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Description	

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Context-dependent Processes and Engagement in Reading Literature

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Abstract

It does not do the act of reading literature any justice to describe it as simply processing text to acquire information or knowledge. We enjoy reading stories, we become *absorbed* in them. Our absorption into stories is related to their contextual structure. We develop a statistical method for the analysis of reading time distributions which allows us to assess the context of a story rather than merely its text. This analysis detects statistically distinct distributions of reading times, with each distribution representing a distinct process or mode of reading. Our experiments support the hypothesis that the temporal change in these modes of reading are related to changes in the degrees of absorption of the subjects and also in the contextual structure of the stories being read.

Keywords: Reading; Literary; Reading-time analysis

Introduction

Reading literature is not just merely the process of attaching literal meaning to prose, but it also evokes various experiences and can affect the way the reader views the world around them. Past studies have argued the potential effects of literary works, and tried to empirically measure their effects on readers (Miall & Kuiken, 1994; Iser, 1976, and see also Miall 1999 for discussion about literariness).

In particular, it has been empirically shown that the context or story plot has substantial impact on readers (Miall, 1988; Rapp & Gerrig, 2006). This finding is related to an earlier argument by Aristotelis (Kassel, 1965). The present study follows this line of research, and investigates the effects of context by analyzing temporal changes of readers' responses in reading.

In past studies, hypothetical constructs such as *story grammar* or *script*, which readers supposedly process while reading, were employed to capture the contextual structures of stories (Thorndyke, 1977; Beaugrande, 1982). Introducing the concepts of story grammar and script, these studies claimed that narratives have their own internal structure like a grammar but at the discourse level, and these structures can be expressed as combinations of elements such as setting, theme, characters, or goals. However, using such frameworks allows us to analyze only limited classes of stereotypical stories, such as folk tales(Miall, 1989; Beaugrande, 1982). These limitations are due to the inflexibility of the constructed frameworks. There have been other approaches to capture the contextual structure of stories but none of them has yet offered a satisfactory description.

In the present study, rather than assuming a specific story grammar, we focus on temporal changes in reading process across different contextual structures of stories. Miall (1988) analyzed the relationship between readers' ratings and reading times of introductory sections of novels. He analyzed readers' responses by assuming two stages in the reading process. The first was called the "registration stage", in which readers form expectations about the likely meaning of narrative, and the second was called the "interpretation stage", in which readers use their expectations to comprehend the narrative. Miall supposed shifts between these stages would depend on both the context of the story and a reader's background knowledge. From his analysis, he concluded that the reading process form a cycle and repeatedly shifts between the two stages in the reading of a narrative.

Taking as a working hypothesis that there are separable stages in reading processes correlated to the contextual structure, as suggested by Miall, we investigate the stage-like changes involved in reading an entire story, not just an introductory portion.

In this study, we investigate the "modes" of reading processes, which are supposedly correlated to the context of the story or a reader's background knowledge. The "modes" are operationally defined by statistical properties of reading times of each unit of text. We will further discuss these modes in the next section.

Statistical analysis of reading time

We assume the reading processes is composed of several qualitatively distinct subprocesses, and we call such a subprocess *reading mode*. The question is, given reading data, how we can infer the number of reading modes reflected in the data? In previous studies about short texts and more rapid processes, differences in reading time alone have been interpreted as reflection of two qualitatively distinct processes (Miall, 1988; Gernsbacher, 1997). However, reading time may vary depending on multiple factors like frequency, familiarity, and the lengths of words (Inhoff & Rayner, 1986; White, 2008). We cannot, therefore, naively interpret reading time alone as an indicator of multiple reading modes.

This observation motivates the development of a new technique for the analysis of reading time. The analysis we present as an alternative is based on a statistical theory of processing time (Hidaka, 2013). In this theory, the presence of multiple different modes of processing can be detected by the statistical distribution of the processing time. If the reading

