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The types of cues that help you learn

Pedagogical implications of a computational simulation on learning the English tense/aspect system from exposure

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Despite a considerable amount of research conducted on the development of tense/aspect (TA) usage in English by second language (L2) learners, nuances in uses of TAs remain elusive to many L2 learners of English: the grammatical accounts proposed appear difficult to apply as they are either too general or too specific and fail to provide learners with a conceptual understanding of the system. Merging insights from psychological models of learning, corpus-based, and cognitive linguistics approaches to second language acquisition we use the results of computational simulations of learning of the TA system conducted by Romain et al. (2022) and propose an approach to TA teaching that focuses on the cues that have been identified as crucial for accurate TA use. Our pedagogical approach draws learners' attention not so much to the cues themselves but to the type of cues that are the most reliable in the choice of different TA combinations. This approach allows teachers to equip learners with a long-term learning strategy that will help them focus on the most useful type of information, and thus gradually build up a bank of knowledge specific to each TA combination.

Keywords: tense/aspect, EFL/ESL, associative learning, cognitive linguistics, usage-based theories

Learning how to use the English Tense Aspect (TA) system is one of the more challenging dimensions of mastering English. While the morphological patterns underlying the formation of different TA combinations are rather straightforward, the usage contexts for each of the forms are not. Despite the considerable amount of research conducted on TAs most has not made its way into classrooms, and the differences in use, e.g., between the past simple and the present perfect, remain

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elusive to many learners of English as a Foreign Language (EFL). The rules that are proposed in approaches that are anchored in traditional linguistic accounts appear difficult to apply: general rules fail to capture the peculiarities of individual instances and overly specific rules fail to provide learners with a conceptual understanding of the system. Our approach aims to combine generalisability and authenticity: running data from the BNC through a computational algorithm based on findings from research on learning, we zoom in on the cues that are crucial for the use of the different TA combinations in British English. In line with previous usage-based research on first and second language acquisition, we propose to work with a large number of exemplars, but by drawing on results from Romain, Ez-Zizi, Milin, and Divjak (2022), we point learners' attention beyond the individual forms, towards cues that are crucial for accurate TA use. We thus outline a novel framework for corpus-driven language learning that distinguishes itself by supporting learners to identify those cues that are not only optimal for mastering the phenomenon but are also directly available in the input.

1. The role of frequency and association in learning

A crucial aspect of learning is identifying which aspects of the experience are useful and reliable and which can be disregarded as uninformative. This also applies to language learning (L1 or L2). Having reviewed findings from the literature on the acquisition of linguistic structures and the effects of frequency, prototypicality and association, we will focus specifically on the acquisition of TA combinations, explain the novelty of our study and situate it within the usage-based approach to language learning and teaching.

a. Construction learning: Frequency and association

It has long been known that a certain amount of learning occurs via association; that is, learning to associate a cue (e.g., a bell) with an outcome (e.g., the appearance of food). This type of learning was famously studied by Pavlov (1927), and Skinner (1957) was the first to apply it to language learning. This approach relies notably on contingency. A good analogy for contingency learning is the identification of members of the category 'birds': all birds have eyes and all birds have wings but only wings are a distinctive feature of birds, as it sets them apart from other animals which all have eyes. This shows that raw frequency is not sufficient for acquisition and that contingency is crucial in the formation of a category. This has also been found to be true in language, where it is not only frequency of occurrence that plays a role in learning but contingency of form and meaning and

strong associations between words and structures that facilitate the acquisition of categories (Ellis, 2006a, 2006b; Gries & Stefanowitsch, 2004; MacWhinney, 1987).

This idea has been pursued within the framework of construction grammar, where researchers have found that both semantics and frequency of input play a crucial role in children's acquisition of their L1. Studies on non-linguistic categorisation (cf. Casalosa, 2005 and references therein) have shown that it is easier for learners to induce a new category if they start learning from a low-variance sample: categorisation is facilitated by initial exposure to a small set of input that shares salient properties. In linguistics, Boyd and Goldberg (2009, p. 420) argued that exposing learners to a small set of semantically coherent verbs in one argument structure construction in the initial phase of learning facilitates category learning. Previously, Goldberg, Casenhiser, and Sethuraman (2004) had explored the hypothesis that exposure to a prototypical type with high token frequency helps learners acquire constructional meaning. Their study on native speakers of English in three distinct conditions (no training, balanced training and high token frequency training) found that exposure to the high token frequency training improved identification of constructional meaning and accurate extension of the use of the construction to new verbs and new situations (Goldberg, Casenhiser, & Sethuraman, 2004, p. 302). Likewise, in the acquisition of constructional meaning, general-purpose verbs tend be the most informative: Ninio (1999) and Goldberg, Casenhiser, and Sethuraman (2004) reported similar findings on the role of these verbs in the acquisition of semantic and syntactic generalisations. However, these sets do not need to be engineered: they occur naturally in language use. Divjak (2017) analysed the differences between the *that*-construction and the infinitival construction in a naturalistic usage sample and found that the infinitival construction has a low type but high token frequency whereas the *that*-construction has a high type but low token frequency. This facilitates generalisation at a more schematic level and makes it easier to extend the *that*-construction to new items whereas lexical restrictedness of the infinitival construction facilitates the creation of a category. Wonnacott, Boyd, Thomson, and Goldberg (2012) likewise concluded that higher type frequency facilitates extension to new items. They found that L1 children tend to extend a construction more readily to new items if they have previously been exposed to more variety in the input.

