Second language verb-argument constructions are sensitive to form, function, frequency, contingency, and prototypicality

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We used free association tasks to investigate second language (L2) verb-argument constructions (VACs) and the ways in which their access is sensitive to statistical patterns of usage (verb type-token frequency distribution, VAC-verb contingency, verb-VAC semantic prototypicality). 131 German, 131 Spanish, and 131 Czech advanced L2 learners 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. For each VAC, we compared these results with corpus analyses of verb selection preferences in 100 million words of usage and with the semantic network structure of the verbs in these VACs. For all language groups, multiple regression analyses predicting the frequencies of verb types generated for each VAC show independent contributions of (i) verb frequency in the VAC, (ii) VAC-verb contingency, and (iii) verb prototypicality in terms of centrality within the VAC semantic network. L2 VAC processing involves rich associations, tuned by verb type and token frequencies and their contingencies of usage, which interface syntax, lexis, and semantics.

Keywords: construction grammar, usage-based acquisition and processing, free association task, semantic networks, contingency, processing, transfer

1. Constructing a second language

Cognitive linguistic 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, 2008b; Trousdale & Hoffmann, 2013). Usage-based approaches to language acquisition hold that schematic

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constructions emerge as prototypes from the conspiracy of memories of particular exemplars that language users have experienced. There are many commonalities between first language (L1) and second language acquisition (L2A) that can thus be informed by corpus analyses of input and from cognitive- and psycho-linguistic investigation of construction acquisition following associative and cognitive principles of learning and categorization, hence increased attention to usage-based approaches within L2A research (Collins & Ellis, 2009; Ellis, 1998, 2003; Ellis & Cadierno, 2009; Robinson & Ellis, 2008b). This paper investigates L2 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.

Our experience of language allows us to converge upon similar interpretations of novel utterances like "it mandooled across the floor" and "she spugged him the borg." You know that *mandool* is a verb of motion and have some idea of how *mandooling* works — what its action semantics are. You know that *spugging* involves some sort of gifting, that she is the donor, he the recipient, and that the *borg*, whatever that is, is the transferred object. How is this possible, given that you have never heard these verbs before? One possibility is that there is a close relationship between the types of verbs that typically appear within constructions, hence their meaning as a whole is inducible from the lexical items experienced within them. So your reading of "it mandools across the …" is driven by an abstract 'V *across* noun' VAC which has inherited its schematic meaning from all the relevant examples you have heard, and your interpretation of *mandool* emerges from the echoes of the verbs that occupy this VAC — the 'exemplar cloud' of tokens including *come*, *walk*, *move*,…, *scud*, *skitter* and *flit*.

The specific claim under examination in this paper is that L2 speakers, like L1 speakers, have schematic VAC meanings that are inherited from the constituency of all the verb exemplars experienced within them, weighted according to the frequency of their experience and the reliability of their association to that construction (their contingency), and their degree of prototypicality in the semantics of the VAC.

Previous research that addressed this claim for L1 speakers involved two steps: (1) an analysis of VACs in a large corpus of representative usage, and (2) an analysis of the processing of these VACs by fluent native speakers.

In step one, 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, in press). This corpus linguistic research demonstrated:

1. The frequency profile of the verbs in each VAC follows a Zipfian profile (Zipf, 1935) whereby 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.
2. The most frequent verb in each VAC is prototypical of that construction's functional interpretation, albeit generic in its action semantics.
3. 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.
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.

In step two, Ellis, O'Donnell, and Römer (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 one minute. For each VAC, they 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, 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. Further, usage-based linguists (e.g., Boyd & Goldberg, 2009; Bybee, 2008, 2010; Ellis, 2008a; Goldberg, 2006; Goldberg, Casenhiser, & Sethuraman, 2004; Lieven & Tomasello, 2008; Ninio, 1999), influenced by psychological theory relating to the statistical learning of categories, have proposed that these three factors make concepts robustly learnable — that it is the Zipfian coming together of linguistic form and function that makes language learnable despite learners' idiosyncratic experiences.

To test the generalizability of these phenomena to L2A, this paper extends the methods of step 2 to test German, Spanish, and Czech advanced learners for comparability with the native English speakers from Ellis et al. (2014).

2. Experiments: L2 sensitivity to VAC usage

In order to determine whether these factors affect L2 VAC processing, we used the same free-association tasks asking respondents to generate the verbs that come to mind when they see schematic VAC frames such as 'he __ across the …,' 'it __ of the …,' etc. Free-association tasks like this are standard in psychology for determining category representation (Battig & Montague, 1969; Rosch & Mervis, 1975; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). Similar methods have also been used in cognitive linguistic investigations of construction grammar (Dąbrowska, 2009).

2.1 Participants

The participants were predominantly university students recruited through emails sent by members or associates of the research team, either to the students directly or to one of their instructors. The L1 German, L1 Czech, and L1 Spanish learners were students enrolled at research universities in Germany, the Czech Republic, and Spain.[1] The mean number of years of English instruction was 10.04 years for German, 11.37 for Czech, and 12.68 for Spanish learners. L1 English speakers were mostly students enrolled at a large mid-western research university. The following numbers of participants volunteered to complete the VAC survey: 285 native English speakers, 276 L1 German learners of English, 185 L1 Czech learners of English, and 131 L1 Spanish learners of English. To ensure comparability across datasets, we based our analyses on only 131 responses from each of the four participant groups, including all of the L1 Spanish responses and 131 randomly selected responses each from the native speaker, L1 German, and L1 Czech groups.

2.2 Method

A survey was designed and delivered over the web using Qualtrics (http://www.qualtrics.com/). Participants were instructed: "We are going to show you a phrase with a verb missing, and ask you to fill in the gap with the first word that comes to your mind. For example, for the phrase: he __ her the … you might respond he *gave* her the … or he *sent* her the … And for the phrase: it __ down the … You might respond it *rolls* down the … Or it *fell* down the … On each page you will be presented with a phrase like one of these with a line indicating a missing word. In the text box type the first word you think of and press the [ENTER] key." They then saw the 20 sentence frames shown in Table 1 shown once with the subject *he/she* and once with *it*. These 40 trials were presented in a random order. We recorded their responses and the time they took on each sentence. The survey as a whole took between 5 and 15 minutes. Responses were lemmatized using the Natural Language Toolkit (Bird, Loper, & Klein, 2009).

