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Research Article

Disfluencies and Strategies Used by People Who Stutter During a Working Memory Task

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Purpose: Working memory (WM) deficits are implicated in various communication disorders, including stuttering. The reading span test (RST) measures WM capacity with the dual task of reading sentences aloud and remembering target words. This study demonstrates a difference in strategy between people who stutter (PWS) and people who do not stutter (PWNS) in performing the RST. The impact of the effective strategy and the stuttering-like disfluencies during the RST were investigated.

Method: Twenty-six PWS and 24 people who do not stutter performed the RST and a simple reading aloud task. After the RST, they were asked which strategy ("imagery" or "rehearsal") they had used in order to remember the target words during the task.

Results: The proportion of those who used an "imagery" strategy during the RST was significantly smaller in the PWS group. However, the RST scores of those who used an "imagery" strategy were significantly higher than the RST scores of those who used a "rehearsal" strategy in both groups. The "rehearsal" users were asked to undertake one more RST with an "imagery" strategy, which resulted in an increased score for both groups. The disfluency frequency of the PWS group was significantly reduced during the RST than during the oral reading task, irrespective of the employed strategy.

Conclusions: PWS tended to use the less effective verbal "rehearsal" strategy during the RST. The differential effects of switching strategies on the measured WM capacity and on the disfluency rate suggest that the enhanced fluency during the RST would be mostly attributable to the reduced attention to speech motor control. Therefore, the use of the "imagery" strategy and focusing on the contents of communication, away from speech motor control, should help PWS communicate better in daily conversation.

Stuttering is a speech disorder, which is characterized by an abnormally high frequency or long duration of stoppages in the forward flow of speech (Bloodstein & Bernstein Ratner, 2008; Guitar, 2013; Van Riper, 1971). The stuttering-like disfluencies (SLD) include part-word or sound/syllable repetitions, prolongations, and arrests of speech (also known as blocks; Yairi, 2007; Yairi & Ambrose, 2005). Due to the disfluency, people who stutter (PWS) experience difficulty in communication throughout their activities at home, in school, or at work (Bloodstein & Bernstein Ratner, 2008; Guitar, 2013; Van Riper, 1971). It has been long known that PWS speak fluently when there is no audience and that they do not focus attention on their speech motor acts or under noise masking conditions (Bloodstein & Bernstein Ratner, 2008; Cherry & Sayers, 1956; Iimura et al., 2016). These observations indicate that PWS have the capability to speak fluently and automatically. However, the disfluency itself may explain only part of the disorder. PWS often report that their stutter appears to increase with tension, anxiety, and agitation (Bloodstein & Bernstein Ratner, 2008). They also experience the anticipation of stuttering (Jackson et al., 2015; Van Riper, 1936). These emotional and mental events tend to induce PWS to focus more on stuttering or on how to speak without stuttering than on the content of the communication (Jackson et al., 2015; Kamhi & McOsker, 1982). Focusing on the evasion of stuttering then often makes them engage in maladaptive coping behaviors or strategies, such as word substitution, pausing, silent rehearsals, and other safety behaviors, to avoid difficult syllables/words

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(Lowe et al., 2017; Vanryckeghem et al., 2004). Those proactive responses, efforts thereof, and attentional fixation on the conscious motor control of speech organs may rather hinder fluent (effective) communication in spite of the speaker's intent otherwise, as postulated by the constrained action hypothesis and the OPTIMAL (optimizing performance through intrinsic motivation and attention for learning) theory of motor learning (Eichorn et al., 2016, 2019; Freedman et al., 2007; Wulf & Lewthwaite, 2010, 2016).

Conscious attention control and mental resource allocation are mostly governed by working memory (WM). Therefore, this study investigated the relationship between WM and stuttering.

WM and Its Measuring Method

The act of daily verbal communication is a rapid complex task that requires well-organized use of WM (Baddeley, 1986; Osaka, 2002) and long-term memory. WM refers to a short-term cognitive system for temporarily storing and processing information (Baddeley, 1986, 2000; Baddeley & Hitch, 1974). It plays an important role in various cognitive tasks, such as language comprehension, learning, and reasoning (Baddeley, 1986, 2000; Daneman & Carpenter, 1980; Just & Carpenter, 1992; Osaka, 2002; Takano & Noda, 1993), as well as verbal communication. Baddeley (2000) proposes a multicomponent model, in which WM comprises an attentional control system—the central executive—together with three subsystems, namely, the phonological loop, the visuospatial sketchpad, and the episodic buffer. The phonological loop is assumed to be responsible for the manipulation of verbal-based information. It has two components: the phonological store and the articulatory rehearsal system. The visuospatial sketchpad is assumed to be responsible for manipulating visual and spatial information. The episodic buffer is assumed to form a temporary storage system that allows information to flow from the subsystems to be combined with that from long-term memory into integrated chunks. The central executive function is responsible for controlling the other three subsystems as well as regulating and coordinating all of the cognitive processes involved in the WM performance (Baddeley, 2000, 2003).

