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The impact of co-occurrence and context on the prediction of long-distance separable prefixes

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ABSTRACT

Current inquiry into language processing focuses on predictive capabilities in anticipating words. This study investigates the predictability of separable verb prefixes in German, when they occur in sentence final position, often with much intervening material. Forty-nine speakers of German completed a cloze-task to measure their ability to predict missing sentence-final separable prefixes. The results are compared to statistics drawn from a corpus that show German speakers accurately predict sentence-final prefixes and accuracy is strongly correlated to both cue strength between particular prefix-verb pairs and the effect of contextual clues. The discussion links this work to the implications for evolutionary advantages of prediction via alignment and the ability to use corpora both for the creation and assessment of language testing procedures.

1. Introduction

Recent studies have placed an increased focus on the ability of listeners to predict upcoming verbal elements. Functional approaches to language acquisition such as the Competition Model (Bates and MacWhinney, 1987; MacWhinney, 2014), connectionism (Baronchelli et al., 2013), and usage-based linguistics (Bybee, 2010; Ellis et al., 2015) all support a view of language skills that emerge from statistical patterns in the input (Erickson and Thiessen, 2015). Studies have shown how frequency and statistical associations can facilitate word recognition (Balota and Spieler, 1999), syntactic processing (Spivey and Tanenhaus, 1998) and production fluency (Yoshimura and MacWhinney, 2007). Due to our shared experiences, the recurrence of distributional patterns through usage is largely shared across individuals, especially within communities that interact within a shared social space. While individuals share much linguistic input in a particular setting, each individual lives a different life with different experiences and different interlocutors and sources of language input. As Hoey (2005) points out, each individual has his or her own encounters over their lifetime, which result in an individual's particular statistical network of language cues, entrenched patterns, and primings. In sum, the underlying forces of cue strength, frequency, and validity play a major role in a person's ability to accurately predict upcoming words, and these forces vary by individual.

Within psycholinguistics, research related to speakers' ability to predict upcoming words has typically focused on words in close proximity, often immediately next to one another; for example, in studies looking at gender cues (Friederici and Jacobsen, 1999) or size of language knowledge (Mani and Heuttig, 2012). This study expands the literature by

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investigating the predictability of separable verb prefixes in German when they occur separated from the verb in sentence final position, often with a large amount of intervening material. These separable prefixes are mostly members of a closed class of about 60 words (prepositions and adverbs) that are bound to particular verb stems, with the exception of a few prefixes that cannot stand alone (*e.g. dar-* and *inne-*). When the stem of the verb appears in the inflected, second-position of a sentence, the prefix is most often placed in clause-final position. Often the meaning of the prefix-verb combination is idiosyncratic and not a simple semantic combination. Thus, speakers cannot fully interpret the meaning of the verb until they reach the end of the clause, which creates a long-distance dependency between the two parts of the prefix-verb complex. Since most verbs can have multiple separable prefixes, with a few exceptions, such as *ausmerzen* and *abkanzeln*, it is unlikely that a person could know with absolute certainty what the sentence final prefix should be. While the verb itself establishes the probability of particular prefixes, the additional sentence-internal context adds to and changes these probabilities, and therefore the probabilities for and against particular prefixes are continuously changing as more and more of the sentence is revealed. The results of the current study show that German speakers are able to accurately predict sentence-final prefixes, and that accuracy is strongly correlated to both cue strength between particular prefix-verb pairs and the effect of other contextual clues.

2. Literature review

2.1. Language processing and prediction

An emphasis on the role of prediction in language processing has both waxed and waned over the past fifty years. Van Petten and Luka (2012) noted that in the 1960s, researchers (Miller and Isard, 1963; Tulving and Gold, 1963) emphasized the extent to which listeners "generate hypotheses about upcoming words." In the same vein, Goodman (1967) referred to reading as a "psycholinguistic guessing game". However, in the 1980s, researchers (Forster, 1981) noted that, in general, the cloze probability for any given following word is so small that general use of prediction must be a fairly unlikely behavior with a "low payoff", which was the idea that prediction used up significant mental resources with only a small likelihood of success. This critical stance held sway until the late 1990s, when advances in research technology, including eye-tracking and event related potential (ERP) methods, brought the idea of prediction back into the picture (Van Petten and Luka, 2012).

A new wave of research into predictive linguistic behaviors has put a focus on the dynamic nature of prediction. Theories in language processing, such as the Competition Model (Bates and MacWhinney, 1987; Mitsugi and MacWhinney, 2016), neural network modeling (Christiansen and Chater, 1999) and surprisal theory (Hale, 2006), point to an online, continual process where probabilities are being calculated during the entire process as new sentential elements are being introduced, and that these probabilities are being refined and corrected as more and more of a sentence is processed.

