Construction diversity analyzer: A tool to measure (nonnative) language development

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Overview

- Literature review: Measures of language development/proficiency
- Development of a new measure
- Application of the new measure
- Discussion

Literature Review: Measures of Language Development/Proficiency

Traditional Syntactic Complexity Indices

Category	Index Name	Index Description
Length of Production	Mean length of clause	Number of words per clause
	Mean length of sentence	Number of words per sentence
	Mean length of T-unit	Number of words per T-unit
Sentence Complexity	Clauses per sentence	Number of clauses per sentence
Subordination	Clauses per T-unit	Number of clauses per T-unit
	Complex T-unit ratio	Number of complex T-units per T-unit
	Dependent clauses per clause	Number of dependent clauses per clause
	Dependent clauses per T-unit	Number of dependent clauses per T-unit
Coordination	Coordinate phrases per clause	Number of coordinate phrases per clause
	Coordinate phrases per T-unit	Number of coordinate phrases per T-unit
	T-units per sentence	Number of T-units per sentence
Particular Structures	Complex nominals per clause	Number of complex nominals per clause
	Complex nominals per T-unit	Number of complex nominals per T-unit
	Verb phrases per T-unit	Number of verb phrases per T-unit

(Lu, 2010)

Length of Production

- Mean Length of Utterance
  - Computed by dividing the number of morphemes by the number of utterances
  - Widely used as a measure of morpho-syntactic development in first language (L1) acquisition

(Brown, 1973)

- Others
  - Mean length of T-unit, mean length of c-unit, mean length of clause

(for a detailed review, see Park, 2014; see also Hunt, 1965; Loban, 1976; Scott, 1988)

Rate of Subordination

- Mean number of subordinate clauses per T-unit
  - Computed by dividing the number of subordinate clauses by the number of T-units

(Elder & Iwashita, 2005)

- Others
  - Mean number of subordinate clauses per c-unit, mean number of subordinate clauses per AS-unit

(for a detailed review, see Park, 2014; see also Skehan & Foster, 2005; Michel, Kuiken & Vedder, 2007)

Research Gap 1

- Many of the traditional morpho-syntactic indices have been found to have age effects, with older children tending to receive higher scores regardless of proficiency

  (Loban, 1976; Unsworth, 2005)

  → This casts doubt on the validity of these indices as measures of language proficiency/development
- The traditional indices obscure the more sophisticated linguistic variation in development

  (Kyle & Crossley, 2017)

Kyle & Crossley (2017)

- Proposal of an alternative: Syntactic sophistication indices
- Constructionist/usage-based approaches
  - Frequent constructions are learned earlier/more easily
  - Verb argument constructions are initially used with a single prototypical path-breaking verb (Ninio, 1999)

Verb Argument Construction

- Verb argument construction (hereafter, construction):
  a form–meaning pairing that denotes a sentence's meaning independent of its individual lexical items

  (Goldberg, 1995)

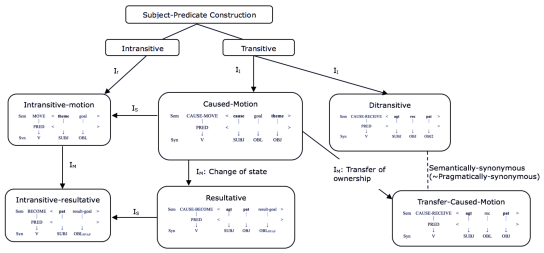


Figure 1. Inheritance hierarchy of constructions. Adapted from Goldberg (1995).
A metaphorical extension link (I_M) denotes the relations between the two metaphorically related constructions. A subpart link (I_S) represents that one construction is a proper subtype of the other construction. An instance link (I_I) is used if one construction is a special instance of another construction.

Kyle & Crossley (2017)

- Finer-grained indices of syntactic sophistication
  - Frequency of constructions
  - Frequency of main verb lemmas
  - Frequency of verb-construction combinations
  - The strength of association of verb-construction combinations
  - Many others

Kyle & Crossley (2017)

- Method: Learner corpus
  - 2 prompts × 240 independent TOEFL essays
  - min. 300 words written in 30 minutes
  - Rated on a 5-point scale by min. 2 ETS raters

    → Dependent measure in this study

Kyle & Crossley (2017)

