Technology and Vocabulary

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Introduction

Vocabulary knowledge is one of the most important components of L2 proficiency (Schmitt, 2010). At the same time, the acquisition of L2 vocabulary is particularly challenging because it is item-based as opposed to rule-based acquisition of grammar. That is to say that vocabulary items (words and multiword units) need to be learned one-by-one, which requires repeated exposure and practice. Furthermore, learners need to be actively engaged with the target lexical items for them to be committed to memory and eventually acquired. With the exponential growth of technological applications for L2 learning in recent years, many tools and methods have come to the aid of learners by increasing both the frequency of exposure and the level of engagement.

Historical Perspectives

Historically, the importance of L2 vocabulary knowledge has been downplayed in comparison to grammar both in Second Language Acquisition (SLA) research and in language teaching. González-Fernández and Schmitt (2017) found that the dominant method of language teaching since the end of the 18th century and well into the 20th century has been the grammar translation method that largely neglected vocabulary while focusing entirely on grammar. The subsequent theories and methods have continued this "relative neglect" and "a lack of a

principled approach for vocabulary teaching" (González-Fernández & Schmitt, 2017, p. 281): the audio-lingual method, the cognitive method, and even the communicative language teaching method. The interest in vocabulary started re-emerging in the late 1970s with an especially strong impetus provided by Nation's (1990) book *Teaching and Learning Vocabulary,* "which nearly singlehandedly inspired a renewed interest both in vocabulary research and teaching" (González-Fernández & Schmitt, 2017, p. 281).

Nation's (1990) main contribution was his proposal of a principled approach to teaching vocabulary based on word frequency. This approach, which promptly gained popularity, has also sparked a close collaboration between L2 vocabulary researchers and corpus linguists. Importantly for the theme of this volume, this collaboration also represents one of the first intersections between SLA research and technology. Word frequency lists could be automatically extracted from electronic corpora, large electronic collections of texts. Such lists have laid the foundation for much of SLA vocabulary research that established Lexical Frequency Profiles – the number of words from different frequency bands that the learner knows (Laufer & Nation, 1995). Furthermore, these lists were used in so-called 'lexical syllabi' proposed by Willis (1990) that were based on a systematic teaching progression from more frequent to less frequent words.

Beyond the applications of the corpus-informed frequency principle, the technology strand lagged behind in vocabulary acquisition research that tended to focus on paper-based teaching materials (books, dictionaries, printouts). Only a decade ago, Martinez and Schmitt (2010) noted that "formal research into the effect various technologies have on vocabulary acquisition is still in its infancy" (p. 26). Around the same time, however, the situation began to change drastically with the rapid development of ever more sophisticated technologies and associated research. The SLA theories undergirding this research have also been getting more

diverse. Although the interactionist perspective has traditionally been and still is prevalent in L2 vocabulary research, other approaches such as sociocultural theory and complexity theory have also been gaining attention (Godwin-Jones, 2018).

Critical Issues and Topics

One of the generally acknowledged fundamental facts about word knowledge is that it is complex and multidimensional. According to Nation's (1990) seminal taxonomy, it includes three main aspects –form, meaning, and use – each consisting of multiple dimensions, each, in turn, being realized as receptive or productive knowledge. For example, having receptive knowledge of the spoken dimension of a word form means knowing what the word sounds like, whereas having productive knowledge of the same dimension means ability to pronounce the word. Research has shown that the acquisition of these multiple dimensions is not linear but complex and incremental (Schmitt, 2010). Receptive knowledge generally is more easily and quickly acquired than productive knowledge. Further, vocabulary knowledge can grow horizontally, thus increasing its breadth, or vertically, thus increasing its depth. The first process involves the expansion of the vocabulary size, i.e., learning more and more basic L2 form-meaning mappings, whereas the second process involves learning more and more about the same word, such as its usage patterns, collocations, synonyms, etc. L2 knowledge breadth has generally been shown to develop earlier than L2 knowledge depth. Breadth of knowledge is considered critical for achieving intermediate L2 proficiency, as a certain quantitative threshold is necessary for learners to be able to use the language at a functional level. Depth of knowledge is acquired incrementally over time and is usually associated with more advanced L2 proficiency levels. Recent large-scale quantitative studies convincingly demonstrate that receptive and

productive knowledge, on the one hand, and vocabulary breadth and depth, on the other hand, are strongly intercorrelated yet clearly distinct constructs (González-Fernández & Schmitt, 2020; Koizumi & In'nami, 2020).

