Evaluating individual reading time differences through a psychological measure

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Abstract It has been shown that a psychological scale, such as Autism-Spectrum Quotient (AQ), strongly correlates to individual differences with respect to sentence processing. Kiyama, et al. (2012) have shown that the AQ score from each participant can explain the reaction time data with respect to the appropriate use of Japanese sentence final particles. In this study, we investigate how well the subjects' AQ score can explain the reading time data obtained through a self-paced reading experiment about aspectual coercion (the interpretational system which occurs when aspectual information of elements in a sentence is not congruent (Bott, 2010)). We will also report data on word categories and factors related to aspectual properties of the sentences.

Keywords Sentence processing, self-paced reading task, aspect, Autism-Spectrum Quotient, Japanese

1. Introduction
This study takes up the following two research questions. First, we investigate how people deal with aspectual information by conducting a self-paced reading experiment. Many studies demonstrate that not only verbs but other pre-verbal constituents such as objects have an important function of determining telicity of the sentences. Controlling telicity of stimuli by changing the noun types (specific vs. general), we conducted a self-paced reading experiment. We examined whether the mismatch of aspectual information induces difficulty in a sentence processing and whether noun types in the direct object position influence on the processing the event structure of the sentences.

Secondly, we examined the correlation between AQ score and reading time data. It has been shown that a psychological scale, such as Autism-Spectrum Quotient (AQ), strongly correlates to individual differences with respect to sentence processing.

In next section, we survey the literature of aspect and the experimental studies of aspectual coercion (Piñango, Zurif and Jackendoff 1999, Long, Ono and Sakai 2010). The following section refers to the experiment which we had conducted. The last section summarizes this study in brief.

2. Previous studies
2.1 Aspect
Mihara (2004) stated that both tense and aspect belong to the grammatical category which is related to time. However, they are different in that tense expresses the point when the event happened, while aspect shows how the event develops/developed with temporal breadth.

Aspect is broadly divided into two types. The first type is grammatical aspect. Perfective and progressive are typical examples. The second type is lexical aspect. In Japanese, Kandaichi (1950) classified Japanese verbs into four types according to the interpretation of the event when a grammatical aspect marker (-teiru) is added to verbs. Verbs that can co-occur with -teiru are classified as activity verbs, accomplishment verbs, and achievement verbs. While, stative verbs can not co-occur with -teiru (progressive form). Moreover, he categorized verbs according to the meanings of -teiru form. (1) shows the list of verb types.

(1) a. Stative: aru ‘exist’, iru ‘exist’, dekiri ‘possible’
   b. Activity: yomu ‘read’, kaku ‘write’, naku ‘cry’
   c. Accomplishment: sima ‘die’, mitukaru ‘find’, kieru ‘disappear’
   d. Achievement: sobieteiru ‘tower’, sugureteiru ‘superior’

As for English, Vendler (1957) classified predicates into four large groups using three standards; change (stative vs dynamic), duration (durative vs punctual), and bound (telic, bounded vs atelic, unbounded). Vendler’s predicate classification is shown below in (2).

(2) a. Stative: belong, know, resemble, lie, be asleep
   b. Activity: run, play, study, push a cart
   c. Accomplishment: build a house, eat an apple, run a mile, push a cart to the supermarket
   d. Achievement: find, notice, reach, recognize

The verb phrase push a cart is classified as activity. However, once the destination is added, such as push a cart to the supermarket, it becomes accomplishment.

2.2 Aspectual coercion
Coercion is an interpretational system which occurs when aspectual information of elements in a sentence is not congruent (Bott, 2010). It is broadly divided into two
types: complement coercion and aspectual coercion. In this study, we will focus on aspectual coercion.

Aspectual coercion is invoked when the aspectual information such as telicity of constituents in a sentence (such as verbs and adverbs of time) mismatched. Comprehenders need to adjust the aspectual meaning of a verb phrase.

(3) a. The girl slept until dawn.
b. The girl jumped until dawn.

Piñango, Zurif and Jackendoff (1999) presented two sentences to illustrate aspectual coercion. In (3a), both of the verb sleep and the adverb until dawn are atelic. On the other hand, the verb jump in (3b) has an explicit end point as telic, and thus, the telicity of the verb and adverb is incongruent. In order to dissolve the mismatch of telicity, the interpretation of the verb jump is coerced into a repetitive event as Mary ‘kept’ jumping until dawn.

Most of the previous studies in the literature have delved into aspectual coercion in head-initial languages such as English (Todorova et al. 2000, Proctor et al. 2004, Pickering et al. 2006). Long et al. (2010) investigated aspectual coercion in Japanese, a head-final language. They investigated whether the mismatching of aspectual information between an adverb and a verb increases the processing load. They manipulated Type of Adverb (atelic adverb (10-pun-kan ‘for 10 minutes’) vs. telic adverb (10-pun-de ‘in 10 minutes’)) and Type of Verb (atelic verb (rensyuusuru ‘exercise’) vs. telic verb (sooziisuru ‘clean’)). Participants were instructed to read sentences in the self-paced reading task.