As a recent example of the way in which speakers use lexically specific data to predict upcoming words, Arai and Keller (2013) studied the effects of verb-specific information. In their study, the researchers used a visual world experiment (Tanenhaus and Spivey-Knowlton, 1996) modeled after Altmann and Kamide (2007), in which participants listen to sentences and view a scene that contains the target items, as well as distractor items. Participants' eye-movements were tracked to detect whether certain verbs, such as *eat*, were more likely to drive attention to food items in the picture than verbs like *move.* Like Altmann and Kamide (2007), Arai and Keller (2013) found that verb-specific information aided in participants' abilities to narrow down and ultimately predict direct objects. In addition, Arai and Keller (2013) found that this verb-specific information can be used to avoid garden path ambiguity.

While visual world studies provide evidence that predictive behaviors do take place, one shortcoming of this type of study compared to real-world processing is the limited number of items from which one has to predict. Because the visual world studies limit the possible items that could be used in the sentences, it is difficult to tell whether predictive behaviors are limited to scenarios with ample context and limited choices, or if speakers make these predictions in a more general way as a basic part of language processing. While this question is still unanswered, these findings indicate that speakers are not only integrating syntactic structure to predict upcoming words, but also word-specific semantic information.

ERP studies have provided further evidence for online lexical prediction. These studies have observed brain sensitivity to semantically inappropriate words (Federmeier and Kutas, 1999; Kutas and Hillyard, 1980, 1983) and to words that fail to agree morphologically with other expected words (Tokowicz and MacWhinney, 2005; Dusias and Sagarra, 2007). These effects can be generated both by lexical and discourse contexts (Otten and Van Berkum, 2008).

The majority of the studies reviewed above have examined the prediction of open-class words (i.e. nouns, verbs, adjectives) from other open-class words. Problems regarding the complexity of predictions within this domain were at the focus of the critique of prediction models in the 1980s (Jackendoff, 2002). However, it is also possible that closed-class words that are closely associated with open-class words could play a major role in prediction. For example, in a sentence like *John picked ____ the book*, the word *up* immediately comes to mind, whereas *John put ____ the book*, elicits the opposition direction of *down.*

From the previous example, the connection between verb and prepositional choice is quite clear, but there is a problem. In these two sentences, the prepositions *up* and *down* are only obvious in print because we can see that the preposition occupies

the slot between the verb and the direct object. Until we have processed the direct object, the sentences could also contain continuations such as *John put his hat on*, or *John picked out his favorite hat*. In German, however, the normal word order places direct objects before the postposed preposition. For example, *John picked up the book* in German becomes *John nahm das Buch auf* [John picked the book up]. Because of this, speakers of German have more information from which they should be able to predict the lexical identity of sentence final separated prefixes.

2.2. German separable prefix verbs

German sentences can be described by a structure known as the *Verbklammer*, or verbal bracket. This structure of a main clause is composed of two related verbal elements that serve as a left and right bracket, which surrounds other clausal elements. With main clauses that contain multiple verbs, the finite verb makes up the left bracket and the other verbs make up the right bracket. Because of this, German speakers must often wait a long time to hear the verb at the end of a clause (Thurmair, 1991). In sentences where there is only one verb, the finite verb is positioned in the left bracket after the initial element with the right bracket remaining empty. This causes an interesting effect with separable prefix verbs, which are composed of two elements: a verb stem and a prefix. If a separable prefix verb is the finite verb, then the prefix moves to the right bracket, leaving the finite verb stem in the left bracket position (Thurmair, 1991, pp. 194–195). Some scholars might argue that the separable prefix verb is generated in the right bracket and the verb stem is the item that actually moves to the left bracket, with the prefix remaining in its original position, but in either case, the resulting distance between verb and prefix remains the same. It must also be pointed out that in some instances, the separable prefix does not necessarily come at the end of a clause because of the addition of further extensions, which usually involve extra-positions, postposed adverbial or prepositional phrases. However, these extensions have no bearing on the predicate structure and could be completely left out with no effect on the grammaticality of the sentence.

The following example with the verb *vorstellen* illustrates how the single verb is used to fill in both the left and right brackets:

Ich stelle mich deinen Eltern vor
I place me your parents in front of
“I am introducing myself to your parents.”

The separable prefix verb *vorstellen* has a particular meaning that only becomes transparent once the sentence-final prefix *vor* appears well after the verb stem *stellen*. Note that *stellen* can also take other prefixes in combinations such as *einstellen*, *aufstellen*, or *anstellen*. Thus, the prediction of the sentence-final preposition cannot be based solely on the identity of the stem.

Separable prefixes do not always separate from their verbs. In sentences with a modal verb, the verb and the prefix remain together in the right bracket at the end of the sentence.

Ich muss mich deinen Eltern vorstellen
I have to me your parents introduce
“I have to introduce myself to your parents.”

This is important because it shows that the probability of a verb-stem and separable prefix combination is driven by both its occurrence as a combined and separated verb. This will be a key aspect to keep in mind during the analysis.

