

New digital methodologies for old grammar problems: Corpus analyses and eye-tracking to discover non-native English article usage preferences¹

This contribution illustrates how old research questions in English linguistics can be tackled again successfully by digital humanities approaches in data collection, analysis, and presentation: Our pilot project uses digital data, which are collected in two forms, a problem-specific corpus and informant-recordings from eye-tracking sessions. The main focus of this study is, however, on the mix of two methodologies: one digitises language production data, and the other is born-digital language perception data. These two methodologies allow us to combine two independent pieces of evidence to come to more convincing conclusions about relationships of linguistic variables. The presentation of digital data is used to illustrate how visualisation can help to generate new hypotheses for further analysis and interpretation of the data. Finally, we also find that digital humanities may not only solve old language questions, but even raise new ones.

1. Problem-specific introduction

1.1. Dimensions of English article usage

The English determiners are a specific problem, because the development of the English article system from the system of demonstrative pronouns has been researched as an intricate development, unlike that in many other languages. When article choice is a problem even for German learners and advanced users of English, who share a rather similar linguistic subsystem with English, it is understandable that the English article system appears extremely complex for learners and users of English that have a first language without a grammaticalised article system. This makes Chinese users of English but also many others like Russians and some Africans, for instance, stand out as advanced users that can be identified as non-native speakers through their article usage alone, or rather through their non-usage of articles and extended use of zero articles in English. We call this specific grammar problem old, because research on it covers three decades (e.g. Huebner 1985; Lardiere 2004; Parrish 1987; Robertson 2000; White 2003; Zdorenko & Paradis 2011).

The literature suggests several dimensions that influence article use in second-language (L2) Englishes: the semantic concept of definiteness governs article usage in native English (L1; e.g. Schönenberger 2014), which is complemented by specificity to determine the use of articles in Germanic languages, speaker knowledge, and scope of the utterance in L2 Englishes. We are going to concentrate on the influence of definiteness and specificity in our paper, which will be discussed in detail in section 2.

¹ We are grateful for discussions on the data and help with the collection of data to our research assistants, Sven Albrecht and Michelle Klein, [and for reference to standard Chinese learning materials to Tony McEnery](#). Of course, we also welcome further discussion on the issues raised here to develop our claim further that digital humanities are not a welcome addition to linguistic research but they have been an integral part of it for a long time.

1.2. Theoretical assumptions of the pilot project

In our study, we assume that the Fluctuation Hypothesis (Ionin et al. 2004, 8; Prévost and White 2000, 103) is able to explain the linguistic behaviour of L2 learners by stating that they are aware of features like definiteness and have full access to universal grammar (cf. Schwartz & Sprouse 1994, 1996) when learning English. We further presume that in Chinese grammaticalisation of demonstratives and numerals has rather recently begun, as suggested, for instance, by Chen (2003, 2004), Huang (1987), and Li & Bisang (2012). And finally, we are convinced that eye-tracking is suitable to spot article substitution and omission (or overuse) errors through long fixations and regressive saccades (e.g. cf. Koops et al. 2008; Pickering & Traxler 1998; Roberts & Siyanova-Chanturia 2013).

2. Literature review

2.1. Definiteness and specificity

According to Ionin et al. and Ko et al., a Determiner Phrase (DP) of the form [D NP] is [+definite], when the speaker and the hearer presuppose the existence of a unique individual in the set denoted by the noun phrase (NP). A DP is [+specific], when the speaker intends to refer to a unique individual in the set denoted by the NP and considers this individual to possess some noteworthy property (2004, 5; 2009, 288). An example for a definite DP is (1).

- 1) Joan wants to present the prize to *the* winner
 - a) but he doesn't want to receive it from her.
 - b) so she'll have to wait around until the race finishes (Lyons 1999, 167; example 19).

In (1a) the winner is specified further by possessing the noteworthy property that he does not want to receive the prize from Joan, which makes the definite DP [+specific]. In (1b) the winner does not receive any noteworthy property, making the definite DP [-specific].

An example for an indefinite DP is (2).

- 2) Peter intends to marry *a* merchant banker...
 - a) even though he doesn't get on at all with her.
 - b) though he hasn't met one yet (Lyons 1999, 176; example 51).

