MIND, BRAIN, AND EDUCATION

Grounding Second Language Vocabulary Instruction in Cognitive Science

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ABSTRACT— Cognitive neuroscience has gained significant insight into the mechanisms underlying the mental lexicon and their impact on second language vocabulary learning. However, relatively little effort has been put into understanding how these mechanisms may impact instructional practices. We attempt to bridge this gap. Towards that end, we first describe three main properties of the mental lexicon: words have distinct form and meaning representations; these representations are organized in multilingual network structures organized by similarity; and the representations differ in strength. Next, we translate the properties into a visual framework that we use to reflect upon how this knowledge affects three important choices in vocabulary instruction: composing word lists, selecting an instruction method, and consolidating newly acquired words. Lastly, we discuss opportunities for both science and practice, highlighting the importance of improving the ecological validity of scientific models and theories, and of developing instructional methods grounded in cognitive science.

Acquiring vocabulary is essential to second language (L2) learning (Coady & Huckin, 1997). Learned words are integrated in the (multilingual) mental lexicon, the collection of all the words we know, represented as neural traces in the long-term storage of the brain (henceforth "representations"). It has a complex structure and involves mechanisms that enable efficient word retrieval and learning (Karuza, Thompson-Schill, & Bassett, 2016). The past decades have offered many insights on these underlying mechanisms and their effect on learning (Karuza et al., 2016; Kersten, 2010). However, overall relatively little effort has been put into understanding how they may impact instructional practices.

This is regrettable, because these sometimes unintuitive insights may have implications for L2 instruction. For example, intuition might suggest that the multilingual mental lexicon is organized akin to a dictionary: word-to-word associations, organized in alphabetical language-specific lists, with all words of equal importance. Instead, the form and meaning of words are represented differently in the brain. These representations are, in fact, organized in network structures, where similarity, rather than language membership, is an important organizing principle. And the representations of words in the network actually differ in strength (or ease of access). These are three of the key properties of the mental lexicon that affect the way new words are learned (Meade & Dijkstra, 2017).

We believe that the time is ripe to relate these three properties of the mental lexicon to L2 vocabulary instruction, to ground and move forward vocabulary learning science and practice. This fits the broader movement to bridge the gap between educational practices and cognitive (neuro)science (Battro, Fischer, & Léna, 2010). We use "cognitive science" in the remainder of the paper, as an umbrella term for neuroscience, cognitive science, and cognitive psychology. In this paper, we aim to build such a bridge by developing a visual framework that facilitates a structured reflection on the relations between insights into the mental lexicon and L2 vocabulary instruction.

We first provide a brief review of the cognitive science research into the three mentioned properties and introduce the framework. Next, we use this framework to reflect upon how these properties impact three important choices in vocabulary instruction, namely: 1) selecting which

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words to learn, 2) deciding on a learning method, and 3) using strategies to consolidate the newly acquired vocabulary (Schmitt, 2008). With this aim in mind, we provide a high-level overview of some crucial properties of the mental lexicon and their link to the explicit instruction of vocabulary (for an in-depth review, see for example Kersten, 2010).

THREE IMPORTANT PROPERTIES OF THE MENTAL LEXICON

In the mental lexicon, word representations are coded on two dimensions (form and meaning), in a network structure, with differing strengths between representations. To facilitate reflection on instruction in relation to the three properties, we translate them to a three-dimensional visual framework (Figure 1). Different points within this framework represent the extent to which instruction focuses on form or meaning, takes into account the surrounding network, and strengthens representations. Evaluating methods using this framework helps to determine which aspects can still be improved.

Form and Meaning

Words are largely arbitrary mappings between a form and a meaning. The mental lexicon thus includes two distinct, but interacting, representational dimensions: printed (orthographic) and spoken (phonological) representations in the form dimension; and representations of the knowledge referred to by this form in the meaning (semantic) dimension (Aitchison, 2012).

These dimensions are differently encoded in the brain. Robust connections between the dimensions enable fast transitions from meaning to form (i.e., word production) and from form to meaning (i.e., word comprehension). Acquiring new L2 words implies building new form and sometimes meaning representations, as well as these connections (Abutalebi, 2008; Tagarelli, Shattuck, Turkeltaub, & Ullman, 2019; Yang, Gates, Molenaar, & Li, 2015). The manner in which form and meaning are represented influences how they can best be learned, and creating quality form and meaning representations enhances learning (Perfetti & Hart, 2002).

