

# Understanding the Relationship between Social Cognition and Word Difficulty

## A Language Based Analysis of Individuals with Autism Spectrum Disorder

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### Keywords

Autism, ASD, autistic spectrum disorder, language ability, natural language, social communication

### Summary

**Background:** Few quantitative studies have been conducted on the relationship between society and its languages. Individuals with autistic spectrum disorder (ASD) are known to experience social hardships, and a wide range of clinical information about their quality of life has been provided through numerous narrative analyses. However, the narratives of ASD patients have thus far been examined mainly through qualitative approaches.

**Objectives:** In this study, we analyzed adults with ASD to quantitatively examine the relationship between language abilities and ASD severity scores.

**Methods:** We generated phonetic transcriptions of speeches by 16 ASD adults at an ASD workshop, and divided the participants into 2 groups according to their Social Responsiveness Scale™, 2nd Edition (SRS™-2) scores (where higher scores represent more severe

ASD): Group A comprised high-scoring ASD adults (SRS™-2 score:  $\geq 76$ ) and Group B comprised low- and intermediate-scoring ASD adults (SRS™-2 score:  $< 76$ ). Using natural language processing (NLP)-based analytical methods, the narratives were converted into numerical data according to four language ability indicators, and the relationships between the language ability scores and ASD severity scores were compared.

**Results and Discussion:** Group A showed a marginally negative correlation with the level of Japanese word difficulty ( $p < .10$ ), while the “social cognition” subscale of the SRS™-2 score showed a significantly negative correlation ( $p < .05$ ) with word difficulty. When comparing only male participants, Group A demonstrated a significantly lower correlation with word difficulty level than Group B ( $p < .10$ ).

**Conclusion:** Social communication was found to be strongly associated with the level of word difficulty in speech. The clinical applications of these findings may be available in the near future, and there is a need for further detailed study on language metrics designed for ASD adults.

## 1. Introduction

Human communication is generally believed to be characterized by talking, writing, listening, and reading to each other. However, there are few studies, quantitative or otherwise, that have ascertained the actual specifics of the relationship between our society and its languages. In this study, we begin to explore this classic but uncharted relationship between these two major aspects of human behavior by analyzing the speech of individuals with autism spectrum disorder (ASD) using natural language processing (NLP) techniques.

As described in the 2013 guidelines of the American Psychological Association, ASD is a neurodevelopmental disorder that involves “social-communicative and behavioral deficits” and “restricted, repetitive, and stereotyped patterns of behavior” that are present since childhood [1]. It has been reported that 6 to 7 out of every 100 Japanese children and one out of every 88 American children have autism [2], and data has shown that ASD has become one of the most prevalent disorders throughout the world [3–5]. Despite this, few methods have been established to improve the difficulties in the social relationships of ASD patients, which are a major obstacle to their successful integration into society [6, 7].

One of the scales of ASD severity, the SRS™-2 test provides a quantitative measure of autistic-like behavior, primarily focused on social relatedness. This test is a “measurement of the severity of autism spectrum symptoms as they occur in a

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child's natural social settings" [8], and this test has been validated against the Autism Diagnostic Interview-Revised (ADI-R) scoring system, with a strong correlation ( $r = .7$ ) reported between SRS scores and ADI-R scores [9, 10]. The instrument is unique in that it measures autism spectrum conditions by identifying the presence and extent of autistic social impairment. The test takes an average of 15 to 20 minutes to conduct, and consists of a total of 65 items; the scores from the individual items are summed to produce a total score. The SRS<sup>TM</sup>-2 also includes the following five subscales: 1) social awareness: representing the ability to pick up socially relevant information; 2) social cognition: representing the ability to interpret, manipulate, and respond to socially relevant information; 3) social communication: representing the "motoric" aspects of reciprocal social behavior; 4) social motivation: representing the motivation to engage in social-interpersonal behavior; and 5) restricted interests and repetitive behavior: representing the stereotypical or highly restricted interests characteristic of autism.

Several studies have focused on the narratives of ASD adults and children [11–14]. Most of these studies are qualitative analyses, although some recent studies have also employed quantitative approaches. However, many narrative analyses, such as the Self-Defining Memory Task [15] and the Autobiographical Memory Test (AMT) [16], are heavily reliant on the interpretation of experienced coders and researchers, and the results are invariably influenced by the investigators [17]. Accordingly, there is a need for narrative analytical methods that have high throughput with low investigator bias and cost. Analytical methods for the study of overgeneralizations in autobiographical memory (which were initially developed for individuals with post-traumatic stress disorder, acute stress disorder, and other mood disorders) are increasingly used in clinical applications for ASD. A study by Williams and Broadbent in 1986 used the AMT to quantify the differences in the ability of mood-disordered individuals to recall specific memories, but this method is also heavily reliant on each investigator's interpretations [18, 19].