The results of the experiment revealed that the mismatch of telicity between adverbials and verbs increased a processing load, which was realized as a reading-time delay. This suggests that the mismatch of aspectual information affects a sentence processing in Japanese as well as English. Nonetheless, what should be noted here is the word order difference between the two languages. As discussed in Long et al. (2010), Japanese is a head-final language that has a verb, which conveys aspectual information, at the end of the sentence, and this seems to enhance the expectation against the verb in the following manner. When a parser encounters a telic adverb, it expects a telic verb. If telicity of the verb meets its expectation, it does not increase a processing load. On the other hand, if a parser encounters an atelic verb against its expectation, it causes a reading-time delay because the parser has to recalculate the sentence meaning.

3. The current study

As Long et al. (2010) claimed, it seems that the mismatch in aspectual information leads to a processing cost in Japanese. However, there is a point that needs to be addressed regarding their stimuli. They used different verb types depending on the conditions of telicity. They used activity verbs for the atelic verb conditions and accomplishment verbs for the telic verb conditions. This entails a change in other factors such as transitivity of the verbs between the conditions. It would be better if these variables are controlled in observing the effect.

To eliminate this extra factor, we aimed at controlling the telicity without changing verbs, and examine whether the mismatch of telicity induces a processing cost or not. It has been pointed out that the telicity of the event is controlled by the direct object even without changing verbs. According to Tenny (1994), mass or count property of the direct objects influences telicity of the verb phrase. In English, specific or count noun objects (such as an apple) co-occur with telic adverb as shown in (4a), which indicates a telic event. On the contrary, uncountable nouns (4b) and bare plural nouns (4c) are compatible with atelic adverbs and these sentences represent an atelic event.

(4) a. Chuck ate an apple [*for an hour / in an hour].
b. Chuck ate ice cream [for an hour / *in an hour].
c. Chuck ate apples [for an hour / *in an hour].

(Tenny, 1994: 24)

Tenny (1994) claims that a count noun (an apple) has fixed quantity and delimitedness. As to a mass noun (ice cream), the quantity is indefinite, and this triggers atelic interpretations.

Proctor et al. (2004) verified this noun type effect by conducting an experiment. They used the self-paced reading task, in which they manipulate three factors (2 × 2 × 2): Type of verb (observation verb vs. consumption verb) × Boundedness of the noun (mass vs. count noun) × Interval of time (for X minutes vs. in X minutes). A sample target set is shown below (5).


An increase of the processing cost was observed when telicity of adverbs was mismatched with verb phrases. This means that participants utilize aspectual information of verb and object to define the telicity of event.

Different from English, Japanese does not distinguish singular and plural nouns as well as their definiteness, it is difficult to make a clear distinction between the atelic event and telic event by using noun types (mass vs. count). Nonetheless, as Mihara (2004) exemplified, nouns which express a category or general information do not fit well with telic adverbs (6a), as opposed to the case where a noun provides more specific information (6b).

(6) a. #Taro-wa samazama-na kuni-o Taro-TOP various-ADJ countries-ACC 2-syuu-kan-de mawatta. two-weeks-in travel-PST “Taro traveled various countries in two weeks.”
b. Taro-wa toonazania-no kuni-o Taro-TOP Southeast Asia-GEN countries-ACC 2-syuu-kan-de mawatta. two-weeks-in travel-PST “Taro traveled the countries of Southeast Asia in two weeks.”

(Mihara, 2004: 29)
According to Mihara (2004), the direct object samazamana kuni (various countries) in (6a) corresponds to bare plural nouns because the noun phrase samazamana kuni does not delimit the number of countries. On the other hand, as for toonanazia-no kuni (the countries of Southeast Asia) in (6b), the number of countries which belongs to the category of Southeast Asia is fixed. Accordingly, it goes well with telic adverb.

In our experiment, we employ this property of nouns for distinguishing telic and atelic events of verb phrases and examine whether the mismatch of aspectual information induces difficulty in a sentence processing. In addition, we investigate to what extent noun types influence telicity of the sentences. Furthermore, using each participants’ reading time data, we examine the correlation between Autism-Spectrum Quotient (AQ) score and reading time data. As for this issue, we explain in detail in Section 4.6.

4. Experiment

Participants are 54 undergraduate students at Tsuda College. All of them are native speakers of Japanese.

