Usage-based theories of Construction Grammar:

Triangulating Corpus Linguistics and Psycholinguistics

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1 Usage based approaches to Language

Usage-based linguistics explores how we learn language from our experience of language. It is founded upon established findings from four complementary areas of empirical investigation:

(i) Corpus linguistics demonstrates that language usage is pervaded by collocations and phraseological patterns, that every word has its own local grammar, and that particular language forms communicate particular functions: Lexis, syntax, and semantics are inseparable (see Biber & Reppen, 2015; Sinclair, 1991, for reviews).

(ii) Cognitive linguistics shows how language meaning is grounded in our experience and our physical embodiment which represents the world in particular ways. Language consists of many tens of thousands of constructions—form-meaning mappings, conventionalized in the speech community, and entrenched as language knowledge in the learner's mind. Schematic constructions emerge from the conspiracy of memories of particular exemplars that language users have experienced (see Dabrowska & Divjak, 2015; Tomasello, 2003, for reviews).

(iii) The psychology of learning shows that humans have a range of abilities for implicit associative and statistical learning, concept learning and categorization, and explicit declarative learning and analogy-making. These are relevant to the learning of the symbols, sequences, and patterns of language that imbue our every waking moment (see Rebuschat & Williams, 2012; Sawyer, 2006, for reviews).

(iv) Psycholinguistics shows that our language processing is sensitive to the statistical regularities of language experience at every level of structure (see Ellis, 2002; Traxler & Gernsbacher, 2011, for reviews).

Together, this research shows that "language is never, ever, ever random" (Kilgarriff, 2005). Not in its usage, not in its acquisition, and not in its processing. It follows that theories of language acquisition and processing that ignore the regularities of usage are missing important characteristics of the problem space, characteristics that might have considerable influence on language learning and processing. We should see how the regularities in each of these domains inter-relate.

The usage-based research program necessitates extensive analysis both of the usage from which learners learn, and of learner usage and processing as it develops, both for first language acquisition (Behrens, 2009) and for second language acquisition (Granger, Gilquin, & Meunier, 2015). In our recent monograph (Ellis, Römer, & O'Donnell, 2016) we give considerable detail to research which triangulates the psychology of learning, first (L1) and second (L2) language acquisition, psycholinguistics, corpus linguistics, and computational linguistics. In this chapter I will briefly summarise some relevant steps before presenting one new psycholinguistic study.

Usage-based theories of Construction Grammar posit that language comprises many thousands of constructions—form-meaning mappings, conventionalized in the speech community, and entrenched as language knowledge in the learner's mind (Goldberg, 1995; Robinson & Ellis, 2008; Trousdale & Hoffmann, 2013). Usage-based approaches to language acquisition hold that schematic constructions emerge as prototypes from the conspiracy of memories of particular exemplars that language users have experienced (Ellis, O'Donnell, & Römer, 2012). The experimental study I will describe investigates processing of abstract Verb-

Argument Constructions (VACs) and its sensitivity to the statistics of usage in terms of verb exemplar type-token frequency distribution, VAC-verb contingency, and VAC-verb semantic prototypicality.

VACs are schemata which bind patterns of lexical, morphological and syntactic language form to meaningful and functional interpretations. Goldberg and her collaborators use argument structure configurations involving nonce verbs to argue for the superiority of constructional meaning over lexical meaning (in particular verb meaning) in determining the overall meaning of an utterance (Bencini & Goldberg, 2000; Goldberg & Bencini, 2005). Consider how your language experience allows you to interpret novel utterances such as "it mandools across the ground" or "the teacher spugged the boy the book." You know that *mandool* is a verb of motion and have some idea of how *mandooling* works – its action semantics. You know that *spugging* involves transfer, that the teacher is the donor, the boy the recipient, and that the book is the transferred object. How is this possible, given that you have never previously heard these verbs? Each word of the construction contributes individual meaning, and the verb meanings in these VACs is usually at the core. But the larger configuration of words as a whole carries meaning too. The VAC as a category has inherited its schematic meaning from the conspiracy of all of the examples you have heard. *Mandool* inherits its interpretation from the echoes of the verbs that you have heard occupy this VAC – words like *come, walk, move, ..., scud, skitter and flit*. As you read these utterances, you parse them and identify their syntagmatic form: "it mandools across the ground" as a Verb Locative (VL) construction, "the teacher spugged the boy the book" as a double-object (VOO) construction. Then the paradigmatic associations of the types of verb that fill these slots are awakened: for the VL 'V *across* N' pattern *come, walk, move, ..., scud, skitter and flit,* for VOO *give, send, pass, ..., read, loan, and fax*.

If constructions are indeed learned like this, as schematic signs, as form-meaning pairings, then the general principles of associative learning and categorization should be evident in their processing (Ellis & Ogden, 2015). The learning and processing of cue-outcome contingencies should be affected by: (1) form frequency in the input, (2) contingency of form-function mapping, and (3) function (prototypicality of meaning).

2 Principles of the Associative Learning of Categories

2.1 Construction frequency

Frequency of exposure promotes learning and entrenchment (e.g., Anderson, 2009; Ebbinghaus, 1885). Learning, memory and perception are all affected by frequency of usage: the more times we experience something, the stronger our memory for it, and the more fluently it is accessed. The more times we experience conjunctions of features, the more they become associated in our minds and the more these subsequently affect perception and categorization (Harnad, 1987; Lakoff, 1987). The last 50 years of psycholinguistic research has demonstrated language processing to be exquisitely sensitive to usage frequency at all levels of language representation: phonology and phonotactics, reading, spelling, lexis, morphosyntax, formulaic language, language comprehension, grammaticality, sentence production, and syntax (Ellis, 2002). Language knowledge involves statistical knowledge, so humans learn more easily and process more fluently high frequency forms. So, in particular, verbs which appear more often in particular VACs should be more associated with those frames, and processed faster.