As in (1a) above, in (2a), the speaker intends to clarify that the merchant banker is difficult to cope with for Peter, i.e. the banker receives a noteworthy property which makes the indefinite DP [+specific]. In (2b), the merchant banker is not specified in any way, so that the indefinite DP is [-specific].

2.2. The Fluctuation Hypothesis

Originally postulated by Ionin (2003, 23), the Fluctuation Hypothesis for article choice in English learned as a second language states that

- a) L2-learners have full access to the features that can underlie article choice cross-linguistically, i.e. the features [+definite] and [+specific], and that

b) L2-learners fluctuate between dividing English articles on the basis of definiteness vs. specificity, until the input leads them to choose the definiteness option. (Ionin et al. 2004, 8)

In other words, the feature specificity competes with the feature definiteness when it comes to article choice in English language production. As outlined in Table 1, the Fluctuation Hypothesis predicts that the indefinite article *a* is overused in [+definite] and [-specific] contexts, and that the definite article *the* is overused in [-definite] and [+specific] contexts. In the remaining two contexts, the hypothesis does not predict any article choice errors.

	[+definite] (target <i>the</i>)	[-definite] (target <i>a</i>)
[+specific]	correct use of <i>the</i>	overuse of <i>the</i>
[-specific]	overuse of <i>a</i>	correct use of <i>a</i>

Table 1. Predictions for article choice in L2-English (Ko et al. 2009, 292)

2.3. Eye-Tracking

Known from psychological experiments, eye-tracking in linguistics is about the recording of eye-movement and non-movement during either reading exercises (cf. Pickering & Traxler 1998; Roberts & Siyanova-Chanturia 2013) or associations of, for example, pronunciations and real-world manifestations (cf. Koops et al. 2008). Linguistic eye-tracking studies focus on learners' sensitivity to ambiguities and ungrammaticalities (Roberts & Siyanova-Chanturia 2013).

Eye movements are referred to as saccades during which no new information is acquired by a reader (Pickering & Traxler 1998). The mean saccade length is on average between 7 to 9 letter spaces (Rayner 2009). The time between the saccades is called fixations, meaning no eye movement for a longer period of time in milliseconds. The number and duration of fixations signal text processing during reading. Experiments have shown that word recognition requires a minimum length of 200 milliseconds, and that the mean fixation length is about 200 to 250 milliseconds (Altmann 2011; Rayner 2009).

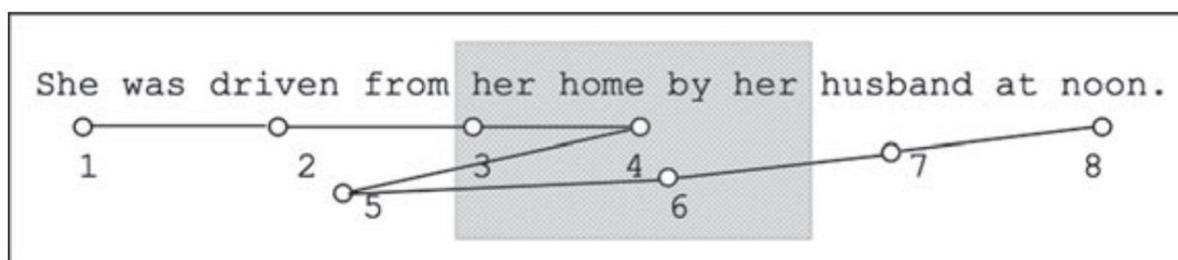


Fig. 1 Hypothetical eye-movement record. The shaded area represents the region of interest. Figure taken from Roberts & Siyanova-Chanturia (2013, 218).

Figure 1 shows a hypothetical eye-movement record. The points represent fixations and the connecting lines are saccades. The grey area is an area of interest (AOI) which

marks a certain linguistic cue, mistake or ambiguity. When the duration of the first fixation in the AOI (fixation 3) is added to those of the remaining fixations, we have calculated the gaze duration, which is sensitive to syntactic anomalies. The line connecting fixations 4 and 5 is a regressive saccade, which leads to the onset of a rereading process, comprising the durations of fixations 5 and 6. Rereading usually occurs after the readers have encountered a problem (Roberts & Siyanova-Chanturia 2013). Figure 2 shows a real eye-movement record without an AOI taken from our informant recordings.