Distinct Representations for Form and Meaning

Word form involves sublexical information consisting of a combination of visual referents (orthography), i.e., clusters of letters in alphabetical languages that map onto certain sounds and articulatory characteristics (phonology). Orthographic and phonological information is represented separately in the visual and auditory regions of the brain, but also closely interlinked, with some regions having joint neural representations of word form (Chee, O'Craven, Bergida, Rosen, & Savoy, 1999; Zhao et al., 2017). In the remainder of the paper, "word form" will refer both to orthography and phonology when no distinction is required. Orthography to phonology mappings can be one-to-many (same orthography for different pronunciations, e.g., *–ough* in *cough* or *through*) or one-to-one, with complex mappings making learning more difficult (e.g., Burt & Blackwell, 2008).

For meaning, some theories postulate a single semantic store, encoding concepts and their features (e.g., a *bird* has *wings*) (Smith, Shoben, & Rips, 1974). In contrast, embodied cognition theories postulate that meaning is grounded in interactions with the world and are coded in a distributed fashion over a large portion of the brain (Binder, Desai, Graves, & Conant, 2009). For example, the meaning of *walking* can be understood because we have had sensorimotor experiences with walking (Hauk, Johnsrude, & Pulvermüller, 2004). The neural representations may depend on the type of concepts words represent. For example, concrete nouns or action words rely more on embodiment than abstract words (Wang, Conder, Blitzer, & Shinkareva, 2010), and learning concrete but not abstract words involves brain regions associated with imagery (Mestres-Missé, Münte, & Rodriguez-Fornells, 2009). More embodied words are easier to learn (De Groot & Keijzer, 2000).

Associations between Form and Meaning

There are inherent differences in how form-meaning associations are created between L1 and L2. In L1, linking form and meaning is often implicit, facilitated by statistical learning over repeated cross-situational experiences with words and concepts, supplemented by explicit instruction using images of concepts for example (Romberg & Saffran, 2010). In L2 learning, words are often primarily acquired more explicitly, organized according to an instruction method, and in a limited context such as the classroom (Coady, 1997). In such a context, learning can overly emphasize L1–L2 form links, for example, when learning with word lists. Comesaña, Perea, Piñeiro, and Fraga (2009) propose that though learners still rely on conceptual knowledge with such methods, they do so to a lesser extent than in conceptually richer contexts. A conceptually poor context leads to shallow L2 word knowledge, which may be limited to L1–L2 form links (Schmitt, 2014).

Creating these connections is also affected by the complexity of form and meaning associations naturally occurring in language. Even within a language, these are often not one-to-one (Pavlenko, 2009). For example, one word may have multiple meanings (e.g., *bank*); or words can look the same, but have different meanings depending on their pronunciation (e.g., *lead*). Between languages, words can also have similar forms but different meanings (false friends, e.g., *room* in Dutch and English), only subtly differ in form (cognates, e.g., *bel* and *bell* in Dutch and English), or represent

