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Vocabulary accessibility and acquisition: do you get more from a fincestor or a sociophite?

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Abstract

Background: The purpose of the current study was to examine how the morphological structure of a real word or novel word affected the incidental vocabulary learning of participants and to examine how these target items are processed as they are read. In addition, we examined the roles of vocabulary depth and breadth in the process of incidental vocabulary learning.

Methods: We had participants read short passages that contained real words or novel words that differed on their morphological accessibility as we collected eye movement data. Participants also completed several vocabulary depth and breadth measures.

Results: Accessible real words and novel words were learned better than inaccessible and less accessible items, but there was a processing cost associated with accessible real words compared with inaccessible real words. In contrast, participants spent more time on the less accessible novel words compared with accessible novel words, but that extra processing time did not translate into better acquisition scores. Finally, both vocabulary breadth and depth explained variance in incidental vocabulary acquisition, while breadth explained variance in gaze duration and depth explained variance in regressive eye movements.

Conclusions: Accessibility of the targets affected both acquisition and reading time, and depth and breadth are both individual differences that explain variance in incidental acquisition and the processing of those words.

Keywords

eye movement data; incidental vocabulary acquisition; morphological structure; vocabulary breadth; vocabulary depth

Research has established that vocabulary knowledge is important for reading comprehension (Anglin, Miller, & Wakefield, 1993; Bolger, Balass, Landen, & Perfetti, 2008; Elleman, Lindo, Morphy, & Compton, 2009; Nation, 2009; Nation & Snowling, 2004; Qian, 1999; Verhoeven, van Leeuwe, & Vermeer, 2011). For a person to understand what they are reading, they need to know a number of words and how to use and integrate them into the ongoing text representation (Nation, 2009). Studies have demonstrated that if as few as 2–5% of the words in the passage are unknown, comprehension is hindered for readers (Carver, 1994; Hu & Nation, 2000; Nagy & Scott, 2000). In addition, when word meanings are well-represented in readers' lexicons, processing efficiency is gained (Perfetti & Hart, 2002). That is, words that are well-known can be accessed quickly and that may free up resources to build a strong mental representation of the passage compared with a situation in which

words are less well-known and the reader has to struggle to figure out the meaning of individual words.

During the school years, and even into adulthood, readers encounter a number of new words for which they may have to infer the meaning. This process is typically referred to as lexical inferencing, or incidental vocabulary learning, and includes constructing meaning without direct instruction. Past research has demonstrated that there are a number of factors that contribute to incidental vocabulary acquisition. For example, the richness of the surrounding context contributes to vocabulary learning (Chaffin, Morris, & Seely, 2001; Lowell & Morris, 2017; Mori & Nagy, 1999) as does the number of times a reader might encounter the new word in varied contexts (Bolger et al., 2008; Eskenazi, Swischuk, Folk, & Abraham, 2018). Additionally, the lexical characteristics of the word, such as the morphological structure, have been shown to influence the ease of acquisition (Baumann et al., 2002; Graves & Hammond, 1980; McCutchen & Logan, 2011; Mori & Nagy, 1999; Nagy & Scott, 2000; Wysocki & Jenkins, 1987). Other research endeavours have demonstrated relationships among vocabulary acquisition and readers' working memory, reading comprehension, and morphological abilities (Cain, Oakhill, & Lemmon, 2004; Daneman & Green, 1986; McCutchen & Logan, 2011; Nicholson & Whyte, 1992; Swanborn & de Glopper, 2002). In this project, we sought to understand how other individual differences, namely, vocabulary depth (i.e., the quality of the knowledge readers have about words such as familiarity with a word's multiple meanings) and breadth knowledge (i.e., the number of words readers know), were related to how well the readers learned words that varied on morphological dimensions. While most studies that investigate these issues examine how well the words were acquired, we also wanted to understand the process by which the words were learned. Thus, we monitored readers' eye movements as they read passages containing less familiar and novel words in context.

Incidental vocabulary acquisition

As mentioned above, a number of studies have investigated incidental vocabulary acquisition during reading. In these studies, the participants typically read sentences or short passages that contain less familiar or novel words, and then following the reading session, the participants are given a surprise vocabulary test. These studies have demonstrated that readers can learn new words with as little as a single encounter (Williams & Morris, 2004), as well as finding that multiple encounters with new words strengthen their acquisition (Bolger et al., 2008; Pellicer-Sánchez, 2016; Reynolds, 2015). Within the literature on word learning, some theoretical accounts have suggested that acquisition occurs incrementally, such that each encounter with a word in context adds some new piece of information about it (Adlof, Frishkoff, Dandy, & Perfetti, 2016; Bolger et al., 2008; Fukkink, Blok, & de Glopper, 2001; Jenkins, Stein, & Wysocki, 1984; Nagy, Anderson, & Herman, 1987; Nagy, Herman, & Anderson, 1985). Each word a reader comes across activates that letter string, if present, and other similar or related letter strings in the lexicon. The more frequently a reader activates a certain word, the stronger it becomes within their knowledge base, eventually taking residence as an established word (Bolger et al., 2008; McKeown, 1985; Myers & O'Brien, 1998; Reichle & Perfetti, 2003). The morphological structure of the less familiar or novel word has also been investigated, and researchers have shown that this can

be a valuable source of information for readers as they attempt to establish a meaning for the word (Baumann et al., 2002; Graves & Hammond, 1980; McCutchen & Logan, 2011; Mori & Nagy, 1999; Nagy & Scott, 2000; Wysocki & Jenkins, 1987). For example, if a person has learned the meaning of the word *migrate*, they may be able to infer the meaning of *migration*, *migratory*, *immigration* and *emigration*. That is, if readers can use their knowledge of roots and affixes, they have a better chance of inferring the meaning of the unfamiliar word (Anglin et al., 1993). Consistent with the theoretical framework presented above, roots or affixes in the new word that are represented in the lexicon can be activated, and that may help in the acquisition of the new word.