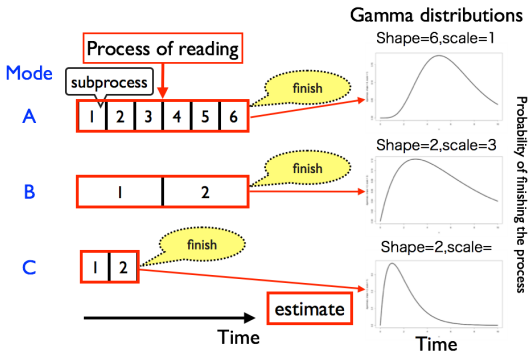

Figure 1: Three hypothetical processing modes, A, B, and C, which have different numbers of subprocesses with different average rates. In each mode, all the subprocesses run in the serial order, and its reading time follows a gamma distribution. Mode A: six subprocesses, each takes short time on average, Mode B: two subprocesses, each takes long time, and Mode C: two subprocesses, each takes short time. The average of both Mode A and B is the same, but their distributions (on the right hand side of the figure) are different.

process consisted of n subprocesses with the same constant processing rate over time, and finished only when all these subprocesses have finished, the reading time would follow a gamma distribution with shape parameter n. If, on the other hand, the reading process consisted of one subprocess with process rate t^k as a function of the process time t, then the process finished when at least one subprocess has finished, reading time would follow a Weibull distribution with shape parameter k.

This statistical analysis allows us to distinguish processes which have a same average speed of processes but have different number of subprocesses (Figure 1, A and B), and to distinguish processes which have same number of subprocesses but have different average speed of processes (Figure 1, B and C). This subprocess estimation gives an advantage over the previous studies analyzing differences in the reading time alone.

We adopt this statistical account of processing time in evaluating the number of reading modes based on reading time. If each observation in a reading time dataset follows essentially the same distribution as the others, we would treat this as an indicator of a single reading mode. If, on the other hand, the data set appears to have been generated by sampling from a mixture of distributions, we treat it as an indicator of multiple reading modes (Figure 2). Each dataset in question is composed of observations about a single subject. This technique therefore removes overall reading speed as a factor in the analysis.

Approach

When reading, one is generally also engaged in many other processes – eye movements, posture management, etc. If one were only lightly engaged in reading and more heavily preoccupied with a number of these other activities, it is entirely possible that their preoccupation could appear as distinct reading modes in our statistical analysis. To prevent the detection of such false modes, it would be valuable to have a measure of reading engagement independent from reading time. We could then test the results of our statistical analysis based on their correlation with that measure.

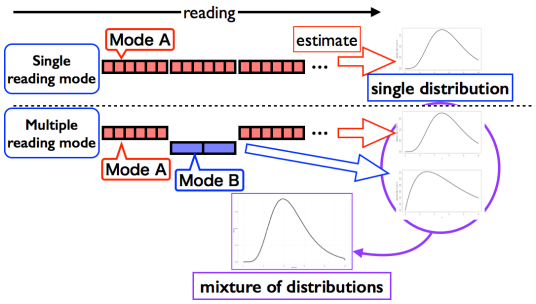

Figure 2: (top) if one type of reading mode is repeated across multiple pages, it would result in a gamma distribution. (bottom) if both two types of reading modes, A and B, take place across different pages, it would result in a mixture of two gamma distributions.

Since the analytic technique we will use is statistical in nature, it requires relatively large datasets in order to produce meaningful results. To this end, and although this is not typical of existing studies of reading, we use entire novels as the texts in our experiments.

Given the burden that reading such long texts places on the subjects of our experiments, our first experiment consisted of only one subject – Miho Fuyama, the first author of this paper. She is an avid reader, which suggests that she is generally easily engaged in reading as an activity. In Experiment 1, we studied her reading time and the degree of engagement in reading, in order to empirically establish the validity of our analysis and test whether her reading process has a single or multiple reading modes.

Having validated our statistical analysis, we adopted it in our second experiment to a cross sectional study of multiple subjects. In Experiment 2, we asked ten subjects to read a short novel. This experiment was designed to evaluate whether our findings from Experiment 1 hold in general. We also evaluated changes in reading modes could be related to the semantic structure of the text itself. To do so, we analyze the consistency of the dynamics governing the change of reading modes across subjects and treat the consistent dynamics as text-specific semantic effects in reading.

Experiment 1

The first author was the sole subject of several high-load reading tasks. We asked her to read 20 Japanese novels. Each session took one day including breaks. The set of samples from these 20 sessions of 20 novels was submitted to statistical analysis using the scheme described in the previous section, and we estimated the statistical distribution of her reading time for each two pages. For two of the novels (novels 17 and 18 in Table 1), she evaluated her degrees of absorption

Table 1: The novels read in Experiment 1.