Similar effects have been reported in L2 acquisition. Based on their analysis of argument structure constructions in L2 learner corpus data, Ellis and Ferreira-Junior (2009) found that learning and acquisition of constructions is facilitated by a combination of high frequency exemplars, prototypicality and semantic genericity of the lexical types used in a construction. This confirms that it is not sufficient for an item to be frequent, it also needs to be identifiable as a proto-

type of the category to facilitate acquisition of the category. It therefore seems crucial to identify verbs that are prototypical and accessible to L2 learners. While Year and Gordon (2009) found no clear effects of skewed vs. balanced input in their participants' ability to rate the grammatical acceptability of grammatical instances of the ditransitive construction, Year (2009) found that early in the acquisition process, participants exposed to skewed input are better at identifying incorrect instances of the ditransitive (giving them lower acceptability ratings than the balanced group). This shows that participants exposed to skewed input have a better grasp of constructional meaning (and constraints) in the early phases of acquisition. Year (2009) also noted that participants from the balanced input condition eventually catch up and achieve equivalent results to those of the skewed input group.

Overall, several factors play a role in the acquisition of linguistic structures. Low type but high token frequency, prototypicality of the types and their semantic genericity seem to conspire to facilitate the acquisition of categories (e.g., argument structure constructions) at least in the earlier stages of acquisition. Higher type frequency allows learners to generalise beyond the input, at a more schematic level and facilitates the extension of use of a construction to new items. In order to facilitate acquisition of TA combinations, it thus seems relevant to first introduce prototypical, semantically generic and coherent types in each construction, which can later be extended to new items.

b. TA learning: Aspect, tense, associations

Much of the previous literature in the acquisition of TA has discussed the role of verbs' inherent semantic aspect in both L1 and L2 learners, which has led some researchers to argue for the primacy of aspect, also known as the (Lexical) Aspect Hypothesis; for an overview see Chapter 4 of Bardovi-Harlig (2000). Shirai and Andersen (1995) found that children initially restrict their use of either the past or the progressive to semantically perfective (telic, punctual, resultant-state) or imperfective (activity and iterative achievements) verbs respectively but that they tend to extend the use of the progressive to other verbs sooner than they do with the past. They also point out that this usage pattern matches that of the input these children receive. Andersen and Shirai (1996) argued that while there is evidence for the primacy of aspect, it is only relative, not absolute. While it has been reported in the literature that L1 learners seem to rely on the semantics of the verb in their acquisition of TA morphology (Li & Shirai, 2000) and that aspect tends to be acquired first, in both L1 and L2 acquisition, this assumption is not uncontested (Weist, Pawlak, & Carapella, 2004 among others). Another potentially complementary approach is the Default Past Tense Hypothesis (DPTH) put

forward by Salaberry (2008), which states that learners initially start by marking tense with a default perfective tense marker (past) before relying on semantic and discursive elements as they become more proficient (Salaberry, 2008, p. 13).

We remain agnostic as to the primacy of aspect but what these studies do show is that there seems to be some degree of association between the inherent semantics of verbs and the TA combinations they occur in, and that, as we will show in Section 3, this also holds true for tenses.

This association between the inherent semantics of the verb and the TA combinations in which they occur the most has led to hypotheses regarding the acquisition of these combinations. The semantics of the verbs and their frequency of occurrence in certain tense-aspect combinations are among the facilitating effects for the acquisition of tense-aspect markers. Wulff, Ellis, Römer, Bardovi-Harlig, and Leblanc (2009) use L1 and L2 corpus data to test the hypothesis that the telicity of the verbs used with different TA constructions is prototypical of the construction (perfective or imperfective). They find that the progressive should be easier to acquire as the verbs that are the most distinctive for the progressive are also the most frequently encountered and it is this correlation that facilitates learning. They also find that the verbs that occur the most with the progressive are action verbs that tend to be more inherently atelic. These findings corroborate previous studies that report a facilitating effect when the semantics of the verb match the semantics of the construction. Nevertheless, it should be noted that Wulff et al. (2009) focused solely on the semantics of the verb, not the context in which they are used, which might also facilitate the acquisition of a TA combination, e.g., the co-occurrence of adverbials such as *already* with the perfect. Further, Bardovi-Harlig and Reynolds (1995) found that beginner learners tend to underuse the non-progressive with verbs of activity (i.e., *they walked, she sang*) and to overuse the progressive form for these verbs. Based on an analysis of a learner corpus (German learners of English), Fuchs, Götz, and Werner (2016) find that the present simple is among the last TA combinations to be learned and is only properly acquired by advanced learners. As to the use of adverbials by learners, Götz, Werner, and Fuchs (2019) find that learners initially use definite (e.g., *in 1986*) and indefinite (e.g., *already*) temporal adverbials with both the past simple and present perfect, thus deviating from target-like associations between adverbials and TA combinations.

L2 learners often acquire their language in the classroom and what they learn and in which order they do so is therefore intricately entwined with what is taught yet there remains a gap between research conducted on the acquisition of tense and aspect and its classroom applications (Bardovi-Harlig & Comajoan-Colomé, 2022). Niemeier and Reif (2008) deplore the fact that two of the most widespread English grammars used in German classrooms do not differentiate

between tense and aspect but rather offer a rule-based focus on form and use, presenting combinations as blocks without explaining the function of tense and aspect individually. There are, however, more extensive grammars such as Longman (Alexander, 2005) that differentiate between tense and aspect and provide more detailed descriptions in an attempt to describe each construct individually.