The field of information processing has developed automatic analytical technologies for examining large quantities of data, such as those from social network services. In particular, recent NLP technologies are able to automatically aggregate narrative data that contain enormous amounts of lexical information. One medical application of such technology was the analysis of over 100 diaries, written before the owners' suicides, to classify the sentiments that may have led to suicide [20]. Another study had quantified the fillers used in the speech of ASD children [21], but did not address the lexical content or the narrative itself. There are varieties of NLP analytics used on clinical data, and there are several application categories, such as information extraction, document and patient classification, and sentiment analysis [22]. This study has focused on the patient classification category, and there are many preceding studies in this category on various diseases, such as Roark [23] classified the Mild Cognitive Impairment patients by using lexical features, Pakhomov [24] examined similar research for Frontotemporal Lobar Degeneration, employing not only lexical features but also acoustic features, and Rouhizadeh [25] examined ASD patients. All the above studies utilized the heuristic measures. In contrast, several studies recently employed machine learning, such as SVM and Decision Tree. Fraser [26] examined diagnosing the patients with Primary Progressive Aphasia by using SVM, and Orimaye [27] classified Alzheimer's Disease patients by using machine learning as well. Machine learning means, however, require rather bigger sample size for analysis, and therefore, we have used the heuristic measure in this study to cover the size of participated subjects.

The purpose of this study was to analyze the narratives of ASD adults using NLP technologies with low investigator bias to ascertain the aspects of language that may hinder social interactions. Here, we compared several language ability scores from narrative data of the study subjects and their severity scores in social activities using the Social Responsiveness Scale<sup>TM</sup>, Second Edition (SRS<sup>TM</sup>-2). In this way, we aim to further the understanding of the re-

lationship between society and language abilities.

## 2. Objectives

In this study, we analyzed adults with ASD to quantitatively examine the relationship between language abilities and ASD severity scores.

## 3. Methods

### 3.1 Ethics Statement

This study was approved by the Office for Life Science Research Ethics and Safety, the University of Tokyo, Japan. All participants provided written consent prior to their participation in the project.

### 3.2 Participants

Study participants were recruited from among the attendees of the "Necco workshops", which are a series of peer-support workshops for adults with developmental disorders held at the eponymous "Alternative Space Necco", located in Tokyo, Japan. The Alternative Space Necco is a meeting place for these individuals, and provides various types of support aimed at ameliorating their difficulties in interacting within society. From among 76 workshop attendees, 16 (male: 7, female: 8, not specified: 1) adults with ASD aged 29 years to 60 years (mean age: 43.88 years; SD: 7.79) agreed to participate in our study and provide their SRS<sup>TM</sup>-2 test scores. The participants were randomly selected and not biased, and there was no significant difference between those who participated and those who did not. All of the participants had education of high school and above, but from the viewpoint of privacy protection, we did not obtain further educational information from each attendee who did not participate in this research. The aim of these workshops is to allow participants to "speak out about his/her own experiences, listen to each other to share the experiences of other people, and finally, develop and discover new expressions of his/her own". The guidelines of this workshop are as follows:

Necco Workshop Number	Number of Attendees (incl. facilitator and observers)	Number of Participants Attended	Total Number of Words Spoken during Workshop	Number of Words by Other Attendees	Number of Words by Participants	Dates
28th	21	5	11883	6184	5700	2012/Sep/03
29th	23	4	15309	11151	4159	2012/Sep/19
30th	25	4	10065	5845	4221	2012/Oct/01
35th	21	6	9795	4643	5151	2012/Dec/19
36th	32	6	5164	3028	2136	2013/Jan/07
38th	31	11	12789	7324	5465	2013/Feb/04
39th	25	7	11017	4766	6251	2013/Feb/20
47th	23	9	8214	2997	5217	2013/Jun/19
48th	23	8	10188	5808	4380	2013/Jul/01
51th	23	8	10827	5848	4979	2013/Aug/21

**Table 1**  
Dates and number of attendees of each Necco Workshop

- Each participant speaks in turn.
- One or more theme(s) are set and provided at each meeting in advance, and each participant speaks according to the theme.
- The period for each speaker is three minutes per theme.
- Only one speaker speaks at a time, and there should be no crosstalk or advice giving.