2.2 Contingency of form-function mapping

Psychological research into associative learning has long recognized that while frequency of form is important, more so is contingency of mapping (Shanks, 1995). Consider how, in the learning of the category of birds, while eyes and wings are equally frequently experienced features in the exemplars, it is wings which are distinctive in differentiating birds from other animals. Wings are important features to learning the category of birds because they are reliably associated with class membership; eyes are neither. Raw frequency of occurrence is less important in categorization than is the contingency between cue and interpretation (Rescorla, 1968). Contingency/ reliability of form-function mapping and associated aspects of predictive value, information gain, and statistical association, are driving forces of learning. They are central in psycholinguistic theories of language acquisition (Ellis, 2006a, 2006b, 2008; Gries & Wulff, 2005; MacWhinney, 1987). Lexical cues which are more faithful to a VAC should be more telling.

There are many available measures of contingency. In our research, we use the one-way dependency statistic ΔP (Allan, 1980) shown to predict cue-outcome learning in the associative learning literature (Shanks, 1995) as well as in psycholinguistic studies of form-function contingency in construction usage, knowledge, and processing (Ellis, 2006a; Ellis & Ferreira-Junior, 2009; Gries & Ellis, 2015).

Consider the contingency table showing the four possible combinations of the presence or absence of a VAC and a verb:

	Outcome	No Outcome
Cue	*a*	*b*
No cue	*c*	*d*

a, b, c, d represent frequencies, so, for example, *a* is the number of times the cue and the outcome co-occurred; *c* is the number of times the outcome occurred without the cue; etc..

ΔP is the probability of the outcome given the cue minus the probability of the outcome in the absence of the cue. When these are the same, when the outcome is just as likely when the cue is present as when it is not, there is no covariation between the two events and ΔP = 0. ΔP approaches 1.0 as the presence of the cue increases the likelihood of the outcome and approaches –1.0 as the cue decreases the chance of the outcome – a negative association.

$$\Delta P = P(O|C) - P(O|\neg C) = \frac{a}{a+b} - \frac{c}{c+d}$$

ΔP is a directional measure. We can consider the association between a VAC as cue and a particular verb type as the outcome (we will call this ΔPcw for construction->word). Alternately we can consider the association between a verb as cue and a particular VAC as the outcome (ΔPwc).

2.3 Function (prototypicality of meaning)

Categories have graded structure, with some members being better exemplars than others. In the prototype theory of concepts (Rosch & Mervis, 1975; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976), the prototype as an idealized central description is the best example of the category, appropriately summarizing the most representative attributes of a category. As the typical instance of a category, a prototype serves as the benchmark against which surrounding, less representative instances are classified. In semantic network theories of meaning, related concepts are more closely and strongly connected, and when one concept is activated, so activation spreads to neighboring nodes (Anderson, 1983). In these views, the prototype has two advantages: The first is a frequency factor: the greater the token frequency of an exemplar, the more it contributes to defining the category, and the greater the likelihood it will be considered the prototype (Rosch & Mervis, 1975; Rosch et al., 1976). Thus it is the response that is most associated with the concept in its own right. But beyond that, it gets the network centrality advantage. When any response is made, it spreads activation and reminds other members in the set. The prototype is most connected at the center of the network and, like Rome, all roads lead to it. Thus it receives the most spreading activation. Ellis, O'Donnell, and Römer (2014) consider spreading activation as it might apply to VACs. As symbolic form-function mappings, the VAC lexico-syntactic frame is associated by usage experience with a network of meanings. When the VAC is activated, prototypical verb meanings are more readily awakened.

Previous research which investigated these ideas involved two steps, first an analysis of VACs in a large corpus of representative usage, and second an analysis of the processing of these VACs by fluent native speakers.

3 Corpus analysis of VACs in Usage

Ellis and O’Donnell (2011, 2012) investigated the type-token distributions of 20 Verb-Locative (VL) VACs such as ‘V(erb) *across* n(oun phrase)’ in a 100-million-word corpus of English usage. The other locatives sampled were *about, after, against, among, around, as, at, between, for, in, into, like, of, off, over, through, towards, under,* and *with*. They searched a dependency-parsed version of the British National Corpus (BNC, 2007) for specific VACs previously identified in the Grammar Patterns volume resulting from the COBUILD corpus-based dictionary project (Francis, Hunston, & Manning, 1996). The details of the linguistic analyses, as well as subsequently modified search specifications in order to improve precision and recall, are described in Römer, O'Donnell, and Ellis (2014). This corpus linguistic research demonstrated:

(1) The frequency profile of the verbs in each VAC follows a Zipfian profile (Zipf, 1935) whereby a few verbs take the lion's share: the highest frequency types account for the most linguistic tokens. Zipf's law states that in human language, the frequency of words decreases as a power function of their rank: the most frequent verb occurs roughly twice as often as the second most frequent, roughly three times as often as the third most frequent, etc.

(2) VACs are selective in their verb form family occupancy: individual verbs select particular constructions; particular constructions select particular verbs; there is high contingency between verb types and constructions. This means that the Zipfian profiles seen in (1) are not those of the verbs in English as a whole – instead their constituency and rank ordering are special to each VAC.

(3) The most frequent verb in each VAC is prototypical of that construction's functional interpretation, albeit generic in its action semantics.