- Analysis
  - Using Tool for the Automatic Analysis of Syntactic Sophistication and Complexity, both usage-based sophistication indices and traditional syntactic complexity indices were measured (Kyle, 2016)
- Results
  - Usage-based sophistication indices explained greater proportion of the variance (R^2 = .142) in writing scores than traditional syntactic complexity indices (R^2 = .058)

Research Gap 2

- Constructions defined in Kyle and Crossley (2017) are closer to syntactic patterns (e.g., Pronoun-Modal-Verb-Adverb-Adjective) rather than **argument structure constructions**
- There are currently no automatic tools that compute the **diversity** of different syntactic constructions

The Present Study: Development of a New Measure

Goal

- To develop an automated index of **constructional diversity (CD)** for use as a measure of:
  1. syntactic complexity
  2. L1/L2 syntactic development
- Our tool calculates constructional diversity by categorizing all the clauses in a text as one of **11 different constructions** and then using these labels to calculate the moving-average type-token ratio (MATTR) for the text

Constructions 1–6

The first six constructions come from the literature on Construction Grammar (Goldberg, 1995):

#	Construction	Example	Dependency Information
1.	Caused-motion	*Mary faxed a letter to John.*	nsubj-verb-dobj-prep
2.	Ditransitive	*Mary faxed John a letter.*	nsubj-verb-dative-dobj
3.	Intransitive motion	*The fly buzzed into the room.*	nsubj-verb-prep
4.	Intransitive resultative	*The pond froze solid.*	nsubj-verb-acomp
5.	Phrasal verb	*The girl looked the name up.*	nsubj-verb-dobj-prt
6.	Transitive resultative	*The boy painted the barn red.*	nsubj-verb-dobj-advcl

Constructions 7–11

The other five are common English constructions (Hornby, 1978):

#	Construction	Example	Dependency Information
7.	Attributive	*The boy is a student.*	nsubj-verb-attr
8.	Passive	*The sheet was folded.*	nsubjpass-auxpass-verb
9.	Simple intransitive	*The man worked.*	nsubj-verb
10.	Simple transitive	*The man kicked the ball.*	nsubj-verb-dobj
11.	*There*-expletive	*There is a house.*	exp-verb-attr

Procedure for Calculating CD in Python

1. Import modules and dictionaries
2. Label each clause in the text as one of the 11 constructions using the spaCy module (Honnibal & Montani, to appear)
3. Calculate the MATTR value for the text

How to Calculate MATTR

1. Calculate the type-token ratio (TTR) for the first 11 clauses in the text (number of construction types / total number of clauses)
2. Continue to calculate TTR for all the remaining successive windows of 11 clauses in the text (clauses 2–12, 3–13, etc.)
3. Compute the mean of all the individual TTR values


```
##################################################################
############ 1. Import modules for the VAC counter ###############
##################################################################
from __future__ import division

from operator import itemgetter
import nltk
nltk.download('punkt')
from nltk.tokenize import sent_tokenize
from collections import Counter

import spacy
import en_core_web_sm
nlp = spacy.load('en_core_web_sm')


##################################################################
############ 2. Import dictionaries ##############################
##################################################################

## Ditransitive verb list -- reference: https://www.cse.unsw.edu.au/~billw/ditransitive.html + Levin (1993, pp
ditransitive_verb = open("dictionaries/ditransitive_verb.txt", "r", encoding="utf-8-sig").read().split("\n") #

## List of verbs taking a predicate complememt -- reference: Levin (1993, pp. 180–185)
pred_comp = open("dictionaries/predicative_complement.txt", "r", encoding="utf-8-sig").read().split(", ") #ope

## List of intransitive motion verbs -- reference: Levin (1993, pp. 263–270)
pred_intransitive_motion = open("dictionaries/intransitive_motion.txt", "r", encoding="utf-8-sig").read().spli
```

Step 1: Importing modules and dictionaries


```
##########################################################
########## 3. Construction diversity analyzer ############
##########################################################

def vac_type_counter(text):
    counter_th = 0 #there
    counter_at = 0 #attributive (copular)
    counter_si = 0 #simple intransitive
    counter_im = 0 #intransitive motion
    counter_ir = 0 #intransitive resultative
    counter_pa = 0 #passive
    counter_st = 0 #simple transitive
    counter_cm = 0 #caused motion
    counter_di = 0 #ditransitive
    counter_re = 0 #resultative
    counter_pv = 0 #phrasal verb
    counter_na = 0 #non-applicable
    counter_clause = 0

    #text_tokenized = sent_tokenize(text) #tokenize text into sentences

    if len(text) == 0:
        return "Text must include more than one clause."

    else:
        for sent in text: #iterate through texts
            doc = nlp(sent) #process text with spacy

            for token in doc: #iterate through tokens
                if token.pos_ == "VERB" and token.dep_ != "aux": #if the token is a main verb

                    vac_dep = [[token.lemma_+"-verb",token.i]] #add lemma+verb, index
                    vac_dep_wo_verb = [["verb",token.i]] #add verb, index
                    vac_lem_dep = [[token.lemma_+"-verb",token.i]] #add lemma+verb, index
```

