Using Verb Frames for Text Difficulty Assessment

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Abstract

This paper presents the first investigation on using semantic frames to assess text difficulty. Based on Mandarin VerbNet, a verbal semantic database that adopts a frame-based approach, we examine usage patterns of ten verbs in a corpus of graded Chinese texts. We identify a number of characteristics in texts at advanced grades: more frequent use of non-core frame elements; more frequent omission of some core frame elements; increased preference for noun phrases rather than clauses as verb arguments; and more frequent metaphoric usage. These characteristics can potentially be useful for automatic prediction of text readability.

Keywords: Mandarin VerbNet, verb frames, frame elements, readability

1. Introduction

FrameNet (https://framenet.icsi.berkeley.edu) and other similar resources have supported a large range of natural language processing (NLP) tasks including semantic role labeling (Gildea and Jurafsky, 2002), information extraction (Fader et al., 2011), sentiment analysis (Ruppenhofer and Rehbein, 2012) and language learning (Carrión, 2006; Xu and Li, 2011). However, they have yet to be exploited for analyzing text difficulty, which is also known as *readability assessment*. Given any text, the system is to predict its reading difficulty, by estimating the age or school grade (e.g., Grades 1 to 13) required for readers to understand the text; by assigning it a difficulty score, such as Lexile (Stenner, 1996); or by locating it on a proficiency scale, such as the six-level scale in the *Common European Framework of Reference for Language* (2001).

Previous research on automatic readability assessment has mostly relied on lexical and syntactic features. A common lexical feature is the level of vocabulary difficulty, for example according to the number of "difficult words" (Kincaid et al., 1975). Syntactic features may include parse tree patterns or, as a proxy, average sentence length. While lexical complexity and syntactic complexity have been shown to be effective predictors of text readability, they do not capture all aspects of reading difficulty. Consider the pairs of example sentences in Table 1. The sentences in each pair have comparable vocabulary difficulty and sentence length. Sentences (1a) and (1b) both have the verb 'worry'. The verb in (1a) takes as object a short clause 'you would get sick', but in (1b) it takes an abstract noun, 'your health', which may be more difficult to process. Likewise, sentences (2a) and (2b) are semantically similar, but the reason construction 'because [he] missed the exam' in the latter may make it harder to read than the former. Finally, sentence (3b) is likely more challenging to understand than (3a) due to a metaphorical usage.

Semantic analysis can be expected to improve the readability assessment for such sentences. While some existing assessment models already incorporate semantic features, they are mostly limited to anaphora patterns, word senses and semantic categories of individual words (Pilán et al., 2014; Sung et al., 2015; Schumacher et al., 2016). Salient features may potentially be derived from semantic frames, such as those in FrameNet, Chinese Framenet (You and Liu, 2005), or Mandarin VerbNet (Liu, 2016; Liu and Chang, 2016; Liu, 2018; Liu, 2019). Based on Mandarin VerbNet, a verbal semantic database that adopts a frame-based approach, this paper investigates the correlation between verb frames and text difficulty.

2. Research Questions

We hypothesize that the verb usage patterns encoded in verb frames can be associated with different levels of reading difficulty. The distribution of frame-related attributes in a text may therefore be correlated with readability. More precisely, this paper tests the following hypotheses:

- H1: Non-core frame elements are more frequently used in more difficult texts (Section 5);

- H2: Core frame elements are more frequently omitted in more difficult texts (Section 6);

- H3: For verbs that can take either a noun phrase (NP) or a clause as argument, NPs are more frequently chosen in more difficult texts (Section 7).

- H4: Metaphor is more frequently used in more difficult texts (Section 8).

The rest of this paper is organized as follows. After a summary of previous research on readability assessment (Section 3), we describe our dataset (Section 4). We then present results on the four hypotheses above (Sections 5 to 8).

3. Previous Work

This section reviews the variety of lexical, syntactic and semantic features that have been explored for readability assessment.

3.1. Lexical Features

Most readability formulas rely on shallow features such as word length, sentence length, and vocabulary lists (Kincaid et al., 1975). The Lexile framework incorporates features derived from word frequencies, for instance lexical richness based on the type-token ratio (Stenner, 1996).