It is well known that there are individual differences in the WM capacity. One of the most used means of measuring WM capacity is a complex span paradigm that requires the examinee to concurrently perform a secondary task that limits the use of an arbitrary strategy and adds to the WM load (Baddeley, 1986; Baddeley & Hitch, 1974; Conway et al., 2005; Daneman & Carpenter, 1980; Dehn, 2008). The typical complex span paradigm for measuring WM capacity includes a reading span test (RST; Daneman & Carpenter, 1980), a counting span test (Case et al., 1982), an operation span test (Turner & Engle, 1989), and a spatial span test (Shah & Miyake, 1996). These can respectively measure various aspects of the WM system.

WM in PWS

Various experimental paradigms have been used to measure WM abilities of PWS, such as rhyme judgment, letter recall, and phoneme monitoring (Bosshardt et al., 2002; Jones et al., 2012; Sasisekaran & Basu, 2017). In particular, nonword repetition task and dual task have been repeatedly employed in previous studies (Anderson & Wagovich, 2010; Anderson et al., 2006; Arends et al., 1988; Bosshardt, 1993, 1999, 2002; Bosshardt et al., 2002; Byrd et al., 2015, 2012; Eichorn et al., 2016, 2019; Hakim & Bernstein Ratner, 2004; Kamhi & McOsker, 1982; Metten et al., 2011; Sasisekaran, 2013; Vasić & Wijnen, 2005).

Studies using a nonword repetition task purposefully exclude confounding factors such as semantics and pragmatics in order to solely focus on the phonological aspects of WM (Anderson & Wagovich, 2010; Anderson et al., 2006; Bosshardt, 1993; Byrd et al., 2015, 2012; Hakim & Bernstein Ratner, 2004; Sasisekaran, 2013). The errors and other parameters are studied for the repeated nonwords of various syllable lengths in these studies. Some studies did not detect a group difference on a nonword repetition task between children (Bakhtiar et al., 2007; Sasisekaran & Byrd, 2013; Smith et al., 2012) or adults (Sasisekaran, 2013; Smith et al., 2010) who stutter and do not stutter. However, other studies found that children who stutter produced significantly fewer correct responses for nonword repetitions than children who do not stutter (Anderson & Wagovich, 2010; Anderson et al., 2006; Hakim & Bernstein Ratner, 2004; Oyoun et al., 2010; Pelczarski & Yaruss, 2016; Spencer & Weber-Fox, 2014). Some other studies reported that adults who stutter produced significantly less accurate nonword repetitions than adults who do not stutter (Byrd et al., 2015, 2012; Coalson & Byrd, 2017; Ludlow et al., 1997; Sasisekaran & Weisberg, 2014). Although the discrepancy among those studies cannot be well explained, most of the results indicate the existence of a deficit in the WM of PWS. However, since those nonword repetition tasks did not involve semantics or pragmatics, it is not clear to what extent the deficit is relevant to the complex nature of the handicap that PWS experience in daily conversation.

Regarding the fluency performance, a reduction of disfluencies during dual-task conditions is reported (Arends et al., 1988; Bosshardt, 1999; Eichorn et al., 2016; Vasić & Wijnen, 2005), even with no significant group differences in the secondary-task performance between PWS and people who do not stutter (PWNS) in some of the dual-task paradigms (Bosshardt, 1999; Bosshardt et al., 2002; Eichorn et al., 2016, 2019). In these studies, while the primary task (speech) is in the verbal domain, the secondary tasks are in a different domain, such as spatial and mental arithmetic tasks. However, increases (Bosshardt, 2002; Metten et al., 2011) or no change (Bosshardt et al., 2002; Kamhi & McOsker, 1982) in the stuttering rate are also reported in comparison to single-task performances. Reasons for the discrepancy may include differences in the relative difficulty (e.g., too simple secondary movement task in Kamhi & McOsker, 1982; too demanding Stroop test in Caruso et al., 1994) and degrees of interference between the two tasks (both tasks in the same verbal domain; Bosshardt et al., 2002; Metten et al., 2011), as "the speech-production system of PWS makes it more vulnerable to interference from concurrent attention-demanding" tasks. The apparent discrepancy in the direction of change in stuttering rates may be summarized as that disfluencies decrease or stay the same if the secondary task does not involve the speech production system simultaneously and if the primary task is not too demanding (Arends et al., 1988; Bosshardt, 2002; Eichorn et al., 2016, 2019; Metten et al., 2011).

Theoretically, inattention to own speech could enhance fluency, as typically seen during talking alone to oneself. Thus, some of the dual tasks, with little interference between the tasks, result in a reduction of attention to the speech task and, consequently, in less disfluencies (the "regression" hypothesis; Arends et al., 1988; Eichorn et al., 2016, 2019). The hypothesis assumes that, while the automatized speech becomes fluent even in PWS, as in talking to oneself without audience, "regress to a controlled way of speech production" during a single task results in increased disfluencies. (Note: The "control" in this context denotes the conscious and active attempts to manipulate/modify otherwise implicit articulation, vocalization, and respiration processes in real time during speech, which is unrelated to the executive "control" of WM.) On the other hand, a more complex speech task would overload the assumed insufficient phonological capability of PWS, as shown in nonword repetition tasks (see above) and disrupt the otherwise automatized fluent speech, which calls for attended motor control of production and may yield more disfluencies (the "overload" hypothesis; Arends et al., 1988). However, both of the seemingly alternative hypotheses of Arends et al. (1988) have in common the relationship between the attentional focus on the speech motor process and the increase in disfluencies. The relationship may also underlie the novelty effect or distraction on temporary fluency enhancement (Bloodstein & Bernstein Ratner, 2008). Excessive attentional focus on well-learned motor sequences can break the automatized fluid performance due to dechunking of the sequence into effortful movement patterns (Wulf & Lewthwaite, 2010, 2016). When the task load could be adjusted by individual participants, no change in stuttering rates may be observed between single- and dual-task conditions (Bosshardt et al., 2002, pp. 267–273). In order to understand the relationship between fluency and task complexity, one must also be cautious about the individual variability in the capacities of speech production command WM strategies and attentional focuses, as well as the interference levels and relative difficulties between the concurrent tasks. In this study, using the RST paradigm, attentional focuses were controlled with a simple oral reading task, individual task performances were measured with stepped difficulty levels, and the effects of different strategies were investigated.