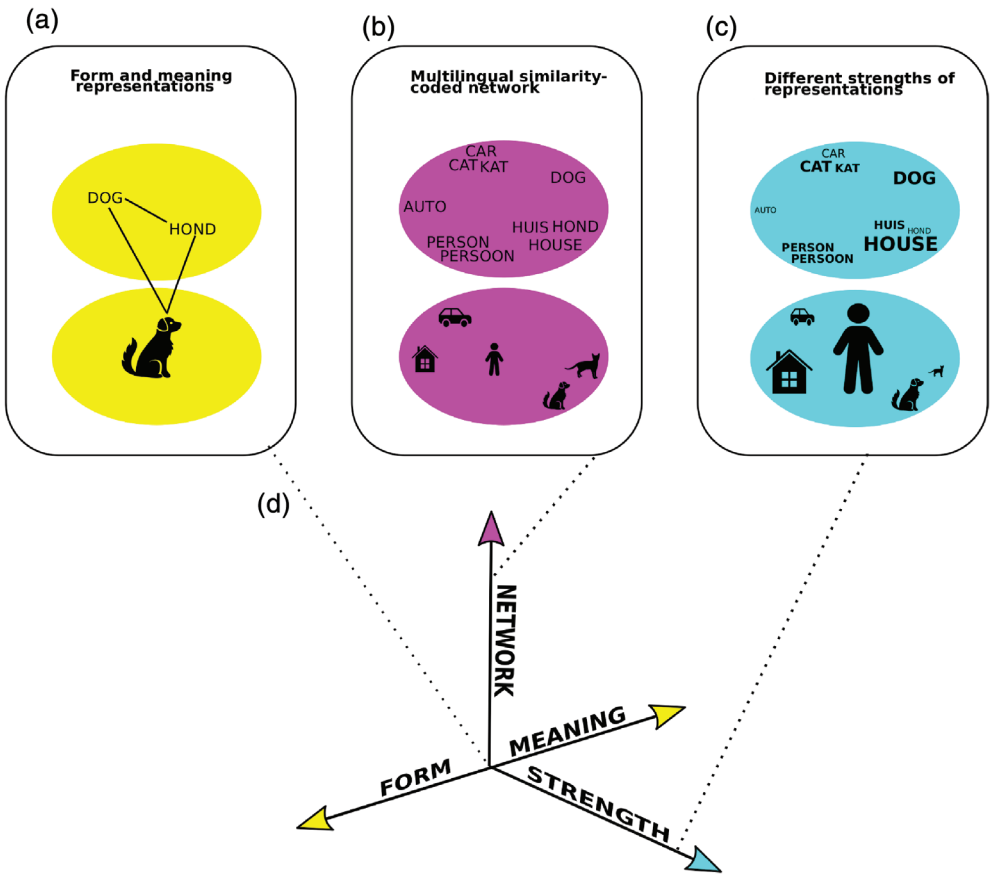

Fig. 1. Visual framework of the three main properties of the mental lexicon. (a) Distinct, but associated, form and meaning representations. On the one extreme of the form-meaning axis, the focus is primarily on written or spoken word form, on the other primarily on meaning. (b) Similarity-coded networks for form and meaning (e.g., *cat* and *car* are close in form, far in meaning; opposite for *cat* and *dog*). On the network axis, at the base the network of a word is not taken into account, while on the other end a large part of the network is accounted for. (c) Different strength of representations (indicated by size of icon). The strength axis describes to what extent instruction focuses on the strength and strengthening of representations.

nondefined meaning in the other language (e.g., the Dutch word with no literal English translation *gezelligheid*). Again, complex associations between form and meaning impact learning (Meade & Dijkstra, 2017). How this is the case is not always straightforward: for example, learning cognates is easier than noncognates (e.g., Tonzar, Lotto, & Job, 2009). However, acquiring the correct L2 form when it only subtly differs from the L1 can be challenging and can cause learners to map their native pronunciation onto L2 words (Amengual, 2012; Trude & Tokowicz, 2011) and make spelling mistakes, for instance, Italian learners of German spelling the word 'Karaffe' as 'Carafe' (Tonzar et al., 2009).

Network Structure

These two separate form and meaning dimensions in turn consist of interconnected networks, in which similarity is a primary organizing principle (Karuza et al., 2016). Many recent models of the lexicon posit that, based on this similarity, words compete for *retrieval*, both within and between languages (Dijkstra & van Heuven, 2002; McClelland & Rumelhart, 1981).

A Similarity-Coded Network

Behavioral studies show that words similar in form (e.g., *rat* and *mat*) or meaning (e.g., *tiger* and *lion*), so-called "*neighbors*," are stored closer together, creating form and meaning *neighborhoods* (Marslen-Wilson, 1987; McClelland & Rumelhart, 1981; Meyer & Schvaneveldt, 1971). Meaning similarity also includes associations, such as in the case of collocations. Neuroimaging experiments also show more similar neural activation patterns in the regions coding the respective dimension for words similar in form or meaning (Zhao et al., 2017; Zinszer, Anderson, Kang, Wheatley, & Raizada, 2016), even reflecting individual associations (Charest, Kievit, Schmitz, Deca, & Kriegeskorte, 2014). Such neighborhoods could influence learning

both positively and negatively (Karuza et al., 2016; Lally, Taylor, Lee, & Rastle, 2020; Meade, Midgley, Dijkstra, & Holcomb, 2018; Stamer & Vitevitch, 2012, Storkel, Armbrüster, & Hogan, 2006; Weber & Broersma, 2012).

