
**Advancing research in second language writing through computational tools and machine learning techniques: A research agenda**

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**Abstract:** This paper provides an agenda for replication studies focusing on second language (L2) writing and the use of natural language processing (NLP) tools and machine learning algorithms. Specifically, the paper introduces a variety of available NLP tools and machine learning algorithms and demonstrates how these tools and algorithms could be used to replicate seminal studies in L2 writing that concentrate on longitudinal writing development, predicting essay quality, examining differences between L1 and L2 writers, the effects of writing topics, and the effects of writing tasks. The paper concludes with implications for the recommended replication studies in the field of L2 writing and the advantages of using NLP tools and machine learning algorithms.

**Biographical note**

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1. Introduction

A key component to L2 proficiency is learning how to communicate ideas through writing. Writing in an L2 is an important skill for students interested in general language learning and professionals interested in English for specific purposes (e.g., business, science, law). From a student perspective, writing at the sentential and discourse level is a key skill with which to convey knowledge and ideas in the classroom. Writing skills are also important components of standardized assessments used for academic acceptance, placement, advancement, and graduation. For professionals, writing is an important instrument for effective business communication and professional development.

At heart, communicative and pedagogical issues are at the root of L2 writing research. While a pedagogical focus may differ depending on the role of culture, of L1 literacy development, language planning and policy (Leki, Cumming & Silva 2005; Matsuda & Silva 2005), specific purposes (Horowitz 1986), and genre (Byrnes, Maxim, & Norris 2010), a vital element of pedagogy is still a focus on the written word and how the combination of written words produce the intended effect on the audience (i.e., how well the text communicates its content). Thus, fundamentally, it is the quality of the text that learners produce as judged by the reader that is central. Obviously, how the L2 writers arrived at these words and their combination (via the writing process and the sociocultural context of the learning) is also important; however, such considerations are most likely unknown and potentially irrelevant to the reader, whose interest lies in developing a situational and propositional representation of an idea or a narrative from the text.

The situational model of the text develops through the use of linguistic cues
related to the text’s situational model (i.e., the text’s temporality, spatiality, causality, and temporality; Zwaan, Magliano & Graesser 1995). The propositional meaning is arrived at through the lexical, syntactic, and discoursal units found within a text (Just & Carpenter 1987; Rayner & Pollatsek 1994). Traditionally, L2 writing researchers have examined propositional meaning in students writing for a variety of tasks including longitudinal writing development (Arnaud 1992; Laufer 1994) predicting essay quality (Connor 1990; Ferris 1994; Engber 1995), investigating differences between L1 and L2 writers (Connor 1984; Reid 1992; Grant & Ginther 2000) examining difference in writing topics (Carlman 1986; Hinkel 2002; Bonzo 2008; Hinkel 2009) and writing tasks (Reid 1990; Cumming et al. 2005, 2006). Fewer studies have investigated how situational models develop in L2 writing (cf. Crossley & McNamara 2009).

Many of the studies mentioned above provide foundational understandings about the linguistic development of L2 writers, how L2 writers differ linguistically from L1 writers, and how prompt and task influence written production. These studies are not only foundational in our understanding of such things as L2 writing development, writing quality, and writing tasks, but are also prime candidates for replication (Language Teaching Review Panel 2008; Porte 2012; Porte & Richards 2012). Replication of these studies from a methodological standpoint is warranted because recent advances in computational linguistics now allow for a wider range of linguistic features that measure both situational and propositional knowledge to be automatically assessed to a much more accurate degree than in the past. The output of these tools can also be analyzed using machine learning techniques to predict performance on L2 writing tasks and provide strong empirical evidence about writing development, proficiency, and
differences. Such tools and techniques afford not only approximate replications of previous studies, but also constructive replications that query a wider range of linguistic features that are of interest in L2 writing research.\(^1\) The purpose of this paper is to provide a research agenda that combines L2 writing research with newly available automated tools and machine learning techniques.

1.1 Natural language processing

Any computerized approach to analyzing texts falls under the field of natural language processing (NLP). NLP centers on the examination of how computers can be used to understand and manipulate natural language text (e.g., L2 writing texts) to do useful things (e.g., study L2 writing development). The principle aim of NLP is to gather information on how humans understand and use language through the development of computer programs meant to process and understand language in a manner similar to humans.