(4) VACs are coherent in their semantics. This was assessed using WordNet (Miller, 2009), a distribution-free semantic database based upon psycholinguistic theory, as an initial resource to investigate the similarity/distance between verbs. Then networks science, graph-based algorithms (de Nooy, Mrvar, & Batagelj, 2010) were used to build semantic networks in which the nodes represent verb types and the edges strong semantic

similarity for each VAC. Standard measures of network density, average clustering, degree centrality, transitivity, etc. were then used to assess the cohesion of these semantic networks and verb type connectivity within the network. Betweenness centrality was used as a measure of a verb node's centrality in the VAC network (McDonough & De Vleeschauwer, 2012). In semantic networks, central nodes are those which are prototypical of the network as a whole.

These corpus analyses thus demonstrated that these psychological principles of categorization and the associative learning of categories applied in usage. But what about in human cognition?

4 Analysis of knowledge of VACs

Ellis et al. (2014) used free association and verbal fluency tasks to investigate verb-argument constructions (VACs) and the ways in which their processing is sensitive to these statistical patterns of usage (verb type-token frequency distribution, VAC-verb contingency, verb-VAC semantic prototypicality). In experiment 1, 285 native speakers of English generated the first word that came to mind to fill the V slot in 40 sparse VAC frames such as 'he __ across the....', 'it __ of the....', etc. In experiment 2, 40 English speakers generated as many verbs that fit each frame as they could think of in a minute. For each VAC, we compared the results from the experiments with the corpus analyses of usage described above for step 1. For both experiments, multiple regression analyses predicting the frequencies of verb types generated for each VAC showed independent contributions of (i) verb frequency in the VAC, (ii) VAC-verb contingency (ΔPcw), and (iii) verb prototypicality in terms of centrality within the VAC semantic network.

Ellis et al. (2014) contend that the fact that native-speaker VACs implicitly represent the statistics of language usage implies that they are learned from usage.

4.1 Motivations for the current experiment

These findings show that lexis, syntax, and semantics are richly associated in VAC processing. However, free-association tasks can be quite conscious production tasks, especially those achieved over the timespan of a minute. All sorts of conscious strategies can come to play. It is difficult to conclude, therefore, that these results imply that that VACs are "mentally represented" as part of the constructicon. Although the findings are compatible with that idea, they are far from conclusive. For example, the native speakers in the one minute tasks might be building ad hoc categories (Barsalou, 2010) based on information (such as frequency information, contingencies, etc.) in order to engage in the association task. An ad hoc category is a novel category constructed spontaneously to achieve a goal relevant in the current situation (e.g., constructing *ways of catching moles* while seeing their destruction of the back lawn). These categories are novel—they have not been entertained previously. They are constructed spontaneously and do not reside as knowledge structures in long-term memory waiting to be retrieved. They help achieve a task-relevant goal by organizing knowledge relevant to the current situation in ways that support effective goal pursuit.

Therefore, none of the data provided in the free-association data force the conclusion that frequency, contingency, and prototypicality of verb-frame pairings are mentally represented as a separate construction. The 'first verb that comes to mind' variants of the task are more compelling in this respect than the one-minute tasks, but still further studies using a range of on-line processing tasks are needed to explore the generality of these findings and their implications for representation. The more these tasks tap implicit, automatic processing, the closer they are to reflecting language as it is stored rather than as it is marshaled (Ellis, 1994; Ellis, Loewen, Erlam, Philp, & Reinders, 2009; Segalowitz, 2010). This was the motivation for the following study.

5 Experiment: Naming Latency

There is no time for conscious deliberation when you are asked to name visually presented words as quickly as possible. Since Cattell (1886), there have been many demonstrations that high frequency words are named more rapidly than low frequency ones (Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004; Balota, Ferraro, & Connor, 1991; Forster & Chambers, 1973).

Cattell also was the first to demonstrate the effects of sequential dependency:

> "I find it takes about twice as long to read (aloud, as fast as possible) words which have no connexion as words which make sentences, and letters which have no connexion as letters which make words. When the words make sentences and the letters words, not only do the processes of seeing and naming overlap, but by one mental effort the subject can recognize a whole group of words or letters, and by one will-act choose the motions to be made in naming them." (Cattell, 1886, p. 64).
>
> The current experiment aims to assess the degree to which verb-VAC connexions [in terms of Verb-VAC frequency, contingency (ΔPcw), and semantic prototypicality of the verb in the construction (betweenness centrality)] affect the naming latency of the VAC preposition.

5.1 Participants

The participants were 28 university students at a large mid-western university taking an introductory course in psychology and so volunteering in the subject pool for course requirement. The age range was 18-22 years.

5.2 Method

5.2.1 Stimulus Materials

Ellis et al. (2014) identified the verb lemmas which together covered the top 95% of verb token uses in the BNC. They then counted their token frequencies in the BNC (Verb-Corpus Frequency), along with the frequency with which they occupied Verb-Locative (VL) VACs such as ‘V(erb) *across* n(oun phrase)’ (Verb-VAC frequency), the contingency between construction and word (ΔPcw), and the semantic prototypicality of the verb in the construction (betweenness centrality). The range of VL VACs included *about, across, against, among, around, between, for, into, like, of, off, over, through, towards, under, with*. The current experiment required a subset of stimuli which as far as possible factorially manipulated these dimensions, keeping them as independent as possible. The first step, therefore, was to regress each of the factors against the others. So, for example, log10VACfrequency was regressed against log10corpusfrequency, log10ΔPcw, and log10centrality, and the log10VACfrequency residuals were saved for each verb. In similar fashion, log10 ΔPcw was regressed against log10corpusfrequency, log10VACfrequency, and log10centrality, and the log10ΔPcw residuals were saved for each verb. And so on. Thus, for a verb-VAC pairing, we knew whether a verb was particularly high (or low) on one of these dimensions against the background of what might be expected from the levels of the other predictors. For each VAC, we then chose example verbs which reflected high, medium, and low semantic prototypicality, high, medium, and low VACfrequency, high, medium, and low ΔPcw. We also selected high (+), medium (0), and low (-) corpus frequency verbs which never appear in the construction. Examples for the case of ‘V *about* n’ are sem+ *move about*; sem0 *float about*; sem- *lie about*; vacfreq+ *chat about*; vacfreq0 *jump about*; vacfreq- *point about*; ΔP+ *talk about*; ΔP0 *understand about*; ΔP- *tell about*; never *reduce about*; never *catch about*; never *appoint about*. In this experiment, we stripped the VACs down from ‘V(erb) preposition n(oun phrase)’ to their bare minimum, i.e., the verb preposition collocation. The complete set of 192 stimuli so constructed are shown in Appendix 1 alongside their Verb-Corpus Frequency, Verb-VAC frequency, VAC-verb contingency, and Verb-VAC semantic prototypicality. These steps did not achieve complete orthogonality, but they did reduce the association of these predictors from the higher levels typically found in natural language to those correlations shown in Table 1.