No.	Title (Abbreviated)	Author	Page length
1	Shikisai	H. Murakami	370
2	Kamisama	H. Mori	314
3	Nameraka	H. Kawakami	189
4	Tenchi	T. Ubukata	474
5	Chinmoku	Y. Ogawa	308
6	Hikari	S. Miura	297
7	Kuchi	M. Banto	309
8	Mizuumi	B. Yashimoto	206
9	Kogoeru	A. Shino	401
10	Self-Reference	T. Enjo	308
11	Shi no izumi	H, Minagawa	427
12	Kisetsu no kioku	K. Hosaka	316
13	Eien no deguchi	E. Mori	313
14	Hokanaranu hito he	K. Shiraishi	295
15	Shorou tomurai dou	N. Kyogoku	498
16	Kodoku no utagoe	A, Tendo	312
17	Neko	Y. Ogawa	359
18	Ruto 225	C. Fujino	282
19	Yasashii uttae	Y. Ogawa	260
20	Burahuman	Y. Ogawa	146

each two pages as an indicator of her engagement to reading. Specifically we asked her how absorbed she was in reading every pair of pages in these novels. These absorption ratings were used to validate the statistical analysis.

Participant

The subject was the first author, Miho Fuyama, who was 30 years old when the experiment was conducted. She is a native Japanese speaker, is a regular reader, and has normal vision.

Material

We used 20 Japanese novels, which the first author read for the first time in this experiment. The titles, authors, and page lengths of books are listed in Table 1. We selected as texts books written by authors who have won Japan's prestigious literature prizes, such as the Naoki Prize or Akutagawa Prize.

Procedure

In each session of the experiment, the subject was asked to read a novel. Each session lasted several hours (including breaks), but was completed in one day. The subject reported her degrees of absorption for every two pages read in novels number 17 and 18. These reports were made approximately 100 days after the reading sessions. Her degree of absorption was measured on a five-level scale – "extremely bored", "bored", "normal", "absorbed", and "deeply absorbed". This scale was coded using the numbers $-2, -1, 0, 1$, and 2 respectively for each of the states. As the experiment required her to focus on and to become absorbed in such long texts, the subject was allowed to perform her readings at her home in order to minimize her tension. She was also allowed to have breaks whenever she wanted. The breaks were typically 5 to 15 minutes long, but there were also several hour-long lunch breaks. While reading, she sat at her desk and was videotaped with two small web cameras.

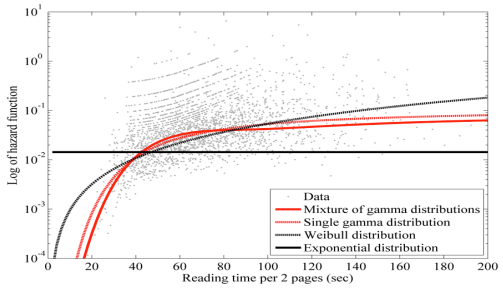

Figure 3: The hazard function for the sample (dots) and for the estimated probability distributions (lines) of reading time.

Analysis

From the videos, we transcribed the reading time for each pair of pages. These reading times were measured as the lengths of time between page turns, excluding time spent on break. The statistical analysis is performed on these transcribed reading times. We analyzed the aggregate of the data gathered across all the sessions of the experiment in order to increase the statistical power of our analysis.

In our analysis, we fitted mixtures of exponential distributions, those of Weibull distributions, and those of gamma distributions to the aggregate data. For each mixture distribution, ranging from 1 to 5 components, we estimated the parameters by maximizing likelihood. As these statistical models have different numbers of parameters, we chose the model with the smallest Bayesian Information Criterion (BIC) (Schwarz, 1978) as the one which best explains the data.

Results and discussion

We found that a mixture of two gamma distributions provides the best fit to the aggregate data amongst all the distributions considered. Figure 3 illustrates the differences between these various classes of distributions in explaining our data. It shows the hazard function $H(t)$ of the page-turn interval t. The hazard function $H(t)$ is the probability (density) to finish reading on condition of the reading being unfinited unitl t. Weibull, gamma and exponential distributions show qualitatively different hazard curves.