There are a variety of NLP tools recently developed for English that are freely available (or for a minimal fee) and require little to no computer programming skills. These tools include Coh-Metrix (Graesser et al. 2004; McNamara & Graesser 2012), Computerized Propositional Idea Density Rater (CPIDR; Brown et al. 2008), the Gramulator (McCarthy, Watenebe & Lamkin 2012), Lexical Complexity Analyzer (LCA: Lu in press), Linguistic Inquiry and Word Count (LIWC: Pennebaker, Francis & Booth 2001; Chung & Pennebaker 2012), L2 Syntactic Complexity Analyzer (Lu 2011),

\(^1\) Approximate replications involve close duplication of methods while constructive replications use new methods or designs to verify original findings. See Language Teaching Review Panel (2008), Porte (2012), and Porte & Richards (in press) for more information.
and VocabProfiler (Cobb & Horst 2011). These are discussed briefly below. For a complete summary of each tool, please see the references above.

1.1.1 Coh-Metrix

Coh-Metrix is a state-of-the-art computational tool originally developed to assess text readability with a focus on cohesive devices in texts that might influence text processing and comprehension. Thus, many of the linguistic indices reported by Coh-Metrix measure cohesion features (e.g., incidence of pronouns, connectives, word overlap, semantic co-referentiality, temporal cohesion, spatial cohesion, and causality). In addition, Coh-Metrix reports on a variety of other linguistic features important in text processing. These include indices related to lexical sophistication (e.g., word frequency, lexical diversity, word concreteness, word familiarity, word imageability, word meaningfulness, word hypernymy, and word polysemy) and syntactic complexity (e.g., syntactic similarity, density of noun phrases, modifiers per noun phrase, higher level constituents, words before main verb). An on-line version of Coh-Metrix is freely available at http://cohmetrix.memphis.edu/cohmetrixpr/index.htm.

1.1.2 Computerized Propositional Idea Density Rater (CPIDR)

CPIDR measures the number of ideas in text by counting part-of-speech tags and, using a set of readjustment rules, the number of ideas. CPIDR reports the number of ideas and the idea density (calculated by dividing the number of ideas by the number of words). CPIDR is freely available for download on-line at http://www.ai.uga.edu/caspr.
1.1.3 The Gramulator

The Gramulator reports on two key linguistic features found in text: n-gram frequency and lexical diversity. For n-grams, the Gramulator calculates the frequency of n-grams in two sister corpora to arrive at n-grams that differentiate between both corpora. Specifically, the Gramulator identifies the most commonly occurring n-grams in a contrastive corpora and retains those n-grams that typical of one corpus but are antithetical to the contrasting corpus. The Gramulator also calculates a variety of sophisticated lexical diversity indices (e.g., MTLD, HD-D, M) that do not strongly correlate with text length. The Gramulator is free to download at https://umdrive.memphis.edu/pmmccrth/public/software/software_index.htm.

1.1.4 Lexical Complexity Analyzer (LCA)

LCA computes 25 different lexical indices related to lexical richness (i.e., lexical sophistication and lexical density). These include sophisticated words (infrequent words), lexical words (content words), sophisticated lexical words (infrequent content words), verbs, sophisticated verbs, nouns, adjectives, and adverbs. The Lexical Complexity Analyzer is freely available for use at http://aihaiyang.com/synlex/lexical.

1.1.5 Linguistic Inquiry and Word Count (LIWC)

LIWC is a textual analysis program developed by clinical psychologists to investigate psychological dimensions expressed in language. LIWC reports on over lexical 80 categories that can be broadly classified as linguistic (pronouns, tense, and prepositions), psychological (social, affective, rhetorical, and cognitive processes) and personal
concerns (leisure, work, religion, home, achievement). LIWC is available for download for a minimal fee at http://www.liwc.net.

1.1.6 L2 Syntactic Complexity Analyzer (L2SCA)
The L2SCA was developed to measure a range of syntactic features important in L2 writing research. The measures can be divided into five main types: length of production, sentence complexity, subordination, and coordination. The L2SCA is free to download at http://www.personal.psu.edu/xxl13/downloads/l2sca.html.

1.1.7 VocabProfiler
VocabProfiler is a computer tool that calculates the frequency of words in a text using Lexical Frequency Profiles (LFP), which were developed by Laufer and Nation (1995). VocabProfiler reports the frequency of words in a text using the first 20 bands of families found in the BNC (the earlier version developed by Laufer and Nation reported on the first 3 bands only). An on-line version of VocabProfiler is freely available at www.lextutor.ca.