The study participants took the SRS<sup>TM</sup>-2 test at the Alternative Space Necco.

### 3.3 Procedure

During the Necco workshops, a microphone was provided to the speaker at his/her turn. The speeches were recorded using an MP3 recorder (ICR-PS285RM [H], SANYO Electric Co., Ltd.), and a phonetic transcription of the speeches was prepared by Kyoto Data Service Co., Ltd. The average recording time for each workshop was 130.3 minutes, with a minimum of 115 minutes and a maximum of 152 minutes. All recordings were collected from workshops conducted between September 3,

2012 and August 21, 2013, and 10 recordings were randomly selected for analysis. The workshop dates and corresponding number of attendees are shown in ► Table 1. The average word count (in Japanese characters) was 1,412.8 characters, with a minimum of 612 characters and a maximum of 3,039 characters (calculated after phonetic transcription). The average number of workshop attendances for each attendee was 4.3, with a minimum of 1 and a maximum of 9.

In this study, we divided the 16 participants into 2 groups according to their total SRS<sup>TM</sup>-2 scores (Note: The SRS<sup>TM</sup>-2 indicates that the scores 76 or higher is the SRS-based “severe” autism range.): Group A comprised participants with a total score of 76 and above, indicating severe social impairment (n = 10; maximum score: 90, minimum score: 76); Group B comprised participants with a total score of less than 76, indicating low to intermediate social impairment (n = 6; maximum score: 70, minimum score: 59). The participants’ age and gender distributions are shown in ► Table 2.

	Severe (SRS <sup>TM</sup> -2 score: 76 and above)	Low, Intermediate (SRS <sup>TM</sup> -2 score: less than 76)
Gender	Men: 3; women: 7	Men: 4; women: 1; not specified: 1
Age, mean (SD)	46.1 years (8.2 years)	40.2 years (5.2 years)

**Table 2**  
Patient characteristics

### 3.4 Language Scores

The phonetic transcriptions were used in the measurement of 4 NLP-based language ability scores. Note that the scores do not directly correspond to overall language abilities. The explanation for each indicator is as follows (summarized in ► Table 3):

Frequency per User (FPU): FPU represents the average use of uncommon words in writing. FPU represents the average use of uncommon words in writing. To calculate the uncommonness of the use of words, this study has utilized the data from social networks. The procedure was as follows. We firstly gathered the text data of 99,964 people for 143 days (November 3, 2009 – March 25, 2010). The total amount of collected words was 4,258,707,255. For each word, we investigated the number of people who had used the word. Please note that this procedure was different from the frequency of the occurrence of the word, since such frequency deals with the number of the usage of the word no matter who the users are, whereas FPU deals with the number of people who use the word. Thus, when a particular word is used by one person many times but not by others at all, the frequency of the occurrence of the word raises, but the FPU score stays low since it cares the population of the users of the word. Popular words, such as “the” and “I”, have many word users (when a word is used by all the people we have examined, the number of the word users would be

99,964). In order to quantify such word population frequency, we normalized the word users by the occurrence of the word. We call this value Frequency Per Users (FPU).

The formalization of FPU of a word( $w$ ) is as follows:

$$\text{FPU}(w) = \text{word frequency}(w) / \text{word users}(w)$$

FPU indicates the uncommonness of a word. When a word frequency is balanced with the number of word users, the FPU value would be low, and when the number of the users of a word is low, the FPU value would become high, indicating that the particular word is considered to be uncommon in FPU manner. We developed the FPU Dictionary, which consists of 20,000 words, available on the web. Further details are provided elsewhere [22]. In this study, we extracted target nouns from each participant's transcript and derived their average FPU score.

$$\sum_{w \in W} \text{FPU}(w) / |W|$$

where  $W$  is a set of nouns in the transcription of a target participant.  $|W|$  is the number of nouns in the transcription of a target participant.