RST and the Strategy

In a natural, conversational situation, one has to think and say at the same time what one wants to communicate effectively. Properly assessing such a multitasking ability requires the measurement of the central executive related to the allocation of attentional resources. In order to investigate the WM related to language processing, we employed the RST (Daneman & Carpenter, 1980). In the RST, the subjects are required to read aloud a series of unrelated sentences while target words in respective sentences are to be remembered for later recall (Daneman & Carpenter, 1980; Just & Carpenter, 1992; Osaka, 2002; Osaka & Osaka, 1992). The additional cognitive load for the primary task (memorization) may make PWS shift their attention away from the conscious control of speech motor production (articulation, vocalization, and respiration) for reading aloud (the secondary task), which is expected to result in more fluent speech than simple oral reading, similar to other dual-task conditions described above.

The RST score is affected by the effectiveness of the employed strategies for maintaining target words. The strategies have been categorized into effective (e.g., creating mental images, creating stories, relating words to personal experience) and less effective (verbal rehearsal or "doing nothing"; Bailey et al., 2008; Friedman & Miyake, 2004; Kaakinen & Hyönä, 2007; McNamara & Scott, 2001). Since the RST measures the WM performance during multitasking, the investigation of the relationship between its performance and that of the strategies taken would likely give a more ecologically relevant indication of the functioning of WM in real-life situations than simple span tests. However, to the best of our knowledge, no previous study has utilized the RST to investigate the WM capacity of PWS.

Purpose and Rationale of This Study

As shown in Eichorn et al. (2016), the frequency of disfluencies of spontaneous speech is reduced under the dual-task condition. Although speech production during the RST is not spontaneous, the disfluencies in the RST may be reduced similarly. Eichorn et al. (2019) showed that the disfluency rates were similar between two different (spatial and mathematical) tasks that took attention away from the speech motor control of concurrent spontaneous speech. Because the phonological WM of PWS has certain limitations (Byrd et al., 2015, 2012; Coalson & Byrd, 2017; Ludlow et al., 1997; Sasisekaran & Weisberg, 2014), an interesting and clinically important question is raised: Which is the more relevant factor for the reduction of disfluencies—WM capacity or the attentional shift away from speech motor control? In order to answer the question, either WM capacity or attention should be independently manipulated while WM capacity and rate of disfluencies are measured, which would be possible with the RST. Therefore, first, we investigated whether the rate of SLD was reduced in the RST, compared with that in a simple reading aloud task. Second, since the RST score is influenced by the strategy (Osaka et al., 2012), we investigated the strategies chosen for the RST by PWS and PWNS in order to learn whether the assumed smaller WM capacity of PWS was due to their phonological or other speech motor deficits or to the use of the less effective strategy. Finally, in order to differentiate the effects of the central executive of WM, including attentional control, and WM capacity, WM capacity was manipulated by changing the strategies for the RST for the same individuals, and any corresponding changes in the disfluency rate were investigated.

Method

Participants

Twenty-six PWS (22 men, four women; 19–38 years of age) and 24 PWNS (14 men, 10 women; 19–37 years of age) participated in the study. The participants were native speakers of Japanese. They were recruited via the home page and flyers of the National Rehabilitation Center for Persons with Disabilities in Japan. The summary background information of the participants is shown in Table 1. A Mann–Whitney U test revealed no significant age difference between the two groups, $Z = 1.31$, $p = .19$. There was a nonsignificant difference in the male-to-female ratios between the two groups (Fisher's exact test, $p = .06$). Due to the small number of female subjects in the PWS group, no statistical comparisons were performed between the gender groups. Since the RST score was not significantly different between the males and the females in the PWNS group, $t(22) = -0.56$, $p = .58$, it is assumed that the different male-to-female ratios did not significantly affect the results of this study.