Table 1 about here

5.2.2 Procedure

The experiment was scripted in PsychoPy v1.80.03 (Peirce, 2007) and run on iMac computers. Participants were instructed that they would be shown two words side-by-side and that they should read them aloud as quickly as possible after they appeared. Since we were recording their responses and how fast they made them, they were to speak loudly and clearly. Participants pressed the space bar when they were ready for the next trial. Trial order was randomized individually for each participant. On each trial, at 300ms., a beep started for 200ms. The onset of the beep was synchronous with the appearance of the word pair presented in Arial font, 0.15 letter height, slightly above mid-screen. This was exposed for 2 seconds in all. Throughout the trial we recorded audio using the internal microphone. At the end of each trial we saved this as a .wav file. The experiment as a whole took about 30 minutes to 40 minutes.

We post-processed the audio files first by concatenating them using xACT (Brown, 2014). A linguistics student then loaded each participant file into Audacity 2.0.2 (Audacity Team, 2014) and went through each trial marking and labeling the section between beep onset and the onset of the participant's naming of word 2. These voice onset times in ms. (VOTs) were exported for statistical analysis. Differences in word 2 VOT as a consequence of the nature of the verb-VAC characteristics could thus be assessed. Trials where the participant failed to made a response, or a loud enough response, were marked and removed from analysis. The VOT data files for each participant was then matched to their random trial sequence and these were then concatenated into a data file which was analyzed using R (R Development Core Team, 2012).

5.3 Results

In order to remove outliers, VOT data were Winsorized within each participant, trimming 5% of responses: For each participant, this set RTs below the 2.5th percentile to the value of the 2.5th percentile, and RTs above the 97.5th percentile to the 97.5th percentile. The resultant mean Word 2 naming latency over all participants and items in the experiment was 1.064 sec (*SD* = 0.20). We used the R package lme4 (Bates & Maechler, 2009) to estimate a linear mixed model of Word 2 VOT against the five predictors Verb Length in Letters, Preposition Length in Letters, Verb-Corpus Frequency, Verb-VAC frequency, VAC-verb contingency, and Verb-VAC semantic prototypicality, with random intercepts for both participants and VACs and independent random slopes for Verb-VAC frequency, VAC-verb contingency, and Verb-VAC semantic prototypicality. The summary results are shown in Table 2 where it can be seen that there were four significant independent effects upon the latency of preposition naming in the context of a preceding verb. First and foremost was verb length (*t* = 27.82): the longer the verb which was spoken before the onset of word 2, the longer the word 2 VOT. Frequent verbs in the language were spoken more quickly (*t* = -3.28). On-top of these ubiquitous psycholinguistic findings there were two effects which are VAC-specific: The more a verb appears in that VAC in usage, the quicker participants began to say the VAC preposition (*t* = -11.44). Likewise, the more semantically prototypical the verb in that VAC, the quicker they began to say the VAC preposition (*t* = -2.54). The R^2 for this analysis was 0.642.

In future research it would make sense, as suggested by a reviewer, to look for interactions between these predictors since it is possible, for instance, that verb contingency has a stronger effect when frequency is higher (because, for example, the higher frequency would mean there is more evidence for the high contingency). However, we have not done this here because we wanted to use the same analysis model as we did in Ellis (2106 a,b) which report a wider range of outcome measures including recognition threshold and lexical decision.

Table 2 about here

6 Discussion

It is standard that the recognition of individual words is a function of their prior experience as indexed by word frequency in the language. Therefore, the finding that naming of VACs is affected by the frequency of the verb (*t* = -3.28) is no surprise. The effect of Verb-VAC frequency (*t* = -11.44) is more potent: perception and naming is sensitive to the pairing of the verb and the VAC. This could reflect sensitivity to syntagmatic sequence, i.e. their collocation, or it could reflect sensitivity to the binding of the verb to the VAC as a whole, meaning and all. There are many other demonstrations that language users have implicit knowledge of sequences of language (for reviews see Ellis, 1996, 2001, 2012). For example, reading time is affected by collocational and sequential probabilities. Bod (2001), using a lexical-decision task, showed that high-frequency three-word sentences such as “I like it” were reacted to faster than low-frequency sentences such as “I keep it” by native speakers. Ellis, Frey and Jalkanen (2009) used lexical decision to demonstrate that native speakers preferentially process frequent verb-argument and booster/maximizer-adjective two-word collocations. Durrant and Doherty (2010) used lexical decision to assess the degree to which the first word of low- (e.g., *famous saying*), middle- (*recent figures*), high- frequency (*foreign debt*) and high frequency and psychologically-associated (*estate agent*) collocations primed the processing of the second word in native speakers. The highly frequent and high-frequency associated collocations evidenced significant priming. Arnon and Snider (2010) used a phrasal decision task (‘Is this phrase possible in English or not?’) to show that comprehenders are also sensitive to the frequencies of compositional four-word phrases: more frequent phrases (e.g. *don’t have to worry*) were processed faster than less-frequent phrases (*don’t have to wait*) even though these were matched for the frequency of the individual words or substrings. Tremblay, Derwing, Libben and Westbury (2011) examined the extent to which lexical bundles (LBs, defined as frequently recurring strings of words that often span traditional syntactic boundaries) are stored and processed holistically. Three self-paced reading experiments compared sentences containing LBs (e.g., *in the middle of the*) and matched control sentence fragments (*in the front of the*) such as *I* *sat in the middle/front of the bullet train*. LBs and sentences containing LBs were read faster than the control sentence fragments in all three experiments.