Table 1. The VAC prompts used here

s/he	it___about the…	s/he	it___in the…
s/he	it___across the…	s/he	it___into the…
s/he	it___after the…	s/he	it___like the…
s/he	it___against the…	s/he	it___of the…
s/he	it___among the…	s/he	it___off the…
s/he	it___around the…	s/he	it___over the…
s/he	it___as the…	s/he	it___through the…
s/he	it___at the…	s/he	it___towards the…
s/he	it___between the…	s/he	it___under the…
s/he	it___for the…	s/he	it___with the…

2.3 Analyzing effects of Frequency

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 relation between frequency of experience and entrenchment following a power law (e.g., Anderson, 2000; Ellis, 2002; Ellis & Schmidt, 1998; Newell, 1990). The more times we experience conjunctions of features or of cues and outcomes, the more they become associated in our minds and the more these subsequently affect perception and categorization (Harnad, 1987; Lakoff, 1987; Taylor, 1998). If constructions are acquired by general learning mechanisms, these general principles of cognition should apply to VACs, too.

This leads to Analysis 1: The accessibility of verb types as VAC exemplars in the generative tasks should be a function of their token frequencies in those VACs in usage experience.

2.4 Analyzing effects of Contingency

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, 2008b; MacWhinney, 1987) and in cognitive/corpus linguistic analyses as well (Ellis & Cadierno, 2009; Ellis & Ferreira-Junior, 2009b; Evert, 2005; Gries, 2007, 2012; Gries & Stefanowitsch, 2004; Stefanowitsch & Gries, 2003).

This leads to Analysis 2: Verbs which are faithful to particular VACs in usage should be those which are more readily accessed by those VAC frames than verbs which are more promiscuous. To measure this, 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, 2009b; Gries, 2013).

Consider the contingency table shown in Table 2. 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 $\Delta P = 0$. ΔP approaches 1.0 as the presence of the cue increases the likelihood of the

Table 2. A contingency table showing the four possible combinations of events showing the presence or absence of a target cue and an outcome

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

a, b, c, d represent frequencies, so, for example, a is the frequency of conjunction of the cue and the outcome, and c is the number of times the outcome occurred without the cue. The effects of conjoint frequency, verb frequency, and VAC frequency are illustrated for three cases below:

	ΔP Construction → Word				**ΔP Word → Construction**			
	Conjoint Frequency a	**VAC Frequency a+b**	**Verb Frequency a+c**	**ΔPcw**	**Conjoint Frequency a**	**Verb Frequency a+b**	**VAC Frequency a+c**	**ΔPwc**
lie across	44	5,261	13,190	0.0076	44	13,190	5,261	0.0030
stride across	44	5,261	1,049	0.0083	44	1,049	5,261	0.0416
crowd into	44	50,070	749	0.0008	44	749	50,070	0.0559

outcome and approaches –1.0 as the cue decreases the chance of the outcome — a negative association.

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

ΔP is affected by the conjoint frequency of construction and verb in the corpus (a), but also by the frequency of the verb in the corpus, the frequency of the VAC in the corpus, and the number of verbs in the corpus. For illustration, the lower part of Table 2 considers three exemplars, *lie across*, *stride across*, and *crowd into*, which all have the same conjoint frequency of 44 in a corpus of 17,408,901 VAC instances. This is the value that Analysis 1 would consider. However, while ΔP Construction → Word (ΔPcw) for *lie across* and *stride across* are approximately the same, the one for *crowd into* is an order of magnitude less. ΔPwc shows a different pattern — the values for *stride across* and *crowd into* are over ten times greater than for *lie across*. In this experiment, we are giving people the construction and asking them to generate the word, and ΔPcw is the relevant metric.

2.5 Assessing the effects of Semantic Prototypicality

In our analyses of VAC semantics in usage, we determined prototypicality in terms of the centrality of the verb in the semantic network connecting the verb types that feature in that VAC (Ellis & O'Donnell, 2011, 2012). We used the measure 'betweenness centrality,' which was developed to quantify the control of a human on the communication between other humans in a social network (McDonough & De Vleeschauwer, 2012).

This leads to Analysis 3: The verb types that are produced more frequently in the generative tasks should be more prototypical of the VAC semantics as indexed by their degree in the semantic network of the VAC in our usage analyses.

2.6 Results

The verb types generated for each VAC were aggregated across participants and the *s/he* or *it* prompt variants. Scrutiny of our corpus analyses demonstrated that we were unable to achieve sufficient precision in our searching for the *after*, *at,* and *in* VACs because these occur in a wide variety of temporal references as well as locatives. They were therefore removed from subsequent analyses, leaving 17 VACs for the correlations and regressions.

We restrict analysis to the verb types that cover the top 95% of verb tokens in English usage. In the BNC, the most frequent 961 verbs in English cover this range. This threshold is necessary to avoid the long tail of the BNC frequency distribution (very low frequency types and hapax legomena) dominating the analyses. Without this step, results of such research are over-influenced simply by the size of the reference corpus — the larger the corpus, the longer the tail (Malvern, Richards, Chipere, & Duran, 2004; Tweedie & Baayen, 1998).

Statistical analyses were performed using R (R Development Core Team, 2012). All subsequent analyses involve the log10 transforms of the variables: (a) token generation frequency in the VAC, (b) token frequency in that VAC in the BNC, (c) ΔPcw verb-VAC in the BNC, (d) verb centrality in the semantic network of that VAC, (e) verb frequency in the whole BNC. To avoid missing responses as a result of logging zero, all values were incremented by 0.01.

Table 3. 131 ENGLISH L1 Respondents: Correlations (*r*) and their significance level (*p*) between log10 verb generation frequency and (a) log10 verb frequency in that VAC in the BNC, (b) log10 ΔPcw verb-VAC in the BNC, (c) log10 verb centrality in the semantic network of that VAC, (d) log10 verb frequency in the whole BNC. Signif. codes: '**' 0.01, '*' 0.05

VAC	*n verb types*	*r* log BNC VAC freq	*p* of *r*	*r* log ΔPcw	*p* of *r*	*r* log VACSEM centrality	*p* of *r*	*r* log BNC verb freq	*p* of *r*
V about	31	0.53	**	0.68	**	0.13	*ns*	0.37	*
V across	24	0.52	**	0.50	*	0.37	*ns*	0.44	*
V against	26	0.57	**	0.51	**	0.29	*ns*	0.48	**
V among	27	0.69	**	0.64	**	0.53	**	0.71	**
V around	28	0.52	**	0.32	*ns*	0.58	**	0.62	**
V as	41	0.20	*ns*	−0.09	*ns*	0.30	*ns*	0.33	*
V between	30	0.63	**	0.37	*	0.49	**	0.49	**
V for	41	0.67	**	0.74	**	0.62	**	0.52	**
V into	27	0.51	**	0.54	**	0.55	**	0.42	*
V like	38	0.58	**	0.54	**	0.55	**	0.24	*ns*
V of	26	0.77	**	0.68	**	0.49	**	0.61	**
V off	25	0.58	**	0.60	**	0.50	**	0.41	*
V over	29	0.27	*ns*	0.10	*ns*	0.16	*ns*	0.25	*ns*
V through	32	0.62	**	0.66	**	0.59	**	0.48	**
V towards	26	0.61	**	0.67	**	0.70	**	0.41	*
V under	29	0.59	**	0.42	*	0.55	**	0.43	*
V with	33	0.51	**	0.38	*	0.48	**	0.48	**
MEAN	30.1	0.55		0.48		0.46		0.45	