All participants in the PWS group stated that they had stuttered since childhood and had no history of speech-language, hearing, or neurological disorders except stuttering. They were diagnosed with developmental stuttering prior to the experiment by a specialized physician (fourth author) and a speech-language pathologist (second author). The stuttering frequencies and severity were assessed by the Japanese Standardized Test for Stuttering (Ozawa et al., 2013). The stuttering assessment in this study included the frequency of SLD (part-word repetitions, prolongations, and blocks) in oral reading, scene descriptions, and spontaneous speech. The individual SLD during the stuttering assessment are shown in Table 1. To understand the participants' characteristics and profiles, 24 PWS over the age of 20 years answered the Japanese version of the Overall Assessment of the Speaker's Experience of Stuttering for Adults (OASES-A-J; Sakai et al., 2017; Yaruss & Quesal, 2010). The OASES-A-J is a questionnaire for measuring the impact of stuttering on a person's quality of life, including (a) general perspectives about stuttering; (b) affective, behavioral, and cognitive reactions to stuttering; (c) functional communication difficulties; and (d) the impact of stuttering on the speaker's quality of life (Sakai et al., 2017; Yaruss & Quesal, 2010). As shown in Table 1, the degrees of severity of the OASES-A-J ranged from mild-to-moderate to severe levels. Informed written consent was obtained from all participants prior to the experiment in accordance with the protocol approved by the National Rehabilitation Center for Persons with Disabilities Review Board in Japan.

Materials

The Japanese version of the RST (Osaka, 2002) was administered to measure the participants' WM capacity. The RST included a total of 70 short sentences that had been collected from Japanese high school textbooks (Osaka & Osaka, 1992). There were 20–30 characters per sentence written in a mixture of Kanji (Chinese characters) and Kana (Japanese syllabary) as in orthographic Japanese writings (see Figure 1 for examples). Kanji symbols were originally imported from China, and some were created in Japan. Most content words in Japanese are written in Kanji even though they are pronounced with the Japanese phonetic sounds represented by Kana. In Figure 1, the characters "農民，稲，麦，豊，実，期待，男，会議，熱弁，警告，発，彼，下宿，寝，知，聞，起" are Kanji characters, whereas the others are Kana characters, which represent respective single syllables. Inflectional parts of content words are also written in Kana. Since Japanese orthography does not include spaces between words, starting content words with Kanji provide convenient demarcation. The Japanese version of the RST consisted of 451 *bunsetsu* in total. (Note: *Bunsetsu* represents a grammatical unit of the shortest independent phrases comprising a single content word and optional function words that make Japanese sentences.)

The participants were required to read aloud one sentence at a time and to remember the target word (content word) underlined in red in each sentence, as shown in Figure 1. The procedure is different from that in Bosshardt's (2002) study, in which concurrently presented target words were different from the orally repeated words. Thus, the competition for a single resource ("overloading"; Arends et al., 1988) at the time of target presentation is unlikely in the RST. In the original version of the RST (Daneman & Carpenter, 1980), participants were asked to recall the last words of respective sentences. However, since the last content word of a sentence is almost always a verb in Japanese, the target word in the Japanese version of the RST was made to be located at a random position in a sentence, which enables a target word to be any of the following: a noun, a verb, an adverb, or an adjective (Osaka & Osaka, 1992). The Japanese version of the RST included two to five sentence levels. Each sentence level has five trials. There was no semantic relationship among the sentences, and there were no semantic or phonetic similarities among the target words within each trial. Trials of the same levels were chunked together, and administered in order of increasing levels, without randomization. Since each level consists of five trials, there were 10 sentences in total in the "two sentences" level, 15 sentences in the "three sentences" level, 20 sentences in the "four sentences" level,

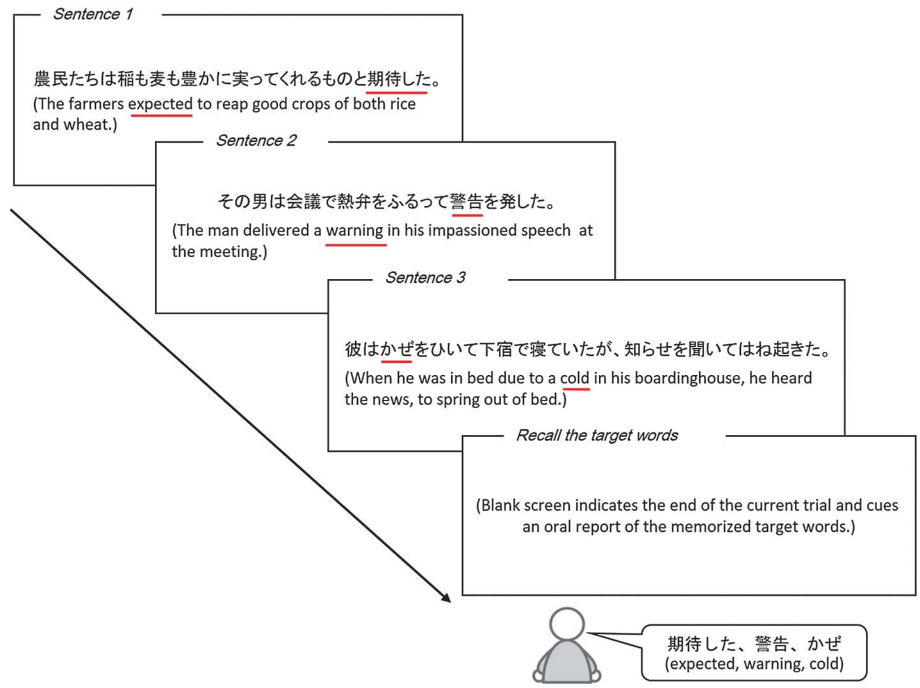
Table 1. Participant characteristics.