Understanding about the nature of L2 vocabulary knowledge and the associated challenges faced by learners discussed above has largely been established through laboratory experiments or corpus studies comparing native speaker and learner vocabulary usage. Another research strand, Instructed Second Language Acquisition (ISLA), has proposed and explored instructional methods that can aid learners in overcoming these challenges. Synthesizing the findings of this research, Laufer (2017) summarized the three I's necessary for successful L2 vocabulary acquisition: Input, Instruction, and Involvement. The Input principle acknowledges the item-based nature of vocabulary knowledge learning and the need for extensive and repeated exposure to specific lexical items. Learners can enlarge their lexicon incidentally through extensive reading, i.e. without explicit instruction or another form of teacher mediation (Pellicer-Sánchez, 2016). The Instruction principle, however, posits that the acquisition process can be accelerated by instructional interventions. For example, research has shown that seeding instructional texts with target words (Webb et al., 2013) or input enhancement such as underlining (Boers, Demecheleer, et al., 2017) can attract learner attention to target items and improve learning of both words and collocations. Finally, the Involvement principle states that learners need to actively do something with the target vocabulary to learn it (Laufer & Hulstijn, 2001). By now, ISLA research has proposed a range of instructional tasks and activities beneficial for the acquisition of different dimensions of vocabulary knowledge.

Technology has been used by L2 vocabulary researchers to explore the questions and to test the principles listed above. Corpus studies have helped create lexical frequency profiles of

native speaker and learner usage; technology-based data collection and analysis methodologies (e.g., eye tracking, key logging, data mining) have been used for data collection and analysis; and different instructional technologies have been proposed and their effectiveness tested in ISLA vocabulary studies. The research overview in this chapter is primarily focused on this latter direction.

Current Contributions and Research

Multimedia Input: Digital Reading, Listening, and Viewing

Extensive reading has long been considered the best method for incidental vocabulary acquisition (e.g., Rott, 1999). Recent technological advances have significantly extended and augmented the ways to engage learners with L2 input. Mobile electronic devices (e-readers) provided the convenience of access and storage of large amounts of reading texts. Beyond reading, listening to songs (Pavia et al., 2019) and viewing TV programs (Peters & Webb, 2018) have been found beneficial for L2 acquisition. Furthermore, technology afforded new ways of input enrichment: instead of reading texts seeded with repeated target words sequentially, the learners could now receive double or triple input simultaneously by reading and listening to the same text and seeing associated pictures or viewing a video. Viewing videos with captions has been found to be an effective learning tool (Montero Perez et al., 2013; Wang, 2019) that can be turned on and off to adjust scaffolding to learners' individual needs and proficiency levels (Godwin-Jones, 2018).

Theoretical support for this method can be found in Mayer's (2014) Cognitive Theory of Multimedia Learning (CTML), which argues that presenting information in multiple media

simultaneously reduces the cognitive load imposed on the learner. Generally, this argument was borne out in empirical research. For example, learners who engaged in reading while listening (RWL) made significant short-term and long-term receptive and productive gains in vocabulary learning (e.g., Webb et al., 2013), and also higher gains than learners who were merely reading (e.g., Webb & Chang, 2012). Subsequent research, however, has pointed out many moderating factors. For example, RWL was found better for learning word meaning than spelling and use (Chang, 2019) and more or less effective depending on learners' working memory and aptitude (Malone, 2018). In their recent meta-analysis, de Vos et al. (2018) did not find enough studies to statistically confirm any added value of audio and audiovisual input for word learning from spoken input, thus suggesting a promising avenue for future research.