Several studies demonstrate that readers do indeed use morphological information during lexical inferencing. For example, Finnish third and sixth graders were more successful at learning derived words that contained multiple morphemes than monomorphemic words (Bertram, Laine, & Virkkala, 2000). Hamada (2014) demonstrated that even the least-skilled adult L2 readers used morphological information to infer the appropriate meaning by asking participants to select the definition for a pseudo-compound word (e.g., ‘rainfime’) from a list of supplied options that were related to either the morphological structure of the word or the context in which the word appeared. Additionally, Mori and Nagy (1999) demonstrated that undergraduates in the United States learning Japanese combined morphological and contextual information to learn new words when given a test on unfamiliar Kanji compounds. They tested participants using semi-transparent, morphologically complex words that were either embedded in context; the Kanji was presented alone, or the context was presented to the participant, and they had to select the right choice. They found that participants overwhelmingly performed better when they were able to use both the morphological and contextual information.

McCutchen and Logan (2011) found that fifth and eighth grade readers were better able to select the correct meaning of a low frequency word when the root was accessible in a morphologically complex word compared with a low frequency monomorphemic word. For example, *horrific* is morphologically accessible as the reader might identify the root *horror*, while its matched inaccessible partner would be *vile*. Because the inaccessible word is monomorphemic, there are no extra cues in the word itself to aid in establishing its meaning. In McCutchen and Logan’s study, each inaccessible word was chosen to be a synonym for an accessible word so that they could fit into the same sentence context. In addition to these low frequency words, they also included novel words that varied in how subjectable they were to morphological analysis. For the accessible items, they selected a real-word stem and attached a familiar affix to create a novel word, such as *blanding*. *Bland* is a real adjective, which means boring or uninteresting, so *blanding* would become a verb that could mean a way to make something boring or uninteresting. For the less accessible items, they generated new portmanteau words, or words created by merging two real words together, such as *financestor*. The participant would need to combine the meaning of *finance* with *ancestor* to come up with a reasonable definition of this new word. They argued that the portmanteau words do not consist of generative morphemes, so they are less accessible. These words were then embedded into meaningful contexts. Not only were children more successful at selecting the correct meaning of a real word or novel word if it was morphologically

accessible but measures of morphological awareness also explained variance in their vocabulary acquisition scores.

Brusnighan and Folk (2012) demonstrated that college-age readers were more likely to acquire a meaning of a novel compound word when the compound word was transparent compared with opaque and when it was found in a supportive context compared with a neutral context. Unlike the other studies, Brusnighan and Folk recorded eye movements during vocabulary acquisition so that they could examine the number of words that were learned and the process by which those words were acquired. They found that readers spent less time on the target words when the novel compounds were transparent and were found in informative contexts compared with either opaque targets or neutral contexts; thus, both factors facilitated reading of these words. There is a growing body of research that has used eye-tracking methodologies to study incidental vocabulary acquisition. This work has provided valuable information on the types of factors that impact processing and how processing of these novel words unfolds over time (Brusnighan & Folk, 2012; Chaffin et al., 2001; Elgort, Brysbaert, Stevens, & Van Assche, 2018; Joseph, Wonnacott, Forbes, & Nation, 2014; Lowell & Morris, 2014, 2017; Williams & Morris, 2004).

Individual differences and incidental vocabulary acquisition

Studies have shown that a number of individual differences are related to incidental vocabulary acquisition. A recent study has shown that higher ability spellers are better able to learn new words in context compared with lower ability spellers (Eskenazi et al., 2018). Other studies have shown that working memory abilities are implicated in the acquisition process (Cain et al., 2004; Daneman & Green, 1986). Individuals with lower working memory abilities may be less able to hold in memory the relevant context that links the meaning with the unfamiliar word. Studies have also shown that reading comprehension skills are related to incidental vocabulary acquisition (Cain et al., 2004; Swanborn & de Glopper, 2002). Cain et al. (2004) argued that less-skilled comprehenders are less likely to draw the inferences that are necessary to learn the meaning of the new word. Additionally, other studies have demonstrated a positive relationship between morphological awareness and vocabulary knowledge (Ku & Anderson, 2003; McBride-Chang, Wagner, Muse, Chow, & Shu, 2005; McCutchen & Logan, 2011; Zhang, 2015). Researchers have argued that the ability to extract the roots and affixes from words helps the reader to gain an understanding of the unfamiliar word.

Recently, several researchers have argued that morphological abilities are a part of the larger construct of vocabulary depth (Binder, Gilbert Cote, Lee, Bessette, & Vu, 2016; Proctor, Silverman, Haring, & Montecillo, 2012; Schmitt, 2014). Unlike vocabulary breadth, which refers to the number of words that one knows, vocabulary depth pertains to the quality of the knowledge one has about words. Proctor et al. (2012) argued that knowledge of vocabulary depth is akin to metalinguistic awareness and includes an understanding of the semantic, syntactic, and morphological aspects of words. For example, vocabulary depth for the word *board* would include the knowledge that it can be used as a noun synonymous with *plank*, but that it can also be used as a verb to describe how we enter airplanes, as in the phrase “*boarding* the plane.” There are other senses of the word to consider as well. For example,

you can play a *board* game, one can have a house *boarded* up during a storm, one can have a meeting in a *board* room, one can pay room and *board*, one can be a member of the *board*, and so forth. In this way, vocabulary depth implies an understanding of the role a word plays in all of these contexts, along with its meaning.