Fig. 2 Real eye-movement record without an AOI.

2.4. Deriving the research questions

The Fluctuation Hypothesis has already been empirically tested by, for instance, Ko et al. (2009), Hawkins et al. (2006), Snape et al. (2006), and White (2008) using forced elicitation tasks. Albrecht (2016, 2017) complemented grammaticality judgment tests with data from the SYSU-Corpus (compiled by Küchler 2015) in order to test the Fluctuation Hypothesis in his master thesis. The results of these studies partially support the predictions of overuse of *the* and *a*, and they support overuse of zero article.

More specifically, Ko et al. (2009), Hawkins et al. (2006), and White (2008) report an overuse of *a/the* in [+definite] [-specific] and [-definite] [+specific] contexts; as well as with implicit and explicit partitive indefinites. Snape et al. (2006) found an overuse of *a* in [+definite] [+specific] contexts, which the Fluctuation Hypothesis cannot explain. Chrabaszcz & Jiang (2014), Crosthwaite (2014), and Snape (2009) state that an overuse of zero article is generally low in their data, and, according to Albrecht (2016) even more so in the SYSU-Corpus. Snape et al. (2006) also found that the Chinese fluctuate less than predicted by the Fluctuation Hypothesis which they suggest to be due to the ongoing grammaticalisation process (cf. section 1.2).

Unlike elicitation tasks and grammaticality judgements, eye-tracking does not rely on participants' strategic responses (Rayner 2009). The task conditions force the reader's focus to the details of the input either where processing is most nativelike (Indefrey 2006) or where participants' idiosyncrasies become influential (Roberts 2012; Roberts & Siyanova-Chanturia 2013, 214).

Thus, from the previous investigations we can formulate the following research questions (RQ):

1. Can the fluctuation patterns found in the literature be reproduced when using a recorded reading exercise instead of forced elicitation?

2. If yes, are the patterns similar to those reported in the literature?
 - a. overuse of *a* in [+definite] [+specific] contexts (Snape et al. 2006)
 - b. overuse of *a/the* in [+definite] [-specific] and [-definite] [+specific] contexts (Ko et al. 2009; Hawkins et al. 2006; White 2008)
 - c. low overuse of zero article (Chrabaszczyk & Jiang 2014; Crosthwaite 2014; Snape 2009)
3. Which participant idiosyncrasies or social variables do exert an influence (age, gender, years of exposure, education) on article errors?

3. Data and Methodology

3.1. Data – Set 1: SYSU Corpus of Chinese Academic Writing

For the first part of our analysis, we selected a database that was already available at Chemnitz and that includes English texts produced by the same group of English users that we used for the second part, the reading test.

The SYSU Corpus consists of texts compiled by Jessica K uchler in 2014 for her MA thesis (K uchler 2015). It provides a condensed collection of predominantly MA theses and term papers mainly in linguistics produced by students from Sun Yat-sen University in Guangzhou, China. The corpus consists of almost one million words, which is not very large by modern corpus-linguistic standards, but quite enough for our purposes, especially when we analyse a high-frequency phenomenon like English articles.

The data provided in the corpus are relatively dirty, in particular no POS tags are provided (cf. K uchler 2015, 105 for more details). This made the cleaning of data necessary, which mainly consisted of the removing the headings, and the remnants of converted captions, graphs or tables and encoding the general errors.

In the qualitative analysis of our pilot study using AntConc (3.4.4), we randomly chose 200 sentences from the SYSU-Corpus. They were manually coded for definiteness, specificity, and article overuse, as shown in (3).

- 3) For example, if we developed (a) cultural empathy excessively, it would result in (b) the over-adaptation to (c) the western culture; [...]. (CMAC05CU_28)

This provides us with the following categorisation for each of the article slots in the sentence:

- a) [-definite] [-specific]
- b) [-definite] [-specific] overuse of *the* for *an*
- c) [-definite] [+specific] overuse of *the* for *zero article*

Slot (3a) is thus indefinite and non-specific and shows that no article has been used by the author of the text. This conforms to native English grammar and is hence not further commented on. (3b) and (3c) show instances of article misuse by the author, which have been specified as overuse of *the* for *an* and overuse of *the* for *zero article*, respectively.