The exponential distribution, with a constant hazard function, did not fit the data well in Figure 3 (BIC = 29421.71). Likewise, the Weibull distribution has large deviation from the data at the tails of distribution ($t < 30$ and $140 < t$) (BIC = 26146.06). The single gamma distribution fits better than the exponential and Weibull distributions (BIC = 25722.64), but the mixture of two gamma distributions provides the best fit (BIC = 25655.29). In addition, mixtures of three gamma distributions (BIC = 25677.24) or more did not provide better fits than the two-component gamma distribution.

Figure 4 shows the probability density function of empirical reading intervals and the estimated probability density function, which is a mixture of two gamma distributions. One subcomponent, Distribution 1, has shape 13.80 and scale 4.24. The other subcomponent, Distribution 2, has shape 7.58

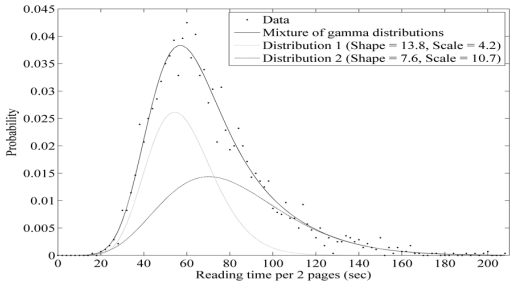

Figure 4: Sample (dots) and estimated (solid) probability distribution of reading time. The two curves under the fitting curve shows subcomponents of the gamma mixture distribution.

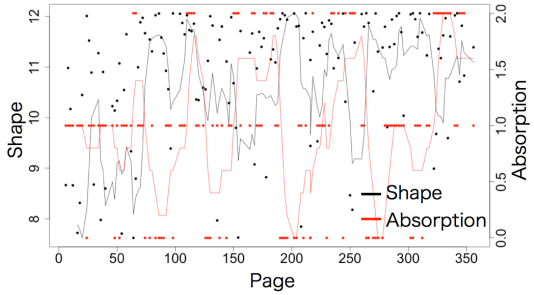

Figure 5: Page-based temporal profile of the statistical property (shape parameter) of reading time and the absorption ratings of the case No.17.

and scale 10.67. This result suggests that the subject shows of two distinct modes in her reading, with each mode involving different reading subprocesses.

Correlation to reading engagement We now address the question of whether the two distinct modes identified in our analysis are actually reflective of the text being read. In order to test this, we analyzed the correlation between the temporal change in mode and the degree of absorption reported by the reader. We obtained the reader's post-hoc report on engagement for each two pages of the books No. 17 and 18.

Taking the book No. 17 as a representative case, Figure 5 shows the temporal profile of the weighted-average of shape parameters (black dots) and the reader's degrees of absorption (red dots). The weights was given by the mixture of the two gamma distributions for each reading time of two pages. The corresponding moving average of the two over 5 data points are shown as black and red line, respectively.

We performed correlation analysis for a pair of the estimated shape parameters and the degrees of absorption. For the book No. 17 across 141 pairs of pages, we had correlation -0.284 ($p < 0.001$). For the book No. 18 across 118 pairs of pages, we had correlation -0.283 ($p < 0.01$).

In order to eliminate the possible effects of the number of letters, we additionally performed regression analysis on the book No. 17 with both the degrees of absorption and the number of letters as predictors. The results shown in the Table 2. The degree of absorption was significant variable as well as the number of letters to explain shape (both p <0.001). In sum, these analyses suggest that the temporal changes in the modes identified from our reading time analysis (Figure 5) does indeed reflect changes in reading engagement.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	15.318	0.803	19.07	<0.001**
Absorption	-0.515	0.134	-3.88	<0.001**
Letters	-0.004	0.001	-4.94	<0.001**

Table 2: Summary of multi-regression analysis with data of "Neko".

Remember that the shape parameter can be interpreted as the number of subprocesses involved in processing a given text, and the scale parameter can be interpreted simply as inverse of reading speed. Taking this theory into account, we conclude that the two modes estimated in this analysis are likely to represent a fast reading mode (Distribution 1) with a larger number of subprocesses and a slow reading mode (Distribution 2) with a smaller number of subprocesses.

Experiment 2

In Experiment 1, our statistical analysis detected two different modes of behavior in the reading data generated by the experiment. We further showed that the change in mode over time had a statistically significant correlation to the degree of absorption with the text reported by the subject. Our goal of Experiment 2 is to establish whether or not these findings are consistent across multiple subjects and, if so, to identify the factors involved with the reading modes detected in Experiment 1.