Multimedia Glosses

The most prominent research direction in multimedia vocabulary learning has focused on glossing. Glosses are translations or short definitions of selected words. Whereas paper glosses are provided at the bottom or on the margins of a text, digital glosses are provided through hyperlinks to text, graphics, audios, or videos (Yun, 2011). The main purpose of glosses is to enhance incidental learning, i.e., to aid reading comprehension in a relatively unobtrusive way that does not much distract the learner from reading for meaning. Empirical studies spanning the last 25 years have corroborated this principle, showing that generally, visual glosses (pictures or videos) in combination with text glosses were better for L2 vocabulary learning (especially receptive skills) than text glosses alone (e.g., Boers, Warren, et al., 2017; Chun & Plass, 1996; Yun, 2011).

Many researchers caution, however, that the information should not become too redundant, thus setting limits to Mayer's (2014) CTML principles (see above). Ramezanali et al.'s (2020) meta-analysis confirms that dual-media glossing is overall more efficient than single-medium glossing (medium effect, g=0.46, for immediate posttests and small effect, g=0.28, for delayed posttests) but using more than two gloss modes is not. Moreover, even dual-media glossing may lead to worse learning than single-medium glossing for lower proficiency learners (Boers, Warren, et al., 2017; Peters et al., 2016). Ramezanali and Faez (2019) further found that high proficiency learners benefited more from L2 definitions and low proficiency learners from L1 translations. Montero Perez et al. (2018) showed that students who watched videos with glossed keyword captions (with access to meaning) scored better on the form recognition and meaning recall tests than students who watched videos without captions, with full captions, and with non-glossed keyword captions. Significant effects were found for intentionality of learning (Khezrlou et al., 2017), auditory or visual learning style (Rassaei, 2018), working memory (Gass et al., 2019), as well as text and test type (Ramezanali et al., 2020) suggesting that the efficacy of glossing is moderated by a wide range of factors.

One new direction in multimedia glossing is augmented reality (AR) technology. Godwin-Jones (2016) listed a number of emerging marker-based AR projects in which virtual glosses (markers) were assigned to physical objects by digital devices, such as European Kitchen (Seedhouse et al., 2014). Reports on these projects uniformly showed a high level of student engagement and motivation, although studies of specific learning outcomes have been rare. A notable exception is Ibrahim et al. (2018) who investigated the efficacy of the ARbis Pictus application. During the experiment, participants (US university students) walked around a room with a Microsoft HoloLens AR display mounted on their heads and looked at objects marked

with virtual textual labels with object names in a foreign language completely unknown to them (Basque). The authors found that participants made significant gains on immediate and delayed receptive and productive vocabulary tests. Moreover, their productive knowledge improved significantly more than with a traditional flashcard method. Additionally, participants enjoyed the AR method more, and it was especially efficient for lower ability students. The authors conclude by calling for more research into the effectiveness of AR applications.

Computer-Mediated Communication (CMC)

The first CMC platforms that emerged in L2 learning contexts at the turn of the millennium were text-based and divided into synchronous (SCMC, such as text chat or messenger) and asynchronous ones (ACMC, such as email or discussion board). They were soon expanded through video-based platforms (such as Skype). The rapid growth in the popularity of these applications was undergirded by the interactionist theory claims that meaning-focused interactions are, at the same time, conducive to learners' focusing on form and noticing (Gass, 1997). Additional benefits of CMC in comparison to face-to-face (FTF) interactions were a less threatening environment and chat logs (in text-based CMC) that scaffolded learner comprehension and production. Early empirical studies have indeed confirmed that CMC led to many spontaneous discussions of form (a. k. a. language-related episodes, or LREs), vocabulary in particular (e.g. Blake, 2000; Tudini, 2003). For example, Smith (2003) found that 34% of all learner SCMC production was focused on negotiations for lexical meaning, while Smith (2004) showed that learners retained words that were focused on during LREs better than those that were not.