The additional independent effect of verb prototypicality (t = -2.54) show that these are not mere syntagmatic effects, but rather that VAC meaning is represented as well, and that VACs containing verbs which are more semantically central are processed faster. There results parallel the semantic priming effects first observed in two-word (Meyer & Schvaneveldt, 1971) and in three word interrupted lexical decision (Meyer & Schvaneveldt, 1971), which they took as evidence of spreading semantic activation rather than facilitated lexical access.

A relevant conceptualization is that of interactive-activation in connectionist models of lexical processing (Balota, Yap, & Cortese, 2006; McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982; Seidenberg & McClelland, 1989). Models with multiple independent layers of detectors (features, letters, words, meanings), with mutual inhibition of units within levels, but activation cascading both upwards and downwards between these levels, allow partial activation of meaning-level activations to in turn partially activate the representations that produced those representations (Balota et al., 1991, p. 213; Balota et al., 2006; Steyvers & Tenenbaum, 2005). Seeing *jump* activates the VL VACs with which *jump* is associated, which activates *VL-down* semantic space, which in turn sends activation downwards to the logogen for *down*, making it more likely to fire. It is not just statistical association between word forms (that's the effect of verb-VAC frequency). It really involves semantics, because additionally, verbs more prototypical of the VAC semantic meaning cause greater activation.

Ellis (2016b) reports another naming experiment using these materials. In that design, the two-word VAC sequence was presented sequentially, first the verb which was to be named independently, and then, 1200 ms. later, the preposition whose VOT was independently measured from preposition onset. Like here, it demonstrated effects of Verb-VAC frequency (t = -3.65) upon preposition naming latency. However, unlike here, there were no effects of semantic prototypicality. I believe that separating the two elements as in Ellis (2016b) disrupts fluent processing and hence misses these interactive-activation effects. Many priming effects are sensitive to inter-stimulus interval (Neely, 1991). Other experiments reported in (Ellis, 2016a, 2016b) look at effects of usage as reflected in language corpora upon automatic language processing in a variety of paradigms including recognition threshold, lexical decision, naming, and meaning judgement.

6.1 Limitations

There are many limitations to our study. Stripping down the VAC to the verb-preposition collocation adds problematic confounds to our interpretation. Consider, for example, the verb-preposition collocation *throw up*. If this were presented to subjects, then whatever reaction they had could be due to *throw up* as an intransitive prepositional verb (e.g., He threw up because he had too much to eat), or as an idiomatic transitive phrasal verb (e.g., He threw up his hands in despair), or as a compositional transitive phrasal verb (e.g., He threw up his car keys to her). Thus, there is an as yet unidentified amount of variability on the data that may create, amplify or weaken the correlations found here. A second problem is that, however hard we tried, it was impossible to achieve a sample of stimulus items where the predictor variables were completely orthogonal. A third is that some of our variables, particularly contingency, are patchily distributed. Finally, it would be sensible to replicate this research with different samples. The stimuli used here were the end of a long series of operationalizations of measures including NLP searches of one 100 million word corpus, statistical and definitional decisions regarding semantic analysis, and network building. Each step has its own associated error. Starting again from scratch, possibly using a different but comparable corpus, would be the best triangulation.

Our use of the BNC as representative of the usage experience of any one of our participants is, of course, a stretch. The BNC is reasonably balanced and was large by the standards of the mid 1990s. It was a huge accomplishment. But standards change and expectations rise. However well it represents a sum of 1990s English language, it is not representative of any one user in detail. There is much interest within corpus linguistics and psycholinguistics in the ways in which language differs according to speakers, genre, and register. Ideally, we want individualized dense corpora which properly reflect the usage experience of individualized language users.

7 On Methodological Triangulation

The concept of triangulation comes from geographical surveys where territories were mapped by means of the tracing and measurement of triangles to determine the distances and relative positions of points. The position of an single point in space can be determined with reference to the convergence of trigonometric measurements of angle and length taken from two other distinct points. Such techniques allowed surveyors equipped simply with a theodolite to map our planet with great accuracy. The physical remnants of these efforts are still to be found as markers (known as ‘trig points’ in the UK, or ‘triangulation points’ in the US) at the top of prominent hills and mountains. The methodological legacy is the recognition that cross-verification from two or more sources is important to data validation. The limitations of single method, single-observer, and single-theory studies can be mitigated by combining multiple observers, theories, methods, and data.