Competition in the Lexicon

When retrieving a word (e.g., *car*), not only the target form and meaning, but also its form (e.g., *cat* and *far*) and meaning neighbors (e.g., *bike* and *train*) are activated (Collins & Loftus, 1975; de Groot, 1983; McClelland & Rumelhart, 1981; Meyer & Schvaneveldt, 1971). During the retrieval process, the different word candidates compete until only the correct one remains. This process, including effects of neighborhood size, could help learning by co-activating known words and thereby strengthening new representations (Stamer & Vitevitch, 2012; Storkel et al., 2006); but it could also make recognizing spoken L2 words more challenging (Weber & Broersma, 2012).

A Multilingual Lexicon

The mental lexicon of a multilingual is widely assumed to contain not only semantic representations but also form representations from all known languages. It is also assumed to be integrated across languages and accessed similarly in all of them (Dijkstra, 2007; for a contrasting view in which L1 and L2 forms are stored separately, see Kroll & Tokowicz, 2005). Soon after a learner is exposed to a new L2 word, it enters its neighborhood and takes part in the competition (Bowers, Davis, & Hanley, 2005; Gaskell & Dumay, 2003). Hence, words similar in meaning or form from all known languages initially become activated during retrieval (Talamas, Kroll, & Dufour, 1999; van Heuven & Dijkstra, 2010). This implies that, especially for similar languages, L2 learning is influenced by the L1 (Meade & Dijkstra, 2017).

Strength of Representation

In the lexical network, both form and meaning representations and their connections in the network can vary in strength (Anderson, 1976). Consequently, accessing words in the lexicon is effortless for some words, while finding others is much harder. Strength of representation/association depends (amongst others) on word frequency and on the multimodality of representation.

Word Frequency

Words that are encountered and retrieved more often are more easily retrieved due to stronger representations and neural paths between the form and meaning representations (Alexandrov, Boricheva, Pulvermüller, & Shtyrov, 2011; Diependaele, Lemhöfer, & Brysbaert, 2013). In L1, frequency of encounter largely depends on how often words naturally occur in daily language usage (natural "frequency"), which can differ between individuals. In an L2 instruction setting, frequency of encounter is instead often synonymous with frequency of presentation (Webb & Nation, 2017). This implies that L2 frequency distributions often do not correspond to the L1 natural frequency distribution.

Not only the absolute frequency of a word, but also its relative frequency compared to its neighbors influences how easy it is to retrieve. Highly frequent neighbors are stronger competitors, and hinder or facilitate the retrieval of a target word depending on the task (Segui & Grainger, 1990). For late learners, L2 frequencies of usage are subjectively generally lower than L1 frequencies of translation equivalents or similar words. This can lead to a disadvantage in terms of L2 lexical access (Gollan, Montoya, Cera, & Sandoval, 2008), and in turn to decreased fluency (Schmidt, 1992).

Multimodality

The more modalities words or concepts are encountered in, the stronger their representation. The stronger representations are believed to result from a richer set of retrieval cues, stored as more interconnected patterns in the brain (Alexandrov et al., 2011; Shams & Seitz, 2008). For form, multimodality means reading, listening, writing, and speaking words (Schneider & Kulmhofer, 2016). For meaning, it means an embodied experience of what a concept looks, feels, or sounds like; how it moves; what emotions it triggers in us; or what gestures depict it (Glenberg, 2008; Macedonia, Müller, & Friederici, 2010). Words learned in a semantically rich context have been shown to activate brain regions concerned with the integration of information coming from multiple modalities (Ferreira, Göbel, Hymers, & Ellis, 2015). Accordingly, multimodality helps learning (Macedonia et al., 2010; Schneider & Kulmhofer, 2016).

RELATING VOCABULARY INSTRUCTION TO THE MENTAL LEXICON

After providing an overview of the three main properties of the mental lexicon, we next relate them to three important choices in vocabulary instruction: composing the list of words to learn, choosing a method of instruction, and selecting strategies that help consolidate knowledge by strengthening representations. Each choice can primarily be guided by one plane in the visual framework (Figure 2). Our aim here is not to make strict recommendations, but to highlight different aspects of these steps where the characteristics of the mental lexicon may come into play. These are aspects that instructors should have in mind when teaching L2 vocabulary.