Subsequent studies have shifted their attention to exploring the effectiveness of different learning tasks and CMC types, albeit with mixed results. Smith (2003) found that decision-making tasks in written SCMC elicited many more LREs focusing on target vocabulary, whereas jigsaw tasks triggered many more LREs focusing on non-target vocabulary. Yilmaz and Granena (2010) concluded that the dictogloss task elicited more lexical LREs than the jigsaw task, while Yanguas and Bergin (2018) found the jigsaw task more conducive to lexical LREs, and Yilmaz (2011) did not find any difference. These non-uniform findings may be attributed to contextual differences between studies (institutional and cultural context, CMC mode, and learner proficiency and age). Regarding the role of specific CMC media, Yanguas and Bergin (2018) found that the video and audio CMC groups produced an equal number of lexical LREs.

Another research strand focused on teacher-learner SCMC exchanges and the effectiveness of teacher recasts (implicit feedback expressed as teacher repetition of learner utterances with errors corrected). For example, Smith (2012) showed that lexical recasts were much more efficient than grammatical ones in terms of learner noticing and post-intervention recall than grammatical recasts. Henderson (2019) found that learners who received either immediate or delayed teacher feedback via lexical error repetition and recast outperformed learners who received no feedback, indicating that any type of feedback aids vocabulary acquisition. This result is especially impressive because learning was measured with production (picture description) tests that are more difficult than receptive tests that have been more prevalent in research.

Collectively, these studies are in line with the interactionist SLA theory showing that learner interaction, including CMC, is beneficial to L2 vocabulary acquisition. However, it is still unclear if CMC is better than FTF communication. In fact, the two available meta-analyses

found a small advantage of FTF communication over CMC for lexical learning (Lin, 2015: g=0.616; Ziegler, 2016: d=0.34), although only three empirical studies were considered in each meta-analysis. In a recent study, Li and Cummins (2019) demonstrated that texting was better than traditional deductive instruction for vocabulary learning. Therefore, much more research is needed to explore the effects of the interaction mode.

Corpus-Based, or Data-Driven, Learning

Corpora have been used in L2 teaching since their emergence in the 1960s, first as reference resources for lexical syllabi. In the late 1980s, more direct applications started emerging, termed by Johns (1990) as Data-Driven Learning (DDL). Boulton (2017) explains the theoretical tenets of DDL as follows: "[Contact with corpora] provides the massive contextualised exposure needed for language learning, but in a more controlled way than purely haphazard exposure via regular reading or listening, thus promoting or enhancing noticing, language awareness, autonomy, and ultimately producing 'better learners'" (p. 483). This benefit of DDL can be explained from the central argument of usage-based SLA theories that languages are best learned from repeated exposure to multiple usage examples in different contexts (Ellis, 2017). Another principle associated with DDL since Johns (1990) is discovery learning, when students peruse corpora directly in search for word use patterns. Some studies have indeed found that such inductive, hands-on DDL leads to significant gains in lexical and collocational knowledge, often higher than with textbook-based deductive teaching methods (e.g., Garner, 2013). Furthermore, the benefit of hands-on DDL with open-access corpora extends beyond the classroom and can become a life-long learning tool (Vyatkina, 2020a). However, DDL researchers highlight the importance of tailoring it to specific learner populations. Success with

'hard', hands-on (Gabrielatos, 2005) versions of DDL, in which learners explore corpora independently, has mostly been associated with cognitively mature learners with relatively high L2 proficiency. In contrast, 'softer' DDL with corpus examples preselected and printed by teachers has been recommended for younger and lower proficiency learners (Crosthwaite, 2019). For example, Poole (2012) found that advanced EAP learners (college students) who learned with online textual glosses enhanced with modified corpus-extracted sentences presented in concordance lines gained more productive knowledge than the group who worked with textual glosses enhanced with dictionary definitions. In contrast, Karras's (2016) secondary school EFL students learned best after longitudinal training that combined online dictionary use and corpus use. Lee et al. (2019) have uncovered hidden differences in learner types and learning styles, finding that some learners performed best on a vocabulary recall test with concordance lines glossing alone, while others benefited more from a concordance-dictionary gloss combination.