Nevertheless, there have been numerous efforts from various branches of linguistics and SLA to propose improvements to the way the TA system is taught. For example, Larsen-Freeman and Celce-Murcia (2016) provide a research-based guide for teachers of English that describes the TA system in great detail, also highlighting potential issues for learners. They explain that the English TA system relies on several layers, notably tense and aspect, which have different functions in the building of meaning. For instance, they provide numerous examples of similar meanings achieved with different TA combinations and of the use of the same TA combination with different meanings. There have also been suggestions to make learning more holistic by encouraging students to actively think about linguistic phenomena. For instance, a branch of research on instruction in SLA focuses on the importance of conceptual knowledge as a means to help learners achieve better understanding of grammatical forms through conceptualisation. This approach is known as Concept-Based Instruction (CBI) and was explored for tense and aspect by Infante and Poehner (2021), among others. This is similar to some extent to Svalberg (2019, among others), who proposes a Language Awareness (LA) approach (Svalberg, 2007), which aims to make learners think about/explore how language works, to the teaching of tense in English. She presents a modified version of Reichenbach's model (Reichenbach, 1947), which is used as a basis for learners to analyse tense usage in texts. The type of analysis proposed by Svalberg leads to potentially very intricate discussions around the notions of time and tense but does not seem to pay much attention to typical uses of TA combinations, which learners probably seek in the first place. The cognitive linguistics branch of SLA has shown that usage-based approaches to language hold great potential for a pedagogical application, but it is still a developing field and extensive studies remain sparse (cf. Bielak & Pawlak, 2011; Comajoan-Colomé & Llop Naya, 2021; Kermer, 2016 for tense and aspect). Nonetheless, methods, tools, and strategies are being developed for the pedagogical application of cognitive linguistics and construction grammar and as Gilquin (2022) shows, pedagogical applications that combine cognitive linguistics and corpus linguistics are very promising. Of noteworthy mention among pedagogical cognitive linguistic approaches to tense and aspect is work by Niemeier and Reif (2008) and Reif (2012) who conducted empirical studies applying the principles of cognitive linguistics/cognitive grammar to the teaching of English tense and aspect. Bringing cognitive approaches into the classroom yielded mixed results: there was no

major difference between experimental and control groups, with the experimental groups showing a tendency to perform better in certain tasks but not in others. Other studies exploring cognitive approaches to language pedagogy have yielded more positive results. For example, Jacobsen (2018) explored teaching English conditionals and found that the cognitive group outperformed the control group. Overall, many researchers conclude that cognitive linguistic approaches to teaching have potential for the effective acquisition of linguistic phenomena and making language learning attractive to learners, but more empirical research is needed to properly assess the benefits to teaching.

In sum, it appears crucial to provide learners with high-frequency semantically coherent exemplars from which they can derive meaning and generalise to identify constructional/structural meaning, notably by pointing learners' attention to the relevant cues in those exemplars. However, an overview of the literature in ESL/EFL indicates that this insight has not yet been implemented in teaching, which relies more on broad generalisations (rather in the form of rules than usage) and the presentation of examples to illustrate exceptions to these rules (cf. Bardovi-Harlig & Comajoan-Colomé, 2022). While work has also been conducted to derive rules from actual language usage (cf. corpus studies of TA), little attention has been paid to learning mechanisms in pedagogical approaches. We propose to bridge this gap by using results from computational simulations of learning as presented in Romain et al. (2022) as basis for pedagogical materials.

2. Associative computational learning

Romain et al. (2022) used the naïve discriminative learning algorithm (NDL), which is based on error-driven association learning. In this section, we provide a summary of the approach used by Romain et al. (2022); and present their results in the next section.

a. Rescorla-Wagner and its uses in learning

In essence, the Rescorla-Wagner rule describes the process by which an organism assimilates information from its environemnt as well as from its own mistakes to effectively adapt to a given task. Specifically, this rule involves the incremental association between the presence or absence of a particular outcome (namely, one of the 11 combinations of TA, as explained in Section 2b) and the presence of a cue (in this context, either a lemma or an n-gram) on an event-by-event basis. Consequently, the rule recalibrates the connection strengths or weights between each cue and outcome following each (annotated) sentence, which serves as a trial in

this study. If a particular cue is consistently found with an outcome across learning trials, the connection strength between them is reinforced. Conversely, if a given cue repeatedly occurs when the outcome is absent, the weight assigned to the connection between them is attenuated. As the weights are updated with accumulating experience, certain cues gradually become indicative of an outcome, while others become irrelevant. With the accrual of experience, any patterns in the occurrences of cue-outcome associations become discernible, and it is these systematic patterns that are learned. The overall level of support that an outcome receives from the cues, known as its activation, is determined by the cumulative sum of the weights on the connections between those cues and the outcome.

The process of dynamic re-estimation minimizes errors based on prior experiences, encompassing both positive and negative evidence. Positive evidence refers to instances where a specific cue is associated with the presence of a particular outcome, while negative evidence pertains to cases where the absence of an outcome contradicts what would be expected given a specific cue. The learning process is driven by the competition among cues to effectively carry weight to match an outcome. It is worth emphasizing that cue competition arises naturally as cue-outcome relationships are typically imperfect, particularly in the context of language, where unambiguous one-to-one mappings are elusive. This imperfection provides a fertile ground for error-driven learning.

b. The model: Data and specifications

Romain et al. (2022) used the entire BNC corpus (Leech, 1992), which includes approximately 100 million words carefully sampled across functional styles from both spoken and written materials. Table 1 (from Romain et al. 2022) displays the structure of their final dataset consisting of more than 7 million instances. It shows a distinct Zipfian distribution, with the majority of data comprised of the present simple tense (46.09%) and the past simple tense (37.62%). The remaining 10 combinations of tense and aspect contribute between 4.84% and less than 0.01% each to the sample. Due to its extreme rarity, the future perfect progressive was excluded from further analysis. We provide examples of each TA in Table 2 for clarity.

NDL learning simulations combine insights that would otherwise require the combination of several different techniques: this method focuses on both lexical and contextual information, bringing together collostructional analyses (Stefanowitsch & Gries, 2003) and corpus linguistic approaches to language learning, be they the descriptive approaches that underlie a range of dictionaries and grammars (e.g. Biber et al. 2021), or theoretically inspired work as practiced by usage-based linguists (for an overview, see Gilquin 2022). While a collexeme

Table 1. Frequency of tense-aspect labels in the sample (Romain et al. 2022: 264)

TA combination/Outcome	Frequency	Percentage (%)
Present simple	3,229,514	46.09
Past simple	2,636,030	37.62
Present perfect	338,791	4.84
Future simple	271,345	3.87
Past perfect	253,110	3.61
Present progressive	139,878	2
Past progressive	108,682	1.55
Present perfect progressive	11,278	0.16
Future progressive	8,021	0.11
Past perfect progressive	7,032	0.10
Future perfect	2,955	0.04
Future perfect progressive	30	< 0.01
Total	**7,006,666**	**100**