Vocabulary breadth and depth have been shown to predict vocabulary acquisition skills. Shefelbine (1990) examined the intersection of breadth and depth and their effects on learning new words in samples of younger school-aged children. He found that children who knew more words were more likely to be able to learn new words from context, not only because of their greater vocabulary breadth but also because they knew more *about* the words with which they were familiar (Shefelbine, 1990). Ehsanzadeh (2012) administered tasks that tapped both dimensions of vocabulary knowledge to L2 college students and also had participants read a passage that included several novel words. The researcher asked the participants to infer the meaning of the novel words, and they were tested on their vocabulary acquisition. Ehsanzadeh found that while both breadth and depth were good predictors of vocabulary acquisition, depth was the better predictor. Similarly, Qian (2005) measured L2 college students' depth of vocabulary knowledge and used that information to create high-depth and low-depth groups. The participants had to learn new vocabulary words in context, and Qian found that high-depth individuals were better able to use informative context to correctly infer word meanings. Low-depth individuals tended just to focus on the new word (e.g., simply repeat the new word over and over). Use of this strategy indicated that they could not effectively find the informative aspects of the context to learn the new word. Thus, depth and breadth appear to be important contributors to incidental vocabulary acquisition.

Current study

The purpose of the current study was threefold: (1) to examine how the morphological structure of a real word or novel word affected the incidental vocabulary learning of participants, (2) to examine how these target items (both real words and novel words) are processed as they are read to establish meaning and (3) to examine the roles of vocabulary depth and breadth in the process of incidental vocabulary learning. To accomplish these goals, we had participants read short passages that contained real words or novel words that differed on their morphological accessibility. The target items (both real and novel words) were either low frequency morphologically complex words, low frequency monomorphemic words, morphologically accessible novel words, or less accessible novel words (i.e., portmanteau words). All target words were embedded in contexts that helped establish their meanings. For example, for the real word conditions, the participants were presented with passages such as: 'The teacher was so talkative. The lecture had concluded. The (prolix/ verbose) teacher made us late for break'. The context of 'so talkative' helps the reader establish the meaning of either *prolix*, the monomorphemic, inaccessible word or *verbose*, the morphologically accessible word. We monitored participants' eye movements as they read the passages, and after reading all of the passages, we administered a surprise vocabulary test. In addition, we administered a number of tests that assessed vocabulary depth and breadth. We hypothesized that morphological accessibility would have a positive effect on vocabulary acquisition in that accessible items would be learned better than the

inaccessible or less accessible items. That is, in the example above, there are no additional cues in the word *prolix* to help the reader get to the right meaning, while for *verbose* the reader might know that the root means ‘word’ and might be familiar with other versions of the root such as *verbosity*, *verboseness*, or *verbosely*. We also hypothesized that morphological structure would be reflected in the reading time data as well. That is, words that afforded morphological analysis would require more reading time to deconstruct the morphemes. Additionally, we hypothesized that word status would influence both acquisition and reading time as well. While we used very low frequency real words, we hypothesized that aspects of those words might be partially represented in the lexicon. That is, for the accessible real words, the root and/or the affixes might be represented, but only partially known. As Bolger et al. (2008) have argued, word meanings are learned incrementally, and our exposure to these items may help build our lexical knowledge. Thus, we thought the real words would be better learned and read faster than the novel words. Finally, we hypothesized that both breadth and depth would explain variance in vocabulary acquisition.

Method

Participants

We tested 94 college students who were attending a women’s college in the northeast region of the United States. We eliminated the data from eight participants because they did not return for the second session of testing; thus, our sample consisted of 86 participants. All participants were female, all had normal or corrected-to-normal vision, and their mean age was 20.5 years ($SD = 4.19$).

Materials

Participants completed vocabulary depth and breadth measures and a reading session in which participants’ eye movements were monitored to measure reading behaviour as they read passages presented on a computer screen.

Vocabulary breadth tasks.—The first breadth task was the 14,000 Word Family version of the Vocabulary Size Test, (Nation, 2012). Participants saw a word and an example of the word in a noninformative sentence context and then had to match the word to the correct definition. For example, participants would see a sentence such as ‘AWE: They looked at the mountain with *awe*’. Their answer choices would be *worry*, *interest*, *wonder*, or *respect*, with the correct answer being *wonder*.

The second breadth task was the Vocabulary section of the Nelson–Denny Reading Test, form H (Brown, Fishco, & Hanna, 1993). Participants identified the correct definition of a given word from five possible choices. For example, one item reads ‘to be *imbued with* is to be: A. *copied*; B. *saturated*; C. *inhaled*; D. *fooled*; E. *frightened*’, with the correct answer being B. *saturated*.

Vocabulary depth tasks.—The Compound Awareness Task (Berninger & Nagy, 1999) tested participants’ ability to successfully use the right-hand head rule (Nagy, Berninger, &

Abbott, 2006; Zhang, 2013). This rule states that the head of a compound word is located on the right and that it contains the primary semantic information of the word. Participants read items such as ‘a bee that lives in the grass’ and had to decide whether the appropriate name for this concept would be *a bee grass* or *a grass bee*, with the correct answer being the latter.

The Test of Word Knowledge (Wiig & Secord, 1992) measured participants’ knowledge of synonyms and use of words in multiple contexts. In the Synonyms task, participants were asked, for example, ‘which word means the same as *wide*?’ The possible answers were *broad*, *loose*, *round* or *stiff*, with the correct answer being *broad*. The Multiple Contexts task contained questions such as ‘what are two possible meanings of the word *glasses*?’ Participants then wrote their responses to each of the items with correct responses, in this case, including ‘the plural form of “glass”’ and ‘the singular form of an object worn on the face to aid sight’. Participants received a point for a correct response if they provided two distinct definitions that captured two different possible meanings of each word. For example, if the participant wrote ‘an object worn on the face to aid sight’ and ‘something you use to help you read’ in response to the word *glasses*, that item would be marked as incorrect because those represent the same concept, or definition, for the word *glasses*.

The Morphological Skill Task (Maag, 2007) presented participants with a morphologically complex word and asked them to select its root word from three possible choices. For example, when shown the word *discovery*, participants were expected to choose *discover* from a list of choices including *disco*, *cover* and *discover*.