3.2. Data – Set 2: Eye-Tracking Experiments

A complementary experiment was set up using a judgement sample of 20 L1-Russian and 24 L1-Chinese university students. They had been learning English for 5 to 18 years and were in their second university semester. In the 2016 recordings, we focussed on young females, born between 1987 and 1997. Since we are not interested in linguistic change, the age range is quite short. Although age and gender are typically the sociolinguistic variables investigated most, years of learning English or years of exposure to English are naturally more influential than age when investigating article choice on L2-English learners. In our data, however, age, years of exposure to English and degree programme (level of education) strongly correlate with one another, meaning that from a statistical point of view they represent the same information in different guises. In such cases, inclusion of all variables in statistical hypothesis testing would yield Type I errors (collinearity). For that reason, we decided to outline degree programme instead of the other two, because the binary variable (MA vs. BA) would introduce the least amount of noise into a statistical model. Table 2 thus shows the stratification of informants as to degree programme and gender.

programme/gender	BA	MA	Total
Male	4	8	12
Female	19	13	32
Total	23	20	44

Table 2: Reading experiment participants' degree programme and gender

3.3. Eye-tracking: Methodological essentials

The respondents were shown 33 slides with one sentence each, most containing article misuse. Most of sentences were taken from Ionin et al. (2004) and Ko et al. (2010), similar to the previous studies (Chrabaszcz and Jiang 2014; Crosthwaite 2014; Hawkins et al. 2006; Ko et al. 2009; Schönenberger 2014; Snape et al. 2006; White 2008), and some from the SYSU-Corpus. The instructions for the volunteers were relatively short: They were asked to read the sentence silently while trying to understand the meaning.

For the eye-tracking recordings, we used SMI Experiment Suite 3.0. The experiment was set up in Experiment Center 3.3, and the recordings were later analysed in BeGaze 3.3.

Each article occurrence on the slides marked an AOI, which yielded 2,371 English article tokens. After data cleaning and cross-tabulation for the analysis, only 1,214 tokens remained. As the literature suggested, we used repeated-measures ANOVA (cf. Ionin 2003; Ko et al. 2009; Ko et al. 2010) in R 3.4.1 for the statistical assessment of the linguistic variables and mixed-effects logistic regression in Rbrul 3.0.2 (Johnson 2009) for additionally assessing the social variables.

4. Analysis and Discussion

4.1. Qualitative Analysis

The SYSU data clearly show an overuse of *a* in [+definite] [-specific] contexts and overuse of *the* in [-definite] [+specific] contexts most often (RQ 2b). An example for the former is (4), and for the latter (5).

4) [...], meaning (a) the acquisition of (b) a skill that will get you (c) a better job and fulfill (d) an American dream. (CC11FMATP_80)

- a) [+definite] [+specific]
- b) [-definite] [+specific]
- c) [-definite] [-specific]
- d) [+definite] [-specific] overuse of *a* for *the*

There is only one American Dream from rags to riches. It is, however, non-specific, because it does not receive a noteworthy property by the writer.

5) In (a) the article [<title>], Saillard put forward (b) the doubt about (c) the actual effect of [...]. (CC10FMATP_144)

- a) [+definite] [+specific]
- b) [-definite] [+specific] overuse of *the* for *a*
- c) [+definite] [-specific]

Overuse of *a* in [+definite] and [+specific] contexts (RQ 2a) occurred less often than the overuse pattern outlined in (4). An example of this is (6).

6) Therefore, (a) the author made (b) a point that several suggestions should be paid attention to. (CC12FMATP_114)

- a) [+definite] [-specific]
- b) [+definite] [+specific] overuse of *a* for *the*

Unlike in (5), in (6), the “point” receives the noteworthy property of considering several suggestions, so that the context of the article is specific.

Article omission errors were the fewest in our corpus data (RQ2c). An example for such a Chinese learner variant is (7).