Table 2. Examples of all 12 possible TA combinations in English (Romain et al. 2022: 262)

	Present	Past	Future
Simple	Tonya skates.	Tonya skated.	Tonya will skate.
Perfect	Tonya has skated.	Tonya had skated.	Tonya will have skated.
Progressive	Tonya is skating.	Tonya was skating.	Tonya will be skating.
Perfect progressive	Tonya has been skating.	Tonya had been skating.	Tonya will have been skating.

analysis is informative as to which verbs preferentially occur in which construction, or TA combination(s) in this case, it discards the context entirely and relies solely on individual lexical items. Consequently, it cannot offer an account of which contextual elements guide the choice of a specific TA combination. Interestingly, context has proven to be relevant: Biber, Johansson, Leech, Conrad, and Finegan (2021, pp. 467–468) observe that the past perfect is usually found with time adverbials and/or in dependent clauses (they report this is the case in 70% of instances in their sample), making the past perfect more context-dependent than the past simple.

In the computational learning model for TA combinations, learning events are individual sentences, each containing one target verb form. The outcomes are the TA combinations, and the cues are the verb lemmas themselves and n-

grams, which are chunks of 1 to 4 words, e.g., *currently, so#far, the#past#weeks, #in#the#next#section* (Romain et al., 2022, p. 265). With each new learning event, the model adjusts the weight of association between e.g., a verb lemma and a TA combination. The key measure in this model is the final association weight between each cue and each outcome. For example, as the model encounters the verb lemma *reply* with the past simple over a number of instances, the association strength between the cue *reply* and the outcome *past simple* is reinforced. By contrast, when the model encounters *reply* with a different TA such as *present perfect*, the association strength between *reply* and *past simple* is weakened while the association strength between *reply* and *present perfect* is reinforced. At the end of the learning process, the association strength between cue and outcome reflects the contingency of the two over N number of learning events. For more details about the computations, see Romain et al. (2022).

3. Results and discussion of the learning simulations

As mentioned, the method used by Romain et al. (2022) presents the advantage of including both lexical and contextual associations with the TA combinations automatically and without prior bias towards one or the other. Furthermore, NDL stays faithful to the raw input and the simplicity of the learning engine offers the added benefit that its workings are transparent and easily tractable; this makes it possible to understand how certain connections are established, and to translate these insights into pedagogical applications. This section provides an overview of the results presented in Romain et al. (2022), which we use as a basis for the pedagogical adaptation presented in Section 4.

a. TA combinations: Simple vs. complex

As Romain et al. (2022) show, the model performed quite well, reaching 93% if it was allowed to mimic human behaviour and make several (three, in this case) suggestions for one given context: Figure 1 presents the accuracy of the three top predictions made by NDL combined for each TA combination. However, Figure 1 shows that simple TA combinations, namely the present simple and past simple, are much better predicted than the other combinations with prediction accuracies of 98.7% and 98.5% respectively. The perfect is also better predicted than the progressive forms, with the past perfect reaching 76.6% accuracy and the present perfect 74.8%. These are closely followed by the future simple with a prediction accuracy of 67.1%. Slightly lagging behind are the present progressive (43.9%) and the past progressive (39.2%). More complex combinations such as the future per-

fect and the future progressive, as well as the double aspect forms (present perfect progressive and past perfect progressive) are hardly ever predicted correctly (Romain et al., 2022, p. 270).

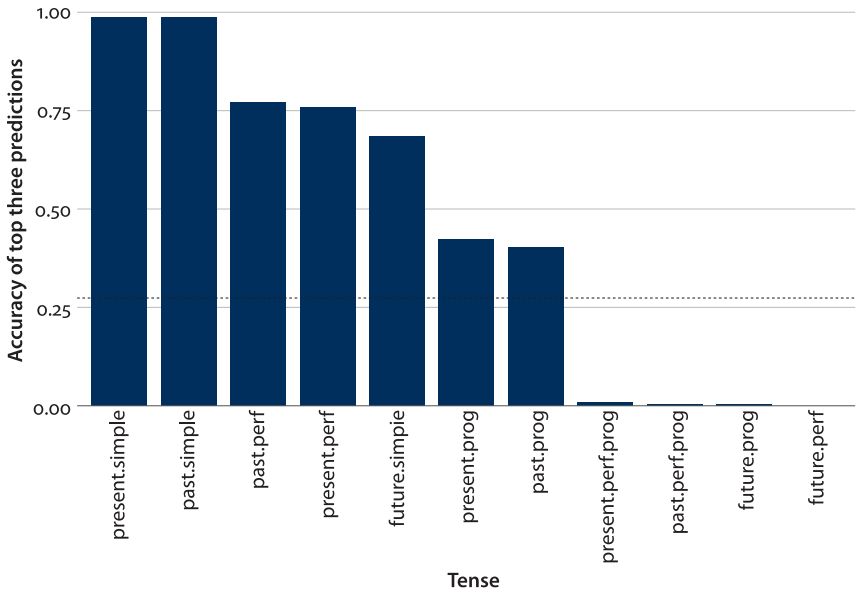

Figure 1. Accuracy for each tense-aspect combination, based on the three most activated outcomes. The dashed horizontal line represents the accuracy level that would be achieved if predictions are made randomly. (Romain et al. 2022: 269)

Romain et al. (2022) conclude that in the TA system, simpler forms are easier to learn while more complex forms show lower and varying degrees of learnability. The most frequent combinations also tend to be better learned. The question now is, beside frequency effects, what plays a role in learnability?

b. Cues: Which elements facilitate learning

Romain et al. (2022) claim that there is a two-fold explanation for learnability: first, the cues that are the most strongly associated with the present simple and past simple are also those that have the highest weights (association strength), and second, these cues are also simpler: most of them are lemmas whereas the cues for the complex TA combinations include a variety of n-grams.