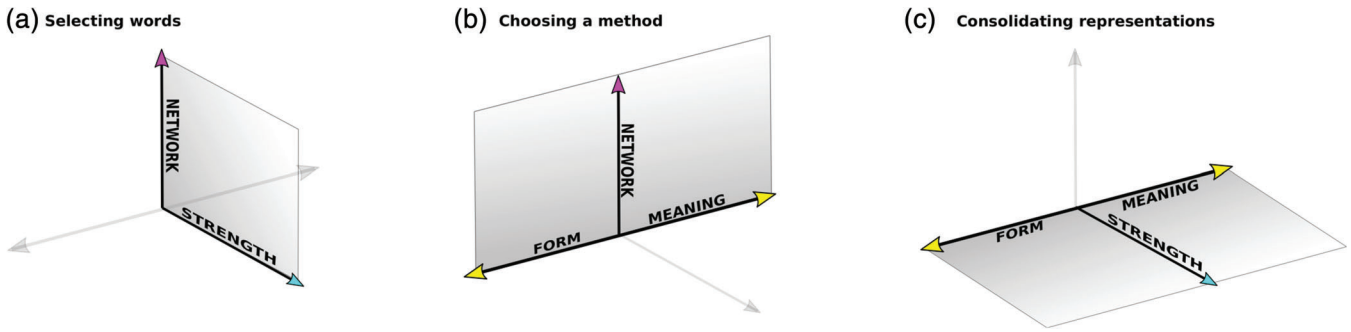

Fig. 2. Three choices in vocabulary instruction and their relation to the visual framework. (a) Selecting words. (b) Choosing a method. (c) Consolidating representations.

Composing the List of Words to Learn

An early step in vocabulary instruction is to decide which words should be learned. At this step, considerations related to the network/strength plane are particularly important; we provide some examples of such considerations. This section highlights the role of teachers and researchers: for teachers, being aware of certain issues when selecting words; for researchers, providing optimized word lists in terms of frequency and similarity.

Network

In practice, handbooks often group words in thematic lexical sets. However, there are mixed findings on which words should and should not be taught together, many of them linked to the network property of the lexicon. For example, semantically related words (e.g., *cat* and *dog*) have been shown to be more difficult to learn together than words that are contextually associated in meaning (e.g., *frog* and *leap*) (Tinkham, 1997). Semantically related words may be producing more interference during learning, but perhaps only when the referents look visually similar (Ishii, 2015; Nation, 2000; Spätgens & Schoonen, 2019). Semantic associations may help learners build mental models and scenarios, thereby also enhancing multimodality through embodiment (Zwaan, 2014).

Furthermore, a significant proportion of spelling mistakes are because of form similarity between words (Llach, 2015). Learning form-similar L2 words (e.g., *comprehensive* and *comprehensible*) has been suggested to cause interference and potentially confuse the learner (Laufer, 1988; Nation, 2000). However, some recent studies have shown a learning benefit when form-similar words are presented together (e.g., Lally et al., 2020; van de Ven, Segers, & Verhoeven, 2018). Whether form similarity helps or confuses may depend on task demands: Indeed, both these studies implicitly required learners to make close distinctions between the similar words. Implicitly directing participants' attention to lexical differences rather than similarities may have led to more precise representations.

Cross-linguistic similarity also influences learning. Sometimes this is positive for learning: When an L2 word is similar to its L1 translation, it is easier to learn, as neighbors act as retrieval cues (e.g., Lotto & de Groot, 1998). On the other hand, learning subtle differences in form or meaning can be more difficult when competing word candidates are more similar to the L1: For example, learning the correct orthography or phonology of the Dutch word *adres* (= address) may be difficult (Schmitt, 2008; Tonzar et al., 2009; Trude & Tokowicz, 2011). Thus, in learning, similarity may help build a global representation but might make building a more specific native one more difficult.

The interplay between the network and strength properties adds intricacy. Newly acquired L2 words may act similarly to low-frequency L1 words (Dijkstra & van Heuven, 2002). As mentioned previously, this can lead to difficulties in lexical access (Gollan et al., 2008), which may impact fluency aspects (Schmidt, 1992). Therefore, choosing words involves awareness of network-related difficulties within the list and within the learner's already known lexicon.