2.6.1 *Analysis 1*

We plot the lemmatized verb types for each VAC in the space defined by log token generation frequency against log token frequency in that VAC in the BNC. The plot for 'V *of* n' is shown in Figure 1 for each of the language groups. Items appear on the graph if the lemma both appears as a response in the generation task for that VAC and it also appears in the BNC. The font size for each verb plotted is proportional to the frequency of that verb in the BNC as a whole. It can be seen

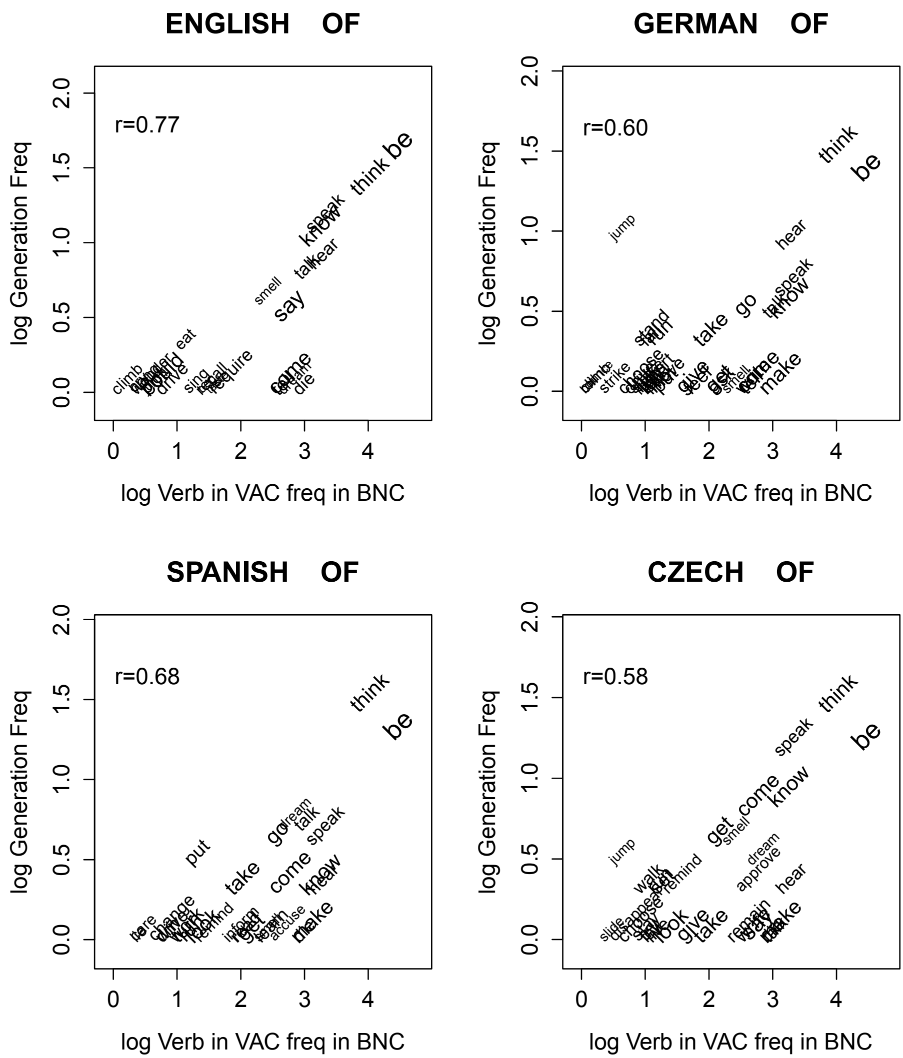

Figure 1. English and German, Spanish and Czech L2 English log10 verb generation frequency against log10 verb frequency in that VAC in the BNC for VAC 'V *of* n'. Verb font size is proportional to overall verb token frequency in the BNC as a whole.

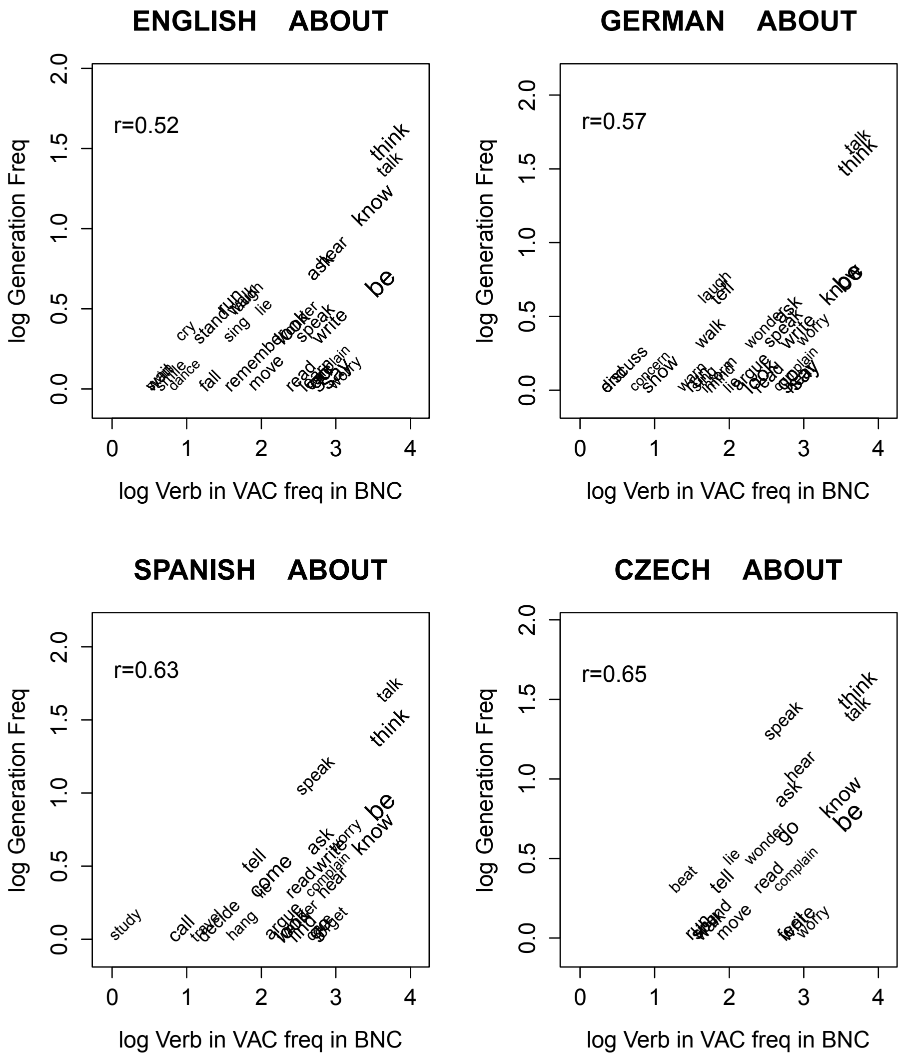

Figure 2. L1 English and German, Spanish and Czech L2 English log10 verb generation frequency against log10 verb frequency in that VAC in the BNC for VAC 'V *about* n'. Verb font size is proportional to overall verb token frequency in the BNC as a whole.