Japanese Educational Lexicon Level (JEL): JEL represents the average difficulty in lexical choices. This metric was originally created for non-native speakers of Japanese. We used the word scores provided in the *Japanese Learner's Dictionary* [28]. In this dictionary, the most common 17,928 words are classified into the following three levels: beginner, intermediate, and advanced. To derive the JEL score, we extracted and totaled the number of nouns that belong to the intermediate or advanced levels, and divided this figure by the sum of intermediate and beginner level nouns (i.e., number of intermediate or higher level nouns/number of intermediate and beginner level nouns). Word level is often quantitated by simply taking the average levels of the participants. However, in the case of daily communication, conversations are carried on by the vocabularies of the beginner and intermediate level. Therefore, this study has focused on the ratio of intermediate words.

**Table 3**  
Language indicators

Indicator	Indication	Part of Speech	Description
FPU	Peculiarity	Noun	(Average of FPU scores)
JEL	Difficulty	Noun	(Number of JEL high-level words)/(Number of JEL defined words)
TTR	Quantity	Noun	(Number of types)/(Number of tokens)
NER	Particularity	Named Entity	(Number of NEs)/(Number of words)

Abbreviations: FPU, Frequency per User; JEL, Japanese Educational Lexicon Level; TTR, Type Token Ratio; NER, Named Entity Ratio

Type Token Ratio (TTR): TTR represents the size of vocabularies, and is derived from the ratio of word type to token (i.e., type/token, where type refers to the number of the use of different words in a text and token refers to the number of words in a text). Note that we have disambiguated Orthographic variants by using Japanese morphological analysis system. For example, "itta (went; past tense)" was normalized into "iku (go; present tense)".

Named Entity Ratio (NER): NER represents the particularity of speech, which is defined by the ratio of proper nouns (nouns that denote particular things or numerals, such as Kyoto and three) to total nouns (i.e., number of proper noun morphemes/number of total noun morphemes). Higher NER scores indicate higher specificity in a sentence. The Japanese language morphological analyzer JUMAN [29] was used for morpheme extraction. We extracted place names, numerals, and proper nouns for each sentence from the participants' transcripts, and calculated the average NER score for each participant.

The phonetic transcriptions of the participants' speeches at the Necco workshop were analyzed using a Perl program, and we calculated the Pearson's correlation coefficient between each language score and the SRS<sup>TM</sup>-2 score. We also conducted t-tests between Groups A and B, as well as between each language score and the SRS<sup>TM</sup>-2 score. Statistical significance was set at  $p \leq .10$ .

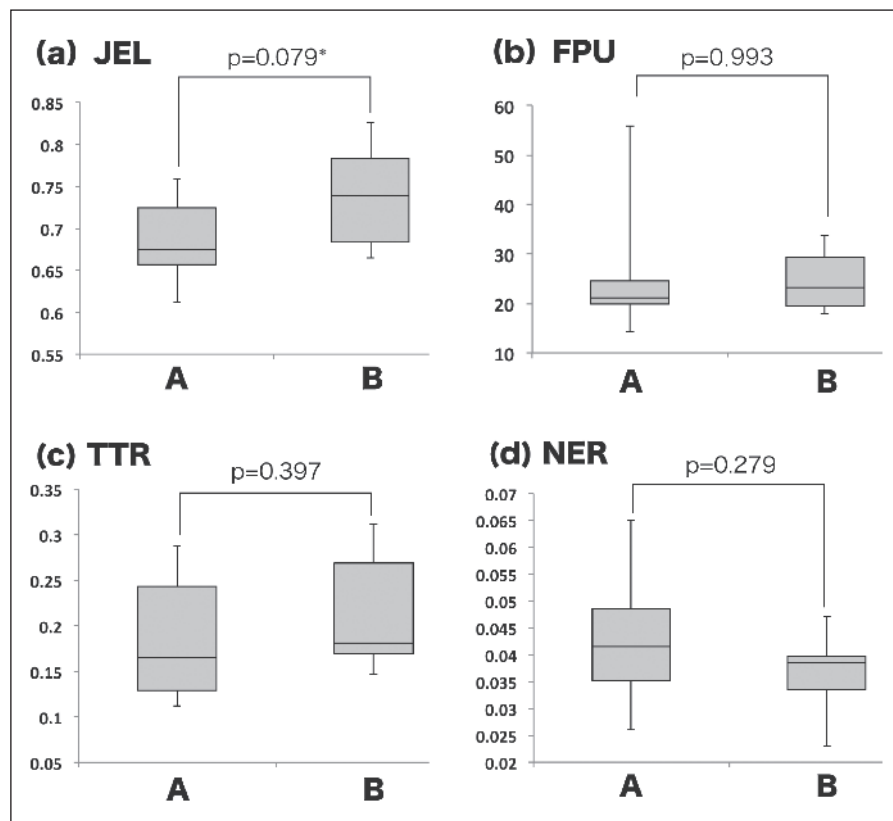
## 4. Results

The differences in language scores between Group A and Group B are shown in ► Figure 1. The significant difference was observed between the groups for the word difficulty language scores (JEL [ $p = .079$ ]); and there were no significant differences observed between the groups for the language scores (FPU [ $p = .112$ ]; TTR [ $p = .397$ ]; and NER [ $p = .279$ ]).