Strength

Regarding strength, a pragmatic recommendation that has often been made is to start by teaching the most commonly used words (Schmitt, 2008). Thinking in terms of frequency, it makes sense: Useful words tend to be used more often, thus increasing frequency of retrieval and strength of representation. Having a knowledge of basic vocabulary enables learners to engage with and use the new language. However, low-frequency jargon words can also be valuable depending on the learners' goal, as it may both increase subjective word frequency and increase the emotional investment of the learner. For example, learning infrequent words while playing video games may be facilitated, because the participants are extra motivated to learn them in the context of the games (Chen & Yang, 2013) and potentially associate strong emotions with these words (next to motivation, emotions

Table 1
Example Vocabulary Instruction Methods and Their Description

Name	*Description*	*Form*	*Meaning*	*Network*
Word Lists	Lists of words in L1–L2 pairwise format.	+[a]	–	–
Flashcards	Cards with L2 word form on recto, L1 translation on verso	+	–	–
Dictionary Work	Looking up L2 words and their definition.	–	+	–
Semantic Grid	Breaking down an L2 word into units of meaning (e.g., "stool" = "chair" + "no back")	–	+	++
Visual imagery	Picture of concept paired with L2 form.	+	+	–
Semantic Mapping	Creating a visual map of L2 words that are connected in meaning.	+	–	++
Word Unit Analysis	Breaking down words into common form units to better understand meaning (e.g., –*nat-* in *innate* and *natural*).	+	+	+
Keyword Method	Visually associating an L2 word with a semantically unrelated L1 form-similar word (e.g., for Spanish word *carta* [letter], visualizing a picture of a cart full of letters).	+	+	+

[a] Relative focus on form or meaning is indicated by + (relatively strong) and - (relatively weak). The extent to which methods take into account the surrounding network in the dimension they focus on is given on a three-point scale, – = no network, + = small part of the network, ++ = large part of the network.

related to the game). When individuals associate words with emotions, these are then embodied, thus reflecting an increasing multimodality (see Niedenthal, 2007). Other multimodality-related aspects such as word concreteness are important to consider, as concrete words are more embodied and easier to learn than abstract words, and abstract words may benefit from being 'grounded' (De Groot & Keijzer, 2000; Wang et al., 2010). The list composition process might thus benefit from instructors looking beyond frequency and also considering multimodality effects.

Choosing an Instruction Method

A range of vocabulary instruction methods (either in analog or digital form) is used in the classroom (for a review, see Oxford & Scarcella, 1994; Sökmen, 1997); for a representative sample, see Table 1). However, there is little guidance to choose which method is appropriate to learn particular aspects of vocabulary. We aim to illustrate how methods can differ in their position on the form-meaning/network pane of the framework, potentially influencing their effectiveness and thus the decision-making process (for an example of how small variations in task can have diverging effects on learning see Nakata, 2016). Differences related to the strength axis are often transferable consolidation strategies, and are discussed in the next section. Note that our aim in this section is solely to illustrate how our framework can be used to review different methods. In practice, more research is necessary to determine which methods or combination of methods will be most effective (see Discussion).

Form-Meaning

Establishing a solid link between the form and meaning of new L2 words requires that both be focused on to some extent. It is important for learners to create solid representations of a new word's form, acquiring the subtle differences in phonology and orthography. Moreover, learning methods should also put sufficient emphasis on subtleties in meaning and not reduce conceptual meaning to the L1 word, because exact word meaning might differ between languages (Pavlenko, 2009).

This seems straightforward, but in practice there often is an imbalance between focus on form or meaning (Laufer, 1988; Schmitt, 2008). For example, *word lists* and *flashcards* train learners to link the L2 form to the L1 translation, without emphasizing the meaning, potentially limiting deep semantic processing and ignoring subtle differences. *Dictionary work* and *semantic grids* (Carter, 1987) focus on meaning, with little emphasis on retaining the form in detail. *Visual imagery* (or picture naming) provides somewhat more of a balance, with the picture emphasizing the meaning and the L2 form being preponderant, even though it is limited to concrete words. Overall though, few documented methods seem to equally focus on acquiring both form and meaning. This is not necessarily problematic, as a carefully chosen combination of activities may suffice to overcome this issue. It is important for instructors to be aware of how much a method may focus on one or the other aspect, so that a suitable combination of methods can be selected. In addition, some words may have a more difficult form or meaning, requiring more attention to one or the other. Research exploring how well form and meaning are acquired depending on the method(s) used is necessary.