There is a clear bifurcation in the type of cues that guide learning. Figure 2 represents the proportion of each type of cue for each TA combination within the top 100 most informative cues. The present simple and past simple once again dif-

fer from other TA combinations as they appear to be almost exclusively lexically supported, whereas other TA combinations are more contextually supported. There is also a cline in the distribution of the cues where the proportion of lexical cues decreases with each TA combination (Romain et al., 2022, pp. 273–274).

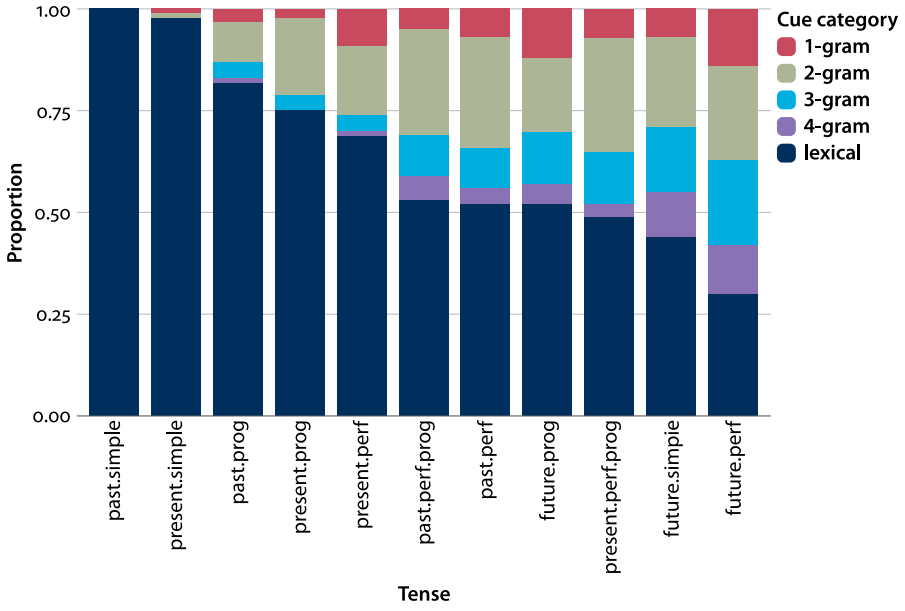

Figure 2. Distribution of lexical and contextual cues within the top 100 cues for each TA combination (Romain et al., 2022, p. 274)

NDL shows that the observation that a TA combination is context-dependent extends throughout the grammatical category: all TA combinations other than the present and past simple appear to be context-dependent (see Romain et al., 2022). In other words, an analysis that takes into account lexical elements as well as contextual information and does this at scale, as NDL does, organically reveals the foundations of the TA system: different TAs require different *kinds* of support. While simple and more frequent forms are also supported by simpler lexical cues, more complex, less frequent TAs are supported by vaguer contextual cues (Romain et al., 2022). Our pedagogical adaptation of this work focuses on directing learners' attention to this difference in cues to optimize their learning.

To illustrate more clearly, we provide the top 20 most positively associated cues in the BNC for the present simple, past simple, past perfect, present perfect, future simple, present progressive and past progressive in Table 3 (as identified by Romain et al., 2022, p. 272); for a more extensive inventory of cues for each TA

combination, we refer to SupMat 1. Lexical cues (verb lemmas) are presented in capital letters, and in n-grams of more than one word length, the individual words are separated by a hash (#).

As mentioned previously, the most informative cues for the present simple and past simple are lexical, that is, it is the verbs themselves that act as cues for a specific TA. The verbs the algorithm identifies align with the corpus findings reported in Biber et al. (2021, p. 457). As shown in Table 3, the past simple is supported by two broad categories of verbs: verbs of speech such as *reply, whisper, murmur, say, mutter*, or *shout*, and verbs of reaction such as *nod, smile, pause, laugh*, or *grin*. The verbs that support the present simple differ from those that support the past simple. These verbs can also be divided into two broad categories, and we use Biber et al.'s (2021) labels here: verbs of emotions or attitudes such as *thank, suppose, hope, hate*, or *believe* and verbs of logical states such as *mean, represent, depend*, or *require*.

The present perfect and the past perfect get both lexical (verbs) and contextual support (n-grams). Romain et al. (2022) find that their results for these TAs also match the findings of Biber et al. (2021, pp. 467–468): both the present perfect and past perfect are activated by cues that are adverbials (*since then, so far, recently*) or indicate another proposition (*is the first time, reported that, remembered*). Interestingly, the lexical cues for the present perfect and past perfect seem to match what is usually considered a prototypical meaning of this TA combination: a process that has a relevance in the present. Verbs such as *change, develop, evolve*, or *increase* match well with the perfect because they denote events that are likely to have consequences for the present time. The contextual cues also denote a notion of accomplishment or a summary of a development that is relevant and potentially assessed at a given point in time: *since then, we already, so far* or *recently*. The future simple also relies on both lexical and contextual cues, and the latter include temporal adverbial phrases such as *in a minute* or *tomorrow*, but we also find expressions of hopes with *it is hoped* and *hopefully*. The most predictive lexical cues for the future simple are more varied but seem to point to an expected result with verbs such as *benefit, help, ensure, affect*, or *result*. The present and past progressive mostly rely on lexical cues as the n-grams identified by the algorithm are actually bits of phrasal verbs such as *what is going on* (what#on) or *we are looking for [..]* (we#for) as the BNC tag set does not accommodate phrasal verb tagging.