DDL research results have been synthesized in recent meta-analytic studies. Boulton and Cobb (2017) found that DDL led to significant learning gains (small effect, d=1.54 for both vocabulary and lexicogrammar) and was better than non-DDL methods (medium effect, d=0.68 for vocabulary and d=0.75 for lexicogrammar). Lee et al. (2018) found an overall medium-sized effect of DDL on vocabulary knowledge for both short-term learning (g=0.74) and long-term learning (g=0.64). Interestingly, Lee et al. showed that DDL was especially efficient for learning aspects of vocabulary depth such as syntactic features and collocations. Therefore, DDL can be suggested as an especially effective method for deepening the knowledge of words already known to learners at the level of basic form-meaning mapping.

Gaming

Digital games are another emerging CALL technology that has been spreading especially rapidly over the recent years. There is a wide variety of game types currently available to users, ranging from downloadable L2 vocabulary apps to commercial off-the shelf (COTS) games to massively multiplayer online games (MMOGs). The number of associated empirical studies has also been growing rapidly. They explore L2 vocabulary learning processes, outcomes, and moderating factors such as learner age, game type, and gaming time. Bytheway (2015) identified 15 vocabulary learning strategies that learners used in MMOGs. Several studies found that game-playing facilitated long-term retention of the target vocabulary significantly more than textbook-based learning, both as a result of playing a COTS game (Hitosugi et al., 2014) and a simple simulation game (Franciosi et al., 2016). Shintaku's (2016) learners of Japanese made significant gains in L2 vocabulary they incidentally encountered during a 3D virtual world game but only game-essential vocabulary was retained. Chen et al. (2019) found a vocabulary learning mobile phone app with game-related functions more efficient than an app without such added functions, while Sundqvist (2019) demonstrated that the time spent on gaming was more important for receptive and productive vocabulary gains than the game type, suggesting that any dedicated games help learners acquire new words. Terantino (2016) and Jensen (2017) expanded research to young learners of English. Both studies found that independent out-of-class gaming with parental guidance led to significant gains in L2 vocabulary knowledge.

Collectively, these studies confirm the benefits of gaming for L2 vocabulary learning, including multiple opportunities for practice, language socialization, and contextualized learning, access to discourse diversity and complexity, and lowered affective filters (Reinders, 2012; Reinhardt & Sykes, 2014). Available research syntheses are based on only a handful of empirical studies, but results are uniformly positive. Chiu et al. (2012) meta-analyzed digital game-based

learning in the EFL setting and found that it had led to significant L2 knowledge gains, with a larger effect size (d=1.1) for meaningful and engaging games than drills (d=0.4). Jabbari and Eslami (2019) conducted a scoping review of different aspects of COTS and MMOGs and concluded that, in the few available empirical studies published in 2000-2015, these games lead to significant improvements in lexical knowledge (Rankin et al., 2006; Sylvén & Sundqvist, 2012).

Main Research Methods

All studies reviewed above have explored the efficacy of technology-enhanced teaching tools and methods for L2 vocabulary development. A comprehensive methodological overview of such recent research was conducted by Elgort (2018), who termed it Technology-Mediated Vocabulary Development (TMVD) research. She identified 82 TMVD studies published between 2010 and 2017 that used the following types of technology: "specialized CALL software (n = 28), digital reference tools, such as glosses and dictionaries (n =15); computer-mediated communication (CMC) (n = 13), digital video-based learning (n = 13), data-driven learning (DDL) and corpora-mediated learning (n = 12), digital games and gaming (n = 10), mobile learning (n = 9), learning management systems (LMS) (n = 4), e-books (n = 3), and social software (n = 2)" (Elgort, 2018, pp. 7-8). The overwhelming majority of studies (78) were quantitative, with experimental-control and/or pretest-posttest designs, or employed mixed methods. The technology treatment in these studies was "input-driven learning, frequently combined with language-focused activities" (Elgort, 2018, p. 12). This shows that TMVD research generally follows the main methodological trends in the mainstream ISLA vocabulary research. Elgort points out some robust trends in TMVD research designs such as a high average