1.2 Machine learning algorithms
As the size and variety of written corpora continue to grow, the amount of information available to the researcher becomes more difficult to analyze. What are needed are techniques to automatically extract meaningful information from these diverse and large corpora and discover the patterns that underlie the data. Thus, replication research in L2 writing should not only include the use of advanced computational tools, but also
machine learning techniques that can acquire structural descriptions from corpora. These structural descriptions can be used to explicitly represent patterns in the data to predict outcomes in new situations and explain how the predictions were derived (Witten, Frank & Hall 2011).

The output produced by the tools discussed above can be strengthened through the use of advanced statistical analyses that can model the human behavior found in the data. These models usually result from machine learning techniques that use probabilistic algorithms to predict behavior. The statistical package that best represents these advances and is the most user-friendly is likely to be the Waikato Environment for Knowledge Analysis (WEKA: Witten, Frank & Hall 2011). WEKA software is freely available from http://www.cs.waikato.ac.nz/ml/weka and it allows the user to analyze the output from computational tools using a variety of machine learning algorithms for both numeric predictions (e.g., linear regressions) and nominal classifications (e.g., rule-based classifiers, Bayesian classifiers, decision tree classifiers, and logistic regression). WEKA also allows uses to create association and clustering models.

1.3 The Intersections of L2 writing, NLP, and machine learning algorithms
Thus, we find ourselves at an interesting point in L2 writing research. We currently have available large corpora of L2 writing samples such as the International Corpus of Learner English (ICLE: Granger, Dagneaux & Meunier 2009). We also have a variety of highly sophisticated computational tools such as those mentioned above with which to collect linguistic data from the corpora. Lastly, there are now available powerful machine learning techniques with which to explore this data. All of these advances afford the
opportunity to replicate and expand a variety of studies that have proven important in our understanding of L2 writing processes and L2 writing development. In this paper, I will focus on a small number of influential studies related to assessing longitudinal growth in writing, modeling writing proficiency, comparing differences between fluent and developing L2 writers, and investigating the effects of prompt and task on L2 writing output. In each case, I will present previous research on the topics and discuss the implications for recent technological advances in replicating and expanding these research areas.

2. Longitudinal studies of L2 writing

A variety of studies have attempted to investigate the development of linguistic features in L2 writing using longitudinal approaches (Arnaud 1992; Laufer 1994). Longitudinal approaches to understand writing development are important because they allow researchers to follow a small group of writers over an extended period of time (generally around one year). While the power of the analysis is lessened because of the small sample size, longitudinal analyses provide the opportunity to analyze developmental features that may be protracted such as the development of lexical networks (Crossley, Salsbury & McNamara 2009; 2010) or syntactic competence. Longitudinal studies also provide opportunities to examine growth patterns in more than one learner to see if developmental trends are shared among learners.

One of the most cited longitudinal studies of L2 writing is Laufer’s (1994) study in which she investigated the development of lexical richness in L2 writing. Laufer analyzed two aspects of lexical richness: lexical diversity and lexical sophistication. Her
index of lexical diversity was a simple type-token ratio score, while her indices of lexical sophistication were early LFP bands (two bands that covered the first 2,000 word families in English), the university word list (UWL: Xue & Nation 1984), and words contained in neither the LFP bands or the UWL. The data for the study came from 48 university students, who wrote free compositions at the beginning of the semester. These 48 students were broken into roughly equal groups, one of which wrote free compositions at the end of the first semester and the other free compositions at the end of the second semester. Laufer then compared the essays written at the beginning of the semester to those at the end of the first and the second semester using the selected lexical indices. Her primary research questions were whether the writers showed differences in their lexical variation and lexical sophistication as a function of time. To assess these differences, she used simple $t$-test analyses.