Table 3. Top 20 most predictive positive cues for the past simple, present simple, present perfect and future simple in the BNC (Romain et al., 2022, p. 272)

Past simple	Cue weights	Present simple	Cue weights	Present perfect	Cue weights	Future simple	Cue weights
REPLY	0.68	THANK	0.71	we#already	0.26	you#able#to	0.23
NOD	0.58	SUPPOSE	0.69	since#then	0.23	BENEFIT	0.20
SMILE	0.55	HOPE	0.68	i#already	0.23	we#you	0.17
WHISPER	0.53	REMEMBER	0.58	CHANGE	0.22	HELP	0.16
MURMUR	0.52	MIND	0.56	i#ever	0.20	i#you#a	0.16
SAY	0.52	MEAN	0.55	DEVELOP	0.19	it#is#hoped	0.15
MUTTER	0.44	LET	0.54	PROVE	0.19	CONTINUE	0.13
SHOUT	0.44	HATE	0.54	so#far	0.18	hopefully	0.13
GLANCE	0.43	BELIEVE	0.54	EVOLVE	0.17	i#you	0.13
ANSWER	0.43	LIKE	0.54	ACHIEVE	0.17	ENSURE	0.13
PAUSE	0.43	RECKON	0.53	IDENTIFY	0.17	in#a#minute	0.12
SHAKE	0.42	KNOW	0.51	INCREASE	0.16	AFFECT	0.12
SIGH	0.41	WISH	0.50	CRITICISE	0.16	RESULT	0.12
ANNOUNCE	0.41	WANT	0.49	traditionally	0.15	if#he#a#statement	0.11
LAUGH	0.40	NEED	0.49	LAUNCH	0.15	will#not#it	0.11
LAY	0.40	REPRESENT	0.48	recently	0.15	tomorrow	0.11
COMMENT	0.39	DEPEND	0.47	over#the#last	0.15	i#you#what	0.11
STAR	0.38	CONTAIN	0.47	FINISH	0.15	COST	0.11
GRIN	0.38	SOUND	0.46	SIGN	0.15	will#not#you	0.11
ADD	0.38	REQUIRE	0.46	APPOINT	0.14	DEPEND	0.11

4. L2 teaching/learning of TA combinations: How to apply these findings in the classroom

We will now discuss how the findings from the computational learning simulation in Romain et al. (2022) could be translated into classroom teaching materials that target British English TA use and are designed with intermediate learners in mind. Recall that Figure 2 showed that different TA combinations rely on different types of cues (lexical versus contextual), and the extent to which each TA combination is cued by lexical items or by contextual chunks. Overall, what we consider here the take-home point is that knowing *where to look* for cues that will help select an appropriate TA form is a skill learners need to master. Hence, drawing learners' attention to the type of cues that will help them learn to use TA combinations cor-

rectly is of crucial importance in teaching TA usage. The teaching materials are available from https://doi.org/10.25500/epapers.bham.00004302.

The TA combinations are discussed in the order they are presented in Figure 2, omitting those five combinations that the algorithm could not capture reliably (cf. Figure 1) due to their relative infrequence. Recall that the order in Figure 2 depicts the TA combinations' dependence on lexical versus contextual cues. We will offer examples for each TA form, referring the reader to SupMat 2 for more detailed teaching guidelines and materials.

For the simple tenses the most informative cues are the verb lemmas themselves. Both the present and past simple are used with a wide variety of verbs, so there is not a single semantically coherent group of verbs among the strongest cues. However, for each tense, we can identify a number of semantically coherent clusters. For the present simple, we identified different semantically coherent groups such as verbs of emotion: *hate, love*, as presented in (1); verbs of mental states (2) and verbs of logical state such as *represent, depend, contain* (3).

(1) Verbs of emotion
   a. I *hate* this flat, it is like a prison to me.
   b. Human beings *do not like* change, especially as they get older.
   c. They *love* making chocolate crispies.

(2) Verbs of mental states
   a. It is part of the factory, I *suppose*.
   b. I *hope* that the following notes are helpful.
   c. You *remember* how angry Alain became when he saw me with that book.

(3) Verbs of logical state
   a. Each line in the diagram *represents* a relationship.
   b. Water also *contains* varying amounts of rust grit and silt.
   c. All carpets *require* professional cleaning occasionally.

We also found that some verbs have a strong tendency to be used with the first or the third person, as shown in Table 4. To obtain these groups, we extracted 100 instances of each verb in the present tense from the test dataset (or less if there were fewer instances of these verbs in the dataset) and annotated for person.

We therefore propose to use these findings in sorting exercises: learners are provided a list of sentences where the target verb is in boldface or italics (in order to draw attention to this specific cue) and are asked to sort these sentences into three groups. We expect the learners to rely on the verb sense for classification and for this purpose, we do not provide any group labels at first. Once learners have grouped the sentences, they are told about the three target groups: emotion, mental states, and logical states, and are then presented with a second sorting exercise, this time with groups including group labels (cf. SupMat 2 for details).

Table 4. Use of verbs in the first or third person

1st person verbs				3rd person verbs				Mixed verbs			
Verb	**1st**	**2nd**	**3rd**	**Verb**	**1st**	**2nd**	**3rd**	**Verb**	**1st**	**2nd**	**3rd**
suppose	**0.97**	0.02	0.01	represent	0.01	0	**0.99**	mind	0.40	0.42	0.19
hope	**0.88**	0.04	0.08	depend	0	0	**1**	mean	0.44	0.10	0.46
remember	**0.71**	0.17	0.12	contain	0	0	**1**	believe	0.44	0.07	0.49
hate	**0.79**	0.12	0.09	sound	0.03	0.04	**0.93**	like	0.52	0.28	0.19
				require	0.04	0.03	**0.93**	reckon	0.31	0.15	0.54
				illustrate	0	0	**1**	know	0.38	0.38	0.24
				relate	0.03	0	**0.97**	wish	0.46	0.19	0.35
				exist	0	0	**1**	want	0.48	0.23	0.29
				deserve	0.10	0.04	**0.86**	need	0.21	0.24	0.55
				be	0.04	0.06	**0.89**	love	0.57	0.10	0.33
				include	0.01	0	**0.99**	understand	0.52	0.14	0.34
				lie	0.06	0.05	**0.88**	owe	0.32	0.09	0.59

For the past simple, we broadly divide our verbs into two groups: verbs of reported speech (4) and verbs of reaction (5)

(4) Verbs of reported speech:
   a. "Not if I can help it," he *replied* grimly.
   b. "Apparently not," she *whispered* as her eyes filled with stinging tears.
   c. "I told you so, John," he *added* in a stage whisper.