Sentence	Readability	Remarks
(1a) 我担心你会生病 'I worried you would get sick'	Less difficult	Clause argument for 'worry'
(1b) 我担心你的健康 'I worried about your health'	More difficult	Noun argument for 'worry'
(2a) 他很后悔错过了考试 'He regretted missing the exam.'	Less difficult	Clause argument for 'regret'
(2b) 他因为错过了考试十分后悔 'Because [he] missed the exam, he felt regretful.'	More difficult	Use of reason construction to express cause for regret
(3a) 他没有把书本放在桌上 'He did not put the book on the desk'	Less difficult	No metaphorical usage
(3b) 他没有把问题放在心上 'He did not care about (*lit.*, 'put on heart') this question'	More difficult	Metaphorical usage with 'put'

Table 1: Sentences with varying reading difficulty due to semantic complexity, despite similar lexical and syntactic complexity.

More recent work in NLP has made use of n-gram language models (Collins-Thompson and Callan, 2004; Petersen and Ostendorf, 2009), inflectional and derivational morphology (Hancke et al., 2012), verbal morphology, verb tense and mood-based features (Dell'Orletta et al., 2011; François and Fairon, 2012). Psycholinguistic properties, such as the concreteness, imageability and meaningfulness of words (Wilson, 1988), and the age of acquisition (Kuperman et al., 2012), have also been shown to be helpful.

3.2. Syntactic Features

Even if a sentence is composed of simple words, it can still be difficult to understand because of complicated syntactic structure. Early models often use sentence length and clause length as proxies for syntactic complexity. More recent ones incorporate part-of-speech (POS) features, including the frequency of coordination and subordination; the nominal ratio and the pronoun/noun ratio (Pilán et al., 2014); the number of different kinds of pronouns and conjunctions (Sung et al., 2015); and more generally, the percentage and diversity of POS tags (Vajjala and Meurers, 2014). Parse tree depth, parse scores, subtree patterns (Heilman et al., 2008; Schumacher et al., 2016) and dependency distance (Liu, 2008) have also been found to be useful.

3.3. Semantic Features

Lexical complexity and syntactic complexity do not cover all factors that influence readability. As discussed in Section 1, the (b) sentences in Table 1 can be expected to be more difficult to read than their (a) counterparts, despite their similar lexical and syntactic complexity.

Many readability models have therefore incorporated measures on semantic complexity. Common features include the average number of senses per word (Pilán et al., 2014); the ratio of active/passive voice (Graesser et al., 2011); the number of content words and the number of semantic categories in a sentence (Sung et al., 2015); the number of unique entities per document and the average number of words per entity; and the semantic probability of a sentence, according to a semantic network (vor der Brück et al., 2008).

4. Data

This section first presents Mandarin VerbNet and the verbs to be analyzed (Section 4.1), and then describes the corpus of graded texts on which our analysis is based (Section 4.2).

4.1. Mandarin VerbNet

Mandarin VerbNet is a verbal semantic database with annotation of frame-based constructional features (Liu and Chiang, 2008). In addition to frame elements, its frames make use of a schema-based meaning representation and constructional patterns. Adopting a hybrid approach to the semantic analysis of the lexical-constructional behavior of Chinese verbs, it incorporates tenets of Frame Semantics (Fillmore and Atkins, 1992) and Construction Grammar (Goldberg, 1995).

We selected ten verbs from three different frame categories for this study (Table 2). For more reliable statistics on frame distribution with respect to grade, we have deliberately chosen common verbs that are used in a wide range of grades.

4.2. Corpus of Graded Text

We performed our analysis on a corpus of Chinese-language textbooks constructed at Ludong University, China.[1] The 5-million-character corpus consists of more than 6000 articles, taken from 368 textbooks spanning the twelve grades in the curriculum for Chinese language in mainland China. For analysis purposes, the grades are divided into three categories:

- **1-3**: Grades 1 through 3;
- **4-6**: Grades 4 through 6;
- **7+**: Grades 7 through 12.

Table 2 shows the number of sentences in which the ten verbs appear. We manually and exhaustively annotated the verb frame usage in these sentences.

5. Use of Non-core Frame Elements

Similar to FrameNet, Mandarin VerbNet distinguishes between "core" or "non-core" frame elements. Core frame

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[1]We thank Prof. Xu Dekuan for providing access to this corpus.

Frame Category	Verb		# sentences			
			Grades 1-3	Grades 4-6	Grades 7+	Total
CAUSED-MOTION	放	*fàng* 'put'	24	26	49	99
	丢	*diū* 'cast away'	13	17	24	54
COGNITION	发现	*fāxiàn* 'discover'	125	323	404	852
	注意到	*zhùyìdào* 'notice'	5	18	56	79
	思考	*sīkǎo* 'reflect'	7	30	37	74
EMOTION	担心	*dānxīn* 'worry'	16	48	56	120
	吸引	*xīyǐn* 'attract'	19	50	49	118
	感动	*gǎndòng* 'be moved'	4	20	30	54
	着急	*zhāojí* 'be anxious'	26	28	24	78
	后悔	*hòuhuǐ* 'regret'	9	18	18	45

Table 2: Verbs used in our analysis, and the number of sentences in which they appear in our corpus among texts of the lower and upper grades (see Section 4.2).