For the Morphological Families Task (Binder et al., 2016), participants had to generate as many derivations as possible from a given root word. An example includes, ‘using the root *establish*, how many words can you make?’ Acceptable responses include *established*, *establishing*, *establishment* and *reestablish*.

Vocabulary acquisition during passage reading.—During the eye-tracking portion of the experiment, participants read 36 different passages on a computer screen. These passages were adapted from McCutchen and Logan (2011). That is, while we used the target words they had in their study, we wanted to provide more context so that the reader could use that context to establish a meaning for the word. There were four possible target item conditions, with two of those conditions consisting of real words. Those words were either morphologically accessible real words, such as *verbose* or morphologically inaccessible real words, such as *prolix*. The morphologically accessible words were words with low frequency surfaces but high frequency morphemic constituents. This construction allowed participants to analyse the morphemes to infer the word’s meaning, which may have otherwise been unknown (McCutchen & Logan, 2011). Morphologically inaccessible words also had low frequency surfaces but were monomorphemic and did not allow the participant to break down the constituents of the word to determine its overall meaning (McCutchen & Logan, 2011). The morphologically accessible words were each paired with an inaccessible word such that either word fit into the same passage context, which is described below. McCutchen and Logan ensured that the words had similar surface frequencies. Table 1 shows a summary of the linguistic characteristics of the target words. The surface frequencies, according to the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995),

for the morphologically accessible words ranged from 0 to 5.31, with a mean of 1.16 ($SD = 1.72$), while the morphologically inaccessible words ranged from 0 to 9.39, with a mean of 1.56 ($SD = 2.23$). A paired samples t -test indicated that there was no significant difference between the frequencies of these two word types, $t(17) = 0.62$, $p = .54$.

In addition to the two real word conditions, there were two novel word conditions. There were morphologically accessible novel words, such as *sociophite* and less morphologically accessible novel words, such as *vegislation*, where two real words were combined to make a new one. The accessible novel words took a real word as the base, such as *acquit*, and added an affix to make a new word (e.g., *acquitation*). The less morphologically accessible novel words, also commonly known as portmanteaus, were labelled as such because rather than being entirely inaccessible, they consisted of segments of real words that may be familiar to the participant and may aid in identifying a plausible meaning for the word. Because these are novel words, the surface frequency of the words was 0.

While McCutchen and Logan (2011) did equate these words on surface frequency, they did not equate them on length. The range of word length for the morphologically accessible words was 6–14, with a mean of 9.22 ($SD = 2.10$), and the range of the morphologically inaccessible words was 4–8, with a mean of 5.39 ($SD = 1.14$). The length of the morphologically accessible novel words ranged from 8 to 12 letters, with a mean of 10.33 ($SD = 1.66$), and the range of the morphologically less accessible novel words was 9–14 letters, with a mean of 10.89 ($SD = 1.54$). To test for differences across conditions, we used target length as the dependent variable and target word status (real word or novel word) and accessibility as independent variables in an ANOVA. There were significant main effects for both word status, $F(1, 50) = 47.41$, $MSe = 2.77$, $p < .001$, and accessibility, $F(1, 50) = 11.66$, $MSe = 2.77$, $p = .001$, and there was also a significant interaction, $F(1, 50) = 20.90$, $MSe = 2.77$, $p < .001$. As can be seen in Table 1, the inaccessible words had fewer letters than the other three conditions. Because of the significant difference, word length was used as a covariate in the analyses for the eye movement measures.

The target items were embedded in passages, and each participant read 36 passages. Each of the 36 passages consisted of a context sentence, a filler sentence with no informative context, and a sentence containing the target item. Each participant saw all 36 items, but the morphologically accessible and morphologically inaccessible real words were counterbalanced across participants, while each participant saw all nine morphologically accessible novel words and all nine less morphologically accessible novel words. Participants also saw a comprehension question about the passage they just read before moving onto the next item to ensure that they were engaged and paying attention. Additionally, after reading all of the passages, participants took part in a surprise vocabulary acquisition test to see how well they had acquired the meaning of the target items in the preceding passages. For example, participants would see the question ‘What is the definition of *verbose*?’ and be asked to choose the correct response from a supplied list of three possible answers. In this example, the list contained *disorganised*, *talkative*, and *stern*, with the correct response being *talkative*.

Apparatus

Eye movement data for both the reading comprehension and vocabulary acquisition portions of the study were collected with an SR Research EyeLink 1000 system utilising the desktop-mounted camera option. It has a resolution of 0.01° of visual angle, a sampling rate of 1,000 Hz, and a typical accuracy range between 0.25° and 0.5°. Its gaze tracking range is 32° horizontally and 25° vertically. The camera records eye movements from one eye but permits binocular reading. It was placed directly in front of a 24-inch Ben-Q screen. A chin rest was set 50–55 cm away from the camera, as this is the recommended tracking distance. Students placed their heads on a chin rest to minimise head movements during tracking. The participants used a ResponsePixx 5 Button Box to proceed through the experiment and indicate their answers to the vocabulary questions. The passages were presented in a black, 20-point Courier font.

Procedure

The entire battery of tests was conducted over two sessions to avoid fatigue. In the first session, participants completed the tasks that measured vocabulary breadth. Participants had as much time as was necessary to complete all of the exercises to the best of their ability, and they were instructed to guess if they were unsure of an answer. In the second session, participants read passages on the eye-tracking computer, answered comprehension questions about them, and completed the surprise vocabulary acquisition task at the end of the eye-tracking session. Following the eye-tracking portion of the experiment, the participant completed the remaining vocabulary depth tasks, filled out a demographics questionnaire and was debriefed by the experimenter. The average duration of each session ranged from about 45 minutes to 1 hour, depending on the speed of the participant.