number of participants (67) and vocabulary items (37) per study, inclusion of a delayed posttest (in 35% of the studies), and attention to various task and learner characteristics, such as first and target language, age, proficiency, etc. The majority of studies were conducted in academic settings with university students. The target language was predominantly English (82%), with the most frequent first language being Chinese. Form-meaning mapping was the most frequently investigated aspect of word knowledge, followed by collocational knowledge. This is, again, in line with current trends in mainstream L2 vocabulary research (Elgort, 2018, pp. 13-14). The focus on holistic vocabulary development (overall vocabulary size) was, in contrast, rare. The studies were equally divided by the knowledge type measure, with a third using receptive measures, productive measures, or a combination thereof, respectively. Explicit and offline measures were used more frequently than implicit and online measures. 96% of the studies found that technology-mediated teaching and learning was more effective than traditional methods. In contrast, only 46% of the studies that compared different technology methods found that one was more effective than the other.

Especially promising is the new methodological trend to use technology both as a teaching and research tool. For example, Chukharev-Hudilainen and Klepikova (2016) used their *Linguatorium* adaptive tutoring tool to both teach L2 vocabulary and collect a detailed log of data that documented participants' interaction with the system throughout a semester. This pioneering methodology allowed the researchers to track student day-to-day progress, estimate the time they spent on working with the application, and evaluate their short-term lexical learning as well as long-term retention of the target lexical items. They also showed that EFL learners increased their long-term vocabulary retention threefold after spending only about three

minutes a day with *Linguatorium* over a semester and improved significantly more than a control group, thus tying learner progress directly to the use of a specific tool.

Recommendations for Practice

There are a number of recommendations for teaching L2 vocabulary that can be derived from the above overview. Generally, technology can help realize Laufer's (2017) three I's that are essential for successful vocabulary acquisition: Input, Instruction, and Involvement. Technology provides learners with rich lexical input published in different media (text, audio, video, etc.) on the internet, often with free access. This input can be significantly enhanced by instruction with teachers designing various learning tasks that utilize technology. Such tasks are generally enjoyed by the learners, especially if the technology is novel, creative, easy to use, and attractively designed, thus increasing the level of learner motivation and involvement. While designing these tasks, teachers may avail themselves of many available technology resources. As with any technology, these resources may be dedicated (i.e., designed specifically for language teaching purposes) or non-dedicated (i.e., designed for other purposes or not primarily for language teaching purposes). Examples of the latter are online search engines, electronic dictionaries, and language corpora. Examples of the former are dedicated vocabulary learning programs such as flashcard-based spaced repetition programs (e.g., Nakata, 2011) and mobile applications with vocabulary practice activities (e.g., Stockwell, 2007). With the constantly growing number of resources (see Godwin-Jones, 2018), teachers are faced with a burden of choosing appropriate tools and tasks. Ma (2013) suggests the following list of recommended characteristics of dedicated software: "Vocabulary learning is both contextualized and itemized; it is both meaning and form focused (explicit learning); it combines tutor with tools; it covers

both the initial learning process and the subsequent rehearsal" (p. 235). Opting for such resources that have been found beneficial for learning in TMVD research can be one possible solution for teachers.

Recommendations regarding technology can also be made through extending pedagogical implications from the broader, non-TMVD, L2 vocabulary research domain. González-Fernández and Schmitt (2017, pp. 288-292) list a number of vocabulary learning principle / teaching tip pairs. Four of these pairs are referenced below, with the teaching tips amplified with suggestions for how technology can help.