that for the L1 English group, generation frequency follows verb frequency in that VAC in the BNC with a correlation of $r = 0.77$. After the copula *be*, cognition verbs (*think* and *know*) are the most frequent types, followed by communication verbs (*speak*, *say*, *talk*, *ask*), and also perception verbs (*smell*, *hear*). Thus the semantic sets of the VAC frame in usage are all sampled in the free association task, and the sampling follows the frequencies of usage. The responses for the three ESL groups pattern in a similar fashion: generation frequency follows verb frequency in that

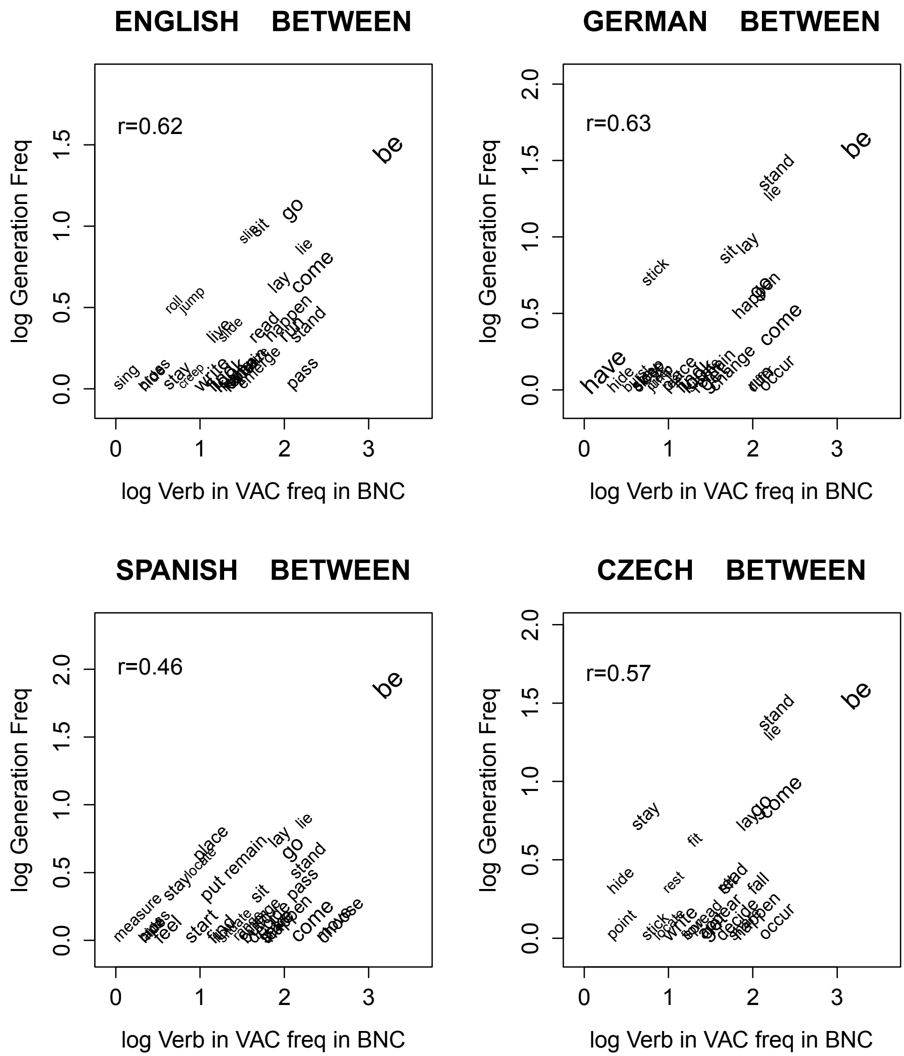

Figure 3. L1 English and German, Spanish and Czech L2 English log10 verb generation frequency against log10 verb frequency in that VAC in the BNC for VAC 'V *between* n'. Verb font size is proportional to overall verb token frequency in the BNC as a whole.

VAC in the BNC with a correlation of $r = 0.60$ for the L1 German group, $r = 0.68$ for the L1 Spanish group, and $r = 0.58$ for the L1 Czech group.

Illustrative plots of the responses for the VACs 'V *about* n', 'V *between* n', and 'V *against* n' against frequencies of the verbs in that VAC in the BNC are shown in Figures 2, 3, and 4 where it can be seen that the advanced L2 English speakers generated a similar set of verb types for these VACs with similar token frequencies.