Results

Prior to examining the vocabulary acquisition accuracy and the eye movement data, we examined the accuracy of the reading comprehension questions as we used those data as an index for participants' on-task behaviour. That is, we used this measure as a check to ensure that participants were engaged in reading for comprehension. The overall accuracy was quite good at 85.6%, and there were no differences across conditions for comprehension accuracy (accessible real words: 85.6%, inaccessible real words: 87.4%, accessible novel words: 86.5%, and less accessible novel words: 83.0%). Vocabulary acquisition accuracy data, as well as several eye movement measurements, served as the dependent variables in the analyses. Linear mixed-effects (LME) regression models were run for each of the dependent measures. The appeal of using this type of regression model to analyse the sizable dataset at hand (i.e., 3,000 + data points) was, in part, due to the ability to incorporate by-subject and by-item influences as random effects into the same analysis while also controlling for other potential extraneous influences as covariates in the model, namely, target word length since that differed across items and conditions (Baayen, Davidson, & Bates, 2008; Bates, Kliegl, Vasishth, & Baayen, 2018). All findings reported below were above and beyond any influence of this covariate. The intercepts for subjects and items and slopes for subjects were included as random effects, while the fixed effects in all of the models included target word condition (real word vs novel word), accessibility (accessible vs inaccessible), word length,

the interaction between word condition and accessibility, and the three-way interaction among word condition, accessibility, and word length. Word condition and accessibility were categorical variables, while word length was a continuous covariate. The data were evaluated for normality prior to analyses, and all dependent measures had skew and kurtosis values within accepted limits. All values were <1.5 . Means and standard errors (SEs) are reported in Table 2. For each effect, regression coefficients (βs), SE , and t -values are reported in Table 3. For the significant interaction between word condition and accessibility, we examined each word type separately, looking for differences across accessibility. We present the βs for each contrast in the text. Fit indices for the null and full models for each measure can be found in the Appendix. The syntax for the analyses can be found in the supporting information.

Accuracy

We examined the number of correct responses that were generated during the surprise vocabulary test. There were a total of nine items per condition. Participants were more accurate on real words compared with novel words. They were more accurate on accessible items than inaccessible items. In addition, there was a significant interaction. The best accuracy was associated with the items that were accessible, and there was no difference in the accuracy between accessible real words and accessible novel words, $\beta = -0.002$, $SE = 0.03$, $t = -0.09$, $p = .93$. However, the responses to the inaccessible real words were more accurate than the less accessible novel words, which had the lowest level of accuracy, $\beta = -0.241$, $SE = 0.06$, $t = -4.17$, $p < .001$. Thus, accessibility helped the participants with vocabulary acquisition. The accessible items were learned better, even when they were not real words, compared with both inaccessible real words and less accessible novel words.

Eye movement data

We examined both early and late processing measures (Binder & Morris, 1995; Radach & Kennedy, 2004, 2013; Rayner, 1998) to understand how processing unfolded over time. Gaze duration is the sum of all fixations on a word before a reader moves past the word and is thought to reflect initial processing time on the target word. Total time is the summation of all fixations on a target word, including regressions made back to the word. We also examined regressive eye movements. We assessed the number of regressions made into each target item and regressions directly out of each target item to other regions of the text. Total time and regressions are thought to reflect later, more integrative aspects of word processing. Again, we conducted LME regression models in which the fixed effects in all of the models included target item condition (real word vs novel word), accessibility (accessible vs inaccessible), and their interaction, while participants and items served as random effects.

Initial processing

For gaze duration, there was a significant effect for word type with readers spending less initial time on real words compared with novel words. Readers also had longer gaze durations for the accessible words relative to the inaccessible words. There was also a significant interaction. For the real words, readers spent more time reading the accessible words compared with the inaccessible words, $\beta = 50.92$, $SE = 14.30$, $t = 3.56$, $p < .001$, but for the novel words, there were no differences between the less accessible novel words and

the accessible novel words, $\beta = -4.03$, $SE = 15.22$, $t = -0.27$, $p = .79$. Thus, for real words, readers take more time to read the targets that are morphologically accessible, but for the novel words, there was no difference across accessibility. As mentioned above, item length was entered as a covariate in the model because length was not controlled. Length did not have a significant main effect, nor did it have a significant three-way interaction with word type or accessibility. Thus, these findings are not due to length being confounded with condition.

Later stages of word processing

For total time, there was a significant effect for word type with readers spending less initial time on real words compared with novel words, a significant main effect of accessibility with readers spending more time on accessible targets compared with less accessible targets, and there was also a significant interaction. For the real words, readers spent more total time reading the accessible words compared with the inaccessible words, $\beta = 92.59$, $SE = 25.86$, $t = 3.58$, $p < .001$, but for the novel words, they spent more time on the less accessible novel words than the accessible novel words, $\beta = -58.67$, $SE = -29.12$, $t = -2.02$, $p = .04$. Thus, for real words, readers took more time to read the targets that were morphologically accessible, but for the novel words, readers took more time to read the less accessible words. Again, item length did not have a significant main effect in the model for total time, nor was the three-way interaction among length, word type and accessibility significant.

When considering the regressions made to the targets, word type and accessibility interacted, which showed that for the real words, readers did not differ in the number of regressions to the target, $\beta = 0.02$, $SE = 0.05$, $t = 0.45$, $p = .65$, but for the novel words, there were more regressions into the accessible novel words compared with the less accessible novel words, $\beta = 0.23$, $SE = 0.03$, $t = 6.63$, $p < .001$. When examining regressions out of the target item, we found that readers were more likely to make a regression out of a novel word compared with a real word. In addition, readers were more likely to regress back to the target when it was inaccessible compared with when it was accessible. However, these main effects were qualified by an interaction. For both real words and novel words, readers were more likely to make regressions back to the inaccessible items compared with the accessible items, but the magnitude of the difference was greater for novel words compared with real words (real words: $\beta = -0.08$, $SE = 0.03$, $t = -2.54$, $p = .01$; novel words: $\beta = -0.29$, $SE = 0.03$, $t = -9.67$, $p < .001$). Once again, item length did not have a significant main effect in the model for regressive behaviour, nor was the three-way interaction among length, word type and accessibility significant for either of the regression measures.