This study investigates (i) the structure of language usage using corpus linguistic methods, (ii) psycholinguistic processing, in this case naming latency, and (iii) the degree to which the latent structures of usage affect psycholinguistic processing. These three triangulation moves are by no means equivalent in terms of their contributions to establishing the reliability and validity of language research. Language usage, processing, and representation are quite different phenomena, however much they are in constant interaction and influence. Having reliable and valid estimates of a language user's usage history is one triangulation issue in its own right, one that is the focus of corpus linguistics. Having reliable and valid descriptions of language processing phenomena and of their uniformity or variation across different task demands is another, one that is the scope of psycholinguistics. Corpus linguistics (e.g., Biber & Reppen, 2015; McEnery & Hardie, 2012), learner corpus research (e.g., Granger et al., 2015), and psycholinguistics (e.g., Gaskell, 2007; Traxler & Gernsbacher, 2011) each have quite well-established theories and methods. The edge estimation that is more novel and more of a stretch is that from usage to processing. It is a more recent research enterprise, one more of exploration than of validation in that is testing usage-based theories of language acquisition and representation. There is some work on establishing the approach (Ellis & Larsen-Freeman, 2009; MacWhinney & O'Grady, 2015; Robinson & Ellis, 2008), and some on the general methods (Gries & Divjak, 2012; Rebuschat, Meurers, & McEnery, 2017), but this new land as sketched in the current volume has an excitement that goes more with travel than it does with settlement.

The current study is just one expedition. Its findings as reported here, in Ellis (2106 a,b), and further in Ellis, Römer and O'Donnell (2016) lead to a conclusion that speeded automatic on-line VAC processing involves rich associations, tuned by verb type and token frequencies, their contingencies of usage, and their histories of interpretations, both specific and prototypical, which interface syntax, lexis, and semantics. So it encourages the conception of a unified constructicon where words and VACs alike are symbolic representations, acquired from usage, statistics and all, with their subsequent processing tuned probabilistically to usage experience. So also it is encouraging of further collaborations between corpus linguistics and usage-based language research.

Abstract

Ellis, O'Donnell, and Römer (2014) used free-association tasks to investigate knowledge of Verb-Argument Constructions (VACs). They demonstrated that English speakers have independent implicit knowledge of (i) verb frequency in the VAC, (ii) VAC-verb contingency, and (iii) verb prototypicality in terms of centrality within the VAC semantic network. They concluded that VAC processing involves rich associations, tuned by verb type and token frequencies and their contingencies of usage, which interface syntax, lexis, and semantics. However, the tasks they used, where respondents had a minute to think of the verbs that fitted in VAC frames like 'he __ across the....', 'it __ of the....', etc., were quite conscious and explicit. The current experiment therefore investigates the effects of these factors in on-line processing. The experiment had participants read aloud verb-VAC arguments like "leaned over", "thinks over", "knock over" as quickly as possible. These exemplars varied in their corpus-derived verb-VAC frequency, verb-VAC contingency, and verb prototypicality within the VAC semantic network. Responses were audio recorded and Audacity was used to measure the latency of naming the second word (the preposition) after simultaneous visual presentation of the verb-VAC arguments. A mixed linear model including random intercepts for participant and VAC, and random slopes for frequency, contingency, and prototypicality, explained 64% of the variance. It demonstrated that naming latency of the VAC preposition was affected by verb length, verb frequency in the corpus, verb-VAC frequency and semantic prototypicality. These results demonstrate the effects of usage on VAC knowledge, and particularly that VAC processing is sensitive to the statistical co-occurrence of verbs, VACs, and their meaning.

Keywords

Usage-based acquisition and processing, Construction Grammar, Naming Latency, Frequency, Semantic prototypicality, Contingency, On-line Processing.

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Table 1

The intercorrelations of the predictor variables for the stimulus set

	L10corpusfreq	VACLength	L10VACfreq	L10ΔPcw	L10 centrality
L10corpusfreq	1.000				
VACLength	-0.216	1.000			
L10VACfreq	0.202	-0.221	1.000		
L10ΔPcw	-0.035	0.019	0.433	1.000	
L10centrality	0.449	-0.214	0.436	0.235	1.000

Table 2

A linear mixed model predicting word 2 VOT in ms.

Random effects:

Groups	Name	Variance	Std.Dev.
Participant	(Intercept)	1.515e-02	0.123
VAC	(Intercept)	1.510e-03	0.038
Participant	L10vacfreq	9.528e-07	0.000
Participant	L10ΔPcw	2.183e-04	0.015
Participant	L10centrality	9.546e-04	0.030
Residual	1.619e-02	0.1272268	

Number of obs: 5376, groups: participant, 28; VAC, 16

Fixed effects:

	Estimate	Std.Error	t value
(Intercept)	0.861307	0.049603	17.36 **
L10corpusfreq	-0.011265	0.003429	-3.28 **
L10vacfreq	-0.015592	0.001362	-11.44 **
L10ΔPcw	0.003846	0.008834	0.43
L10centrality	-0.026994	0.010614	-2.54 **
PrepLength	0.005291	0.006326	0.83
VerbLength	0.029249	0.001051	27.82 **

$R^2 = 0.642$

Appendix A.

The complete set of 192 stimuli with their Verb-Corpus Frequency, Verb-VAC frequency, VAC-verb contingency (ΔPcw), and Verb-VAC semantic prototypicality statistics. For each VAC, there are verbs in Stimulus Classes which reflected high, medium, and low semantic prototypicality (sem+, sem0*,* sem-), high, medium, and low VACfrequency, (vacfreq+, vacfreq0*,* vacfreq-), high, medium, and low (ΔPcw+, ΔPcw0, ΔPcw-), and high, medium, and low corpus frequency verbs which never appear in the construction (never).