Step 2: Sorting clauses into 11 constructions and counting each construction's frequency


```
    if counter_clause == 0:
        mattr = "Text must include more than one clause."
    else:
        mattr = "type-token ratio: " + " " + str(counter_type/counter

    text_clauses = clause_lister(text_tokenized)

    scores = [vac_type_counter(window) / window_size for window in li

    if sys.version_info == 3:
        mattr = mean(scores)
    else:
        mattr = sum(scores)/len(scores)

    import os.path
    ## create/open csv file to save the MATTR/freq data
    VAC_MATTR_exists = os.path.isfile("VAC_MATTR.csv")
    with open ("VAC_MATTR.csv", 'a') as csvfile:
        headers = ["file_name", "total_num_clause", "there", "attributive", "simple_intransitive", "in
        writer = csv.DictWriter(csvfile, delimiter=',', lineterminator='\n',fieldnames=headers)
        if not VAC_MATTR_exists:
            writer.writeheader()  # file doesn't exist yet, write a header
        writer.writerow({"file_name": file_name, 'total_num_clause': counter_clause, 'there': counter_
```

Step 3: Measuring constructional diversity by computing Moving-Average Type-Token Ratio

Evaluating the Accuracy of the Tool

Compared the tool's output to judgments made by human annotators on a test dataset of 1,000 clauses from the American National Corpus (Reppen, Ide, & Sunderman, 2005)

- Inter-annotator reliability: Cohen's Kappa = 1.00, after resolving inconsistencies
- Sorting accuracy: recall = 0.82, precision = 0.86, F1 = 0.82

Application of the New Measure

Implications

- Usage-based perspective on language acquisition
  - Less frequent constructions are learned later
  - Constructional diversity increases as learner proficiency increases

    (e.g., Ellis, O'Donnell & Römer, 2013; Tomasello, 2003)
- The constructional diversity can serve as a reliable indicator of language development/proficiency

Pilot Study: Prediction

- More proficient L2 learners can produce constructions with lower frequencies, thus showing higher constructional diversity

Pilot Study: Data

- Data: Adult L2 written data from the International Corpus Network of Asian Learners of English (ICNALE)

  (Ishikawa, 2013)
  - Learner data size: 8286 clauses from 236 learners
  - Topic: *It is important for college students to have a part-time job*
  - Proficiency levels: B1 (*N* = 201), B2 (*N* = 35)

    - measured by an English vocabulary size test

    (Nation & Beglar, 2007)
  - Country/regions: China (*N* = 32), Indonesia (*N* = 3), Hong Kong (*N* = 7), Japan (*N* = 51), Korea (*N* = 24), Singapore (*N* = 49), Thailand (*N* = 57), Taiwan (*N* = 13)

Pilot Study: Analysis

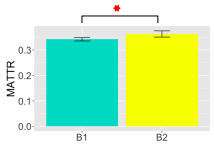
- Measurement of constructional diversity
- Analysis: Linear mixed-effects regression on constructional diversity
  - Fixed effect: Proficiency level
  - Random effect: Country

Pilot Study: Results

- Results: B1 < B2

  → Asian L2 learners of English with higher proficiency displayed higher constructional diversity

  (*b* = 0.018; *SE* = 0.009; *p* = .035)



Discussion

Problem & Solution 1

- Trouble distinguishing **caused-motion construction** from **simple transitive + modifier construction**

  (1) *I gave the present to Mary* (nsubj_verb_dobj_prep)
  (2) *You studied math in the morning* (nsubj_verb_dobj_prep)

- **Solution:** Checked verbs against dative/motion verb corpus

  If in corpus (e.g., *give*) + *to*, *into*, etc. → caused motion
  If not in corpus (e.g., *study*) → simple transitive + adjunct

Problem & Solution 2

- Trouble distinguishing **transitive resultative + verbal complement** from **simple transitive + sentential complement**

