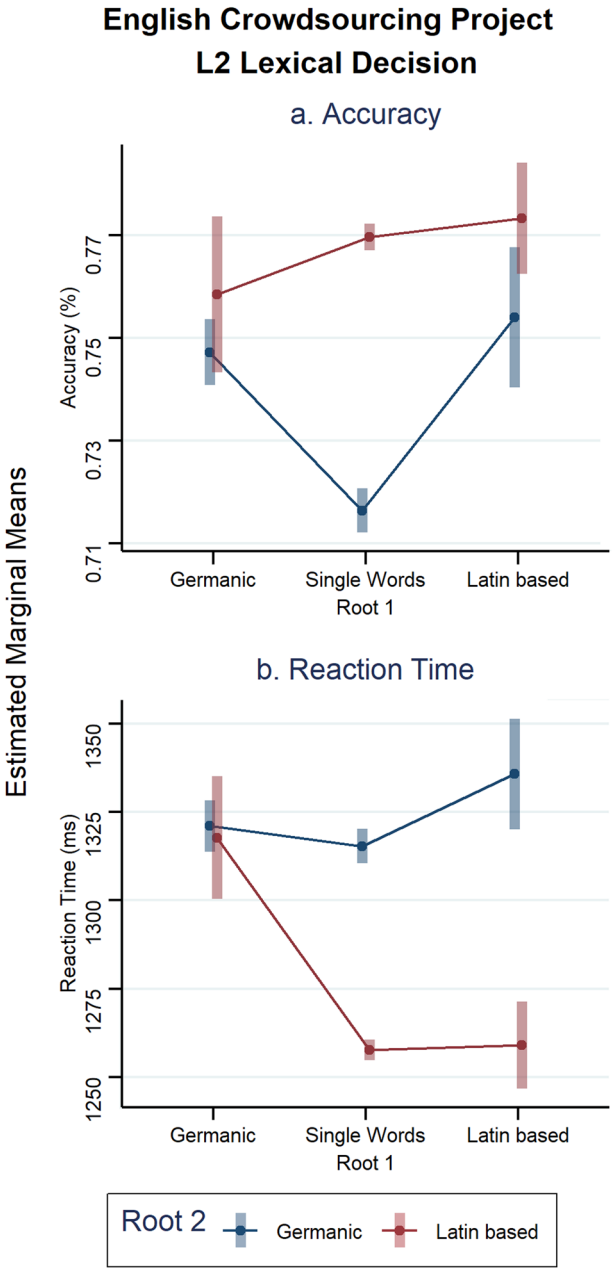

Fig. 5 English Crowdsourcing Project L2: interaction for lexical decision task for accuracy (%) and reaction time (ms).

formation early in life, later learned words are increasingly derived from Latin.

In addition to the analyses with English native speakers, the results with English L2 learners were also illuminating. In this group, the almost exact opposite pattern was observed. Although overall accuracy was lower for L2 speakers, Latin–Latin compounds showed the highest accuracy and lowest reaction times overall. A similar pattern was observed for single words, where Latin singletons showed higher accuracy and lower reaction times relative to single words of Germanic origin. Compounds with any Germanic words in either location led to relatively slower reaction times. The results from L2 speakers suggest that learning English at a later point of life results in preferential processing of Latin-based words. This fits in with Brysbaert's finding that L2 learners may learn more pan-linguistic vocabulary items. The present results qualify these pan-linguistic vocabulary items as coming from Latin.

These results shed light on the plasticity hypothesis in English, which conceptualizes that early learned items form the basis at both the meaning-level and orthographic form level. Because changes in word forms associated with lexical items across age are associated with etymology, plasticity in word recognition in English may be greater than that proposed by previous mapping models of skilled word reading. These findings also shed light on views that see AoA effects as arising when there is NOT a systematic relationship between input and output measures (Zevin and Seidenberg, 2002, 2004). Thus, for word naming, there should be much smaller AoA effects than there are for picture naming where the relationship between the visual stimulus does not bear any systematic relationship to the response. More recent theories support a dual view of AoA, beyond a simple difference in timing of entry into the language (Brysbaert and Ellis, 2016; Chang and Lee, 2020; Dirix and Duyck, 2017). The results from our study are consistent with these newer theories.

To date, studies have sought to select words that meet certain criteria such as early-learned words with an increasing frequency trajectory or words which have single syllables. Since these shorter words that are learned earlier in life are mostly of Germanic origin, they have the potential to skew results from previous studies, which show that adult reading of single words is highly skilled for monosyllabic words, leading to high levels of accuracy and slower reaction times.