Stimulus Class	VAC	Verb Lemma	Verb Corpus Frequency	Verb Frequency in VAC	Contingency ΔPcw	Prototypicality Betweenness Centrality
ΔP-	about	tell	72651	60	-0.001616	0.031554
ΔP+	about	talk	28867	3832	0.156649	0.056935
ΔP0	about	understand	21977	40	0.000414	0.001054
never	about	appoint	7555	0	-0.1	0
never	about	catch	13890	0	-0.1	0
never	about	reduce	17560	0	-0.1	0
sem-	about	lie	13190	90	0.002974	0.000123
sem+	about	move	37573	74	0.000939	0.11688
sem0	about	float	1861	3	1.90E-05	0
vacfreq-	about	point	13693	1	-0.00073	0
vacfreq+	about	chat	1264	63	0.002531	0
vacfreq0	about	jump	4947	4	-0.000114	0
ΔP-	across	see	184478	15	-0.007532	0.01125
ΔP+	across	walk	19994	243	0.045077	0.071111
ΔP0	across	ship	1233	1	0.000121	0
never	across	allow	31708	0	-0.1	0
never	across	define	9306	0	-0.1	0
never	across	predict	3709	0	-0.1	0
sem-	across	live	31402	14	0.000894	0.000852
sem+	across	hit	10278	3	-8.00E-06	0.029071
sem0	across	swim	2151	19	0.003491	0.001779
vacfreq-	across	follow	41428	1	-0.002142	0
vacfreq+	across	flash	1543	32	0.005997	0.001457
vacfreq0	across	chase	2008	3	0.000457	3.50E-05
ΔP-	against	unite	1306	14	0.001487	0.005424
ΔP+	against	vote	5185	217	0.02389	0

ΔP0	against	settle	7061	4	4.80E-05	0.005604
never	against	call	51741	0	-0.1	0
never	against	care	7607	0	-0.1	0
never	against	conceive	1757	0	-0.1	0
sem-	against	stand	30620	173	0.017555	0.002571
sem+	against	break	18399	9	-3.30E-05	0.037351
sem0	against	crash	2160	29	0.00311	0.002037
vacfreq-	against	collect	7727	1	-0.000324	0
vacfreq+	against	brush	1955	74	0.008136	0.001034
vacfreq0	against	advance	2800	4	0.000288	0.002428
ΔP-	among	get	211788	15	-0.006672	0.040913
ΔP+	among	occur	15351	27	0.008581	0.000957
ΔP0	among	vanish	1497	2	0.000615	0.00063
never	among	add	26641	0	-0.1	0
never	among	devoted	2074	0	-0.1	0
never	among	ignore	7043	0	-0.1	0
sem-	among	remain	25526	11	0.002411	0.000254
sem+	among	play	36811	9	0.001077	0.05194
sem0	among	step	5352	3	0.000748	0.001341
vacfreq-	among	die	20979	1	-0.000831	0.001909
vacfreq+	among	circulate	1379	17	0.005869	0.001958
vacfreq0	among	belong	6152	6	0.001753	0
ΔP-	around	spring	1659	4	0.00067	0.00381
ΔP+	around	look	108373	353	0.061248	0.027268
ΔP0	around	bend	3110	3	0.000397	0.004476
never	around	abolish	1858	0	-0.1	0
never	around	consider	28494	0	-0.1	0
never	around	prefer	6608	0	-0.1	0
sem-	around	happen	30997	23	0.002643	0.000763
sem+	around	go	224168	212	0.027829	0.137623
sem0	around	concentrate	6916	8	0.001137	0.002045
vacfreq-	around	burn	4873	1	-8.40E-05	0.003727
vacfreq+	around	tighten	1420	39	0.007361	0.000468
vacfreq0	around	come	143580	51	0.001648	0.010893
ΔP-	between	work	61068	16	-0.001509	0.011308
ΔP+	between	distinguish	3863	697	0.083798	0.000769
ΔP0	between	spill	1296	1	4.80E-05	0
never	between	coincide	1598	0	-0.1	0
never	between	grant	6608	0	-0.1	0
never	between	remember	25331	0	-0.1	0
sem-	between	open	21642	22	0.001433	4.00E-04
sem+	between	run	38688	94	0.009153	0.049416
sem0	between	pause	2978	6	0.000556	0.001114

vacfreq-	between	check	9375	1	-0.000407	0
vacfreq+	between	switch	4301	41	0.0047	0.000547
vacfreq0	between	transfer	5526	7	0.000533	0.003581
ΔP-	for	depart	1352	45	0.000421	0.002162
ΔP+	for	ask	57431	2659	0.026128	0.000292
ΔP0	for	display	5425	4	-0.000263	0
never	for	deem	1856	0	-0.1	0
never	for	protect	8741	0	-0.1	0
never	for	remind	5200	0	-0.1	0
sem-	for	sit	27625	328	0.002061	0.001226
sem+	for	hold	46230	320	0.000921	0.032849
sem0	for	proceed	4134	16	-5.70E-05	0.002099
vacfreq-	for	advise	5273	1	-0.000287	0
vacfreq+	for	opt	1722	513	0.00557	0
vacfreq0	for	flow	2535	3	-0.00011	0
ΔP-	into	squeeze	1921	46	0.000813	0.008907
ΔP+	into	fall	26023	1834	0.035264	0.028624
ΔP0	into	diminish	1369	1	-5.70E-05	0
never	into	expect	27887	0	-0.1	0
never	into	recognize	5799	0	-0.1	0
never	into	respect	1784	0	-0.1	0
sem-	into	smile	10196	53	0.000486	0
sem+	into	travel	8290	33	0.000193	0.030758
sem0	into	pop	1907	88	0.001655	0.002598
vacfreq-	into	raise	18984	1	-0.001051	0
vacfreq+	into	peer	1621	208	0.004074	0
vacfreq0	into	pin	1203	2	-2.80E-05	0
ΔP-	like	give	125313	22	-0.00568	0.02096
ΔP+	like	seem	59547	437	0.024009	0.003818
ΔP0	like	plunge	1355	1	-1.40E-05	0
never	like	acquires	6685	0	-0.1	0
never	like	allege	1820	0	-0.1	0
never	like	require	27944	0	-0.1	0
sem-	like	become	65875	69	0.00061	0.001266
sem+	like	pass	19595	7	-0.000665	0.028837
sem0	like	spin	1650	6	0.000283	0.000266
vacfreq-	like	reflect	11060	1	-0.00056	0
vacfreq+	like	smell	2209	35	0.002067	4.60E-05
vacfreq0	like	gather	4726	4	-1.60E-05	0.000194
ΔP-	of	want	87178	57	-0.003631	0.008277
ΔP+	of	consist	6295	3021	0.067828	0.000195
ΔP0	of	desire	1386	1	-5.60E-05	0
never	of	associate	8054	0	-0.1	0