The $t$-test analyses demonstrated that the lexical sophistication of the writers changed significantly after one semester of instruction and after two semesters of instruction such that developing writers produced fewer basic words (words in the first 2000 word families) and more advanced words (words beyond the first 2000 word families). The findings for lexical diversity were not as clear with students demonstrating significantly greater lexical diversity after one semester, but not significantly greater diversity after two semesters. Laufer argued that the findings from the study demonstrated growth in L2 writing skills over time and indicated that greater emphases should be placed on explicit lexical instruction in L2 writing classes.
Research task 1: Undertake an approximate or constructive replication of Laufer (1994)

Despite having been published some eight years ago, the study remains a solid representation of the basic methods and approaches used in longitudinal writing studies. It is also a prime candidate for approximate and constructive replication, namely because of the computational advances that have occurred in the last 20 years. The study also needs replication because the lexical indices used by Laufer to assess lexical growth were problematic. The LFP bands she used are quite limited in scope (with modern LFP bands as found in VocabProfiler assessing 20 bands each containing 1,000 word families) and potentially ill designed to assess word frequency production because of the possible information loss that comes with grouping words into families. This loss of information occurs because word families contain fewer distinctions than type counts and are naturally biased toward receptive knowledge as compared to productive knowledge. Perhaps even more problematic was her use of simple type-token ratios to assess lexical variation. Simple type-token ratio indices are highly correlated with text length (McCarthy & Jarvis 2010). Thus, it is possible that Laufer was not measuring lexical diversity, but rather the length of the students’ writings.

New computational indices freely available would prove valuable in an approximate replication of this study. For instance, the LFP bands reported by VocabProfiler provide greater coverage of the words in English and are based on much more representative corpora (i.e., the recent BNC version). However, these indices could be problematic because of the grouping approach, which diminishes lexical information and is more geared toward receptive vocabulary. Thus, the frequency indices reported by
Coh-Metrix, which are count-based (i.e., not grouped into word families) may provide greater information on word frequency development in L2 writers. The lexical diversity indices reported by the Gramulator (MTLD, HD-D, and M: McCarthy et al. 2010) control for the text length effects found in simple type/token ratios and gives more accurate values about the lexical diversity of text. An approximate replication study using these newer indices could provide additional support for the trends reported by Laufer (as they already have in spoken L2 production; see Crossley et al. 2009; 2010).

For a constructive replication, researchers may consider addressing other aspects of lexical richness and competence that were not considered in Laufer’s study. For instance, the Lexical Complexity Analyzer reports on a variety of lexica density indices (an integral part of lexical richness) that could be used to assess the growth of L2 writers’ lexical competence. Coh-Metrix also reports on a variety of indices related to lexical richness (e.g., word familiarity) and lexical competence (e.g., word hypernymy, word polysemy, word meaningfulness, word concreteness, and word imageability). These indices could provide additional information about how writing skills develop lexically.

3. L2 writing proficiency

Another important research area in L2 writing is the use of computational tools and machine learning algorithms to investigate L2 writing proficiency. In contrast to longitudinal studies that investigate writing development, studies of writing proficiency might assess the extent to which expert judgments of writing quality can be predicted using a variety of linguistic measures. Such investigations help to pinpoint which
linguistic features most likely affect expert judgments of quality and provide a means from which to understand the proficiency of an L2 writer.

One of the more computationally robust studies to investigate writing proficiency is Grant & Ginther’s (2000) study in which they used an automated tagging system to predict expert ratings of essay quality on a small L2 writing corpus. I select this study as a candidate for replication because it looked at a wide variety of linguistic features to include text length, lexical specificity, cohesive devices, rhetorical features, grammatical structures, and syntactic structures. The data collection methods used were also sound, focusing on L2 writing samples produced in a standardized testing environment and holistically scored by independent raters. However, surprisingly, Grant & Ginther conducted no confirmatory statistical analysis of the findings, leaving interpretation of the study in doubt. This weakness of the study, along with recent advances in computational tools, makes this study a prime candidate for replication.

In the Grant & Ginther study, 90 essays sampled from a larger corpus of essays written for the Test of Written English (TWE) were selected for analysis. The L2 writers taking the TWE were given 30 minutes to write an argumentative essay on a single prompt. The essays had been scored on a holistic scale of 1-6 by two independent raters. Because there were not a sufficient number of essays scored 1, 2, or 6, Grant & Ginther selected 30 essays that were scored 3, 30 essays that were scored 4, and 30 essays that were scored 5. The 90 selected essays were then automatically tagged by the Biber tagger (1988)² for length, lexical specificity (type/token ratio and word length), cohesive devices (conjuncts and demonstratives), rhetorical features (hedges, amplifiers, emphatics,

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² Because the Biber tagger is not available for public use, it was not selected as a potential tool for use in replication studies.
downtoners), grammatical structures (e.g., nouns, nominalizations, pronouns, verbs, models), and syntactic features (e.g., subordination, complementation, relative clauses).