Some combinations of verbs and separable prefixes have very specific meanings, as in the example of *vorstellen*, which could be analyzed compositionally as “in_front_of+place”, although its intended meaning is “introduce”. Others simply add compositionally to the core meaning of the main verb. For example, the verb *gehen*, [to go], can combine with other separable prefixes that do not really change the core meaning of the verb, but rather indicate in which direction one is going (e.g. *ausgehen* [to go out], *runtergehen* [to go down], *hingehen* [to go to]).

Because of these various features, German separable prefix verbs provide an interesting opportunity to test whether the distribution of co-occurrences between specific verb-prefix pairings are strong enough to allow speakers to not only predict what syntactic argument is upcoming, but which specific lexical item is most likely to occur with a particular verb.

2.3. Research questions

The research questions for the study are as follows:

1. Are German speakers able to predict the sentence final separable prefixes used in examples taken from a corpus of authentic material?
2. What differences, if any, exist between the rates of successful prediction between items?

3. How does more or less context affect speakers' abilities to predict sentence final separable prefixes?
4. If there are differences between items, what information can the corpus provide about why these differences appear?

3. Methods

3.1. Participants

Forty-nine native German speakers from the University of Bremen were recruited to participate in this study. All participants were at least eighteen years of age and were currently enrolled at the university.

3.2. Design and measures

To test participants' abilities to predict sentence-final separable prefixes, we chose a cloze task comprised of naturalistic data taken from a written corpus. The items are possible sentences that speakers of German would encounter in everyday life.

The cloze task consisted of 40 sentences containing separable prefix verbs with the verb in the second position and the separable prefix in the sentence final position. First, a list of all possible separable prefixes was compiled and searched for in the corpus. Sentences were selected at random from a corpus of the German newspaper *Rhein-Zeitung* from 1996 to 2011. A newspaper corpus was selected because of its authenticity and the fact that this is the type of written information to which adult speakers of German would have access. This corpus was accessed through the Cosmas II corpus analysis application provided by the Institute for German Language in Mannheim.

In order to search the Cosmas II database for separable prefix verbs, the following command were used for each item:

&VERBSTEM /+s0 SEPARABLEPREFIX
e.g. &gehen /+s0 ein

This command searches for the verb stem in any inflected form and then the separable prefix occurring within the same sentence but not as a connected whole. This search resulted in sentences in which the finite verb appeared in the second position in the sentence and the separable prefixes occurred at the end. Four hundred sentences containing sentence final separable prefixes were identified and from this list forty items were selected at random.

Each item was divided into a more-context and less-context version. In the more-context version, the entire paragraph from the corpus up to and including the target sentence was used as the item. In the less-context version of the item, only the sentence in which the separable prefix was contained was used as the item.

We created a web-based online cloze task to administer the test to participants remotely. Each sentence was assigned an item number and reproduced exactly as it had appeared in the newspaper, with the exception that the sentence final separable prefix was replaced with a blank text box. The items were chosen with equal probability from the two possible versions with either more or less context. Each participant was presented with an equal number of more and less context items.

3.3. Procedures

All participants were tested simultaneously in a lab setting and were monitored by an on-site administrator from the German university in which all participants were enrolled. Participants were given each of the 40 items one at a time, in random order, and randomly given either the more or less context version of an item. As participants completed each item, the home-server collected and stored the data for each participant and item.

4. Results

Regarding research question 1, the results indicate a fairly normal distribution with a slight left-tail skew due to one participant's performance. The distribution is shown in Fig. 1. Overall, the mean accuracy among participants was $M = 27.4$ correct out of 40, with a standard deviation of $SD = 4.1$.

From these descriptive statistics it is evident that this group of speakers was fairly successful at predicting the missing separable prefixes. However, one participant seems quite out of bounds with the rest of the group. One possible explanation is that the participant did not know that he or she was supposed to be limiting responses to separable prefixes, since other words or particles could still be viewed as grammatically correct. Because this result is an extreme outlier, this participant's data have been excluded from the remainder of the analysis. After removal of this participant, the group average increased to $M = 28.02$ out of 40 items (70.05%) with a standard deviation of 2.78.

Regarding research question 2, we can see that there are stark differences between items. While participants showed an overall ability to predict particular separable prefixes, the accuracy level of these predictions varied markedly across items. Fig. 2 shows the percent correct in descending order left-to-right of each separable prefix verb.