never	of	base	19034	0	-0.1	0
never	of	forgive	1934	0	-0.1	0
sem-	of	admit	10839	40	0.000291	0
sem+	of	taste	1423	30	0.000597	0.02661
sem0	of	request	2665	2	-0.000105	0
vacfreq-	of	sound	9235	1	-0.000498	0
vacfreq+	of	dream	2509	415	0.009225	0
vacfreq0	of	whisper	2817	3	-9.10E-05	0
ΔP-	off	round	1376	3	0.001794	0.01193
ΔP+	off	put	67251	26	0.012436	0.006613
ΔP0	off	strip	1517	3	0.001786	0.001001
never	off	experience	6738	0	-0.1	0
never	off	insert	1765	0	-0.1	0
never	off	provide	51092	0	-0.1	0
sem-	off	let	27961	11	0.005289	0.000633
sem+	off	cut	17759	20	0.011478	0.046312
sem0	off	fight	10193	5	0.002546	0.002982
vacfreq-	off	grow	18372	1	-0.00041	0.004147
vacfreq+	off	seal	1388	11	0.006785	0.000748
vacfreq0	off	drain	1592	3	0.001782	0.00024
ΔP-	over	think	142884	60	-0.005002	0.009273
ΔP+	over	take	172544	1696	0.076423	0.050725
ΔP0	over	knock	4333	57	0.002651	0.000913
never	over	described	23107	0	-0.1	0
never	over	invent	1804	0	-0.1	0
never	over	name	5928	0	-0.1	0
sem-	over	lean	4464	227	0.011278	0.001142
sem+	over	cover	18578	26	0.000274	0.030188
sem0	over	struggle	3559	12	0.000409	0.001915
vacfreq-	over	seek	16511	1	-0.000879	0
vacfreq+	over	glance	3693	98	0.00477	5.80E-05
vacfreq0	over	feel	57807	9	-0.002799	0.006049
ΔP-	through	know	177192	29	-0.008638	0.000385
ΔP+	through	read	21154	112	0.004004	0.002188
ΔP0	through	sell	20170	32	0.000348	0.000171
never	through	involve	22543	0	-0.1	0
never	through	own	6331	0	-0.1	0
never	through	translate	2130	0	-0.1	0
sem-	through	watch	18830	26	0.000145	4.40E-05
sem+	through	beat	7952	3	-0.000309	0.019424
sem0	through	warm	1484	5	0.000148	0
vacfreq-	through	aim	7542	1	-0.000379	0
vacfreq+	through	wander	2332	98	0.004415	0.000654

vacfreq0	through	ease	2338	3	7.00E-06	0.00022
ΔP-	towards	make	209036	30	-0.008019	0.025677
ΔP+	towards	turn	43782	368	0.043527	0.042625
ΔP0	towards	stretch	4446	17	0.001874	0.006326
never	towards	include	34858	0	-0.1	0
never	towards	stems	1383	0	-0.1	0
never	towards	welcome	5523	0	-0.1	0
sem-	towards	help	40178	32	0.001737	0.000493
sem+	towards	extend	9524	15	0.001338	0.030295
sem0	towards	leap	1998	8	0.000887	0.000536
vacfreq-	towards	throw	10840	1	-0.000485	0
vacfreq+	towards	drift	1924	62	0.00764	0.0023
vacfreq0	towards	sink	2895	5	0.000462	0.001625
ΔP-	under	find	95330	8	-0.004632	0.00201
ΔP+	under	operate	10040	134	0.011757	0.000765
ΔP0	under	begin	41430	20	-0.000494	0.002829
never	under	aid	1506	0	-0.1	0
never	under	believe	33409	0	-0.1	0
never	under	conclude	5513	0	-0.1	0
sem-	under	claim	18435	23	0.001077	8.50E-05
sem+	under	broke	18399	27	0.001447	0.029654
sem0	under	cook	2895	2	2.10E-05	0.000217
vacfreq-	under	eat	13612	1	-0.000674	0
vacfreq+	under	collapse	2282	39	0.003458	0.001892
vacfreq0	under	fold	1585	3	0.000187	0.002274
ΔP-	with	show	58052	93	-0.002399	0.010654
ΔP+	with	deal	16117	6407	0.060182	0.006339
ΔP0	with	fill	10409	617	0.005294	0.011627
never	with	forbid	1293	0	-0.1	0
never	with	hand	5075	0	-0.1	0
never	with	intend	10483	0	-0.1	0
sem-	with	hope	21003	21	-0.000989	4.00E-05
sem+	with	change	26434	157	1.00E-06	0.108972
sem0	with	trace	2548	2	-0.000125	0
vacfreq-	with	stress	4187	1	-0.000227	0
vacfreq+	with	disagree	1271	348	0.003246	0.000475
vacfreq0	with	promise	6048	4	-0.000304	0