The reading time data were fairly consistent. Readers spent more total time on accessible real words compared with inaccessible real words, which seems to indicate that they were decomposing the accessible real words into their morphological constituents. This decomposition turned out to be helpful as the accessible real words were learned better than the inaccessible real words. On the other hand, for novel words, readers spent more time on the less accessible novel words than the accessible novel words, but that extra processing time did not help them learn the less accessible novel words better.

Multiple regression analysis

We created composite variables for vocabulary depth and breadth. We used those variables to explain variance in the total vocabulary accuracy scores and the eye movement measures. For accuracy, we summed the accuracy of the items across the four word-type conditions to create a composite vocabulary score and used the breadth and depth factors as fixed effects in the LME model. Fit indices for the null and full models for each measure can be found in the Appendix. For accuracy, both depth and breadth were significant predictors. Regression coefficients (β s), SE and t -values are reported in Table 4. When gaze duration was the dependent variable, with both depth and breadth as fixed effects in the LME, only breadth had a significant relationship, while depth did not have a significant effect. Neither breadth nor depth shared significant contributions to total time. However, an interesting pattern emerged when we examined regressive eye movements. For the analyses of regressions into the target region and out of the target region, depth was a significant contributor, while breadth was not. In summary, for accuracy, both breadth and depth play a role. The higher the depth and breadth scores, the higher the accuracy scores. For the reading measures, breadth shares a relationship with depth in that the greater depth an individual has, the less time they spend on the target words. For later processing measures, while total time did not have a relationship with either variable, depth was related to both regression measures. The higher the depth scores, the more likely a reader was to make regressions in and out of the target region.

Discussion

The purpose of the current study was threefold: (1) to examine how morphological structure of a real word or novel word affects the incidental vocabulary learning of participants, (2) to examine how these target items are processed as they are read in the passages to establish meaning and (3) to examine the roles of vocabulary depth and breadth in the process of incidental vocabulary learning. We had several important findings. First, accessible real words and novel words were learned better than inaccessible and less accessible items. Second, there was a processing cost associated with accessible real words compared with inaccessible real words, but that cost aided in vocabulary acquisition. While there were longer processing times on the less accessible novel words compared with accessible novel words, that extra processing time did not translate into better acquisition scores. Third, the eye movement data provided valuable information concerning how these targets were processed. Across both gaze duration and total time, readers spent more time on accessible real words compared with inaccessible real words. For gaze duration, there were no differences between the accessibility conditions, but for total time, readers spent more time on the less accessible novel targets compared with the accessible novel targets. When the reader was fixated on the target, there were no differences in the likelihood of making a regression out of the target when it was a real word. However, when it was a novel word, readers were more likely to make a regression out of the target when it was less accessible compared with when it was accessible. It appears that when it was accessible, the participant could use the word's internal information to process the word, but when it was less accessible, they regressed back to earlier sections of the context to try to establish meaning. Finally, both vocabulary breadth and depth made interesting contributions to both the

acquisition data and the eye movement behaviour. Both variables were related to acquisition, while only breadth was significantly related to gaze duration and only depth shared a significant relationship with the two regressive eye movement measures.

Consistent with McCutchen and Logan's (2011) findings, our results show that the accessibility of both real words and novel words has a direct impact on the processing and acquisition of words. Participants in both studies were significantly more accurate in defining words that were morphologically accessible, regardless of whether they were real words or novel words. This is likely because morphologically accessible words provide more information for the reader to use to decipher their meaning (Baumann et al., 2002; Graves & Hammond, 1980; Mori & Nagy, 1999; Nagy & Scott, 2000; Wysocki & Jenkins, 1987). Furthermore, we found that for real words, participants spent more time on the accessible words than the inaccessible words, and we believe this is a result of decomposition, as is consistent with some models of word recognition (Bertram, Laine, & Karvinen, 1999; Hyönä, Laine, & Niemi, 1995; Lehtonen & Laine, 2003; Niemi, Laine, & Tuominen, 1994). Participants may have been using the extra processing time to break the accessible words down into their morphological constituents, identify which of those parts they were familiar with and then try to create a meaning for the unfamiliar word by combining the meanings of the parts just identified. For example, when they encountered the target word *scarcity*, participants decomposed the target into the root *scarce* and the affix *-ity*, which often makes adjectives into nouns. This additional processing time spent on the accessible real words ultimately aided participants and contributed to better recall in the vocabulary acquisition task at the end of the study.

The same cannot be said for the novel words, though. Participants in our study spent longer on the less accessible novel words than the accessible novel words, but that extra time did not assist with recall during the vocabulary acquisition task. However, we should note that readers spent more time on the accessible novel words than the inaccessible real words, and that extra time translated into benefits for vocabulary acquisition relative to the inaccessible real words, but again, the readers spent the most time on the less accessible novel words. There are a few possible explanations for this. They may have spent longer on the less accessible novel words (*vegislation*; *financestor*) than the accessible novel words (*blanding*; *sociophite*) because they made more regressions out of the less accessible novel words into the context, and then they returned to the target word to process it again. Thus, they did a great deal of rereading, which resulted in longer total time. The additional processing time could also be because the less accessible novel words contained two 'entire' words rather than the building blocks that readers are used to decomposing. If there are two words joined together, but you are not familiar with one of them or you cannot see all of it to break it down, it may be more difficult to solidify the meaning of the word. Combining these two words to create one new word is very different than taking an existing word and adding an affix that the participant has encountered in numerous words across his/her life. For example, over the course of word learning, a person comes to know that adding '-s' makes a noun plural, adding '-er' to a verb makes a noun, adding '-un' means not, and so forth. Many of these morphological rules are consistent across words and readers can exploit this knowledge when learning a new word. These situations are quite different from combining two distinct words. Both vocabulary depth and breadth composite scores explained