Research question three asked whether differing amounts of context would affect the participants' abilities to predict the sentence final particle. A *t*-test for between group differences for the items by more context ($M = 17.03$, $SD = 8.55$) versus less

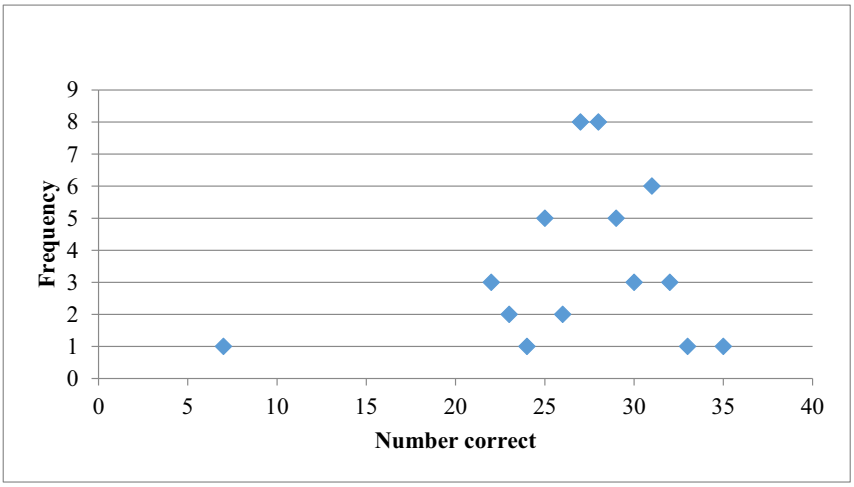

Fig. 1. Participant correct answers frequency plot.

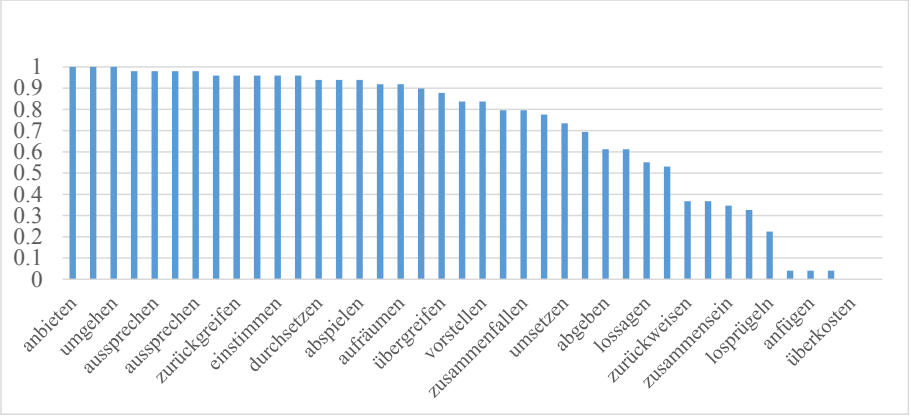

Fig. 2. Percent matching by item.

context (M = 17.08, SD = 8.78) variations revealed no statistical difference between groups (t = 0.026, df = 78, SE = 1.938, p = 0.980) which is unexpected based on previous research that has shown the importance of context in comprehension and prediction.

In order to address the fourth research question, it was important to go back to the corpus to look for the factors that differentiate one verb from another. As a first step, we determined all of the possible separable prefixes for each item stem through the use of an online grammar tool (duden.de). For example, for the verb stem *stimmen* in item 39, which means "to be right" or "to be correct", 17 possible prefixes were discovered. Each prefix changes the meaning of the word stem, as in *abstimmen*, which means "to vote", or *zustimmen*, which means "to agree". The number of co-occurring separable prefixes varied from one verb stem to the next, which can be seen in column four of Table 1.

Once a list of all possible co-occurring separable prefixes was created for each verb stem, the frequency of each possible verb stem and separable prefix pair was investigated within the same written corpus used to select the items. In doing so, the proportion of the actual item could be seen in relation to the total uses of the verb stem by itself and with other separable prefixes. Fig. 3 below shows the scatterplot of percent-correct by number of other co-occurring separable prefixes with the verb stem. There is significant negative correlation between the number of co-occurring verb-prefix pairs and the percent correctly predicted ($R = -0.382$, $p < 0.05$), as is indicated later in Table 2.

Next, the corpus was also analyzed to see if there were any other frequently occurring words within the sentences. This search tracked both non-separated and separated uses for each verb.

&WHOLEVERB oder (&VERBSTEM /+s0 SEPARABLEPREFIX)
e.g. &eingehen oder (&gehen /+s0 ein)

Table 1
Statistics by Item.