For the correlations between the language scores and SRS<sup>TM</sup>-2 scores, JEL was found to have the lowest  $p$  among the four metrics at  $r = -.453$  ( $p < .10$ ). Among the five SRS<sup>TM</sup>-2 subscales, social cognition showed a negative correlation ( $r = -.622$ ;  $p < .05$ ) with JEL (Fig. 3). In addition, social motivation ( $r = -.489$ ) and social communication ( $r = -.466$ ) showed negative, albeit non-significant, correlations ( $p < .10$ ) with JEL. In order to clarify the boundary, we have derived the  $P$ -value for each indicator. According to Dancey and Reidy's (2004) categorization, when the Value of the Correlation Coefficient is between  $|.4 - .6|$ , it has a moderate correlation, and between  $|.7|$  and above represents strong correlation.

► Figure 2 presents the relationship between gender (male,  $n = 7$ ; female,  $n = 8$ ) and JEL. The results showed no significant differences between the two. However, a significant difference at  $p = .078$  ( $p < .10$ ) was observed between the men of Group A and B for JEL scores. In this study, there was only one female participant in Group B, rendering us unable to test the correlation between high and low SRS<sup>TM</sup>-2 scoring groups among women alone.





**Figure 1** Differences in language scores between Group A (SRS™-2 score: ≥ 76) and Group B (SRS™-2 score: < 76); \*p < .10

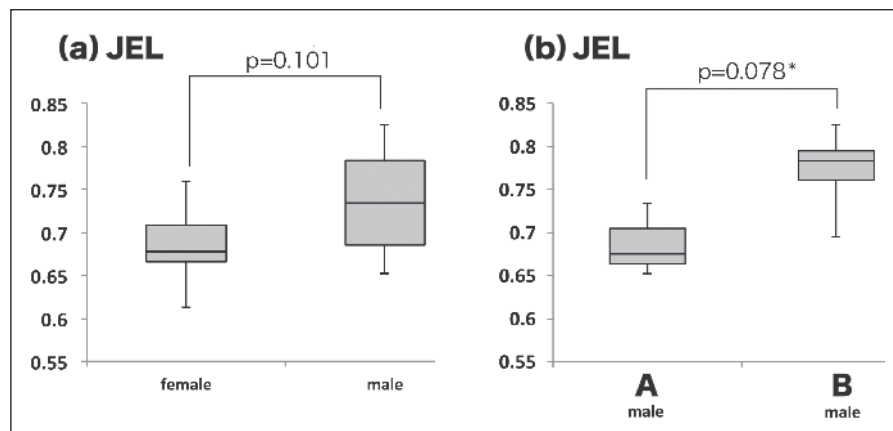
### 5. Discussion

Our study demonstrated a moderately negative correlation between JEL scores (which represents the lexical difficulty of the narratives) and SRS™-2 scores in ASD adults. This suggests that people with