(5) Verbs of reaction:
   a. Forrest *smiled* in approval.
   b. He *laughed* incredulously.
   c. Sam *shrugged* at me.

As the past simple also relies on lexical cues, it is important to draw learners' attention to the verb lemma. We therefore suggest the same type of exercise as with the present simple, this time with two groups instead of three. The aim of the sorting exercise is the same: for learners to identify typical groups of verbs by themselves. To facilitate this grouping, we recommend starting with clear examples of verbs of reported speech that contain markers such as inverted commas. Then, less obvious examples can be given to students. Finally, to reinforce these two TA combinations, we suggest a fill in the blank exercise where learners have to choose the correct form among a number of options (cf. SupMat 2, Section 2c)

in the present simple and past simple. This should highlight the different types of verbs used prototypically with each of these tenses.

Next are the present progressive and past progressive: both TA combinations rely largely (in around 75% of cases) on lexical cues, and the contextual cues that appear for these TA combinations are misleading as they mostly relate to phrasal verbs (cf. Section 3b). The present progressive and past progressive also share cues, among which verb lemmas such as *talk, plan, fight*, or *wait*. It is not an easy task to draw a clear picture from the top cues for either (or both) progressives. Some verbs can be grouped such as *plan* and *prepare* for example, or *investigate, deal, seek*, and *try*, but no clear overarching semantic groupings appear. Interestingly, the picture that emerges differs from what can usually be found in textbooks where the progressive is said to be used for events happening at the time of speech. Instead, several verbs in the dataset denote a process that is not literally happening at the time of speech but rather an event that has started but has not reached its conclusion yet, as illustrated in (6). However, we also found instances where the ongoing event is happening at the time of speech, as we show in (7). To explain further, in (6), the events denoted by the verb and TA have started but have not ended, therefore the focus is on the process itself, but it does not imply that the event is continuous, e.g., the Health officials in Gateshead are not expected to be investigating 24/7. In (7), however, the events appear more foregrounded.

(6) Longer processes
   a. Health officials in Gateshead are now *investigating* why firm action was not taken earlier.
   b. The Riverside Theatre in Coleraine is *preparing* for its first production of the new season.
   c. He was *acting* as courier for some of his family's purchases earlier in the year.

(7) Shorter, more immediate processes
   a. The point I am *trying* to make is that I am guilty of making wholesale judgements about women such as you.
   b. Outside the chauffeur is *waiting* patiently.
   c. He pointed exactly in the direction where Allen was *lying*.

For the progressive, we suggest exercises in which learners are encouraged to reflect on the use of the progressive with particular verbs. By asking them to identify what the verbs used have in common, learners should identify some of the characteristics of the progressive form (cf. SupMat 2, Section 4a). As many learners struggle to choose between the progressive and simple, we also recommend exercises in which they are asked to change the verb form between progressive

and simple and try to identify how this changes the meaning of the sentence (cf. SupMat 2, Section 4b).

While the present perfect and the past perfect differ in their relative dependence on lexical versus contextual cues (70/30 for present perfect and 50/50 for past perfect), they have somewhat similar cues, including the adverb *already*. The top cues for the present perfect are adverbial n-grams as shown in (8), such as *already, since then, ever* and *so far*. While there are many instances of the present perfect without adverbials, we believe that presenting learners with such cues helps them better grasp the uses of the present perfect: these examples constitute their "aha" moment. This is in line with findings from recent research on the Polish tense/aspect system using this same algorithm which shows that adverbials are inserted when they are cognitively and communicatively most needed, e.g., when the lexical items themselves do not have a strong preference for one or the other aspect (Divjak, Testini, & Milin, Under revision). One of the exercises provided in the supplementary materials presents learners with instances of the present perfect without adverbials and encourages them to see whether adding an adverbial changes the meaning of the sentence. The cues for present perfect also include some verbs whose semantics could be argued to express completion and hence potentially to express change, as illustrated in (9) with *change, develop* and *achieve*.

(8) N-grams
   a. We have *already* made some progress.
   b. *Since then* the region has experienced a rash of smaller earthquakes.
   c. That is the best fish and chips I have *ever* had.
   d. *So far* three thousand jobs have been created under the scheme.

(9) Verbs
   a. I haven't *changed* anything for about four years.
   b. Scientific debate about this has *developed* into a veritable battle of faith.
   c. Connie Garden has *achieved* considerable fame in recent years.

We also have a mix of adverbials such as *never, already*, and *previously*, and verb lemmas such as *finish, cease* and *disappear* for the past perfect, for which we provide examples in (10) and (11).

(10) N-grams
   a. She had *never* felt like this before, she thought dazedly.
   b. Perhaps it was just that he had *already* made other plans.
   c. "The the budget is the one that had been approved *previously*." *(sic)*

(11) Verbs
  a. When she had *finished* eating, she wondered what to do next.
  b. The rest of the church had *ceased* to exist for him.
  c. Both car and occupants had *disappeared* without trace.

In order to draw learners' attention to these adverbials, we recommend a fill-in-the-blank type of exercise in which learners are asked to assign one or several adverbials to each sentence based on a list from the original data. Students should be encouraged to discuss cases where several adverbials fit the context (cf. SupMat 2, Section 3a). As it is common for learners of English to struggle when choosing between present perfect and past simple, we recommend an exercise in which sentences contain verbs that are usually found in the past simple (as per our list above) but used in the present perfect in these contexts. We provide such sentences that authentically contain adverbials that are strong cues for the present perfect, thus illustrating the potential difference between the two forms (cf. SupMat 2, Section 3c).

Finally, we arrive at the future simple, which is predominantly contextually cued. The cues for the future simple appear to be mostly patterns such as i#you#a in *I will get you a plate* or *I will find you a chair*, but also semantically expected chunks such as it#is#hoped or individual n-grams such as *hopefully*, which we illustrate in (12):

(12) it#is#hoped, hopefully
  a. And *it is hoped* their visit will prompt more American tourists to follow them.
  b. *Hopefully* he will recover well and be back to normal.