Item #	Item	% Of all verb-prefix tokens	# Of co-occurring prefixes	Strong 2nd collocate	Number correct	% Correct
4	anbieten	0.9632	7		48	1
14	vorlesen	0.1583	14		48	1
23	umgehen	0.1609	15		48	1
10	eingehen	0.0857ss	15	accusative “in”	48	1
13	aussprechen	0.2873	16		48	1
17	abriegeln	0.9719	3		48	1
33	aussprechen	0.2873	16		47	0.979167
1	eintreten	0.0847	13	accusative “in”	47	0.979167
26	zurückgreifen	0.0897	14		47	0.979167
32	eingreifen	0.1944	14		47	0.979167
34	einstimmen	0.2146	6		46	0.958333
38	abstimmen	0.2051	6	über	46	0.958333
6	durchsetzen	0.1414	14	sich	46	0.958333
9	ankündigen	0.8880	5		46	0.958333
28	abspielen	0.0634	13		46	0.958333
25	ausstellen	0.0745	14		45	0.9375
37	aufräumen	0.1850	5		45	0.9375
20	zurückkehren	0.7123	4		44	0.916667
22	übergreifen	0.0755	8		43	0.895833
8	vorkommen	0.0458	17		41	0.854167
11	vorstellen	0.2522	14		41	0.854167
27	wegfangen	0.0015	5		39	0.8125
31	zusammenfallen	0.0043	22		39	0.8125
19	zusammenschließen	0.0289	7		37	0.770833
35	umsetzen	0.1285	14		36	0.75
5	loslegen	0.0251	16		34	0.708333
7	abgeben	0.1089	10		30	0.625
12	vorstellen	0.2522	14		30	0.625
24	lossagen	0.0009	21		27	0.5625
15	mitnehmen	0.0497	20		26	0.541667
16	zurückweisen	0.0410	15		18	0.375
36	zusammenfinden	0.0941	11		18	0.375
18	zusammensein	0.0167	25		17	0.354167
2	zusammenarbeiten	0.1063	17		16	0.333333
39	losprügeln	0.0209	11		11	0.229167
29	einkommen	0.0801	17		2	0.041667
30	anfügen	0.1338	7		2	0.041667
40	weggehen	0.0084	15		2	0.041667
3	überkosten	0.0626	19		0	0
21	unterlegen	0.0518	14		0	0

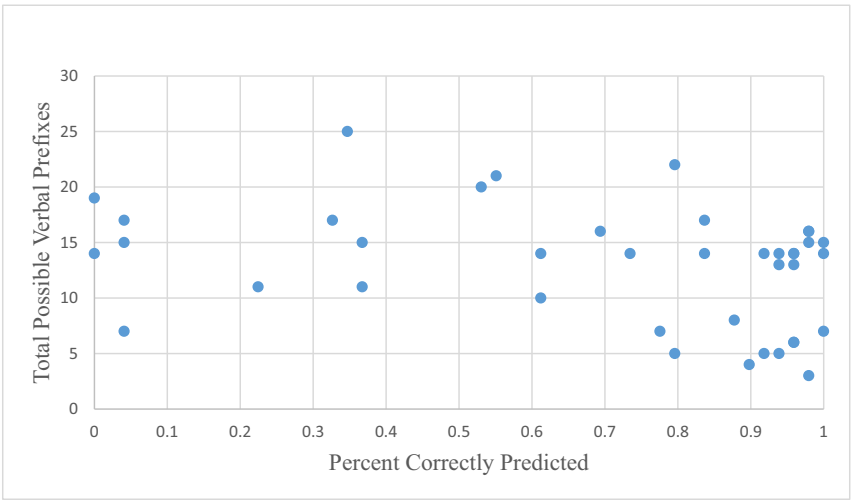

Fig. 3. Effect of # of prefixes per verb-stem on predictability.

Table 2
Pearson correlation of percent correct by independent variables.

	Percent correct	Percent of all verb-prefix tokens	Number of other prefixes	Strong second co-occurrer
Percent correct	1.000			
Percent of all verb-prefix tokens	0.382**	1.000		
Number of other prefixes	−0.316*	−0.548***	1.000	
Strong second co-occurrer	0.270*	−0.073	−0.053	1.000

*$p < 0.05$, **$p < 0.01$, ***$p < 0.005$.

This request pulled all sentences for each verb-prefix pair that were both joined, as in *eingehen* as well as separated, as in *gehen* with *ein* at the end of the sentence.

In order to identify the number of other possible separable prefix pairings with the verb, Duden online (duden.de) and a Google search for separable prefixes for each verb stem was conducted. For example, the stem for item #11 *stellen* was found to have 14 possible prefix combinations, including *vorstellen*, *aufstellen*, *darstellen*, *ausstellen*, and so on. The total number of possible prefix combinations with each verb stem is listed in column four in Table 1 below. In addition to the number of total co-occurring prefixes with each verb stem, column 3 of Table 1 indicates what percentage of the total uses in the corpus were the combination of that particular verb stem and prefix pair. For example, in column three for item #4 *anbieten*, the number 0.9632 indicates that, when the verb *bieten* was used with a separable prefix, it occurred with the prefix *an* 96.32% of the time.

As a further level of analysis, other closed-class words within the sentence were analyzed for relative frequency by running a concordance for each of them with the verb-prefix pairings. In four instances, an additional word was found to be predominantly associated (appearing in over 25% of the token sentences) with the target item. For example, item #10 *eingehen* was found to occur with the accusative preposition *in* more frequently than with any of the other possible *gehen* + prefix possibilities. This is indicated in column five of Table 1 below.

The final two columns of Table 1 indicate the number of correct responses out of 49 and the percent correct by item. Results are organized from the most successfully predicted prefixes to the least successfully predicted.