7) (a) The first one refers to (b) the status of (c) certain language or (d) certain varieties compared to any other language or variety, deciding (e) the users and (f) the registers. (CC10FMAPT_144)

- a) [+definite] [+specific]
- b) [+definite] [-specific]
- c) [-definite] [-specific] omission of *a*
- d) [+definite] [-specific]
- e) [+definite] [-specific]
- f) [+definite] [-specific]

A summary of the findings for the qualitative component of our study is presented in Table 3. As we can see, the error rate was highest in [+definite] [-specific] but not in [-definite] [+specific] contexts. This result only partially supports the predictions of

the Fluctuation Hypothesis, as incorrect article uses in [+definite] and [+specific] contexts should not occur. However, it corroborates Snape et al.'s (2006) findings.

	[+definite]		[-definite]	
	correct	incorrect	correct	incorrect
[+specific]	93%	7%	94%	6%
[-specific]	89%	11%	96%	4%

Table 3. Article choice in SYSU-C. The highest error rate is highlighted in bold.

4.2. Quantitative Analysis

When we initially assessed the perceptual data, the durations of fixations and regressive saccades did not directly support the informants' acknowledgement of article errors on the slides. Since the literature proposed that fixations of more than 200 milliseconds length suggest recognition of words (cf. section 2.3), we determined a first fixation duration of more than 200 milliseconds as article error recognition. Although we were not interested in the informants' underlying reasons for article salience (an informant's determination of which would be indicated by rereading), we included rereading as counts in our statistical assessment, i.e. how often an informant repeated looking at an article error.

Chinese	[+definite]		[-definite]	
	correct	incorrect	correct	incorrect
[+specific]	99%	1%	96%	4%
[-specific]	92%	8%	96%	4%

Russian	[+definite]		[-definite]	
	correct	incorrect	correct	incorrect
[+specific]	100%	0%	99%	1%
[-specific]	89%	11%	99%	1%

Table 5. Results of the L1-Chinese and L1-Russian respondents

Similar to the corpus data, article omission occurred relatively infrequently (approximately in 2% of the cases; RQ 2c), and the majority of overuse errors occurred in [+definite] [-specific] and [-definite] [+specific] contexts (RQ 2b), which is in line with previous research (cf. Ko et al. 2009, 294; Ko et al. 2010, 237). Table 4

provides an overview of the results, separated according to the informants' first language. Although the Russians make more mistakes in [+definite] [-specific] contexts than the Chinese, they are overall more accurate in the use of grammatical forms.

In order to assess whether definiteness and specificity have a significant effect on article errors, we used repeated-measures ANOVA. As in Ko et al. (2009, 294) and Ko et al. (2010, 237), count of errors spotted was the dependent variable, definiteness and specificity were the within-subjects variables. The ANOVA results (cf. Table 6) are very similar to those reported by Ionin (2003, 145), Ko et al. (2009, 295), and Ko et al. (2010, 238).

L1 – Chinese (N=24)	article errors
Definiteness	F(1, 23) = 46.98*
Specificity	F(1, 23) = 13.70*
Definiteness * Specificity	F(1, 23) = 36.11*
L1 – Russian (N=20)	article errors
Definiteness	F(1, 19) = 37.92*
Specificity	F(1, 19) = 8.25*
Definiteness * Specificity	F(1, 19) = 21.67*

Table 6. Effects of definiteness and specificity. NB: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Specificity and definiteness have significant effects on article usage for both first language groups, although only definiteness governs article usage in native varieties of English. According to Ko et al. (2009, 295), the interaction between definiteness and specificity is due to the greater difference in article use between [+specific] and [-specific] definites when compared to [+specific] and [-specific] indefinites (cf. Table 5). These findings support the notion of the Fluctuation Hypothesis, as errors occur in contexts where definiteness and specificity are in conflict.

So as to investigate the effects of the social variables and the linguistic variables (RQ 3), we used logistic regression with mistake (error) as the binary dependent variable (application value: yes). The fixed effects in the model were first language, gender, degree programme, definiteness, specificity, and complexity. The random effects were informant and AOI.

The model with all respondents ($n_{\text{tokens}}=1,214$, $AIC=260$) shows that the fixed effects only explain 6% of the variation ($R^2_{\text{fixed}}=0.06$), and that first language is the only significant effect on article usage (cf. Table 7). The latter result supports the separation of the two first language groups into separate analytical categories (cf. repeated-measures ANOVA). The Chinese respondents statistically favour making mistakes in

4% of 668 article tokens. This behaviour differs significantly from the Russians, who disfavour making mistakes (2% of 546 tokens; $p=0.04$).