Participant	Age	Gender	Educational level	Frequency of stuttering-like disfluencies in the reading aloud task	The range of stuttering-like disfluencies in the Standardized Test for Stuttering	OASES-A-J severity
PWS 1	19	F	US	10.4	2.7–38.0	N/A
PWS 2	23	M	BA	10.4	0.0–8.7	Mild-to-moderate
PWS 3	23	M	BA	20.0	15.0–38.0	Moderate-to-severe
PWS 4	23	M	BA	8.9	4.0–43.2	Moderate
PWS 5	38	M	BA	17.0	6.0–51.5	Mild-to-moderate
PWS 6	25	M	HS	11.1	6.0–18.9	Moderate-to-severe
PWS 7	20	F	BA	13.3	6.1–27.5	Moderate
PWS 8	21	M	HS	9.6	10.0–20.5	Moderate-to-severe
PWS 9	29	M	BA	4.4	0.9–6.0	Moderate
PWS 10	34	M	BA	3.0	2.0–37.5	Moderate
PWS 11	29	M	BA	3.7	2.0–12.0	Moderate
PWS 12	19	M	US	3.0	10.0–22.0	Moderate-to-severe
PWS 13	22	M	US	0.0	0.0–3.0	Moderate
PWS 14	33	M	BA	1.5	1.0–22.0	Mild-to-moderate
PWS 15	31	M	BA	0.7	0.0–4.2	Moderate
PWS 16	37	M	BA	1.5	0.0–12.1	Moderate
PWS 17	37	F	BA	1.5	1.8–3.0	Moderate
PWS 18	24	M	BA	0.7	1.1–3.2	Mild-to-moderate
PWS 19	19	F	US	3.0	3.2–4.2	N/A
PWS 20	32	M	BA	1.5	4.0–12.6	Moderate-to-severe
PWS 21	29	M	BA	0.0	12.0–21.3	Severe
PWS 22	23	M	BA	1.5	0.0–6.1	Moderate
PWS 23	37	M	HS	2.2	1.4–12.0	Moderate-to-severe
PWS 24	22	M	BA	0.0	0.0–29.4	Moderate
PWS 25	38	M	BA	0.0	2.0–9.3	Mild-to-moderate
PWS 26	26	M	HS	4.4	10.0–24.6	Moderate-to-severe
PWNS 1	19	M	US	0.0	N/A	N/A
PWNS 2	21	F	US	0.0	N/A	N/A
PWNS 3	22	F	US	0.0	N/A	N/A
PWNS 4	24	M	BA	0.0	N/A	N/A
PWNS 5	23	F	BA	0.0	N/A	N/A
PWNS 6	37	M	PhD	0.0	N/A	N/A
PWNS 7	24	M	HS	0.7	N/A	N/A
PWNS 8	28	M	BA	0.0	N/A	N/A
PWNS 9	23	M	BA	0.0	N/A	N/A
PWNS 10	32	F	BA	0.0	N/A	N/A
PWNS 11	24	M	BA	0.0	N/A	N/A
PWNS 12	23	F	BA	0.0	N/A	N/A
PWNS 13	23	M	BA	0.7	N/A	N/A
PWNS 14	21	M	US	0.0	N/A	N/A
PWNS 15	21	M	US	0.0	N/A	N/A
PWNS 16	24	M	BA	0.0	N/A	N/A
PWNS 17	23	M	BA	0.7	N/A	N/A
PWNS 18	23	M	BA	0.0	N/A	N/A
PWNS 19	20	F	BA	0.0	N/A	N/A
PWNS 20	37	M	PhD	0.0	N/A	N/A
PWNS 21	23	F	BA	0.0	N/A	N/A
PWNS 22	30	F	BA	0.7	N/A	N/A
PWNS 23	20	F	BA	0.0	N/A	N/A
PWNS 24	25	F	BA	0.0	N/A	N/A

Note. OASES-A-J = Japanese version of the Overall Assessment of the Speaker's Experience of Stuttering for Adults; PWS = people who stutter; F = female; US = undergraduate student; N/A = not applicable/available; M = male; BA = Bachelor of Arts; HS = high school; PWNS = people who do not stutter; PhD = Doctor of Philosophy.

and 25 sentences in the "five sentences" level. The end of the reading and memorizing part of each trial was indicated by the appearance of a blank screen (see Figure 1). The participants were asked to recall and orally report the two to five target words after each trial of reading sentences, whose number depended on the level. They were prohibited from reporting the last target word first within each trial, in order to mitigate the recency effect of recall. Figure 1 shows an example of one trial at the "three sentences" level.

Figure 1. An exemplary procedure of one trial at the "three sentences" level in the reading span test (RST). The example sentences are from the Japanese version of the RST (Osaka, 2002). The English texts in parentheses are the translations of respective Japanese sentences.



The RST score was the total number of words correctly recalled summed across all trials (Friedman & Miyake, 2005). Since there were 70 sentences in the RST, the maximum possible score was 70.

In the reading aloud task, participants were required to read aloud a meaningful text (see Appendix) meant for an introductory Japanese course as a second language and chosen from the study of Arongna et al. (2015), which was unrelated to the reading material in the Japanese Standardized Test for Stuttering (Ozawa et al., 2013) or the sentences used in the Japanese version of the RST (Osaka & Osaka, 1992). It consisted of 26 sentences, with 135 *bunsetsu*. The text and its English translation are provided in the Appendix. The frequency of SLD of the participants in the reading aloud task is shown in Table 1.