In order to meet these goals, we design a short experiment for multiple subjects. In our second experiment, we asked different subjects to read a short novel or a introductory part of long novel but kept the rest of the procedure the same as it was in No.17 and No.18 of Experiment 1. Specifically, subjects were asked to read these short text, and then they were asked to report their degrees of absorption for each two pages. The novel itself took less than an hour to read.

By analyzing their degrees of absorption, we evaluate the cross-experiment consistency, whether basic patterns in readers in the two experiments were consistent. We expect this analysis would reveal the significant factor of the reading modes, either/ both individual reading strategy or/ and the contextual structure of each novel. If the reading modes vary across readers but not within each reader, it would suggest that the reading modes depend on the readers' strategies. While, if the reading modes show similar time course in reading the same text across different readers, it would suggest that the reading modes depend on the context of each novel.

Participants

In Experiment 2, we employed ten participants, five male and five female undergraduate and graduate students at Keio University. Most of these subjects were not regular readers.

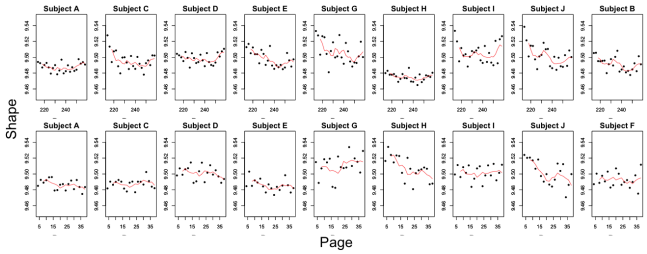

Figure 6: The page-based temporal profile of the estimated shape parameters for each subject. Top panels: "Kino", bottom ones: "Chinmoku".

Procedure

Each participant went through two reading sessions in random order. The procedure of each session was the same except for the text and the environment in which the reading took place. During each session, the participants read a 49-page-long short story "Kino" or 39-page-long introductory part of the story "Chinmoku Hakubutsukan" ("Chimoku" in short). Right after the reading session, the participant was asked to report their degrees of absorption in the same scale as Experiment 1 for each two pages. Five participants read the short story at first, the other five participants read the long introductory part at first. The participant took part again with more than two week interval, and read another text. The short story they read was "Kino" authored by Haruki Murakami. Another text is the introductory part of "Chinmoku" written by Yoko Ogawa. As the introductory partof the second book was chosen, it includes little change of context.

Analysis

For consistent comparison, we analyzed the aggregate of the reading time data across subjects by fitting to it a two-component mixture of gamma distributions. We fixed the class of distributions, instead of identifying it from data. This is due to the small sample size of our data at this point. Each participant provides reading time data for only 23 or 18 pairs of pages, and it did not sufficient statistical power to be conclusive even as its aggregation across subjects. Thus, we employed the statistical distribution estimated in Experiment 1.

Results

The data of two sessions were excluded from the analysis due to the the readers' irregular reading back and forth many times. This makes the completed dataset of 18 sessions in total.

Each panel of Figure 6 shows the page-based temporal profile of the modes estimated from reading time. In each panel, a dot shows estimated shape parameter for each reading time data point, and the line indicates its moving average.

The result shown in Figure 6 exhibit inter-subject consistency in temporal changes in reading modes. Each panel in Figure 6 shows the estimated shape parameter for each reader. The top panels show those of "Kino", and the bottom ones show those of "Chinmoku". We found the within-novel similarity in the shape parameter profile across pages: The readers of "Kino" showed similar U-shape profiles in common, and those of " Chinmoku Hakubutsukan" did similar flat profiles in common.

We performed correlation analysis on all the pairs of the subjects in order to test whether the readers of the same novel showed correlated temporal profiles of the shape parameters. The average correlation across all the reader pairs of "Kino" was 0.67 (from 0.46 to 0.87, $p < 0.02$ for every pair of readers), and that of "Chinmoku" was 0.51 (from 0.05 to 0.86, $p < 0.05$ for 23 out of 36 paris of readers). Thus, this result suggests that each novel showed the effects on the reading-mode profiles, with which the readers showed similar profiles, while individual reader showed little effects on them.