Verb	Frame Element	Lowest	Type	Selected examples
dānxīn 'worry'	Exp	1	Core	我_Exp 担心 我会生病_Target-possible-situation
	Target-Possible-Situation	1	Core	I_Exp worried I would get sick_Target-possible-situation
	Beneficiary	2	Non-core	我_Exp 担心 你的健康_Target-entity
	Target Entity	4	Core	I_Exp worried about your health_Target-entity
	Stim	7	Non-core	
gǎndòng 'be moved'	Affector	2	Core	观众_Affectee 也都被 感动 了，大家拍着手_Result …
	Affectee	2	Core	The audience_Affectee were moved, clapping_Result …
	Result	4	Non-core	他们_Affector … 便 以死_Means 来 感动 …
	Means	6	Non-core	Through their death_Means, they_Affector moved …
xīyǐn 'attract'	Affectee	1	Core	作者_Affector 总是 用思想感情_Means 吸引 你_Affectee
	Act	1	Non-core	The author_Affector attracts you_Affectee with her emotions_Means …
	Affector	2	Core	
	Means	4	Non-core	他_Affector 吸引着 孩子的心_Affectee，让人总在想着他呢_Result
	Affectee Theme	6	Core	He_Affector so attracted the kids_Affectee, making them think
	Result	7	Non-core	of him_Result …
	Reason	7	Non-core	
fāxiàn 'discover'	Cognizer	1	Core	我_Cognizer 在桌上_Medium 发现 一本书_Topic
	Phenomenon	1	Core	I_Cognizer found a book_Topic on the table_Medium
	Means	1	Non-core	
	Topic	2	Core	从 瞄准镜_Instrument 里, 发现 一个火球穿过_Phenomenon …
	Medium	2	Non-core	From the telescope_Instrument, [we] discovered a fireball
	Instrument	7	Non-core	shooting_Phenomenon …
hòuhuǐ 'regret'	Exp	2	Core	如果 不复习_Stim 他_Exp 会后悔的
	Expressor	2	Non-Core	He_Exp would regret if [he] didn't review_Stim
	Given-fact	3	Core	
	Reason	6	Non-Core	他_Affector 因为错过了考试_Reason 十分后悔
	Stim	7	Core	Because of missing the exam_Reason, he_Exp felt regretful.
	Given-fact-description	10	Core	

Table 3: Verbs and their frame elements, showing the lowest grade in which the frame element appears.

elements are fundamental; they commonly appear as a necessary argument in a sentence and plays an essential role in the event frame. Non-core frame elements are optional; they are "potentially relevant", and can be added to a sentence as an adjunct (Liu and Chiang, 2008).

According to the first hypothesis (H1), non-core frame elements are used more frequently in more difficult text. As a preliminary investigation, we identified the lowest grade at which a frame element occurs. As shown in Table 3, many non-core frame elements are found only at higher grades. For *xīyǐn* 'attract', for example, Result and Reason do not appear until Grade 7.

To test H1, we calculated the percentage of sentences with non-core frame elements at each grade. The verb *zhùyìdào* 'notice' does not employ non-core frame elements at any grade level in our dataset. As shown in Table 4, the overall

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Verb	Grades		
	1-3	4-6	7+
zhùyìdào 'notice'	0%	0%	0%
diū 'cast away'	0%	5.9%	**8.3%**
sīkǎo 'reflect'	0%	7.0%	**22.0%**
gǎndòng 'be moved'	0%	**55.0%**	40.0%
fàng 'put'	4.2%	**7.7%**	2.0%
dānxīn 'worry'	6.3%	**12.5%**	10.7%
hòuhuǐ 'regret'	**11.1%**	0%	5.6%
zhāojí 'be anxious'	15.4%	**35.7%**	20.8%
xīyǐn 'attract'	26.3%	18.0%	**42.9%**
fāxiàn 'discover'	40.8%	32.2%	**46.0%**

Table 4: (H1) Percentage of sentences with non-core frame elements.