Using a Pearson test for correlation for the variables of percent correct, the percent of the total verb-prefix pairings for that particular verb-prefix pairing versus the total tokens of all possible verb-prefix parings in the corpus, number of other possible verb-prefix parings, and presence of a strong second collocate, there is a clear relationship between the predictor variables and the outcome variable percent correct, as presented in Table 2.

These test results indicate a significant, positive relationship between the percent correct and both the percentage of the total verb-separable prefix pairs in the corpus ($r = 0.383$, $p = 0.007$) and the presence of a second strong co-occurring word ($r = 0.269$, $p = 0.046$). There is also a significant, negative relationship between the percent correct of a particular item and the total number of possible verb-prefix pairings ($r = -0.318$, $p = 0.023$).

5. Discussion

The accuracy rates coupled with the difference in performance across items are significant to understand the way in which prediction is used (or in some cases maybe not used) by speakers of German. For research question 1, it is evident that native speakers of German are, in general, able to predict sentence-final separable prefixes. What is also quite astounding is the similarity in overall results for the group, with a standard deviation of only 2.78 items. For the overwhelming majority of items (30/40), participants were able to correctly predict the missing separable prefix over 50% of the time, despite the fact that these verb-stems have multiple prefix pairings. This result provides interesting insight into the predictability of different words based on word-class. Because these results show a very successful rate of prediction, we can conclude that arguments against prediction based on the notion of a "low-payoff" do not apply to these types of words.

Research question two asked whether predictability is variable, based on the probability of each individual verb-prefix pairing. Table 1 in the previous section shows that there is a very different probability of success between items. Some items were correctly predicted 100% of the time, while others were never correctly predicted. This variability within a closed-class of words is significant, because it may indicate a complex set of forces that drive predictability.

With regard to research question three, we can begin to understand what some of the underlying mechanisms are that influence these different probabilities. From the current analysis, it appears that these probabilities are altered by the proportion of the frequency of the verb-prefix pair in relation to all other verb-prefix possibilities, the total number of alternate verb-prefix probabilities, and the presence of other sentence-internal cues, among other possible factors such as semantic relevance, or others not specifically investigated in this study. The significant correlations between percent correct, the percent of the total corpus of a particular verb-stem separable prefix pairing, the total number of other possible co-occurring prefixes, and the presence of a second, strong co-occurrer within the sentence all affect the different item results.

First, the amount of the total corpus of possible separable prefixes with a particular verb that one prefix makes up follows a fairly straightforward understanding of predictive abilities based on patterns of usage. The more frequently a separable prefix occurs with a verb stem, the more likely it is that these two will appear together in the future. This is quite apparent for *anbieten* and *abriegeln*, which despite having other possible stem-prefix pairs, make up 96.32% and 97.19%, respectively, of the total number of verb-stem and prefix pairings in the entire corpus for each stem.

Second, the total number of possible prefixes that can appear with a verb-stem helps to delimit the number of possible predictions a person must make. The more separable prefixes that appear with a certain verb-stem, the more uncertainty that is built into the prediction. The third factor, the presence of an additional, strong co-occurrer in the sentence, adds a different layer to the prediction process. Because this was shown to be a contributing factor to successful prediction, it means that prediction ability is not simply tied to the verb-prefix combination, but rather is continuously updated as more and more information in the sentence is revealed to a person. Thus, the likelihood of predicting the correct separable prefix is dynamic across multiple time-frames. The historical, ontogenetic timeline of the person's experiences are combined with the microgenetic time-span of a separable prefix verb's current use and context.

In addition to the overall findings, a deeper analysis of the items provides some interesting insights into the behaviors of the participants. The results show that some items, despite being relatively infrequent, were still correctly assigned to the missing target prefix (e.g. *vorlesen*, *umgehen*), while others with similar frequencies were not (e.g. *anfügen*, *einkommen*). A closer look at the aforementioned cases provides insight into the reasons behind these differences. For the verbs *vorlesen* and *umgehen*, one possibility is that the prefix alters the meaning of the verb root to a larger extent than other prefixes do to their verb roots. The first item, *lesen* [to read], becomes [to read aloud], which is involved in a slightly different context than the act of reading in and of itself. The verb *umgehen* [to be about], from the stem *gehen* [to go], takes an even more drastic shift in its core meaning when paired with *um* [about]. Thus in item 23, the probability that it could be any other preposition to express a similar meaning is seriously limited and the change in meaning is much greater than if it were to be paired with a prefix that simply expressed something like the direction of travel, which would preserve the core meaning of the verb stem.

For the verb *fügen* [to attach], an interesting insight into why it was so infrequently assigned the prefix *an* [to / on] comes from the incorrect answers. Of the 47 "incorrect" responses, all 47 were *hinzu* [to there]. Looking back at the corpus, *hinzufügen* makes up 65.8% of all instances of *fügen* + separable prefix, and *fügen* as an independent verb with no separable prefix occurs only 34,410 times in the corpus compared to the 42,206 times it appears with a separable prefix, and of those 42,206 tokens, 27,764 (65.8%) occur with *hinzu*. The connection strength between the separable prefix *hinzu* and the verb stem *fügen* is undoubtedly motivating the low accuracy on this item.