Procedure

All participants sat alone comfortably in front of a liquid crystal display (screen size: 43.5 cm × 27.5 cm, E207WFPC, Dell) to perform the reading aloud task and the RST in a sound-attenuated room individually. The sentences of the RST were displayed one by one on the liquid crystal display by a computer (Precision T5400, Dell). The distance between the participant and the display was approximately 65 cm. The speech of the participant was recorded with an audio recorder (DR-680, TASCAM) through a microphone (HSC271, AKG).

After the first RST session, the participants indicated which strategy they used in order to remember the target words during the RST. Those who reported to have used no strategy or rehearsal of the target words were categorized as a "rehearsal" strategy group, whereas those who reported to have used semantic- or episodic-based strategies (e.g., creating stories and/or mental images of the target words) were classified as an "imagery" strategy group. Additionally, to verify whether the "imagery" strategy would enhance WM capacity, those who reported to have used the "rehearsal" strategy in the first session were asked to perform another RST (second session), but, this time, with the "imagery" strategy. Due to a time limitation, four participants in the PWS group and one participant in the PWNS group did not participate in the second RST. Furthermore, the six PWS who performed the second session on the same day and the eight PWS who did the same at intervals of 1–9 months were compared for determining whether the second session was affected by the practice effect of the task or the change of the strategies.

Data Analysis

The SLD in the reading aloud task and the RST were identified and counted according to the Japanese Standardized Test for Stuttering (Ozawa et al., 2013). The frequency of SLD per 100 *bunsetsu* was calculated. The interrater reliability for SLD was assessed with six randomly selected speech samples (three from the RST and three from the reading aloud task, totaling 1,758 *bunsetsu*). According to the calculus equation from the study of Sander (1961), the reliability percentage was 91.4%.

To normally distributed data, analysis of variance (ANOVA) was applied for the comparison between groups as implemented in R (Version 3.0.2, CRAN), with a significance level at 5%. To nonnormally distributed data, Wilcoxon signed-ranks tests and the Mann–Whitney *U* test were applied for comparing the frequency of SLD. Fisher's exact probability test was used to compare the proportions of the two strategy users in the PWS and PWNS groups.

Results

Comparison of the SLD in the Simple Reading Task and the RST

The box plots of SLD in the reading aloud task and the RST of PWS are shown in Figure 2. The SLD were significantly reduced in the RST (*Mdn* = 1.01) than in the reading aloud task (*Mdn* = 2.96; Wilcoxon signed-ranks test, $p < .01$). We found that six PWS showed less than 1% SLD in the reading aloud task, whereas 12 PWS showed less than 1% SLD in the RST.

The Strategies Used and the Task Performance During the RST

The strategies used during the RST were found different between the PWS and PWNS groups. Only eight out of 26 PWS (31%) reported to have used the "imagery" strategy, whereas 16 out of 24 PWNS (67%) reported to have used the "imagery" strategy during the RST. The proportion of those who used the "imagery" strategy was significantly greater in the PWNS group than in the PWS group (Fisher's exact test, $p = .02$).

The RST scores of those who used a "rehearsal" strategy (PWS: $M = 37.9$, $SD = 4.3$; PWNS: $M = 40.1$, $SD = 4.8$) and of those who used an "imagery" strategy (PWS: $M = 53.6$, $SD = 6.8$; PWNS: $M = 53.7$, $SD = 6.8$) are shown in Figure 3. A two-way ANOVA with group (PWS, PWNS) and strategy ("rehearsal," "imagery") revealed only a significant main effect of strategy, with the users of the "imagery" strategy scoring higher than those who used the "rehearsal" strategy, $F(1, 46) = 71.52$, $p < .001$. There was no significant main effect for group, $F(1, 46) = 0.44$, $p = .51$, and no interaction between group and strategy, $F(1, 46) = 0.39$, $p = .53$.

The frequency of SLD of 18 "rehearsal" strategy users and eight "imagery" strategy users in the PWS group is shown in Figure 4. There was no significant difference between the two subgroups of the PWS group (Mann–Whitney *U* test, $U = 47$, $p = .17$).

Does Imagery Enhance WM Capacity?

The average RST scores in the first session with the "rehearsal" strategy and in the second session with the "imagery" strategy are shown in Figure 5. A two-way ANOVA with group (PWS, PWNS) and session (first, second) revealed significant main effects for group, $F(1, 19) = 6.48$, $p = .02$, and session, $F(1, 19) = 79.67$, $p < .01$. There was no significant interaction between group and session, $F(1, 19) = 2.25$, $p = .15$.

The RST scores of the PWS in the first and second sessions performed on the same day and on different days are shown in Table 2. A two-way ANOVA with group (same day, different day) and session (first, second) revealed a significant main effect for session only, $F(1, 12) = 29.66$, $p < .01$. There was no significant main effect for group, $F(1, 12) = 1.30$, $p = .27$, or interaction, $F(1, 12) = 0.24$, $p = .63$. Those results suggest that the higher score in the second session was affected by the "imagery" strategy, but not by the practice effect of the task.