Grant & Ginther conducted no confirmatory statistical analyses for the data reported by the Biber tagger and instead used only descriptive statistics (mean and standard deviation) to interpret the data. They interpreted the descriptive statistics as indicating that essays scored as higher quality by expert raters were longer with more unique word choices, included more cohesive devices and rhetorical features, contained a greater number of grammatical features, and incorporated more complex syntactic features.

Research task 2: Undertake an approximate or constructive replication of Grant & Ginther (2000)

Without statistical analysis, such findings cannot be substantiated. Thus, approximate and constructive replications of this study are needed. A major difficulty in such a replication is finding an appropriate corpus that consists of L2 essays holistically scored by expert raters. Often, researchers can approach the authors of the study to access the original corpora. If this is not possible, other, similar corpora are available. For instance, ETS generally releases a TOEFL iBT Public Use Dataset to qualified researchers. The dataset includes about 500 independent and integrated L2 writing samples that have been scored by expert raters. Alternatively, researchers can collect and score their own L2 writing corpora. Once the researcher has secured a database, an approximate replication study would assess similar linguistic features such as text length (CPIDR), lexical specificity (the Gramulator and Coh-Metrix), cohesive devices (Coh-
Metrix), rhetorical features (LIWC), grammatical structures (LIWC), and syntactic structures (Coh-Metrix and L2SCA). The data collected from these sources could then be analyzed using the machine learning algorithms in WEKA to provide confirmatory statistical analyses and to assess the generalizability of the findings on a training set. The researcher could select to investigate the expert scores as categorical functions (using machine learning algorithms such as logistic regressions to classify the essays into groups based on scores) or as continuous variables (using machine learning algorithms such as linear regressions to predict the expert scores).

A constructive replication would expand the number, variety, and types of linguistic features examined but focus on verifying the original findings. For instance, it would be interesting to know how the number of idea units (as reported by CPIDR) contained in a text may relate to judgments of human quality. Likewise, it would be revealing to investigate if the psychological properties of the words (as reported by LIWC) used in L2 writing influenced human judgments of writing quality. Lastly, Grant & Ginther examined a variety of linguistic features using a relatively simple POS tagger based on counts of surface level features. Constructive replications could build on this original study by expanding the nature and depth of the features analyzed using computational tools currently available. For instance, the lexical features reported by Coh-Metrix tap into much deeper attributes of lexical knowledge than simple type/token ratios and word length counts. Likewise, the syntactic structures reported by the L2SCA go beyond simple tags and began to examine clausal complexity, subordination, and coordination.
4. Comparisons of L1 and L2 writing

A third research area that is important in L2 writing is comparisons of L1 and L2 writing. The caveat to comparing L1 and L2 writing is that L1 written samples should be seen as a baseline for comparison and not an ideal. We cannot expect L2 writers to reach the fluency of L1 writers in most cases, but comparisons between L1 and L2 writers can give us a clearer understanding of the linguistic components that characterize L2 writing. These differences have important implications for writing assessment and instruction.

There have been numerous studies conducted on L1 and L2 writing differences in both the writing process and the writing product (see Silva 1993 for an early, but thorough overview). Many of these studies have focused on differences in the use of cohesion devices (Connor 1984; Reid 1992) between L1 and L2 writers (and sometimes between L1 writers of different backgrounds). Perhaps the best study for replication is Reid’s (1992) study in which she compared L1 and L2 writers’ production of cohesion devices (pronouns, conjunctions, and subordinate conjunction openers) along with one indicator of syntactic maturity (prepositions). Reid collected the data for these linguistic features using an automated parser. Her corpus consisted of 768 essays of which 540 were written by L2 learners from three different language backgrounds (Arabic, Chinese, and Spanish). L1 writers wrote the remaining essays (n = 228). The essays were written for two different task types (comparison/contrast/take a position and description/interpretation of a chart/graph) and on four different prompts. The essays were also written under timed conditions (30 minutes). This experimental design allowed Reid to examine difference between L1 and L2 writing in general and between L2 writers from
different language backgrounds. However, I am only going to focus on the former (i.e., differences between L1 and L2 essays).