6. Conclusion

This study has provided evidence to support the claim that German speakers are able to predict sentence final separable prefixes, and that the success of prediction is mediated by context and co-occurrence. The dynamic nature of context and the continually updated probabilities through language use are significant contributors to the success of prediction and overcome the low-payoff critique of previous prediction research. Low-payoff is only the result if one views prediction as reliant on a static relationship between particular words. In a dynamic view of prediction, multiple timeframes combine to constantly alter the scope of likely predictions.

In addition, the use of a corpus allowed us to select appropriate, real-life stimuli, as well as describe the probabilities of each local linguistic environment. By utilizing this approach, the data from the participants was well aligned with the corpus analysis, and the analysis resulted in a more accurate model of effects. By analyzing the corpus in a way that brought in collocations across long distances, there was a way to account for sentence-internal factors that would not have been noticed in a traditional experiment. Without a corpus there would be no way to crosscheck the participants' results. The interaction between the corpus data and participant data allowed for a clearer picture into what incorrect answers actually meant in the grand scale of language usage.

Using this type of mixed methods approach provides interesting insights, but the question remains whether speakers actively predict in non-experimental settings. Because the experimental design of this program was conducted using a cloze task and it is actively asking them to predict information, they are already primed to predict a missing word, which does not mean they actively do so in everyday life in aural or visual sentence processing. However, evolutionary linguistics and social psychology provide interesting avenues to explore why prediction may be a productive human linguistic behavior.

The ability to predict others' words could be viewed as especially important for human development and the formation of communities through alignment. As Garrod and Pickering (2004) and Pickering and Garrod (2006) explain, alignment is the basis for successful communication. This alignment occurs within multiple representations, including the phonological, syntactic, semantic, and situational model. Successful turn-taking depends crucially on the ability to predict within less than a second the end of the previous speaker's contribution (Levinson and Torreira, 2015). While the phonological and syntactic alignment within a conversation is important, it is through our shared life experiences that two speakers can create similar, although certainly not identical, situation models, which seems closely linked to the idea of mental models (Johnson-Laird, 1983; MacWhinney, 2005). When successful, this alignment between two or more individuals can lead to similar mental models of a shared intentional state. This would therefore lead to a mental state that is not so different from the one presented in the visual world studies presented earlier, where the number of possible items is severely limited by the particular mental representation of the environment. If a person was to co-construct this mental representation through interaction with another person or a text, then there would be significant social and evolutionary benefits. For example, Fusaroli et al. (2012) found that linguistic alignment produced significant increases in dyad's abilities to successfully perform tasks. This advantage is certainly in line with Tomasello et al.'s (2005) theory regarding shared intentions. Prediction can be seen as a natural result

of mimicry and understanding. The greater the alignment and the more productive prediction can be, the greater ability to share intentions across individuals, culture, and time.

While there is still a significant amount of work to be done to understand whether prediction as a constantly occurring behavior, this article has provided evidence to support that prediction is not only possible, but most likely a highly productive part of human communication. Especially with closed-class words, people show a very successful predictive ability. The fact that prediction is so reliant on the individual word is also an important finding because it shows how diverse the sources of influence on a particular word are. From an emergent, usage-based account, the dynamic nature of prediction can be linked to its usefulness in human communication, where there are distinct advantages for the species which result from this alignment.

In future experiments, it would be informative to show participants one word of each sentence at a time and have them identify their certainty with their guess, as more and more of the sentence is revealed. This could lead to a better understanding of the dynamicity of probability during sentence processing. As more and more context and more and more words are revealed in online comprehension, statistical probabilities may be refined and updated to make prediction not only more reliable, but a truly productive part of human communication.

Appendix

Less-context item set with verbs italized, separable prefixes underlined.