Figure 2. The stuttering-like disfluencies (SLD) of people who stutter in the reading aloud task and the reading span test (RST). Small circles represent individual participants' data.

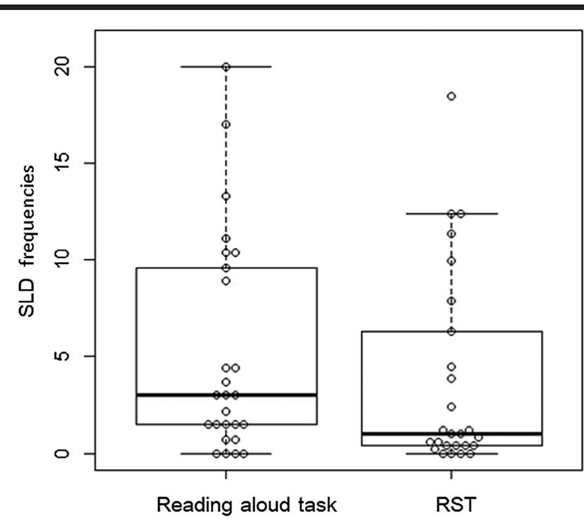


Figure 3. The reading span test (RST) scores of the users of "rehearsal" and "imagery" strategies. Error bars represent the standard error of the mean. PWS = people who stutter; PWNS = people who do not stutter.

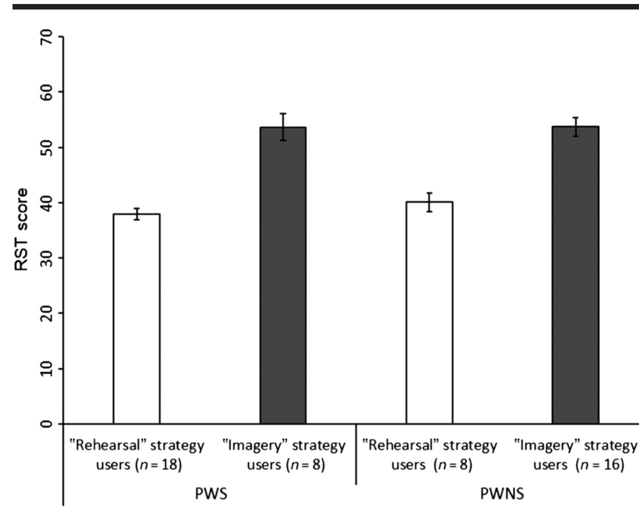
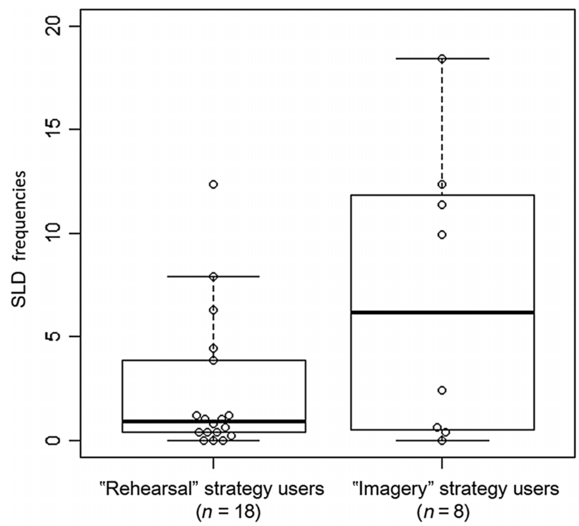


Figure 4. The frequency of stuttering-like disfluencies (SLD) of those who used the “rehearsal” and “imagery” strategies in the group of people who stutter. Small circles represent individual participants’ data.



The frequency of SLD of the PWS in the “rehearsal” strategy and “imagery” strategy categories was calculated (the same subjects as shown in Figure 5); there was no significant difference between the frequency of the two strategy groups (Wilcoxon signed-ranks test, p = .93). Figure 6 shows the box plots of SLD with two different strategies of 14 PWS.

Figure 5. The reading span test (RST) scores before and after the instruction of “imagery” use for those who used a “rehearsal” strategy in the first session. Error bars indicate standard errors of the mean. PWS = people who stutter; PWNS = people who do not stutter.

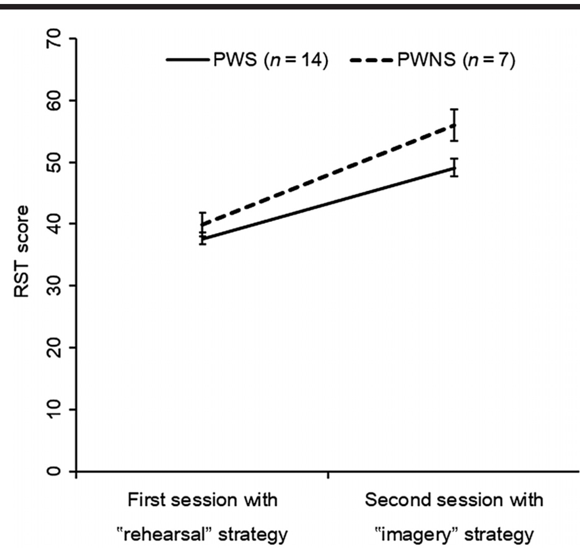


Table 2. The mean reading span test scores (*SD*) by the performed day.