Using a series of ANOVAs, Reid reported that the L1 writers used significantly fewer pronouns than L1 writers and significantly few coordinate conjunctions. L1 writers also produced more prepositions than L2 writers, but no differences were noted in the production of subordinate conjunction openers. Reid argued that the increased use of pronouns by L2 writers may be symptomatic of interactive prose that is common in oral language indicating that L2 writers, unlike L1 writers, may show an unawareness of their audience. Reid interpreted the differences in coordinate conjunctions as also demonstrating a reliance on oral communication on the part of L2 writers because natural conversation includes more coordinated structures, especially the use of coordinated conjunctions. This is unlike L1 writers, who likely alternate between cohesive devices. Lastly, Reid argued that differences in the use of prepositions probably signaled relationships between clausal constituents and the lower use of prepositions by L2 writers indicated less clausal complexity.

**Research task 3: Undertake an approximate or constructive replication of Reid (1992)**

Reid’s study is an excellent example of a comparison study between L1 and L2 writing and one that demonstrates key differences between L1 and L2 writers. These differences offer important details that prove useful for L2 writing assessment and instruction. However, the study requires replication because of the breadth of indices that Reid had available for analysis (only four indices). Current computational tools such as
Coh-Metrix report on a wide variety of cohesion indices that go well beyond those reported by Reid including lexical overlap, semantic co-referentiality, causality, spatial cohesion, temporal cohesion, anaphoric reference, lexical diversity, and a number of different connective and conjunctive indices. Very few of these have been tested on distinguishing L1 and L2 writing samples with the exception of lexical overlap, semantic-co-referentiality, causality, and spatiality (see Crossley & McNamara 2009). In addition, Reid did not distinguish between personal pronouns and other types of pronouns, which did not allow her to strongly support her arguments that L2 writers relied on interactive prose. These distinctions, however, are reported by LIWC. Thus, both Coh-Metrix and LIWC promote approximate replications of this study.

Reid also investigated an index of semantic complexity, which she attributed to cohesion. In many ways, syntactic complexity is related to cohesion because studies have demonstrated that L1 writers first produce cohesive features (McCutchen 1986) and then later move toward the production of more complex syntactic constructions (Haswell 2000). Such trends likely demonstrate that the advanced writers began to utilize syntactic elements such as modification and embedding to implicitly connect ideas (Crossley et al. 2011) as compared to using explicit cohesive devices. With this in mind, replication studies should consider a broader range of syntactic indices not used by Reid. These would include indices of syntactic complexity and syntactic similarity found in Coh-Metrix and L2SCA.

Constructive replication studies could investigate a wider range of linguistic features to address the basic research question about differences between L1 and L2 writers. These replications could include the psychological and rhetorical properties
reported by LIWC, the lexical indices reported by Coh-Metrix, VocabProfiler, and LCA
(see Crossley & McNamara 2009 for a constructive replication study using the Coh-
Metrix lexical indices), and the n-gram indices reported by the Gramulator. Both
constructive and approximate replication studies would benefit from the use of machine
learning algorithms to detect and classify differences between L1 and L2 writers.

5. The effects of prompts on L2 writing

Another important research area in L2 writing is examining the effect of prompt on
writing production. Hinkel (2002; 2003) demonstrated that writing prompts influence the
linguistic output produced by L1 and L2 writers. Knowing that linguistic features are
highly related to human judgments of essay quality, it becomes important to understand
the effects of prompt and how to control for prompt-based differences in writing
assignments that may affect linguistic production and, thus, have implications for L2
assessment.

Perhaps the study that best exemplifies prompt-based effects on linguistic
production in L2 writing is Hinkel’s (2002) study that investigated how different prompts
influence the production of linguistic features for both L1 and L2 writers. Hinkel
examined 6 different prompts related to parents, grades and learning, wealth, manner of
instruction, opinion forming, and selecting a major. The prompts were modeled after
those found in standardized tests such as the TWE, College Board, and the Scholastic
Aptitude Test (SAT). Almost 1,500 students wrote essays in response to the prompts
including 242 native speakers and L2 learners from the following backgrounds: Chinese
(n = 220), Japanese (n = 214), Korean (n = 196), Vietnamese (n = 188), Indonesian (n = 213), and Arabic (n = 184). All the L2 writers were of advanced proficiency.