1. Am 1. Juli 1979 *trat* sie wieder in den Dienst der Sparkasse Rhein-Nahe ein.
2. Verschiedene Anwendungen wie das Kartenprogramm Google Maps und Googles lokale Suche *arbeiten* für Anwendungen dieser Art bei Google Earth zusammen.
3. Doch dieser Luxus *kostet* den kleinen Ort über.
4. Beim Gemüse bieten sich im Winter Rosenkohl, Feldsalat oder Chicorée an.
5. Kaum hatte sich Bohr zusammen mit zehn Teamkameraden beim 27. Silvesterlauf des TuS Waldböckelheim auf den Weg gemacht, *legte* Kommentator Willi Lange los.
6. Bei den Schweinfurter Mad Dogs *setzten* sich die Bären gestern Abend mit 5:4 (2:1, 0:2, 2:1) nach Verlängerung durch.
7. Auch hierauf spekulieren einige Firmen und *geben* nach Auftragserteilung ein vielfach teureres Nachtragsangebot ab.
8. Mit Freundin Martina Eberl, einer Profigolferin, trank er ein Gläschen Sekt und schaute lieber nach vorn: In den "heimlichen" Wünschen *kamen* auch die Olympischen Winterspiele in anderthalb Monaten vor.
9. "Auch in den nächsten Jahren wird es einen Weihnachtsmarkt vor und in der Wiedparkhalle geben", *kündigte* Salz an.
10. In einer Feierstunde *ging* Bürgermeister Karl Heinz Simon in einem Rückblick auf den beruflichen Werdegang seines Mitarbeiters ein.
11. Professor Dr. Andreas Kruse, Vorsitzender der Sachverständigenkommission der Bundesregierung, *stellte* die Ergebnisse des fünften Altenberichtes vor.
12. Die Extraausgabe in der Reihe "Blätter zum Land" *stellt* das neue Haus und die Dauerausstellung bei Hermeskeil im Hunsrück vor.
13. Auch Arbeitgeberpräsident Dieter Hundt *sprach* sich erneut für Kombilöhne aus.
14. Er studierte die Inschriften auf den Wänden des Gebäudes und *las* manche von ihnen laut vor.
15. Umtausch ist auch dort kein Problem: "In der Regel *nehmen* die Kunden direkt neue Ware mit."
16. Die Bundesregierung *wies* Zweifel an der Verfassungsmäβigkeit zurück.
17. Demnach *riegelten* US- Soldaten die Gegend um die Abu Tajmija-Moschee im Westen Bagdads für sieben Stunden ab.
18. Kurz nach dem Start der 5000 Meter *sind* die Läufer noch dicht zusammen.
19. Aufgrund einer kommunalen Gebietsreform *schlieβen* sich die bisher selbstständigen Gemeinden Rijnsburg, Valkenbourg und Katwijk zusammen.
20. Mit einem Sack Nahrungsmittel auf dem Kopf und einer Liegematte unterm Arm *kehrt* sie in ihr Zuhause im Fischerdorf Akkrapattai zurück.
21. Und die meisten Gäste *legten* deshalb das eine oder andere Bratwürstchen unter.
22. Auβerdem *griff* das Feuer auf den Dachstuhl eines benachbarten Wohnhauses über.
23. Sie wissen die wertvollen Stücke zu schätzen und *gehen* vorsichtig damit um.
24. Das Verhältnis zu Moskau hat für Georgien auch eine innenpolitische Dimension: Mit russischer Hilfe *sagten* sich die Regionen Abchasien und Südossetien Anfang der 90er-Jahre von Tiflis los.
25. Schröder *stellte* dem Kreml-Herrscher indes in steter Regelmäβigkeit ein Einser-Zeugnis als Muster-Demokrat aus.
26. Wer sich bei der Dosierung unsicher ist, *greift* am besten auf anwenderfreundliche Fertigprodukte zurück.
27. Delfine müssen nämlich vieles ertragen: Die Meere sind verschmutzt, und Fischer fangen ihnen mit riesigen Netzen die Nahrung weg.
28. Und auch die Nahrungssuche *spielt* sich innerhalb der Gruppe ab.
29. Der Bundestrainer lobte "die gute Mannschaftsleistung", denn Alexander Herr und Michael Neumayer auf den Rängen 15 sowie 17 *kamen* auch im Vorderfeld ein.
30. "Dann kann ich beruhigt in Rente gehen", fügte der Werksleiter Eckhard Günner schmunzelnd an.
31. Die Reformation in Hessen im Jahre 1542 *fällt* mit dem Ende der Nonnenstiftskirche Brunnenburg zusammen.

32. Am Finaltag *greifen* dann Mannschaften wie die Oberligisten TuS Mayen und Hassia Bingen sowie Rheinlandligist FV Rübenach und der Mittelrhein-Verbandsligist VfL Rheinbach ins Turnier ein.
33. Der Vorsitzende der katholischen Deutschen Bischofskonferenz, Kardinal Karl Lehmann, *sprach* sich angesichts zunehmender Verunsicherung vieler Menschen für eine “neue Gelassenheit” aus.
34. Und die Gäste lieβen sich nicht lange bitten und *stimmten* mit ein.
35. Die Ergebnisse seiner Kontaktlinsen-und Skibrillentests *setzt* die Industrie in Spitzenprodukte um.
36. Die weit verstreute Gemeinde Elbergrund -Blickhauserhöhe *fand* sich zusammen.
37. Nach dem Motto “alles Überflüssige weg” *räumt* die neue Bundesregierung derzeit im Subventionsdschungel auf.
38. Die aktiven Musiker *stimmten* über ihren Favoriten ab.
39. Als das nicht gelang und die jungen Damen mit dem Auto wegfahren wollten, *prügelten* die Männer los.
40. Die weitaus gröβere Summe *geht* über Umlagen für Verbandsgemeinde und Kreis wieder weg.

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