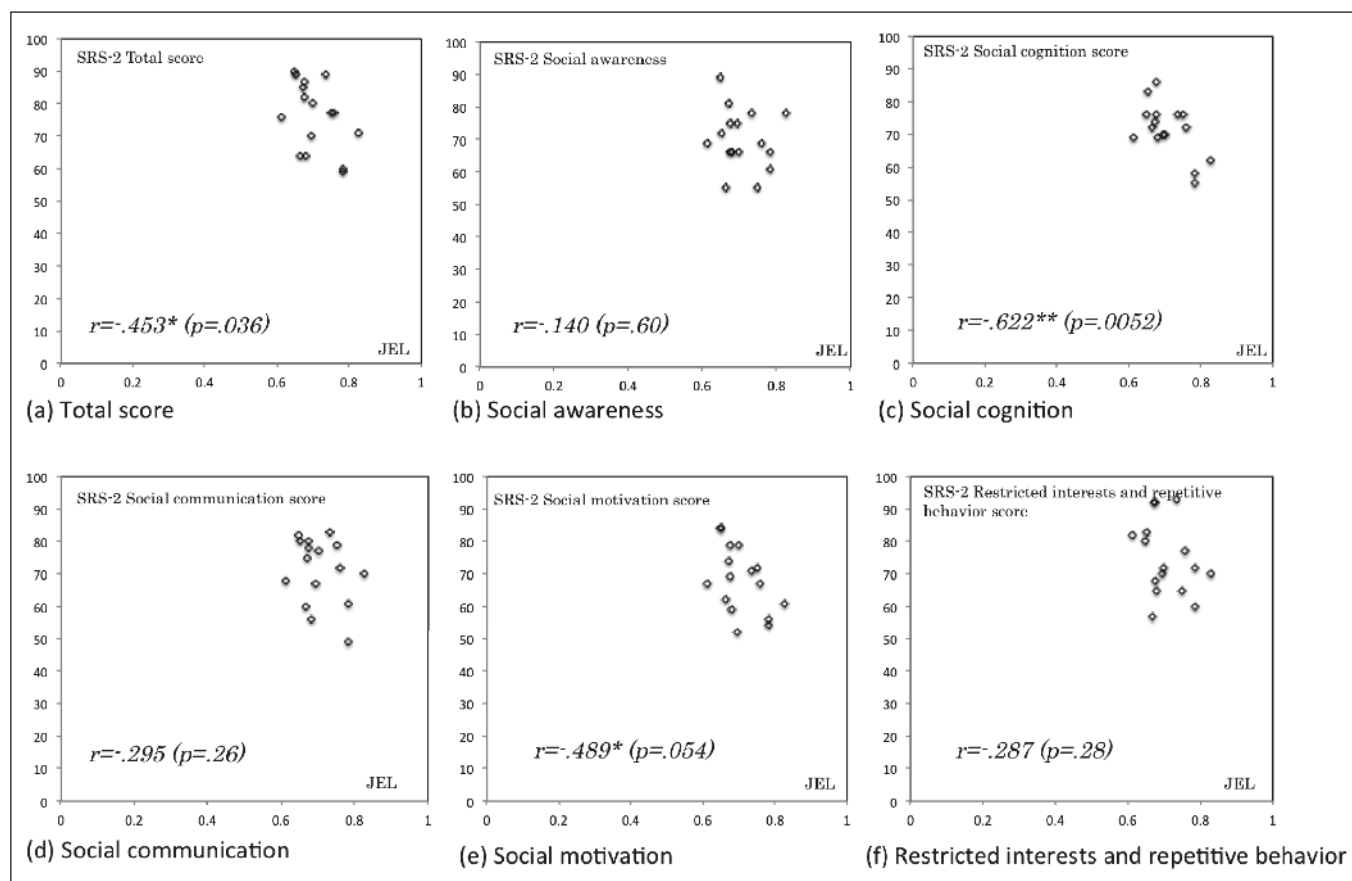
higher SRS™-2 scores (and therefore have more severe social impairments) may have a tendency for using less advanced words when they talk. Note that all participants, both male and female participants, equally have education level of high school graduate or above.

JEL was originally developed for non-native Japanese speakers, and it has been reported that the main obstacle impeding the integration of foreigners into Japanese society is their lack of Japanese language ability [30]. Taking this into consideration, it is possible that one needs to be able to use more advanced words in order to integrate successfully into society, or at least into Japanese society. As one of the major challenges faced by ASD individuals is their difficulty in integrating into society, this result suggests that ASD individuals and foreigners may face similar problems in social communications, in that the lack of advanced words used in their speech may hinder effective and meaningful communication with others.

This issue may be magnified due to the nature of Japanese society, as Japan is essentially still a monolingual society where most people are expected to speak Japanese. In this context, the lack of diversity in language variations may have reinforced such tendencies, and should be investigated in future research. However, it is unusual that although ASD individuals are generally believed to have comparably high language abilities [31, 32], our study showed it was not quite the case: instead, as ASD level increased, the word difficulty level decreased. One possible explanation for this observation is the influence of individual differences among each SRS™-2 scoring group. As this measurement focused on the social impairments that the ASD adults (and not other appraisers) assessed themselves to have, it is possible that the severity of social impairment is not a direct representation of actual autistic severity. The outcome does not seem intuitive that ASD individuals are often said to show high or similar language performances to typically developed individuals in their ability tests such as the Wechsler Scales and the Autism Diagnostic Interview as mentioned. The condition of this study might have been one of the key factors as well that such ability tests do not require actual audiences to communicate with, but, on the other hand, this text/corpus we have used in this study was the actual utterance and free-talks of the near-natural-everyday-situation. In the near future, we are aiming to compare the situ-