1. Substantial vocabulary can be learned incidentally but this requires repeated exposure, for both expanding vocabulary size and learning such aspects of vocabulary knowledge depth as collocations.
    1.1. *Teaching tip:* add extensive reading components to the curriculum.
    1.2. *How technology can help:* engage learners in multimedia reading, listening, and viewing (reading while listening; reading with multimedia glosses; viewing captioned videos, etc.). Consider enhancing reading texts with multimedia glosses that are "adaptive and flexible, providing options to users in terms of nature and extent of glossing information" (Godwin-Jones, 2018, p. 4). Examples of innovative glossing are AR glosses (Ibrahim et al., 2018) and hyperlinks to corpus concordance lines with collocations. In the latter method, inappropriate collocations in student writing are automatically highlighted and a number of suitable collocations from linked corpora suggested (Frankenberg-Garcia et al., 2019; Pereira et al., 2016). Another emerging way to scaffold data-driven learning of collocations is through teacher- and learner-friendly corpus guides and online exercises (e.g., Poole, 2019; Vyatkina, 2020b).

2. Intentional learning can lead to faster, greater, and more durable gains in L2 vocabulary knowledge than incidental learning.
    2.1. *Teaching tip:* determine what words your learners are unlikely to know, create vocabulary lists, make the learners study them before coming to class, and link them with a speaking, listening, reading, or writing assignment that uses these words.
    2.2. *How technology can help:* draw learners' attention to specific vocabulary items when they engage in meaning-focused tasks with digital tools (CMC, digital reading/listening/viewing, gaming) as well as assign focus-on-forms tasks (e.g., corpus-based tasks with concordance lines that enrich the input with many usage examples and enhance it via highlighting of the target words). Webb (2011), for example, recommends intensive viewing of selected video episodes in class accompanied with form-focused exercises and discussion of viewing strategies. Varying the TMVD tasks accordingly, the teachers can expose their learners to all strands proposed by Nation (2007) as beneficial for vocabulary instruction: learning from comprehensible, meaning-focused input; meaning-focused output; language-focused or form-focused instruction; and fluency development.
3. Multiple encounters with a word are necessary.
    3.1. *Teaching tip:* teachers need to create supplementary materials such as word games and speaking activities with a target word list to ensure vocabulary recycling and elaboration.
    3.2. *How technology can help:* Digital texts are easily manipulated, so teachers can use word count tools to establish target item frequency as well as manually increase it. Moreover, there are programs that help create sets of naturally occurring texts so that target items are repeated a predefined number of times, such as *TextLadder* (Ghadiran, 2002).

Furthermore, there are learning apps that use sophisticated adaptive tutoring: spaced repetition algorithms that ensure that vocabulary is recycled at specific intervals, which is conducive to learning (e.g., Chukharev-Hudilainen & Klepikova, 2016, see Godwin-Jones, 2018, for more suggestions). Consider using digital games shown to be beneficial for L2 vocabulary learning while also enjoyable to learners.

4. Teachers should select those words that are as useful for learners as possible.
   4.1. *Teaching tip:* use published vocabulary lists designed for learners at different proficiency levels and for different registers (e.g., academic word lists).
   4.2. *How technology can help:* Vocabulary lists are created using technology with reference to word frequency in native speaker corpora. Beyond that, teachers can use technology themselves for judiciously selecting vocabulary for instruction. There are automated text analyzers, such as *Compleat Lexical Tutor* (Cobb, n.d.), that establish text vocabulary profiles based on vocabulary range and sophistication, so that teachers can select texts at levels suitable for their students (e.g., Chen & Meurers, 2018; see Godwin-Jones, 2018, for more suggestions). Words that are frequent in general corpora contribute more significantly to learner proficiency than infrequent words (Sakata, 2019). Therefore, teachers should incorporate such words in their teaching, especially if they are infrequent in the textbooks they are using, and integrate them with speaking, listening, reading, or writing assignments.