To analyze the factors on the reading times for each story, we performed a regression analysis on the shape parameters across readers and pair of pages with the degree of absorption and the number of letters as the predictors. The estimated regression coefficients and related statistics are summarized in Table 3. For the novel "Kino" on the top of Table 3, both absorption ratings ($p < 0.05$) and the number of letters ($p < 0.001$) were significant. For the novel "Chinmoku" on the bottom of Table 3, only the number of letters was significant ($p < 0.001$), but not the absorption ratings ($p = 0.404$).

Kino	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	9.430	0.012	773.26	<0.001**
Absorption	-0.0023	0.001	-2.04	0.042*
Letters	0.0001	<0.001	7.06	<0.001**
Chinmoku	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	9.4501	0.007	1327.48	<0.001**
Absorption	0.0008	0.001	0.84	0.404
Letters	0.0001	<0.001	6.40	<0.001**

Table 3: Summary of the regression analysis on the data of "Kino" and "Chinmoku". The single and double asterisk indicate $p < 0.05$ and $p < 0.01$, respectively.

Discussion

The results above suggests that there is the novel-specific effect on the statistical properties of reading time, which we can interpret mode switching profiles of reading process. As the page-based temporal profiles within the same novel were similar, it suggests that the contextual structure of each novel has major impact on switching of the reading modes. In addition, the temporal profiles could be interpreted as reflection of the semantic structure of each novel.

According to Miall's theory, a full novel is expected involved with both formation and exploitation of anticipation. Consistently with this theory, we found U-shaped patterns in reading mode switching for "Kino" with its full story, but we found flat patterns in for the introductory fraction of "Chinmoku", which indicated no clear distinct modes. This finding, no clear modes in reading an introductory part, is not well consistent with Miall's theory, but we interpret this that an introductory part of a full novel is likely to include only the formation of anticipation.

The regression analyses are consistent with this interpretation. The regression analysis of the novel "Kino", but not of "Chinmoku", showed a similar trend with that of the novel No. 17 analyzed in Experiment 1– for both cases, the absorption rating was significant predictor of the shape parameter. What was common between the novel "Kino" and No. 17 in Experiment 1, and different from "Chinmoku"? Two novels, which both showed the significant effect of absorption, were used as their full story, but the one, which did not show it, was used as its introductory part. Thus, one possible interpretation is that the full stories, which are supposed to have contextual coherence from the introduction to the end, may be related to temporal changes of the reading modes and the degree of absorption.

In sum, these findings could be treated as a supportive evidence that the temporal profiles in reading distributions relfect context-dependent reading modes.

General Discussion

Reading is an essentially mental and subjective experience. Its cognitive underpinnings have been difficult to characterize directly, and reading time is a major tool for drawing inferences about the underlying cognitive mechanism behind reading. This study offers a new approach to the analysis of reading time, an approach capable of identifying different modes of reading behavior from reading time data.

In Experiment 1, we collected an analyzed reading time data generated by a single subject reading several full novels in a natural situation. We observed significant correlation between subject's report of her engagement in reading and her reading modes inferred from the estimated reading time distribution. This experiment has three major implications:

1. In contrast to conventional studies on controlled, short readings, it is perhaps the first study on involving reading entire books in a more natural situation.
2. It establishes a new analytical technique for reading time data by associating the estimated modes with the subject's engagement in reading.
3. It provides a support evidence that there are at least two distinctive reading modes depended on the contexts in reading of whole novels.

In Experiment 2, we once again observed two distinct reading modes, and found that the mode switches across different subjects reading the same story were consistent with each other. This suggests that, to a large extent, the reading modes are dictated by the contextual structure of the text being read. This interpretation is also supported by the the regression analyses.

What is the contextual structure? We hypothesize that it is related to the predictability of the story. Perhaps, each of which we found as two reading modes can be called low- and high- predictability mode. Considering with reading of "Kino", the major shifts between two modes took place at the beginning and end of the story. At the beginning, any reader has little knowledge on the story, as also discussed in (Miall, 1988), and they need to build knowledge on the characters and stage where they play their roles. At the part approaching to the end, this story has a "twist", which is unexpected for most of readers. This is another place, in which the reader need to rebuild their knowledge on the story. Therefore, with these two parts at the beginning and end, well-predictable part in between them is considered to make the U-shaped temporal profiled in the reading time distributions.

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