4.1 Stimuli

The stimuli were created based on two factors: the Adverb Type factor (atelic adverb vs. telic adverb) and the Noun Type factor (specific noun vs. general noun). As for Noun Type, we chose definite or countable nouns for the specific noun conditions such as nyuusyoosakuhin (prizewinning picture), and sonata (sonata). Regarding nyuusyoosakuhin (prizewinning picture), it is easy to associate with a specific group of pictures, because the number of prizewinning pictures is in general limited ordinarily. As to sonata, it is easy to be counted, because it has an explicit endpoint. On the one hand, we chose abstract or uncountable nouns for the general noun conditions such as kaiga (picture), piano (piano), because these nouns rather represent broad information in terms of delimitiveness. The event such as ‘play the piano’ has no explicit endpoint. We utilized this property and manipulated the telicity of event by changing the noun types. All of the verbs were, as far as their lexical aspect is concerned, activity verbs. Among them, we chose transitive verbs which require objects, for example, kansyoosita (appreciate), rensyuuusuru (exercise). The stimuli consisted of 24 sets of items such as (7a-d).

(7) a. atelic_adverb × specific_noun
   kantyoo-wa gaka-ga 1-zi-kan
   curator-TOP painter-NOM an hour-for
   nyuusyoosakuhin-o bizyutukan-de
   prizewinning picture-ACC artmuseum-LOC
   kansyoosita-to uketsukegakari-ni
   appreciated-COMP receptionist-DAT
   morasita.
   reveal-PST
   “The curator revealed to the receptionist that
   the painter appreciated a prizewinning picture
   for an hour at the art museum.”

   b. atelic_adverb × general_noun
   kantyoo-wa gaka-ga 1-zi-kan

   curator-TOP painter-NOM an hour-for
   kaiga-o bizyutukan-de
   picture-ACC artmuseum-LOC
   kansyooshita-to uketsukegakari-ni
   appreciated-COMP receptionist-DAT
   morasita.
   reveal-PST
   “The curator revealed to the receptionist that
   the painter appreciated the pictures for an hour
   at the art museum.”

   c. telic_adverb × specific_noun
   kantyoo-wa gaka-ga 1-zi-kan-de
   curator-TOP painter-NOM an hour-in
   nyuusyoosakuhin-o bizyutukan-de
   prizewinning picture-ACC artmuseum-LOC
   kansyoosita-to uketsukegakari-ni
   appreciated-COMP receptionist-DAT
   morasita.
   reveal-PST
   “The curator revealed to the receptionist that
   the painter appreciated a prizewinning picture
   in an hour at the art museum.”

   d. telic_adverb × general_noun
   kantyoo-wa gaka-ga 1-zi-kan-de
   curator-TOP painter-NOM an hour-in
   kaiga-o bizyutukan-de
   picture-ACC artmuseum-LOC
   kansyoosita-to uketsukegakari-ni
   appreciated-COMP receptionist-DAT
   morasita.
   reveal-PST
   “The curator revealed to the receptionist that
   the painter appreciated the pictures in an hour
   at the art museum.”

In addition to the target sentences, we included 58 filler sentences. Each participant read a total of 82 sentences in the experiment.

4.2 Procedure

Self-paced reading tasks were conducted by using Linger (v.2.94). The participants were asked to read each sentence silently, as it was presented on a computer monitor phrase by phrase in a noncumulative and moving-window manner as the participants pushed the space bar.
After reading each sentence, they were instructed to answer a comprehension question to measure their understanding of the sentence. There was a short feedback for wrong answers. Before the main session, the participants went through a practice session with 10 items.

4.3 Prediction

If the mismatch of telicity between an adverb and a verb causes a processing cost, along the lines of Long et al. (2010) as well as the studies on aspectual coercion in English (Piñango et al. 1999, Todorova et al. 2000), the reading-time delay should be observed at the verb region in the telic adverb conditions in (7c) and (7d) that contain the telicity mismatch. Since Japanese is a head-final language, when participants encounter a telic adverb in an early phase, they predict the appearance of a non-telic verb. When they detect the incongruence of telicity between an adverb and a verb, the participants have to reinterpret the sentence meaning and this process leads to a processing cost.

Regarding the Noun Type, the difference between the specific noun (prizewinning picture) and the general noun (picture) should be observed if the object type influences the telicity of the verb phrase. To be concrete, as specific nouns (prizewinning picture) are easy to be counted and this property fixes the events’ delimitedness (7a, 7c), it is predicted that specific nouns fit well with telic adverbs. General nouns (picture) are supposedly vague to set the delimitedness of the event. Then, it could be hypothesized that the telicity of the event with general nouns as an object is considered to be atelic, compared to the even with specific nouns (7b, 7d).

4.4 Results

We excluded data from three participants whose mean correct answer rates were less than 70 % as well as data from one participant due to a computer error and four due to their reading times as too short (RT < 300) or too long (RT > 2800) at the critical regions. In addition, we did not include data of one item in the analysis because its correct answer rate was under 75 % as well as data of two items because of deficiencies of the stimuli.