significant, unique variance in vocabulary acquisition accuracy. Consistent with other studies (Ehsanzadeh, 2012; Qian, 2005; Shefelbine, 1990), both the quantity of words and the quality of the representations of those words contribute to new word learning. As mentioned earlier, vocabulary depth represents the complexity of a person's understanding of a word, including aspects such as multiple meanings, uses and connections to related words, as well as how to alter a word's morphology for different contexts. Readers with higher vocabulary depth levels show higher word recognition and reading comprehension levels and, importantly in the context of this study, are more adept at manipulating morphologically complex words, as a deeper understanding of word meaning and form can enable a reader to understand it in multiple contexts and process different word components to decipher its overall meaning (Binder et al., 2016; Ouellette, 2006; Qian, 2005).

We also obtained interesting differences in patterns of influence of depth and breadth for the eye movement measures. For initial word processing (i.e., gaze duration), we found that only vocabulary breadth contributed to explaining variance in gaze duration. Participants who had higher breadth of knowledge spent less time on the targets. This finding is consistent with other studies in the literature. Binder et al. (2016) found that only breadth was related to reading rate. We also found that depth was the only vocabulary factor related to regressive eye movements. That is, participants who had higher depth scores were more likely to engage in regressing in and out of the target region in our study. These are striking differences across our various measures for the role these variables play in the processing of new words. These findings are consistent with Ouellette (2006) who argued that depth and breadth play different roles for various reading skills. Ouellette suggested that many words in a person's lexicon (i.e., vocabulary breadth) aids in the processing efficiency of those words, and this speeds reading rate. However, knowing more about each individual word (i.e., vocabulary depth) also helps one to develop a more coherent representation of the text, thus aiding reading comprehension.

In addition to the importance of morphological awareness to the construct of vocabulary depth, understanding how to use contextual cues to support word learning is crucial, too, and seems to be related to vocabulary depth. Qian (2005) investigated the role of vocabulary depth and strategy use during reading. Participants completed a series of vocabulary depth tasks, a reading comprehension task and a questionnaire about their reading behaviours during the comprehension task. The questionnaire asked about the readers' strategies when they encountered unfamiliar words in the text. Qian found that readers with higher vocabulary depth skills were better at utilising supportive contextual information. The higher-depth participants reported spending more time reading the contextually useful sections of sentences when encountering a sentence with a word they did not understand than those with lower vocabulary depth abilities, who tended to spend more time focusing only on the confusing word. In addition, those with higher vocabulary depth could better identify which sections of the sentence might hold important context clues useful for deciphering the sentence meaning (Qian, 2005).

One of the limitations associated with our study was that we gave participants only a single encounter with the target word, but there is some interesting work that has demonstrated that repeated encounters with new words aids in the acquisition process. Jenkins et al. (1984)

embedded unfamiliar words in contextually rich passages and manipulated the number of passages participants read that contained those unfamiliar words. Participants either had 0, 2, 6 or 10 exposures to the target words. Participants demonstrated learning, and more exposures increased that learning. In addition to manipulating number of exposures, it would be useful to manipulate the form of the target word. That is, if morphologically accessible targets are used, one could keep the form of the target identical across encounters or change the morphological structure across the encounters (e.g., target is *aquatic*, but the participants may also encounter *aquarium*, *aquifer*, *aquanaut* and *aqua-marine*). Varying the form would allow for an examination of transfer of knowledge from one version of a morphologically complex word to another version. Examination of both of these factors could help develop better and more efficient vocabulary training programmes. An additional limitation of our study was that there were more items in the less accessible novel condition in which the targets were either the final word or near the end of the sentence compared with the accessible novel word condition. This is unfortunate because sentence wrap-up effects could contaminate the processing of the targets that are closer to the end. That is, studies have found that readers spend more time processing words that end clauses or sentences (e.g., Hirotani, Frazier, & Rayner, 2006; Rayner, Kambe, & Duffy, 2000) relative to words in the middle of a clause or sentence. However, we are not overly concerned about wrap-up effects being completely at play here. During wrap-up effects, readers may spend more time on those words because they are trying to finalise processing on that phrase or sentence. One might assume that the extra processing would result in better acquisition. That was not the case. In fact, that condition (less accessible novel) had the worst performance in terms of acquisition.

In summary, we have evidence that the morphological structure of a less familiar or unknown word influences how well that word is learned. If the target is accessible through morphological analysis, readers are more likely to acquire that meaning, and there is a processing cost associated with that accessibility. The current results also support the usefulness of context in determining novel word meaning. In addition, we found that an individual's vocabulary knowledge, both breadth and depth, contributes to how well one is able to acquire new vocabulary and the processing that they engage in during vocabulary acquisition.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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APPENDIX

Katherine Binder, PhD, is the William R. Kenan, Jr. Professor of Psychology at Mount Holyoke College. Her research interests include how skilled readers use various sources of

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Table A1.

Fit indices for eye movement measures that assess null model compared with the full models in which word type, accessibility, and the interaction terms are included.

Eye movement measure	Model	Log likelihood	AIC	BIC
Gaze duration	Null	41,159	41,163	41,175
	Full	40,904	40,910	40,928
Total time	Null	45,284	45,288	45,300
	Full	44,714	44,720	44,738
Regression to target	Null	5,615	5,619	5,631
	Full	5,563	5,569	5,587
Regression from target	Null	4,349	4,353	4,365
	Full	4,186	4,193	4,210

AIC, Akaike information criterion; BIC, Bayesian information criterion.

Table A2.

Fit indices for eye movement measures that assess null model compared with the full models in which vocabulary depth and vocabulary breadth are included.