In total, Hinkel examined 68 different lexical features classified as semantic and lexical classes of nouns (e.g., vague and enumerative nouns), personal pronouns, existential slot fillers, indirect pronouns, verb tenses, verb aspects, semantic and lexical classes of verbs (e.g., public, private, and suasive verbs), modal verbs, participles, adjectives, semantic and lexical classes of adverbs (e.g., time, frequency, and place adverbs), noun and adjective clauses, adverb clauses, coordinating and logical conjunctions, and hedges. Hinkel used hundreds of Mann Whitney U tests to assess differences in the linguistic productions of L1 and L2 writers based on prompt difference. She reported that all prompts demonstrated significant differences in the linguistic features produced by the L1 writers and the L2 writers categorized by their L1. For instance, essays written on the manner of instruction prompt contained the fewest present tense verbs for the L1 writers and Korean and Vietnamese L2 writers. The opinion forming prompt led to a greater number of infinitives and, for Chinese writers, the fewest present tense verbs. Selecting a major verb elicited the most personal narratives and nominalizations. These prompts (manner of instruction, opinion forming, and selecting a major) also lead to the highest rates of be-copulas for all but Arabic writers, phrase level conjunctions for L1 and Chinese writers, and fixed strings for L1, Chinese, Japanese, and Indonesian writers.

**Research task 4: Undertake an approximate or constructive replication of Hinkel (2002)**

Hinkel’s study demonstrates that prompts have a significant effect on writers’
linguistic production. Knowing that linguistic features of writing influence human judgments of writing proficiency, understanding prompt-based differences becomes an important area for replication. Specifically, in the case of Hinkel’s study, replication studies should include a variety of linguistic indices that directly link to lexical sophistication, syntactic complexity, and text cohesion. While the features she selected are common in analyses of genre, many of them do not have strong links to writing theory. Thus, from a linguistic perspective, features with stronger links to writing quality would prove beneficial in understanding how prompts effect writer production.

Replication studies should include more standardized lexical features such as indices of lexical diversity and word frequency (as reported by Coh-Metrix, LCA, VocabProfiler). Syntactically, features related to complexity (i.e., t-units, clausal units, and length measure as reported by Coh-Metrix and L2SCA) should also be included in replication studies. Hinkel’s study also reported on only a few indices of cohesion (e.g., coordinating and logical conjunctions). Replication studies should include more cohesion features with stronger links to textual cohesion such as the semantic co-referentiality indices, lexical overlap indices, and anaphoric reference indices reported by Coh-Metrix.

Hinkel also failed to control for Type 1 errors (false positives) in her analysis. That is to say, she conducted multiple statistical tests on her data but did not correct her alpha value to control for chance findings. There are a variety of ways to control for Type 1 errors. Replication studies assessing prompt-based differences would do well to conduct Multiple Analyses of Variance (MANOVAs) with post-hoc analyses that include corrections for multiple comparisons. The indices that are strongest predictors of prompt differences could then be fed into a machine learning algorithm (e.g., a logistic
regression) that uses cross-validated training and test sets to develop a model to classify writing samples as belonging to one prompt or another prompt based on linguistic features alone. Such an analyses would provide strong evidence for prompt-based effects on linguistic production. Such a study would be further bolstered by an analysis of how the prompt-based linguistic features in the writing samples affect human judgments of writing quality (see Research Task 2). A combination of these two areas would provide valuable information about how prompts can control linguistic output on the part of L2 students and how this linguistic output can affect human judgments of essay quality.

6. Effects of task on L2 written production

The last important area of L2 writing that I will discuss is the influence that task plays in writing production. Successful writing tasks provide contextual and authentic opportunities for writers to use language to explain ideas, provide information, compare concepts, interact, or persuade. Perhaps the two most common writing tasks found in academic situations are independent writing (i.e., writing based on personal knowledge) and integrated writing (i.e., source-based writing). Studies have demonstrated that the writing task (e.g., independent or integrated tasks) influences linguistic production (Reid 1990; Cumming et al. 2005; 2006). As with prompt-based differences (see Research Task 4), because linguistic features are predictive of human judgments of essay quality, it is important to understand how the writing task may affect the production of linguistic features.

While earlier studies on task-based differences focused on differences between compare/contrast essays and essays written to explain charts or graphs (Reid 1990), more
recent research has begun to focus on differences between independent writing samples and integrated writing samples as found in the Test of English as a Foreign Language (TOEFL; Cumming et al. 2005; 2006). The Cumming et al. (2005) study is probably the best candidate for replication because it focused on differences between independent and integrated essays using a number of linguistic features that have important links to writing quality.