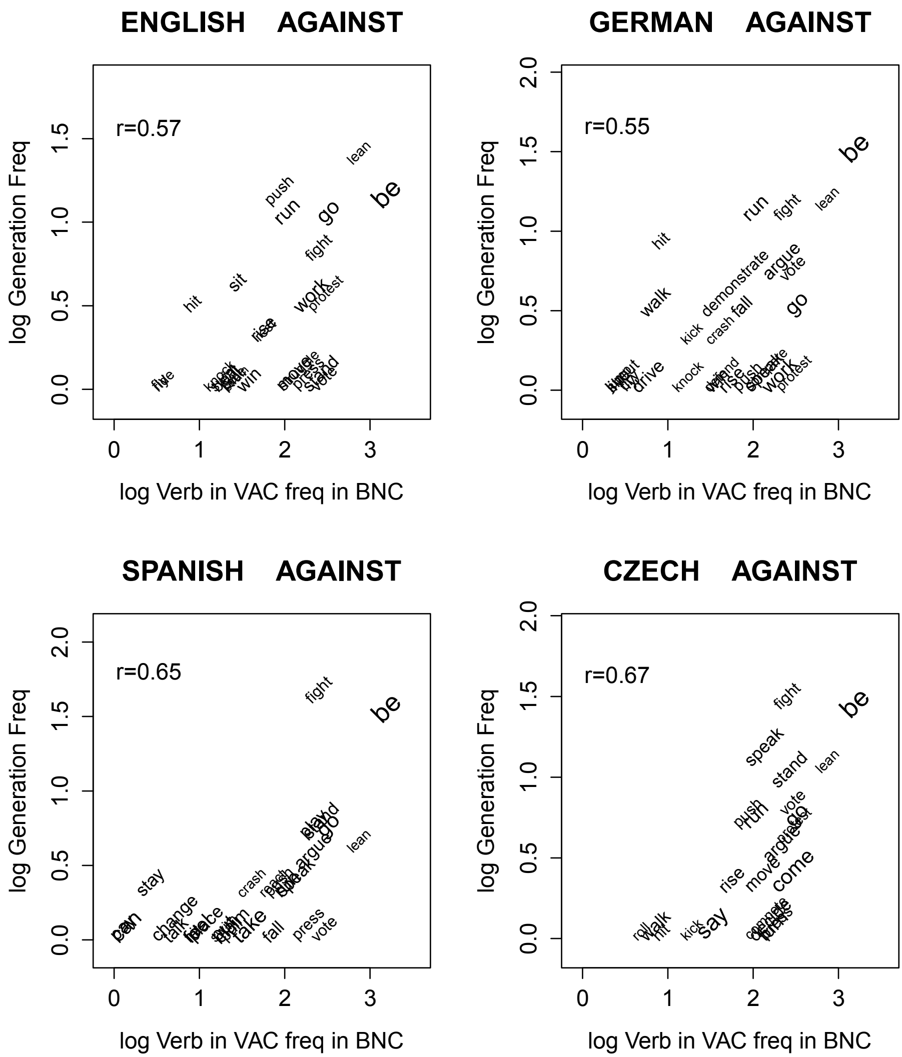

Figure 4. L1 English and German, Spanish and Czech L2 English log10 verb generation frequency against log10 verb frequency in that VAC in the BNC for VAC 'V *against* n'. Verb font size is proportional to overall verb token frequency in the BNC as a whole.

For each VAC we correlate verb generation frequency against verb frequency in the VAC in the BNC. These correlations are shown in the third column of Table 3, their significance levels in column 4 of Table 3 for the native English respondents. These are non-trivial correlations. Their mean is 0.55. The same data are shown for the German respondents in Table 4 where the mean correlation is 0.59, for the Spanish respondents in Table 5 where the mean correlation is 0.65, and for the Czech respondents in Table 6 where the mean correlation is 0.59. The responses of all language groups, L1 and L2 alike, are sensitive to verb usage frequency in the VAC across the 17 constructions sampled.

2.6.2 *Analysis 2*

To assess whether frequency of verb generation is associated with VAC-verb contingency, we correlate this with ΔPcw in the BNC. These correlations and their significance levels are shown in columns 5 and 6 of Tables 3–6. Again they are non-trivial. Their mean is 0.48 for English L1, 0.53 for German, 0.63 for Spanish, and 0.56 for Czech. Across the 17 constructions, the responses of all language groups, L1 and L2 alike, are sensitive to VAC-verb contingency.

Table 4. 131 GERMAN L1 Respondents: Correlations (*r*) and their significance level (*p*) between log10 verb generation frequency and (a) log10 verb frequency in that VAC in the BNC, (b) log10 ΔPcw verb-VAC in the BNC, (c) log10 verb centrality in the semantic network of that VAC, (d) log10 verb frequency in the whole BNC. Signif. codes: '**' 0.01, '*' 0.05

VAC	*n verb types*	*r* log BNC VAC freq	*p* of *r*	*r* log ΔPcw	*p* of *r*	*r* log VACSEM centrality	*p* of *r*	*r* log BNC verb freq	*p* of *r*
V about	29	0.58	**	0.75	**	0.37	*	0.34	*ns*
V across	22	0.73	**	0.72	**	0.44	*	0.56	*
V against	28	0.56	**	0.53	**	0.39	*	0.43	*
V among	25	0.77	**	0.55	**	0.51	*	0.69	**
V around	23	0.63	**	0.43	*	0.65	**	0.64	**
V as	56	0.26	*ns*	0.03	*ns*	0.33	**	0.35	**
V between	28	0.64	**	0.42	*	0.20	*ns*	0.35	*ns*
V for	36	0.60	**	0.74	**	0.16	*ns*	0.35	*
V into	27	0.60	**	0.61	**	0.60	**	0.29	*ns*
V like	34	0.57	**	0.58	**	0.54	**	0.33	*ns*
V of	36	0.60	**	0.65	**	0.25	*ns*	0.39	*
V off	31	0.69	**	0.71	**	0.62	**	0.59	**
V over	33	0.47	**	0.37	*	0.26	*ns*	0.32	*ns*
V through	33	0.53	**	0.77	**	0.62	**	0.18	*ns*
V towards	28	0.69	**	0.64	**	0.64	**	0.58	**
V under	25	0.52	**	0.28	*ns*	0.30	*ns*	0.37	*ns*
V with	34	0.53	**	0.31	*ns*	0.52	**	0.46	**
MEAN	31.1	0.59		0.53		0.44		0.42	

2.6.3 *Analysis 3*

To determine whether frequency of verb generation is associated with semantic prototypicality of the VAC verb usage in the BNC, we correlate frequency of verb generation with the betweenness centrality of that verb in the semantic network of the verb types occupying that VAC in the BNC. These correlations and their significance levels are shown in columns 7 and 8 of Tables 3–6. Their mean is 0.46 for English L1, 0.44 for German, 0.43 for Spanish, and 0.35 for Czech. These associations are more modest: 12/17 are significant in the L1 group and 27/51 in the L2 samples.

Table 5. 131 SPANISH L1 Respondents: Correlations (*r*) and their significance level (*p*) between log10 verb generation frequency and (a) log10 verb frequency in that VAC in the BNC, (b) log10 ΔPcw verb-VAC in the BNC, (c) log10 verb centrality in the semantic network of that VAC, (d) log10 verb frequency in the whole BNC. Signif. codes: '**' 0.01, '*' 0.05

VAC	*n verb types*	*r* log BNC VAC freq	*p* of *r*	*r* log ΔPcw	*p* of *r*	*r* log VACSEM centrality	*p* of *r*	*r* log BNC verb freq	*p* of *r*
V about	26	0.64	**	0.74	**	0.33	*ns*	0.31	*ns*
V across	23	0.61	**	0.59	**	0.46	*ns*	0.53	**
V against	28	0.65	**	0.61	**	0.15	*ns*	0.30	*ns*
V among	22	0.63	**	0.65	**	0.36	*ns*	0.73	**
V around	23	0.63	**	0.46	*	0.68	**	0.76	**
V as	42	0.46	**	0.36	*	0.23	*ns*	0.32	*
V between	30	0.47	**	0.16	*ns*	0.37	*	0.53	**
V for	36	0.60	**	0.74	**	0.27	*ns*	0.47	**
V into	23	0.70	**	0.79	**	0.46	*	0.68	**
V like	23	0.77	**	0.86	**	0.40	*ns*	0.29	*ns*
V of	30	0.69	**	0.61	**	0.35	*ns*	0.48	**
V off	22	0.65	**	0.69	**	0.47	*	0.40	*ns*
V over	29	0.73	**	0.72	**	0.54	**	0.48	**
V through	21	0.79	**	0.84	**	0.59	**	0.54	**
V towards	23	0.73	**	0.69	**	0.71	**	0.35	*ns*
V under	31	0.60	**	0.49	**	0.35	*ns*	0.38	*
V with	25	0.76	**	0.72	**	0.59	**	0.56	**
MEAN	26.9	0.65		0.63		0.43		0.48	

2.6.4 *Combined analyses*

These analyses VAC by VAC and variable by variable have shown that each of our potential causal variables is associated with verb generation frequency. Nevertheless, within each analysis the sample sizes are rather low. Sampling 131 tokens from a Zipfian distribution, where the lead item gets the lion's share, results in variability in the lower frequency items which a respondent might, or might not, generate. Ideally such research would involve larger samples of respondents, or, as in Ellis, O'Donnell, & Römer (2014) Experiment 2, more responses per participant.