  (3) *I made you [come]* (nsubj_verb_ccomp) **Error!**
  (4) *I think [that this class is awesome]* (nsubj_verb_ccomp)

- **Solution:** Check verbs against list of verbs taking sentential complements

  (Levin, 1993)

  If in list (e.g., *think*) → simple transitive + sentential complement
  If not in list (e.g., *make*) → resultative + verbal complement

Limitations

- Misspellings/learner errors can affect accuracy
- Parsing errors coming from spaCy

Next Step

- Test the construction diversity analyzer with more data
- Improve accuracy
- Develop a (web-based) tool

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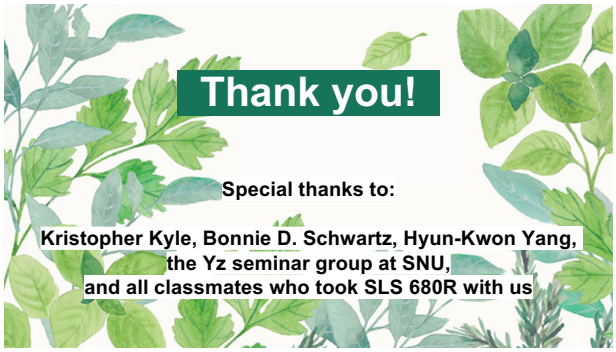

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The first six constructions come from the literature on Construction Grammar (Goldberg, 1995):

1. Caused-motion construction (*She faxed a letter to him*)
2. Ditransitive construction (*She faxed him a letter*)
3. Intransitive motion construction (*It buzzed into the room*)
4. Intransitive resultative construction (*The pond froze solid*)
5. Phrasal verb construction (*She looked the name up*)

Constructions 7–11

The other five are common English constructions:

7. Attributive construction (*She is a student*)
8. Passive construction (*It was folded*)
9. Simple intransitive construction (*I worked*)
10. Simple transitive construction (*The man kicked the ball*)
11. *There*-expletive construction (*There is a house*)

#	Construction	Example	Dependency information
1.	Caused-motion	*Mary faxed a letter to John.*	nsubj-verb-dobj-prep
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3.	Intransitive motion	*The fly buzzed into the room.*	nsubj-verb-prep
4.	Intransitive resultative	*The pond froze solid.*	nsubj-verb-acomp
5.	Phrasal verb	*The girl looked the name up.*	nsubj-verb-dobj-prt
6.	Transitive resultative	*The boy painted the barn red.*	nsubj-verb-dobj-advcl
7.	Attributive	*The boy is a student.*	nsubj-verb-attr
8.	Passive	*The sheet was folded.*	nsubjpass-auxpass-verb
9.	Simple intransitive	*The man worked.*	nsubj-verb
10.	Simple transitive	*The man kicked the ball.*	nsubj-verb-dobj
11.	*There*-expletive	*There is a house..*	exp-verb-attr

Examples of constructions

	VAC	Example	Dependency information
1.	Expletive (*there*)	*There is a house.*	exp-verb-attr
2.	Attributive (copular)	*She is a student.*	-PRON--nsubj-verb-attr
3.	Simple intransitive	*I worked.*	-PRON--nsubj-verb
4.	Intransitive motion	*The fly buzzed into the room.*	nsubj-verb-prep
5.	Intransitive resultative	*The pond froze solid.*	nsubj-verb-acomp
6.	Passive	*It was folded.*	be-verb -PRON--nsubjpass-auxpass-verb
7.	Simple transitive	*The man kicked the ball.*	nsubj-verb-dobj
8.	Caused-motion	*She faxed a letter to him.*	-PRON--nsubj-verb-dobj-prep
9.	Ditransitive	*She faxed him a letter.*	-PRON--nsubj-verb-PRO--dative-dobj
10.	Resultative	*The girl painted the vase red.* *The girl made the can flat.*	nsubj-verb-dobj-advcl nsubj-verb-ccomp nsubj-verb
11.	Phrasal verb	*The girl looked the name up.*	nsubj-verb-dobj-prt

Constructional diversity analyzer

- Procedure
  1. Imports modules and dictionaries
  2. Sorts clauses into 11 constructions using spaCy in Python

     (Honnibal & Montani, to appear)
  1. (a) Measures the type-token ratio for a successive window of

     11 clauses in a speech/text sample by dividing the number of

     construction types (max. = 11) by the total instances of the