We also find some semantic coherence in the verb cues, which likewise tend to denote hopes and promises such as *benefit, help*, and *continue*, as illustrated in (13).

(13) Verbs
  a. The strength which this union brings to the TUC will *benefit* all trade unions.
  b. It will *help* you preserve your independence.
  c. I am quite happy where I am and I will *continue* to do my job.

To draw learners' attention to the relevant cues we suggest an exercise in which learners are given sentences that contain strong contextual cues and asked to identify what these sentences have in common. As for the lexical cues associated with the future simple, we propose a fill-in-the-blank exercise in which learners are presented with a list of verbs and sentences to match these verbs with (cf. SupMat 2, Section 5).

Overall, these results show that some TA combinations are easier to pinpoint in their use while others, such as progressives, do not show a strong preference for clearly defined semantic groups of verbs. We chose not to provide a description of the cues for those TA combinations that are infrequent: there is mileage in following the guidance language provides in the form of the frequency distribution of TAs and focusing on more frequent forms first (Ellis & Ferreira-Junior, 2009). Further, the cues supporting these rarer TA combinations, such as the perfect progressives, appear to be a mixed bag of cues that are also found among the top cues for the perfect and the progressive individually. Our assumption is that learners will progressively identify these combinations of cues as used with perfect progressives and things will fall into place as the more frequent TA combinations are mastered.

Describing TAs in this way also allows to contrast strong cues per tense, thus highlighting similarities and differences between the forms that mark one and the same tense. For example, we can compare the different cues that guide choice of the different past forms, such as past simple, present perfect, past perfect, and past progressive. For the past simple, we divide our verbs into two groups: verbs of reported speech and verbs of reaction. The present perfect (have $V_{\text{PASTPARTICIPLE}}$) relies on cues such as *already, since then, ever* and *so far*, and verbs like *change, develop*, and *achieve*. Likewise, we have a mix of adverbials such as *never, already*, and *previously*, and verb lemmas such as *finish, cease* and *disappear* for the past perfect (had $V_{\text{PASTPARTICIPLE}}$). The past progressive (was/were V-*ing*) is mostly lexically supported by verbs such as *wear, wait*, or *watch*. Both forms of present described in this study rely mostly on lexical cues, but we do find rather different types of verbs for each. While the verb lemmas that support the present simple are easily categorised into different semantic groups such as emotions, mental states and logical states, the progressive offers a more varied array of verbs, yet overall appears to render that an event has not yet reached its conclusion rather than that it is happening at the time of speaking. As to the future, we find that the most frequent and most accurately predicted form, the future simple, relies on both lexical and contextual cues that incorporate a future reference such as *hope*. Other future forms (perfect and progressive) show a mix of the cues found for the future simple and for the various perfect and progressive forms, thus providing an interesting combination of cues for learners. The same type of mix and match was found amongst the cues for the two perfect-progressive forms.

5. Conclusions

Teaching a foreign language aims to equip learners with communicative abilities that allow them to express themselves freely, precisely, and efficiently. English TA combinations are a major stumbling block in this respect, despite significant research in the area, both from a theoretical and an applied perspective. General accounts used for teaching gloss over the peculiarities of individual instances; specific descriptions attempt to cover idiosyncrasies but fail to provide learners with a conceptual understanding of the system. In this paper, we have proposed a novel approach that offers a solution that is based on results from large-scale computer simulations using a transparent algorithm that mimics the way humans learns from data. The outcome of this exercise incorporates the best of both worlds: it stays close to the specifics of input while offering powerful generalisations.

The model stays close to the input through its ability to learn from actual language data: it processes a sample of sentences extracted from a corpus and outputs cues that are real words or chunks that can be related to individual tokens, i.e., existing sentences. This approach ensures a direct link between the computational model and pedagogical materials. It also makes our proposed approach, and the related teaching materials, compatible with existing explanations of the use of TA. Furthermore, because the model learns from actual data, the input can be made to match specific teaching goals. For example, the corpus that is fed to the algorithm can be a general one, such as the British National Corpus used in the simulation described here, or it can be any variety, as well as a corpus that represents a specific genre, a particular style, or a well-defined topic. The results from the simulation will then reflect the peculiarities of the input and highlight, for example, important cues for TA use in academic writing. In other words, our approach relies on structures that are detected in input by applying basic principles of learning, without reliance on linguistic rules. By presenting EFL learners with patterns that are also accessible to L1 learners, we increase their chances of building up the knowledge and cognitive representations that resemble those of L1 users.

At the same time, the large scale at which the model operates enables us to take a bird's eye-view on the cues the model highlights and to draw generalisations at the type-level: we found that the most frequent TA combinations rely predominantly on lexical cues, whereas less frequent TA combinations make use of both lexical and contextual support. Appreciating that there is a difference in the types of cues that are associated with each TA combination makes it possible for teachers to shift focus away from exclusively prescribing usage through concrete examples of cues, towards describing usage in a way that directs learners' attention to the type of cues that is useful for learning a particular TA combination, such as

verbs or adverbials. In this way, teachers can equip learners with a long-term learning strategy that will help them focus on the most useful type of information, and thus gradually build up a bank of knowledge specific to each TA combination. Stronger even, recent work using the Rescorla–Wagner model has started to explore the importance of individual differences. Ez-Zizi, Divjak, and Milin (2023) ran a semi-artificial language learning task in which participants were taught the simplified principles of noun-verb agreement in Polish. By adjusting the parameters of the model to fit the trial-by-trial behavioural choices of participants they showed that the model accurately captures participants' choices, time latencies, and levels of response agreement; gender and working memory capacity affect the extent to which the Rescorla–Wagner model captures language learning. Based on these findings, work is underway to design individualised language learning materials that take the learner's current state of knowledge as starting point, and offer precisely those examples that will gradually nudge the learner towards generally accepted usage.

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