However, we can obtain more power of analysis, as well as assess generalization, by looking across the constructions to assess the degree to which these

Table 6. 131 CZECH L1 Respondents: Correlations (*r*) and their significance level (*p*) between log10 verb generation frequency and (a) log10 verb frequency in that VAC in the BNC, (b) log10 ΔPcw verb-VAC in the BNC, (c) log10 verb centrality in the semantic network of that VAC, (d) log10 verb frequency in the whole BNC. Signif. codes: '**' 0.01, '*' 0.05

VAC	*n verb types*	***r*** **log BNC VAC freq**	***p*** **of** ***r***	***r*** **log ΔPcw**	***p*** **of** ***r***	***r*** **log VACSEM centrality**	***p*** **of** ***r***	***r*** **log BNC verb freq**	***p*** **of** ***r***
V about	22	0.65	**	0.68	**	0.28	*ns*	0.35	*ns*
V across	27	0.67	**	0.66	**	0.44	*	0.49	**
V against	23	0.67	**	0.63	**	0.02	*ns*	0.25	*ns*
V among	25	0.47	*	0.56	**	0.08	*ns*	0.37	*ns*
V around	27	0.66	**	0.54	**	0.65	**	0.60	**
V as	38	0.40	**	0.30	*ns*	0.13	*ns*	0.22	*ns*
V between	25	0.58	**	0.38	*ns*	0.45	*	0.50	**
V for	33	0.70	**	0.80	**	0.23	*ns*	0.17	*ns*
V into	24	0.59	**	0.57	**	0.29	*ns*	0.44	*
V like	23	0.72	**	0.80	**	0.65	**	0.22	*ns*
V of	31	0.58	**	0.51	**	0.25	*ns*	0.28	*ns*
V off	30	0.42	*	0.51	**	0.35	*	0.23	*ns*
V over	27	0.32	*ns*	0.22	*ns*	0.32	*ns*	0.22	*ns*
V through	21	0.71	**	0.70	**	0.70	**	0.61	**
V towards	18	0.76	**	0.78	**	0.68	**	0.32	*ns*
V under	24	0.55	**	0.40	*	0.22	*ns*	0.32	*ns*
V with	36	0.50	**	0.49	**	0.26	*ns*	0.30	*ns*
MEAN	26.7	0.59		0.56		0.35		0.35	

patterns hold across the VACs analyzed here, and the degree to which each causal variable makes an independent contribution. Therefore we stacked the generation data for the different VACs into a combined data set. We included cases where the verb appeared in the language group generations for that VAC and in the BNC in that VAC. If we look within a construction, since the construction frequency remains constant, words with similar conjoint frequencies have similar ΔPcw, hence the similar sizes of correlation for frequency and ΔPcw in Tables 3–6. However when, as here, we compare across VACs of very different frequencies in the corpus (from lows of 1459 for *off*, 2551 *among*, up to 84,648 *for* and 89,745 *with*), verbs with the same conjoint frequency will have markedly different ΔPcw (as in the cases of *stride across* and *crowd into* in Table 2).

The next step is to use these data sets to perform, for each language group, a multiple regression of log generation frequency against log BNC verb frequency in that VAC, log ΔPcw, and log verb betweenness centrality in that VAC usage in the BNC, entering all three independent variables into the regression using glm in R. We also used the R package relaimpo (Grömping, 2006) to calculate the relative importance of their contributions. The resultant coefficients are shown in Table 7.

Consider first the English L1 group. Each of the three predictors makes a highly significant independent contribution in explaining the generation data at $p < .01$. The major predictor is ΔPcw (Relative Importance 0.40), followed by verb betweenness centrality in the semantic network for VAC usage in the BNC (lmg 0.31 and BNC verb frequency in that VAC (lmg 0.29.) Tests for collinearity of the independent variables produce low variance inflation factors well within acceptable limits. All three predictors also make significant independent contributions using rlm robust regression in R (Fox, 2002). The R effects library (Fox, 2003) was used to graph the effects of each of the predictors. The left column of Figure 5 shows these with confidence intervals for English log L1 frequencies of verb types generated for a VAC frame against (i) log frequencies of that verb type in that VAC

Table 7. Multiple regression summary statistics for the analyses of 131 L1 English respondents and 131 German, Spanish and Czech L2 English respondents

Group	R sq	b			Relative Importance		
		Frequency	Contingency	Prototypicality	Frequency	Contingency	Prototypicality
English	0.31	.07**	0.39***	0.30***	0.29	0.40	0.31
German	0.34	.06**	0.48***	0.29***	0.28	0.47	0.25
Spanish	0.44	.06**	0.60***	0.23***	0.29	0.53	0.17
Czech	0.33	.08**	0.54***	0.17***	0.31	0.56	0.14