Verb	Grades		
	1-3	4-6	7+
gǎndòng 'be moved'	100%	100%	100%
xīyǐn 'attract'	100%	100%	100%
zhùyìdào 'notice'	**100%**	**100%**	85.7%
hòuhuǐ 'regret'	**100%**	**100%**	97.2%
dānxīn 'worry'	100%	95.8%	71.4%
zhāojí 'be anxious'	**96.2%**	78.6%	79.2%
fàng 'put'	**91.7%**	69.2%	42.9%
fāxiàn 'discover'	**91.2%**	87.3%	76.0%
sīkǎo 'reflect'	**85.7%**	80.0%	67.6%
diū 'cast away'	**84.6%**	82.4%	66.7%

Table 5: (H2) on subjects: Percentage of sentences with frame elements serving as the subject of the verb.

statistics of the remaining verbs lend support to the hypothesis. Eight of the verbs[2] exhibit a lower percentage of sentences with non-core frame elements at grades 1-3 than at higher grades. Consider *gǎndòng* 'be moved' as an example: non-core frame elements for this verb[3] do not appear in grades 1-3, but account for 55.0% of the sentences in grades 4-6 and 40.0% in higher grades. The difference between grades 4-6 and 7+, however, is less clear-cut. Five of the verbs exhibit higher rates of non-core frame elements in grades 7+, while four exhibit lower rates. More fine-grained analysis is necessary to account for the underlying differences.

6. Omission of Core Frame Elements

To reduce repetition, a writer may omit a verb argument from a sentence, expecting the reader to infer the information from the context. This phenomenon is frequent in Chinese even for some core arguments; for example, pro-dropped subjects account for more than 36% of the subjects in Chinese sentences (Kim, 2000). The number of zero pronouns is likely correlated with the effort needed for resolution. According to the second hypothesis (H2), omission of core frame elements is more frequent in more difficult texts.

6.1. Subjects

We first examine frame elements that normally occupy the subject position before the verb. Table 5 shows the proportion of sentences containing these frame elements.[4] For the verbs *gǎndòng* 'be moved' and *xīyǐn* 'attract', this proportion is constant since all of their sentences at all grades contain subjects. The hypothesis is however supported by the remaining eight verbs. Generally, more sentences lack subjects in the higher grades than in the lower ones. The gap between grades 4-6 and 7+ is usually larger than the

Verb	Grades		
	1-3	4-6	7+
fàng 'put'	100%	100%	100%
diū 'cast away'	100%	100%	100%
fāxiàn 'discover'	**100%**	**100%**	99.4%
zhùyìdào 'notice'	**100%**	94.4%	98.2%
gǎndòng 'be moved'	**100%**	70.0%	86.7%
xīyǐn 'attract'	94.7%	90.0%	**98.0%**
dānxīn 'worry'	**75%**	66.7%	67.6%
hòuhuǐ 'regret'	44.0%	**66.7%**	**66.7%**
sīkǎo 'reflect'	14.3%	23.3%	**32.5%**
zhāojí 'be anxious'	0%	10.7%	**16.7%**

Table 6: (H2) on objects: Percentage of sentences with frame elements serving as the direct object of the verb.

gap between 1-3 and 4-6.[5]

6.2. Objects

We next investigate frame elements that normally occupy the object position after the verb. Table 6 shows the proportion of sentences containing these frame elements.[6] Two of the verbs, *fàng* 'put' and *diū* 'cast away', always have explicit objects in sentences at all grades, as the frame element Figure is indispensable for their semantic expression. Among the remaining eight verbs, the trend is more nuanced compared to the omission of subjects. We will focus on comparing grades 1-3 with the higher grades. Consistent with H2, four of these verbs — *fāxiàn* 'discover', *zhùyìdào* 'notice', *gǎndòng* 'be moved' and *dānxīn* 'worry' — have more sentences in grades 1-3 containing objects. In contrast, for the other four verbs, the sentences in grades 1-3 are more likely to omit the object. These results sug-

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[2] With the exception of *hòuhuǐ* 'regret'.

[3] See Table 3 for example sentences for the non-core frame elements Result and Means.

[4] Among the ten verbs analyzed, depending on their frame category, these frame elements can be Agent, Cognizer, Exp, Placer, Affector or Affectee.

[5] For the verb *dānxīn* 'worry', for example, all sentences in grades 1-3 have subjects, as do 95.8% of the sentences in grades 4-6. However, the figure drops to 71.4% at grades 7+. The only exception to this trend is observed for *zhāojí* 'be anxious'.

[6] Among the ten verbs analyzed, depending on their frame category, these frame elements can be Affectee, Figure, Given_Fact, Given_Fact_Description, Phenomenon, Topic, Target, Target_Empathy, Target-Entity, Target-Situation or Target-Possible-Situation.