L1		$p=0.04$			
factor	log odds	tokens	application value	cent. factor weight	
Chinese	0.459	668	0.039	0.613	
Russian	-0.459	546	0.018	0.387	

Table 7. Logistic regression results for all respondents ($n=44$)

If we look at the Russian informants in isolation, using the same predictors as in the full model (except for the variable first language), we arrive at a model explaining much more of the observed variation ($n_{\text{tokens}}=546$, $AIC=99.8$, $R^2_{\text{fixed}}=0.38$). For the Russian respondents, only specificity seems to have an effect on article usage ($p<0.001$), as they favour making mistakes in 4% of 211 tokens in non-specific contexts (cf. Table 8).

factor	log odds	tokens	application value	cent. factor weight
non-specific	1.331	211	0.043	0.791
specific	-1.331	335	0.003	0.209

Table 8. Logistic regression results for Russian respondents ($n=20$)

The model for the Chinese informants shows that more than specificity ($p<0.001$) has a significant effect on article usage ($n_{\text{tokens}}=668$, $AIC=212.7$, $R^2_{\text{fixed}}=0.22$): degree programme ($p<0.001$) and sentence complexity ($p<0.001$). Explaining 22% of the observed variation, the model suggests that Chinese BA students favour making article errors in complex sentences in non-specific contexts (cf. Table 9).

Russians seem to make fewer mistakes in article error recognition than Chinese, which makes it plausible to assume that the Chinese are at an earlier stage of second-language English article system proficiency. This may mean that variables such as degree programme and sentence complexity only exert a significant influence at lower levels of English proficiency. At later stages, only specificity seems to be influential in article usage, until finally definiteness may govern article usage only.

factor	factor level	log odds	tokens	application value	cent. factor weight
Programme	BA	0.432	277	0.058	0.606
	MA	-0.432	391	0.026	0.394
Complexity	complex	0.701	336	0.060	0.668
	simple	-0.701	332	0.018	0.332
Specificity	non-specific	0.594	280	0.061	0.644
	specific	-0.594	388	0.023	0.356

Table 9. Logistic regression results for Chinese respondents (N=24)

In summary, the quantitative analysis provides the following answers to our research questions: We can partially reproduce the fluctuation patterns suggested by Hawkins et al. (2006), Ionin (2003), Ko et al. (2009, 2010), White (2008) with our eye-tracking data (RQ 1). Although we cannot confirm overuse of *a* in [+definite] and [+specific] contexts (RQ 2a), we find most of the overuse errors in [+definite] and [-specific] contexts, which supports the predictions by the Fluctuation Hypothesis (RQ 2b). In case of [-definite] and [+specific] contexts, we could not find support for the hypothesis. Overuse of zero article is generally low in our data (RQ 2c) and the social variable that significantly influences article usage in our data is degree programme for the Chinese informants only (RQ 3).

5. Conclusion

In this contribution, we hope to have shown that new digital methodologies help solve old grammar problems, that older methodologies can be transferred into digital space (e.g. online questionnaires), and that digital methodologies allow us to see new research questions, analyses and interpretations that did not even turn up in traditional methodologies.

In our special grammar problem of article usage, this would be particularly useful to expand the approaches that try solve a very complex problem by a triangulation of corpus- and psycholinguistic methodologies.

Of course, this was only a pilot study, which has shown that further work is not only possible, but also necessary because of weaknesses in the data and analysis:

It is necessary to invite more respondents to the study, because we can only extract relatively few data points from the rather few respondents we have included so far. It is interesting that the DV duration in milliseconds did not yield significant results and we have to check whether this may be due to the fact that function words are usually not read (Roberts & Siyanova-Chanturia 2013). Such limitations are, however, normal for empirical studies and no problem if conclusions are drawn with the necessary caution.

In this context, we have to admit that the digitalisation in English philology does not have to be equally invigorating in all sub-disciplines, but for empirically based studies it is a (re-)turn to the data and an opportunity to draw new far-reaching conclusions that were not possible before. This keeps our discipline young and vibrant and thus it may convince even outsiders to include it in their academic discourse and perspective.

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