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05

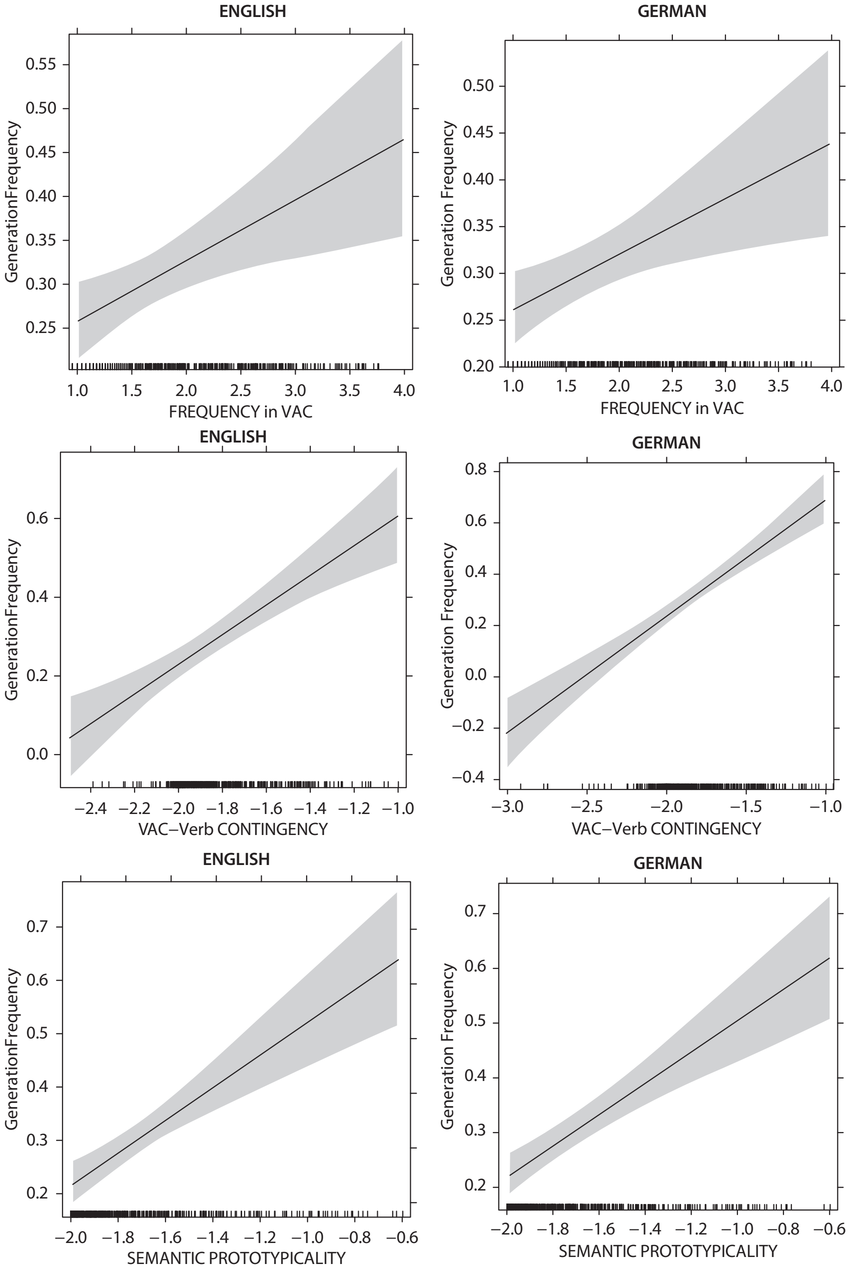

Figure 5. Effect sizes for log10 frequencies of verb generated for a VAC frame against (i) log10 frequencies of that verb type in that VAC frame in the BNC, (ii) log 10 ΔPcw association strength of that verb given that VAC in the BNC, (iii) log10 betweenness centrality of that verb in that VAC semantic network from the BNC data, pooled across the 17 VACs analyzed, for L1 English (left column) and German L2 English (right column).

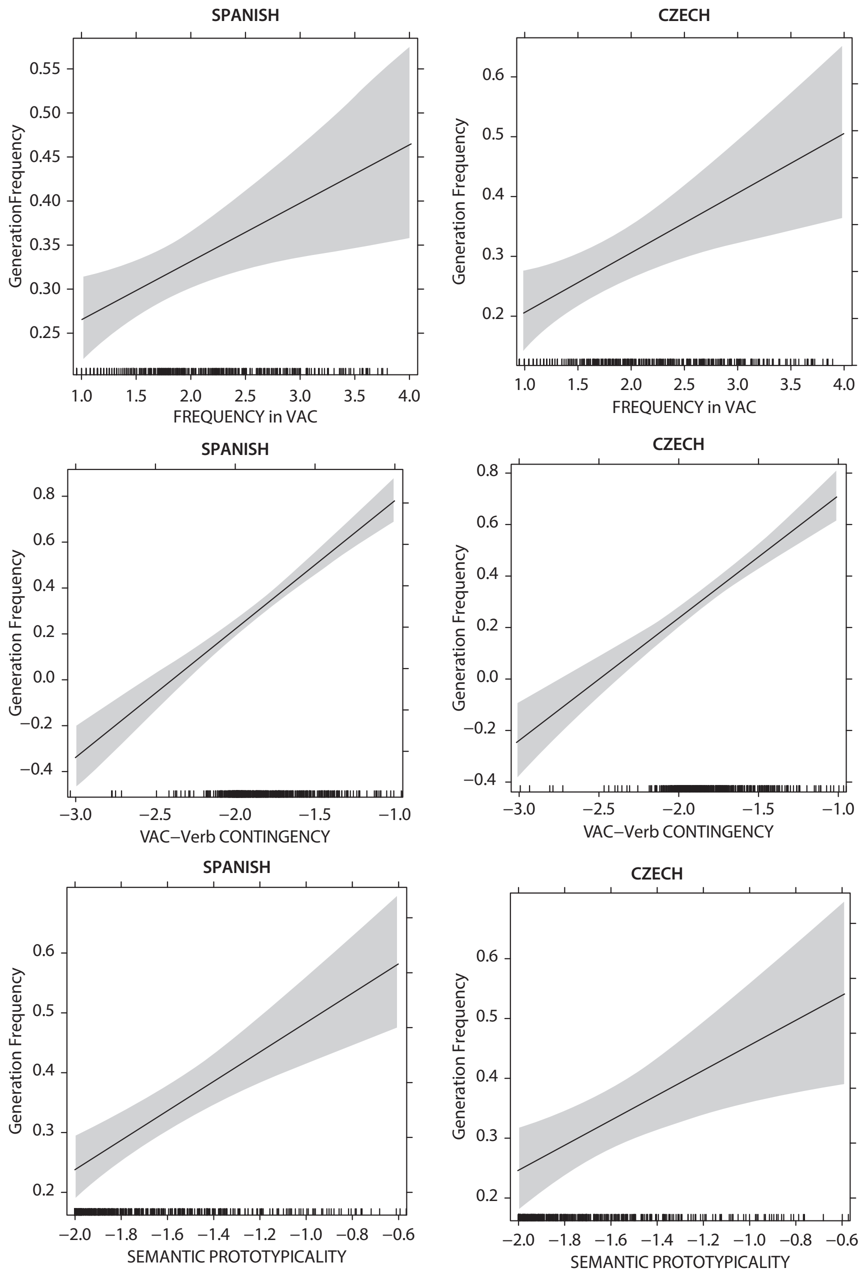

Figure 6. Effect sizes for log10 frequencies of verb generated for a VAC frame against (i) log10 frequencies of that verb type in that VAC frame in the BNC, (ii) log 10 ΔPcw association strength of that verb given that VAC in the BNC, (iii) log10 betweenness centrality of that verb in that VAC semantic network from the BNC data, pooled across the 17 VACs analyzed, for L1 Spanish (left column) and Czech L2 English (right column).

frame in the BNC, (ii) log ΔPcw association strength of that verb given that VAC in the BNC, and (iii) log betweenness centrality of that verb in that VAC semantic network from the BNC data, pooled across the 17 VACs analyzed.