Verb	Argument type	Grades		
		1-3	4-6	7+
zhùyìdào 'notice'	clause	**80%**	55.6%	41.1%
	NP	20%	38.9%	**53.6%**
fāxiàn 'discover'	clause	**78.4%**	57.6%	55.2%
	NP	21.6%	**51.7%**	44.1%
dānxīn 'worry'	clause	**75.0%**	58.3%	53.6%
	NP	0%	8.3%	**14.3%**
hòuhuǐ 'regret'	clause	44.4%	**66.7%**	50.0%
	NP	0%	0%	**16.7%**

Table 7: (H3) Percentage of sentences with clause or noun phrase as argument to the verb.

gest that the impact of the object on text difficulty differs according to usage patterns of individual verbs. The presence of objects in the verbs *zhāojí* 'be anxious' and *hòuhuǐ* 'regret', for instance, can make a sentence harder to read. Since these verbs do not take objects in most instances, the absence of the object should perhaps not be considered an omission.

7. Clause vs. Noun Phrase

As illustrated by the verb *dānxīn* 'worry' in sentences (1a) and (1b) in Table 1, some verb arguments can be either a noun phrase (NP) or a clause. The distinction is reflected by the frame element. Sentence (1a), which contains the clause 'you would get sick' as object, has the frame element `Target-possible-situation`. In contrast, sentence (1b), with the NP 'your health' as object, has the `Target-entity` element. Similar distinctions are made in other frame categories, for example with `Phenomenon` (clause) vs. `Topic` (NP), and `Given-fact` (clause) vs. `Given-fact-description` (NP).

According to the third hypothesis (H3), given a choice between NP and clause for an eventive complement, NP or event nominal is more often used in difficult texts than in easier ones. We analyzed the four verbs in our dataset that offer this choice, and the overall statistics support the hypothesis (Table 7). For all four verbs, sentences in grades 1-3 substantially prefer clause over NP, and the gap narrows in grades 7+; in the case of *zhùyìdào* 'notice', clauses are even outnumbered by NPs in grades 7+. This observation suggests that for these verbs, a clause may be easier for less proficient readers to understand than a noun, especially when it expresses an abstract meaning.

When taking grades 4-6 into account, the statistics are not always consistent with H3. Consider the case of *fāxiàn* 'discover'. While the preference for clause over NP decreases from grades 1-3 (a difference of 56.8%) to grades 4-6 (a difference of 5.9%), it unexpectedly increases again from grades 4-6 to grades 7+ (a difference of 11.1%).

8. Metaphor

Metaphorical usage which involves cognitive transfer from one domain to another tends to make a sentence harder to read, even when the vocabulary and syntactic structures are simple. Consider the example sentences (3a) and (3b) in

Verb	Grades		
	1-3	4-6	7+
fàng 'put'	0.0%	19.2%	**30.60%**
diū 'cast away'	0.0%	11.8%	**33.30%**

Table 8: (H4) Percentage of sentences with metaphoric usage.

Table 1. In (3a), the verb 放 *fàng* 'put' is used in its regular sense, 'put a book on the table'. In (3b), however, it is used in the metaphorical sense in the verb phrase 放在心上 ('remember'; literally, "put on the heart"), which is more difficult to interpret.

Our analysis centered on the two verbs in our dataset — *fàng* 'put' and *diū* 'cast away' — that are more productive in metaphorical usage. In non-metaphorical usage, the frame elements `Ground-Location` (for *fàng* 'put') and `Figure` (for *diū* 'cast away') typically expect physical locations and objects. That is not necessarily the case in metaphorical usage, which allows abstract entities such as 'worry' (e.g., "cast away one's worry") or 'heart' ("put on the heart").

The fourth hypothesis (H4) predicts metaphorical usage to be more frequent in more difficult texts. Table 8 presents evidence for this hypothesis. For both verbs, no metaphor is employed in the texts for grades 1-3. The percentage of metaphorical usage increases to 19.2% and 11.8%, respectively, at grades 4-6. The higher grades see even more substantial amount of metaphorical usage, at 30.60% and 33.30%.

9. Conclusions

We have presented the first investigation on the correlation between verb frames and text difficulty. Based on Mandarin VerbNet (Liu, 2016; Liu and Chang, 2016; Liu, 2018; Liu, 2019), our analysis of ten common Chinese verbs showed that at higher grades, there is generally more frequent use of non-core frame elements; more frequent omission of core frame elements that normally occupy the subject position before the verb; increased preference for a noun phrase over a clause as verb argument; and more frequent metaphorical usage. These patterns can potentially help improve a readability assessment model.

We plan to pursue two directions in future work. First, we plan to expand our analysis to a larger set of verbs from diverse frame categories. Second, we intend to incorporate frame patterns as features in a system for readability prediction.

10. Acknowledgements

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