Network

Aforementioned methods teach words in isolation, without taking their form or meaning network into account. At best, word lists and flashcards are broken down into themes, but without explicit emphasis on these meaning neighbors.

Other methods do take the network into account. For example, *semantic mapping* (Margosein, Pascarella, & Pflaum, 1982) encourages learners to relate a word to its meaning neighbors. However, this method does not consider form similarity. In contrast, *word unit analysis* (Sökmen, 1997) does slightly take into account both the surrounding form and meaning network, though it is limited to words that have common form roots, and does not take into account morphologically unrelated L2 form neighbors.

An example of a successful method that combines form and meaning and utilizes a small part of the network is the *keyword method* (Atkinson, 1975). In addition, this method is useful for learning abstract words, which can be 'grounded' in concrete visual settings (Mastropieri, Scruggs, & Mushinski Fulk, 1990). It is, however, limited in scope, as it is primarily applicable to words with clear word form neighbors, and it only considers a limited set of neighbors. To our knowledge, more widely applicable methods taking network for form and meaning into account do not exist. Empirical studies should explore which method(s) lead to words being best integrated into the network.

Consolidating Learned Words

After the initial exposure to new words, the next step is to consolidate these words. In the past decades, several strategies have become popular learning and consolidation tools. For example, *retrieval practice*, *spaced repetition*, and *elaboration* are usually familiar terms to instructors. The advantage of these strategies is that they can be applied to many methods (e.g., word lists and visual imagery), and are inherent to some (e.g., retrieval practice in flashcards, Nakata, 2015). In this section, we discuss how these different consolidation strategies relate to the strengthening/form-meaning plane of our framework. In terms of our framework, consolidation requires strengthening representations of both form and meaning, as well as their connection, which can be achieved by choosing strategies that boost frequency and multimodality. While we previously could not make specific recommendations on which methods to choose, we do recommend implementing the consolidation strategies we describe here, as there is ample research available demonstrating their effectiveness. However, it is possible that these strategies interact with word characteristics (e.g., relative form or meaning difficulty), thereby mediating their effectiveness. Instructors should keep this in mind, and more research is required to determine whether and how this is the case.

Frequency

To consolidate word form and meaning, frequency of encounter is important. However, the distribution of encounters also matters. *Spaced repetition* (Melton, 1970) tends to mimic how words are naturally learned, as in a naturalistic environment words are encountered at spaced intervals. Accordingly, spaced repetition, as opposed to massed learning (or "cramming"), helps strengthen representations (Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006).

Retrieval practice (Roediger 3rd & Butler, 2011) involves recurrently retrieving the links between words' form and meaning or between the L1 and L2 forms, essentially repeatedly testing a learner's knowledge. This process helps strengthen the association between form and meaning, increasing the relative strength compared to competitors as proficiency increases (Karpicke, Lehman, & Aue, 2014; van Hell & Tanner, 2012). Together, spaced retrieval practice allows to both consolidate word form, meaning, and form-meaning association.

Multimodality

Classroom vocabulary learning varies strongly with regard to the modalities used. However, presenting information in multiple modalities is beneficial. Note, this does not necessarily mean in a specific modality for a specific learner, although the latter option is often, perhaps erroneously, recommended for instruction (Howard-Jones, 2014).

Strategies such as form or meaning *elaboration* can be a way of increasing multimodality, thereby strengthening representations (Barcroft, 2002). Practical examples of how to use elaboration in a way that increases multimodality and enhances learning include form-oriented activities (e.g., saying out loud, writing, or typing words; Schneider & Kulmhofer, 2016) and meaning-oriented activities (e.g. using iconic gestures/full body movements, or adding pictures; Kelly, McDevitt, & Esch, 2009; Skulmowski & Rey, 2018; Tonzar et al., 2009). Many methods can easily be adapted to be more multimodal (e.g., copying words during dictionary work), and some already are to some extent (e.g., visual imagery). Other methods that we have omitted, such as *memory palaces* (Yates, 1966), in which learners build a visual mental model including the new words, are also a form of elaboration. Crucially, the rising ubiquity of technology in classrooms allows for ample options to increase multimodality (e.g., with video games, see Chen & Yang, 2013).