Now consider the L2 learner groups. Each of the three predictors makes a highly significant independent contribution in explaining the generation data for each language group, German, Spanish, and Czech, at $p < .01$. The patterns of Relative Importance are of the same order: Contingency > Frequency > Prototypicality. The right column of Figure 5 shows the effects plots for L1 German. The effects plots for L1 Spanish and Czech groups are shown in Figure 6. The influences of the three causal variables are all significant, and are of a similar magnitude, in each of the language groups.

3. Discussion

These findings demonstrate that for L1 and advanced L2 speakers alike, particular verbs are associated with skeletal schematic syntactic VAC frames like s/he … *of*, it … *on*, etc. Which verbs come to mind when these fluent language users consider these prompts is determined by three factors:

1. Entrenchment — verb token frequencies in those VACs in usage experience;
2. Contingency — how faithful verbs are to particular VACs in usage experience;
3. Semantic prototypicality — the centrality of the verb meaning in the semantic network of the VAC in usage experience.

We take this as evidence for common processes of construction learning from usage in both first and second language acquisition. Not only do these factors show strong and significant zero-order correlations with productivity in the generative task, but multiple regression analyses also show that they make significant independent contributions. These factors have been implicated in usage-based approaches to SLA (e.g., Ellis, 2002, 2008b), although they have not been properly addressed within the same empirical study:

1. Effects of frequency of usage upon language learning, ENTRENCHMENT, and subsequent fluency of linguistic processing are well documented and understood in terms of Hebbian learning (Bybee, 2010; Bybee & Hopper, 2001; Ellis, 2002; MacWhinney, 2001).
2. Effects of CONTINGENCY of association are also standard fare in the psychology of learning (Rescorla & Wagner, 1972; Shanks, 1995), in the psychology of language learning (Ellis, 2006a, 2006b; MacWhinney, 1987; MacWhinney, Bates, & Kliegl, 1984), and in the particular cases of English VAC acquisition (Ellis &

Ferreira-Junior, 2009a, 2009b; Ellis & Larsen-Freeman, 2009) and German L2 English learners' verb-specific knowledge of VACs as demonstrated in priming experiments (Gries & Wulff, 2005, 2009).

3. We interpret the effects of semantic PROTOTYPICALITY in terms of the spreading activation theory of semantic memory (Anderson, 1983). 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 VAC 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. We discuss this further in Ellis et al. (2014).

In the present paper, we investigate L2 constructions in order to relate them to prior work with fluent L1 speakers (Ellis et al., 2014). Like the L1 speakers, and to a similar extent, German, Czech, and Spanish L1 advanced learners of English as an L2 showed independent effects of frequency, contingency, and prototypicality. These findings suggest that the learning of constructions as form-meaning pairs, like the associative learning of cue-outcome contingencies, are affected by factors relating to the form such as type and token frequency; factors relating to the interpretation such as prototypicality and generality of meaning, and factors relating to the contingency of form and function. Language acquisition involves the distributional analysis of the language stream and the parallel analysis of contingent perceptual activity, with abstract constructions being learned from the conspiracy of concrete exemplars of usage following statistical learning mechanisms (Christiansen & Chater, 2001; Rebuschat & Williams, 2012) relating input and learner cognition.

However, despite these fundamental similarities with L1A, there are differences, too. Languages lead their speakers to experience different 'thinking for speaking' and thus to construe experience in different ways (Slobin, 1996). Learning another language involves learning how to construe the world like natives of the L2, i.e., learning alternative ways of thinking for speaking (Brown & Gullberg, 2008; Brown & Gullberg, 2010; Cadierno, 2008) or learning to 'rethink for speaking' (Robinson & Ellis, 2008a). Transfer theories such as the Contrastive Analysis Hypothesis (Gass & Selinker, 1983; James, 1980; Lado, 1957, 1964) hold that L2 learning can be easier where languages use these attention-directing devices in the same way, and more difficult when they use them differently. To the extent that the constructions in L2 are similar to those of L1, L1 constructions can serve as the basis for the L2 constructions, but, because even similar constructions across languages differ in detail, the acquisition of the L2 pattern in all its detail is hindered by the L1 pattern (Cadierno, 2008; Odlin, 1989, 2008; Robinson & Ellis, 2008b).

There is good reason to expect that there will be L1 effects upon L2 VAC acquisition. Languages differ in the ways in which verb phrases express motion events. According to Talmy,

> "the world's languages generally seem to divide into a two-category typology on the basis of the characteristic pattern in which the conceptual structure of the macro-event is mapped onto syntactic structure. To characterize it initially in broad strokes, the typology consists of whether the core schema is expressed by the main verb or by the satellite" (Talmy, 2000, p. 221).

The "core schema" here refers to the framing event, i.e. the expression of the path of motion. Languages that characteristically map the core schema onto the verb are known as verb-framed languages, those that map the core schema onto the satellite are satellite-framed languages. Included in the former group are Romance and Semitic languages, Japanese, and Tamil. Languages in the latter group include Germanic, Slavic, and Finno-Ugric languages, and Chinese. This means that a Germanic language such as English often uses a combination of verb plus particle (*go into*, *jump over*) where a Romance language like Spanish uses a single form (*entrar*, *saltar*).

Römer, O'Donnell, and Ellis (2014) present detailed quantitative and qualitative analyses of the L2 responses residualized against English native speaker L1 responses (rather than the BNC usage analyses reported here), in order to demonstrate additionally that there are differences in the representation of these VACs in L2 speakers that result from L1⇒L2 transfer or "learned attention". These were particularly apparent in L1 speakers of typologically distinct verb-framed Spanish as opposed to German and Czech, which, like English, are satellite-framed. The German learner responses most closely and the Spanish learner responses least closely match the native speaker responses, with the Czech learner responses falling somewhere between these two groups. This was particularly true for the VACs 'V *against* n', 'V *among* n', 'V *as* n', 'V *between* n', 'V *in* n', 'V *off* n', 'V *over* n', and 'V *with* n'.

Our findings reflect L2 knowledge of language that comes from usage. The analyses reported here show effects of L2 usage: independent contributions of (i) L2 verb frequency in the VAC, (ii) L2 VAC-verb contingency, and (iii) verb prototypicality in terms of centrality within the L2 VAC semantic network. L2 VAC processing involves rich associations, tuned by L2 verb type and token frequencies and their contingencies of usage, which interface syntax, lexis, and semantics. Yet L2 learners are distinguished from infant L1 acquirers by the fact that they have previously devoted considerable resources to the estimation of the characteristics of another language — the native tongue in which they have considerable fluency.

Since they are using the same cognitive apparatus to survey their L2 too, their inductions are often affected by transfer, with L1-tuned expectations and selective attention (Ellis, 2006b) blinding the computational system to aspects of L2 form and meaning, thus rendering biased estimates from naturalistic usage. So second language constructions reflect usage of L2 and L1 both.

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