**Figure 2** JEL scores between (a) male (n = 7) and female (n = 8) participants and (b) male participants only in Group A (n = 3) and Group B (n = 4); \*p < .05



**Figure 3** Scatterplots showing the correlations between JEL scores and the SRS<sup>TM</sup>-2 total score (a) and subscales: (b) Social awareness, (c) Social cognition, (d) Social communication, (e) Social motivation, and (f) Restricted interests and repetitive behavior. \* $p < .1$  \*\* $p < .05$

ation-based analysis to examine more delicate detail on language difficulties that appear in use.

With regard to the SRS<sup>TM</sup>-2 subscales, social cognition and social motivation showed significantly negative correlations with JEL scores. On the other hand, social awareness, social communication, and restricted interests and repetitive behavior did not show any statistically significant correlations. The former subscales measure the ability to form interrelationships within society, while the latter are generally a reflection of self-contained efforts; these findings therefore suggest that the social impairments in ASD adults arising from the lack of advanced words used in speech appear mainly at the points of interaction with society. The results also imply that word difficulty would have the strongest correlation to social communication among the language scores.

As mentioned above, studies have reported that ASD individuals tend to exhibit overgeneralizations in their autobiographical narratives, which are often represented by Overgeneral Autobiographical Memory (OGM) scores [33, 34]. The NER indicator (which calculates the number of proper nouns) is similar to the OGM score, which is defined as the ratio of references to “one-time-only” incidents in narratives [35]. However, the NER indicator picks up all the proper nouns that appear in the text, so that it is not capable of extracting only the “one-time-only” event accurately. This may explain why the NER indicator was unable to demonstrate significant differences between the high and low SRS<sup>TM</sup>-2 scoring groups.

Our analysis also included an investigation on whether there was any gender-related bias involved in this comparison, as previous studies have implied [36]. As shown in ► Figure 2, there were no signifi-

cant differences in JEL scores between males and females, whereas a comparison of males only showed a significant difference between the high and low SRS<sup>TM</sup>-2 scoring groups in t-tests. These findings suggest that the relative use of advanced words is more greatly affected by autistic social impairments than by gender. However, since the number of participants was not very large, the difference between the two groups in JEL (► Figure 1a) might due to the difference in male/female composition of the groups (► Table 2). As our study sample did not vary widely in age, the possible bias associated with this factor should be addressed in future studies.

To build upon the findings of this study, our future tasks include the revision and establishment of more language ability indicators to match the specific needs of ASD adult speech patterns. The limited number of participants ( $n = 16$ ) in this study may have affected the correlation analysis, and

future studies should include more participants to increase statistical robustness. The future studies should also include more participants' information, such as their educational levels and ages, to investigate the correlation between such factors as well. Furthermore, this study used third-party phonetic transcriptions of the speeches, which require substantial monetary and time investments. To circumvent the need for these investments, we are currently developing a new voice recognition system for more expeditious analysis. In addition, it is very likely that the narratives of speech and writing may show different outcomes, which is a topic that warrants further investigation. The indicators used in this study focused mainly on the vocabularies of the participants (with an emphasis on nouns), and not on the unit of sentences. This was due to the arbitrary nature of sentence units in utterances. However, we are able to analyze the narratives in complicated sentence structures and modification relationships within a sentence, and plan to also conduct an analysis of written text.

## 6. Conclusions

This study quantified the narratives of ASD adults using NLP-based techniques to examine the relationship between society and its languages. Conventional narrative analyses have mainly used qualitative approaches, and have therefore required skillful investigators to analyze the information. Our approach may support the creation of new procedures that would be less dependent on the abilities and techniques of the investigators.

In this analysis of 16 participants, the results indicated the possibility that adults with severe social impairment may use less difficult words in their speech when compared to those with milder ASD symptoms ( $p < .10$ ). In addition, the social cognition component of the SRS<sup>TM</sup>-2 score showed a negative correlation with lexical difficulty ( $p < .05$ ), indicating that the formation of interactive relationships within society may have been impeded by a lack of advanced words used in speech. Further studies are

needed to identify the clinical applications for these findings.

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