Eye movement measure	Model	Log likelihood	AIC	BIC
Gaze duration	Null	40,679	40,685	40,703
	Full	40,644	40,652	40,676
Total time	Null	44,312	44,318	44,336
	Full	44,256	44,264	44,288
Regression to target	Null	5,384	5,390	5,408
	Full	5,348	5,356	5,380
Regression from target	Null	3,885	3,891	3,909
	Full	3,836	3,844	3,868

AIC, Akaike information criterion; BIC, Bayesian information criterion.

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Highlights

What is already known about this topic

- We know that vocabulary breadth is an important predictor of higher level literacy skills.
- We are beginning to gain an understanding of a different dimension of vocabulary – vocabulary depth. There are a few studies that have demonstrated that breadth and depth are separable dimensions of vocabulary knowledge. We know that for children and second-language learners, vocabulary depth is an important predictor of reading comprehension.
- Incidental vocabulary acquisition is a mechanism by which individuals can grow their vocabulary, and we are beginning to understand how context, word structure, and individual differences contribute to this process.

What this paper adds

- Many studies on incidental vocabulary acquisition simply examine how many new words are acquired. Very few examine the process by which these words are learned. We collected eye movement data to get a better understanding of this process.
- We found that the structure of the word, regardless of whether the target was a real word or a novel word, aided in the acquisition. We also found that readers spent more time processing the morphologically accessible targets compared with the inaccessible real words, but the opposite pattern was found for novel words. Additionally, we found that for the novel words, readers made more regressions out of the less accessible targets compared with the accessible ones, which may indicate that readers could extract information from the target when it was accessible, but when it was not, they tried to search the context to help establish meaning.
- While vocabulary depth has been shown to explain variance in reading comprehension, we have demonstrated that it is important for vocabulary acquisition, too.

Implications for practice or policy

- Both breadth and depth are important in literacy development, and as such, we need to better understand how these constructs contribute to higher level literacy variables.
- Research is beginning to suggest that vocabulary instruction that focuses on developing depth creates more long-lasting vocabulary knowledge in children. In addition, there is some evidence that individuals that have greater depth of vocabulary knowledge are better able to use context to learn the meaning of newly encountered words. Thus, the better we understand vocabulary depth,

the better position we will be in to develop vocabulary instruction that best meets the needs of our students.

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Table 1.

Linguistic characteristics of the target words.

Characteristic	Frequency		Length	
	Mean (<i>SD</i>)	Range	Mean (<i>SD</i>)	Range
Real words				
Accessible	1.16 (1.72)	0–5.31	9.22 (2.10)	6–14
Inaccessible	1.56 (2.23)	0–9.39	5.39 (1.14)	4–8
Novel words				
Accessible	0	NA	10.33 (1.66)	8–12
Less accessible	0	NA	10.89 (1.54)	9–12

Table 2.

Means and standard errors for dependent measures.

Dependent variable	Real word		Novel word	
	Accessible	Inaccessible	Accessible	Less accessible
Vocabulary accuracy	0.61 (0.02)	0.50 (0.02)	0.61 (0.02)	0.26 (0.02)
Gaze duration	365.93 (12.30)	320.92 (16.05)	455.56 (12.71)	460.63 (13.41)
Total time	578.52 (27.71)	505.22 (33.84)	878.75 (28.35)	939.96 (29.48)
Regressions to target	0.39 (0.04)	0.44 (0.04)	0.62 (0.04)	0.41 (0.04)
Regressions from target	0.15 (0.03)	0.22 (0.03)	0.12 (0.03)	0.41 (0.02)

Table 3.

Accuracy and eye movement data.

Dependent variable	β	SE	<i>t</i>	<i>p</i>
Vocabulary accuracy				
Word type	−0.24	0.04	−5.97	<.001
Accessibility	0.12	0.03	3.48	=.001
Word type × Accessibility	0.24	0.04	5.38	<.001
Gaze duration				
Word type	139.66	20.00	6.98	<.001
Accessibility	44.96	16.56	2.71	.007
Word type × Accessibility	−50.03	21.86	−2.29	.02
Length	4.39	2.82	1.56	.12
Word type × Accessibility × Length	0.74	10.09	0.07	.94
Total time				
Word type	434.74	39.88	10.90	<.001
Accessibility	73.30	33.83	2.17	.03
Word type × Accessibility	−134.51	45.14	−2.98	.003
Length	7.63	5.31	1.44	.15
Word type × Accessibility × Length	4.83	18.91	0.26	.80
Regressions to target				
Word type	−0.03	0.05	0.54	.59
Accessibility	−0.05	0.04	−1.15	.25
Word type × Accessibility	0.26	0.06	4.46	<.001
Length	−0.006	0.007	−0.91	.37
Word type × Accessibility × Length	0.03	0.03	1.21	.23
Regressions from target				
Word type	0.19	0.04	4.70	<.001
Accessibility	−0.07	0.03	−2.19	.03
Word type × Accessibility	−0.21	0.05	−4.72	<.001
Length	0.01	0.006	1.73	.08
Word type × Accessibility × Length	−0.02	0.02	−0.79	.43

Table 4.

Multiple regression analyses evaluating the roles of vocabulary depth and breadth in outcome measures.

Dependent variable	β	<i>SE</i>	<i>t</i>	<i>p</i>
Vocabulary accuracy				
Breadth	0.07	0.015	4.32	<.001
Depth	0.04	0.009	4.18	<.001
Gaze duration				
Breadth	-42.82	17.42	-2.46	.02
Depth	3.87	17.44	0.22	.83
Total time				
Breadth	6.22	44.28	0.14	.89
Depth	-14.33	44.32	-0.32	.75
Regressions to target				
Breadth	0.00	0.05	0.01	.99
Depth	0.15	0.05	3.15	.002
Regressions from target				
Breadth	-0.01	0.03	-0.30	.76
Depth	0.12	0.03	4.48	<.001