Future Directions

As far as specific technologies are concerned, the following research gaps have been identified in research reviewed in this chapter. In multimedia viewing/reading/listening research,

the relative effectiveness of different media (e.g., audio vs. audiovisual treatment) remains underexplored (de Vos et al., 2018). Glossing has been studied extensively, but research into the effectiveness of innovative technologies such as corpus-based (Frankenberg-Garcia et al., 2019) and AR (Ibrahim et al., 2018) glossing is still in its infancy. More such research is needed, especially as these technologies become increasingly more widespread and affordable, such as Google Word Lens (https://lens.google.com/). Previous research has convincingly shown that CMC is beneficial to L2 vocabulary acquisition but the conclusion on the relative advantages of different media and task types is still outstanding. Similarly, more empirical research on the relative effectiveness of different games is needed.

Methodologically, it is important to explore a variety of factors, such as time on task and amount of attention, which may play an even bigger role in vocabulary acquisition than technology type or the number of encounters (Gass et al., 2019; Mohamed, 2018; Smith, 2012; Sundqvist, 2019). The L2 repertoire should be expanded, as the overwhelming majority of studies has focused on English. A list of further methodological recommendations can be found in Elgort (2018): 1) participants' overall L2 proficiency should be measured and the measures should be reported; 2) the efficacy of different technology-enhanced methods should be compared, moving away from the still prevalent one-technology vs. no-technology designs; 3) lexical learning should be connected to skills development, for example in explorations of oral and written fluency development; 4) holistic vocabulary growth (vocabulary size) should be explored (see Cong-Lem & Lee, 2020) in addition to the acquisition of aspects of specific lexical items (vocabulary depth); 5) online and implicit measures should be used in addition to offline and explicit measures; and 6) lexical development and the use of technology for this purpose outside of the classroom should be explored (see Lai et al., in press). In the future, the growing

body of empirical research should enable more meta-analyses which would yield more definitive evidence of the relative effectiveness of technology types and tasks as well as reveal various moderating factors.

Finally, combining the use of innovative technology for both teaching and research purposes seems especially promising. Such applications should be based on sound pedagogical principles and assist teachers in using the methods that have been shown conducive to vocabulary learning. Ma (2013), for example, calls for the use of software beyond eye-tracking to explore learner behavior while completing TMVD tasks. Such systems, implemented either as built-in modules in vocabulary learning applications or external plug-ins, allow to "monitor and record a range of data, including mouse clicks, key presses, cursor movement and texts entered, to be assembled into a log file for research purposes" (pp. 235-236). TMVD researchers may also invite app developers to move away from drill-like software. As Nakata (2011) notes, many existing programs do not support students' retrieval efforts and productive use of vocabulary, which have been shown to be crucial for vocabulary acquisition. Chukharev-Hudilainen and Klepikova (2016) respond to all abovementioned calls with their innovative intelligent tool *Linguatorium.* It allowed teachers and learners to enter custom word lists, generate custom exercises, and receive adaptive tutoring support tailored to each specific student's learning trajectory; and it allowed researchers to track learner progress. More similarly flexible and adaptable tools that give students more freedom and autonomy in learning (Ma, 2013) as well as studies exploring the effectiveness of these tools are needed.

Further Readings

Elgort, I. (2018). Technology-mediated second language vocabulary development: A review of trends in research methodology. *CALICO Journal, 35*(1), 1-29.

The first methodological scoping review of the recent (post-2010) technology-mediated L2 vocabulary research.

Godwin-Jones, R. (2016). Augmented reality and language learning: From annotated vocabulary to place-based mobile games. *Language Learning & Technology, 20*(3), 9–19.

A narrative review of innovative CALL tools including different types of vocabulary learning software.

Godwin-Jones, R. (2018). Contextualized vocabulary learning. *Language Learning & Technology, 22*(3), 1-19.

A narrative review of innovative CALL tools for teaching and learning L2 vocabulary as well as associated research.

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A narrative review of L2 vocabulary research in instructed second language acquisition that is structured similarly to the present chapter yet is not focused on technology.

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