Cumming et al. selected 216 essays written for the six tasks in the TOEFL-iBT (two independent writing tasks, two reading-to-write tasks, and two listening-to-write tasks). These 216 essays were written by 36 TOEFL examinees. All essays were scored from 3 to 5 on a six level holistic rubric of writing quality. Cumming et al. selected nine linguistic indices with which to analyze the essays for differences between tasks. These nine indices all had theoretical links to assessments of writing quality. Six of the indices were generated automatically (text length, average word length, type/token ratio, number of clauses per t-unit, number of words per t-unit, and functional use of verb phrases taken from the source text), while human raters coded the other three features (grammatical accuracy, quality of argument structures, and orientation to source evidence). Cumming et al. used non-parametric MANOVAs to examine differences between the independent essays and the integrated essays. The results of this analysis demonstrated that integrated writing tasks prompted shorter essays that contained longer words, a greater diversity of words, and more clauses that were also longer. Integrated essays were also less argumentatively oriented and contained more source material. Cumming et al. concluded that independent tasks produced essays containing extended written arguments and that integrated tasks produced essays responding to textual information.
**Research task 5: Undertake an approximate or constructive replication of Cumming et al. (2005)**

The Cumming et al. (2005) study provides a strong foundation from which to base replication studies (both approximate and constructive). Recent advances in computational tools afford a greater understanding of differences between integrated and independent tasks in reference to their effects on lexical and syntactic features. Lexically, the Cumming et al. study needs approximate replication evidence because the two lexical indices used in the study are problematic. Word length is only a proxy for word frequency and, thus, replication studies should focus on word frequency indices reported by Coh-Metrix or VocabProfiler. As discussed earlier, simple type/token ratio scores are highly correlated with text length. Therefore, it is possible that the type/token ratio scores were conflated with the text length measure. Replication studies should therefore consider using more advanced indices of lexical diversity as found in the Gramulator that control for text length. Lastly, approximate replication studies should consider a variety of other syntactic complexity indices that are now available (as reported by L2SCA and Coh-Metrix). Constructive replications may consider testing a variety of linguistic features not considered by Cumming et al. but that still address their primary research questions. These would include indices related to cohesion features (as found in Coh-Metrix) idea units (as found in CPDIR), and psychological word properties (as found in LIWC). Both approximate and constructive replications should also take advantage of machine learning algorithms that could be used not only to assess differences between independent and integrated essays, but to also create models that could automatically categorize essays as belonging to one group or another.
While not solely related to replication studies, future research into linguistic differences between independent and integrated essays should also consider their effect on human ratings of essay quality. Unlike prompt-based writing analyses, some studies have investigated whether L2 essays demonstrate differences in holistic scores depending on whether the writing task was an independent or integrated task. The results of these studies have been mixed with some research reporting no differences in human scores for independent and integrated tasks (e.g., Gebril 2006) and other research reporting that L2 writers receive significantly higher scores for writing quality on integrated tasks as compared to independent tasks (Esmaeili 2002). Future research should consider not only the human scores, but also how the linguistic features prompted by task influence human judgments of quality.

7. Conclusion

We are at an important intersection of language and technology where practical and accurate computational tools are readily available for advanced text analysis. Such tools have the ability to make an important impact in studies of L2 writing and provide us with the means to replicate studies from key areas of L2 writing research. Such replication studies can both empirically support the original studies as well as provide a deeper understanding of how L2 writing develops, how linguistic features in the text influence human judgments of writing quality, how, why and where L2 writing diverges from L1 writing, how prompts affect text production and what this means for writing quality, and how different writing tasks incline L2 writers to produce different linguistic features. All of these areas of research provide us with foundational knowledge about L2 writing and
the effectiveness of L2 communication. Such knowledge can be used in developing instructional technology, pedagogical practices, and more sophisticated theories of the writing process and SLA in general.

My arguments for replication are linguistic in nature and computational at the core. However, linguistic and computer analyses can only provide answers to a defined range of research questions. Thus, while there are many tasks that computers are well placed to accomplish, there are others at which they readily fail. Many of these are important for a complete understanding of the L2 writing process. For instance, computational tools are fundamentally misaligned with research related to the writing process, literacy development, and language planning, all of which are important attributes of understanding L2 writing. In other areas, computational tools are still in their infancy and their application may be ill-advised (e.g., in sentiment analysis). However, from a linguistic perspective, computational tools provide many advantages to human analysis including reduced costs (compared to human assessors), speed, flexibility, and reliability (Higgins, Xi, Zechner & Williamson 2011). These advantages afford a greater understanding of the written word and how the combination these words is indicative of writing development, writing quality, writing differences, and prompt and task-based effects.
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