The inclusion of items that are more representative of words learned in adolescence would fit in to some extent with the notion of discontinuity and the previous results from Reilly and colleagues as well as newer theories of AoA in general (Brysbaert and Ellis, 2016; Chang and Lee, 2020; Dirix and Duyck, 2017). Early and late learned words do not just differ in AoA, frequency, and all the variants of the latter. Rather, reading English takes on a bidialectal character that has been understudied in the word recognition literature. As Reilly et al. (2007) show, the imageability of words varies with etymology. Take for example the word *foresight* which refers to the act of seeing before something happens. The Latin equivalent *preview* is more abstract, *prediction* is even more abstract, and *Prometheus* is the most abstract. Hence, the use of Latin-based roots, especially those coming from Latin proper (not via French) or from Greek via Latin, are increasingly more abstract and less concrete. A person has foresight or hindsight about the world. We preview something if we are using a computer program or watching a movie. A prediction is something an economist, meteorologist or scientist might make. Prometheus is a form of "forethought" according to some interpretation of the root meaning of this item. In a similar vein, academic language, as well as professional jargon (such as medical or legal register), rely heavily on words and phrases that originate in Latin, so in a knowledge economy, being able to use such lexical items well is critical to both an individual's success as well as the success and viability of the societies those individuals inhabit. The fact that L2 learners of English are able to make decisions about Latin-based words with higher accuracy and speed relative to Germanic words is also consistent with this view. The present study established a reliable effect of etymology for a larger range of AoA's than is typically used in most studies to date.

Limitations and future directions. This is the first study to show —reliably—an effect of etymology focused on lexical processing with a fairly large database that paves the way for a series of follow-up studies that can further clarify the nature of AoA effects. One limitation of our study has to do with the participants

recruited for the ELP, undergraduates that were "native speakers of English." Similarly, the database from which we gathered rated age of acquisition norms was based on responses from native speakers of English. Recent work has found considerable variation in the levels of English that vary by socioeconomic status and educational attainment (Frank, 2018). Given that Latin-based words are learned to a greater extent well into adolescence and that they have been found to be involved in more formal registers leads one to consider how AoA and frequency might change across individuals who have diverse language experiences in English. Adult L2 English speakers did show a different pattern of results relative to native speakers. Nevertheless, some questions that remain include the following. How does the largest segment of English L2 speakers in the United States, those who have Spanish as an L1, differ from a monolingual English speaker? How do other sequential bilinguals who may have a variety of L1s learn English differently? Work with L2 speakers has not probed to a great extent how variations in the age at which English was learned or how differences in the first language affect the processing of Germanic and Latin-based words. Future studies are needed to better elaborate on this point.

Results from the analysis of etymology on L2 speakers revealed an interesting difference relative to native speakers. However, questions remain about the influence of the first language as an entryway into English. Recent work from Hartshorne and colleagues, for example, suggests that whereas Romance language speakers benefit the most when they acquire English as a first language simultaneously, speakers of West Germanic languages have a wider window (from 1 to 5) during which acquisition of the English is best learned (Hartshorne et al., 2018). The fact that Germanic words appear early and Latin words appear later may influence the path that speakers of different languages take when learning English. In a similar vein, research could look at dialectal variants of English such as African American Vernacular English and to some extent more regional or social dialects of English across the US and many other countries.

Finally, future studies could look at the extent to which Latin-based words may serve as an obstacle for those looking to attain college or even post-graduate degrees. In this sense, Latin-based words may occupy the place that they did when the Normans invaded England in the 11th century. As the language of royalty, it created a gap between those with more or lesser means; a gap whose remnants exist in present-day English (for example, *cow* is Germanic in origin, but the "consumable" has a French origin: *beef*, and other analogs include *deer* versus *venison* or *pig* versus *pork*). In some sense, this bidialectal view of English bears some resemblance to the Emergentist view of bilingualism that posit late second language learning as involving a parasitic relationship with a first language (Hernandez et al., 2005). Late learned Latin-based words in this sense may act like a second language vocabulary that is parasitic on the core of early learned Germanic words. Given the increase in the number of Latin-based words that inundate the English language into adulthood, studies in the word recognition literature should continue to more clearly delineate the divide between words of Germanic origin and those derived from Latin and how this divide may affect academic success in secondary and post-secondary education.

Data availability

The datasets generated during the current study are available in the Open Science Framework repository at the following web address: https://osf.io/fkr2j/?view_only=b8fedcffd19a4327ae5780412fd77163.

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Competing interests

The authors declare no competing interests.

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