Instructors should keep in mind that new words need to be consolidated, and that various strategies that relate to the mental lexicon can be helpful in this process.

DISCUSSION

We set out to build a bridge between cognitive views of the mental lexicon and L2 vocabulary instruction. Toward that end, we integrated three main properties of the mental lexicon, namely, that word representations are coded on two

dimensions (form and meaning), in a network structure, with differing strengths of (and between) representations, into a visual framework. We have argued that these properties have implications for three important choices in instruction: selecting words to learn, choosing a method for teaching, and consolidating new words. We now discuss what both science and practice can take away from this bridge.

Opportunities for … Science

We intend our reflection framework to serve as a stepping-stone between cognitive models and the development and evaluation of instructional practices and learning materials. From the cognitive perspective, this calls for a closer consideration of the ecological validity and implications of cognitive models and theories about the mental lexicon. We have presented some of the potential consequences of these theories for vocabulary learning and have reflected on potential implications for instruction. We believe that this deserves more emphasis during the development phase of the models, to increase ecological and societal value of cognitive science findings and theories.

We should now set out to empirically determine the effects of cognitive science-based instruction methods in practice. Indeed, for now it still seems that the bridge between science and practice is under construction. Particularly, the effect of the (multilingual) network property of the lexicon and the interaction between the three properties has received relatively little attention so far. Across the board, we found no vocabulary instructional methods that integrate the three axes. We hence particularly recommend investigating the effects of (combinations of) methods that consider all three properties of the mental lexicon on learning in the classroom. Ultimately, the goal of such methods should be to ensure that both form and meaning are learned fully and in detail, to take into account the neighboring network for new words to correctly integrate into the existing lexicon, and to include consolidation strategies that strengthen representations. In addition, future work should attempt to extend the framework to deeper levels of vocabulary knowledge (Schmitt, 2008) and also consider nonspecific factors such as cognitive load (Mayer & Moreno, 2003).

By explicitly testing existing theoretical knowledge of the mental lexicon in practice, results will be produced that, in turn, can inform research to further develop their models and theories. This cycle will enable the creation of models and new instruction methods grounded in practice and research, respectively.

Practice

With this reflection, we also offer teachers and instruction method developers a scientifically grounded and structured way of thinking about the steps taken in L2 vocabulary instruction. Though a lot remains to be researched, several recommendations follow from the discussed properties.

Most importantly, we encourage stakeholders to use our framework as a guide for critical assessment of their practices. First, the words that are learned and how they can influence learning based both on frequency (e.g., are the words relevant?) and network properties (e.g., are there any potential sources of (interlingual) confusion?) should be assessed. Analyzing learners' errors may uncover such sources of confusion in the word list (e.g., did they confuse (interlingual) neighbors? Did specific words stand out as being more difficult in form or meaning?). Second, the relative strengths and weaknesses of the methods used in relation to the framework should be evaluated, and then reflected on to determine how they can be improved by using alternative or additional methods, which must then in turn be empirically validated. Third, some time should be spent determining how learners can best be helped to strengthen and retain the acquired vocabulary, specifically by adding consolidation strategies such as (spaced) repetition (see Kang, 2016, for some of the challenges instructors face when attempting to space their learning materials and possible solutions) and (digital) multimodality (see Schneider & Kulmhofer, 2016, for some examples of how multimodality can be implemented in the classroom) to the selected method(s).

The role of both method developers / educational publishers and teachers is essential in this process. The former because they offer the methods most used by teachers in the classroom, despite them not necessarily being based on science. Teachers in turn deliver both these and their own methods to students, forming the final link between science and actual learning. While scientists can contribute to the development of methods, teachers are front-of-line when it comes to testing their applicability in L2 instruction settings, highlighting the value of teacher-led research initiatives (Churches & Dommett, 2016) and classroom and curriculum-based studies (see Greene, 2015, for an overview of the challenges and implications of carrying out such research).

In conclusion, our reflection offers a framework for a shared understanding of L2 vocabulary learning between cognitive science and educational practice. We hope this common ground will contribute to more ecological valid cognitive theories and models and instruction methods grounded in cognitive science, expectedly improving their effectiveness.

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