ANOVA was conducted with two within-group factors: Adverb Type (telic adverb / atelic adverb) × Noun Type (specific noun / general noun). The mean reading times (RTs) for four conditions are presented in Figure 1.

In Region 6 (the critical region which contains an activity verb), ANOVAs revealed a main effect of Adverb Type (F1(1,45)=4.821, p<.05; F2(1,20)=0.731, ns), and also a main effect of Noun Type (F1(1,45)=5.645, p<.05; F2(1,20)=7.542, p<.05). There was no interaction between the two factors (F1(1,45)=2.268, ns; F2(1,20)=3.441, p<.10). Moreover, there was a significant effect of Adverb Type in the specific noun conditions (prizewinning picture) (F1(1,90)=6.539, p<.05; F2(1,40)=3.503, p<.10). Noun type effect was observed in the atelic adverb conditions (for an hour) (F1(1,90)=7.113, p<.01; F2(1,40)=9.972, p<.005).

4.5 Discussion

We examined whether the mismatch of aspectual information induces difficulty in sentence processing and verified to what extent the delimitedness of noun type influences on sentence processing.

Figure 2 shows the mean reading times of Region 6 (verb) which is the critical region with respect to identifying the telicity congruence.

A delay was observed in the telic adverb (in an hour) conditions, which bears a telicity mismatch with the atelic verb, compared with the telic adverb (for an hour) conditions. Therefore, it is plausible that when participants encounter a sentence in the telic adverb condition, they changed the interpretation to generate a telic event. What should be noted here is this tendency differs depending on noun types. In the specific noun (prizewinning picture) condition, a significant reading time delay was observed when the aspectual information was mismatched. On the other hand, in the general noun (picture) condition, this tendency was not observed. Contrary to our prediction that the specific noun condition fits well with the telic adverb, reading-time data suggests...
that specific noun (prizewinning picture) × telic adverb (in an hour) condition induces processing cost. At this point in time, we do not have a solid account with substantial evidence as to what differentiates the noun types, which we leave for future research.

Regarding the atelic adverb conditions, the general noun (picture) condition was read slower than the specific noun (prizewinning picture) condition. We predicted that the general noun condition fits well with atelic event, and a delay of reading time would not be observed. However, a delay was observed in the general noun condition rather than the specific noun condition. This suggests that an effect of verb prediction comes into play. There is a possibility that specific nouns (prizewinning picture) narrows the choice of the following verb types to be encountered. On the other hand, in the general noun condition (picture), the choice of verbs that participants could expect was rather wide. This difference in terms of the expectation might be a cause of reading-time difference. To discuss the effect of verb prediction, further research is needed.

4.6 AQ score

In the literature on the relationship between autism spectrum disorders (ASD) and language, there is a general consensus of a correlation with pragmatic impairments (Eigsti and Schuh 2016). Nieuwland et al. (2010), for example, employed the Communication subscale of the Autism-Spectrum Quotient questionnaire (the AQ; Baron-Cohen et al. 2001) to measure pragmatic language abilities of their participants and argue for a correlation with scalar (pragmatic) processing in English. Regarding Japanese, Kiyama et al. (2012) address a relationship between an interpretation of sentence-final particles that requires a pragmatic inference and the AQ score on the Japanese version of the questionnaire (Wakabayashi et al. 2004).

In this study, we investigated whether the AQ score is correlated with reading times obtained from the self-paced reading experiment. Prior to the reading experiment, participants were asked to answer the AQ questionnaire. The mean of their AQ scores is 23.20, ranging from 6 to 36, with the standard deviation of 6.45, where higher scores indicate stronger presence of traits associated with ASD.

Figure 3 shows a relationship between the AQ score and the sum of reading times of each participant. Although the Pearson’s correlation does not identify a significant correlation in the data (r = −0.16, t(52) = −1.19, p = .24), the tendency represents a decrease of the reading time as the AQ score becomes high.

In addition, we constructed a linear mixed-effects model in the R environment (R Core Team 2016), where a word difference was put as a fixed factor, in addition to the AQ score as a fixed factor. The model reported a significant effect of the AQ score on the reading time (coefficient estimate = −4.77, standard error = 0.72, t = −6.60, df = 13137, p < .0001), which indicates the decrease of the reading time as the increase of the AQ score. The results were sustained with the data excluding reading times with +/-3 standard deviation.

5. Conclusion

In this study, we investigated two research questions: (i) whether the mismatch of aspectual information induces difficulty in a sentence processing and to what extent telicity of noun types influences on sentence processing, (ii) the correlation between AQ score and reading time data. Concerning the first question, the results showed that the mismatching of telicity between an adverb and a verb increases the processing load. At this point of time, the noun type effect is different from what we have predicted. It needs more consideration.

As to the correlation between, AQ score and self-paced reading time data, the results showed that as the AQ score becomes high, participants read the sentences faster.

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