Group	First session with the “rehearsal” strategy	Second session with the “imagery” strategy
“Same day” group (n = 6)	39.2 (2.5)	49.5 (5.3)
“Different day” group (n = 8)	36.5 (3.6)	48.9 (5.3)

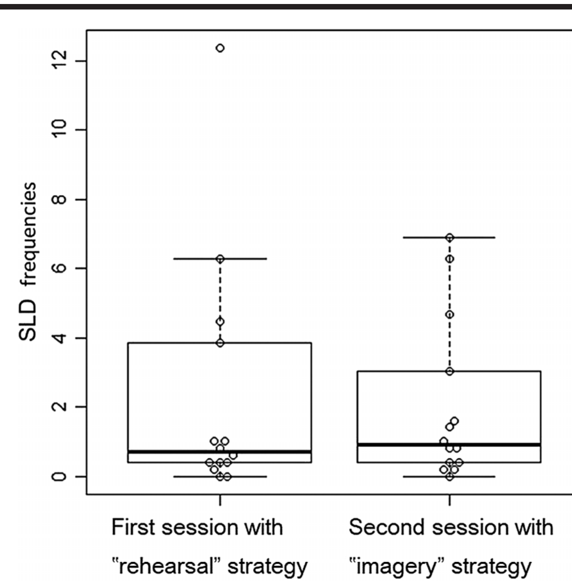
Discussion

In this study, we have investigated the disfluencies and strategies in a WM task (RST). The results show (a) that PWS significantly reduced their SLD in the RST compared to those in the simple reading aloud task, (b) that the strategy used by the majority of the PWS was different from that used by the majority of the PWNS in the RST, (c) that “imagery” strategy users showed significantly higher scores than “rehearsal” strategy users in either group, (d) that switching to the “imagery” strategy enhanced the WM capacity for both the PWS and the PWNS, and (e) that the frequency of SLD did not change significantly with the strategies taken.

Factors Contributing to Reduction of Disfluencies in Dual Tasks

Previous studies have shown that PWS reduced their disfluencies during dual-task conditions if the primary task did not involve overloading speech output (Arends et al., 1988; Bosshardt, 1999; Eichorn et al., 2016; cf. Bosshardt, 1999, 2002; Caruso et al., 1994; Metten et al., 2011), which our result reconfirmed (see Figure 2). Almost half of our

Figure 6. The frequency of stuttering-like disfluencies (SLD) of people who stutter, before and after the instruction of “imagery” use for those who used a “rehearsal” strategy in the first session. Small circles represent individual participants’ data.



participants (12 out of 26 PWS) showed less than 1% SLD during the RST. In this study, since different reading materials were used in the reading aloud task (a long but simple text at the introductory Japanese level) and in the RST (short sentences from high school textbooks), it is unlikely that the more fluent speech in the latter was influenced by the former (practice or habituation effect) or attributable to the different levels of difficulty of the texts. As shown in the previous studies, the different characteristics of the two tasks are the only logical explanation for the resultant stuttering rates. During the reading aloud task, participants are asked to just read aloud the text, which would allow the PWS to "regress to a controlled way of speech production" (Arends et al., 1988). Their attention to speech motor control is habitual in oral reading as well (Iimura et al., 2016). The consciously attended speech motor performance would be less fluent at least for some PWS than the automatic fluent speech, as experienced during talking alone by most PWS. Although automaticity with incidental fluency may break if the speech material is too complex or too difficult for PWS ("overload" in Arends et al., 1988; Bosshardt, 2002; Metten et al., 2011), this was not the case with the reading materials used in this study. Other possible compounding factors influencing automaticity are the task design and the relative difficulty between the two concurrent tasks, which affect the placement of the focus of attention. If verbal interference between the tasks exists or if the primary task is too simple or sequential to the secondary speech task, conscious attentional focus could remain on, or return to, speech control in an attempt to remain fluent. This could explain the discrepant task-dependent changes in stuttering rates in some other studies (Bosshardt et al., 2002; Kamhi & McOsker, 1982).

Since the RST measures the ability to process and store information during oral reading, the resultant cognitive load is heavier than a simple reading aloud task. Under such heightened cognitive load, PWS may not have enough mental resource left to control or pay due attention to their speech motor function as they otherwise would like to do. Taking attention away from own speech motor may cause more fluent speech (Arends et al., 1988; Eichorn et al., 2016, 2019), which could have important implications for the treatment of stuttering. Whereas the reduction of the experiential "loss of control" should be addressed for the long-term efficacy of stuttering therapy (Guntupalli et al., 2006), the results of the dual-task paradigm suggest that consciously attended control of speech produces more disfluencies than automatized fluent speech production, as long as the attentional focus is on the concurrent nonspeech task, be it lexical, memory, or cognitive (Arends et al., 1988; Bosshardt, 1999; Eichorn et al., 2016, 2019; Vasić & Wijnen, 2005; the current study).

Strategy Choices and Scores of the RST

The proportions of "rehearsal" strategy users and "imagery" strategy users were found markedly different between the PWS and the PWNS. That 67% of the PWNS reported to have used the "imagery" strategy is comparable to the studies of Osaka and Nishizaki (2000) and McNamara and Scott (2001). In Osaka and Nishizaki (p. 215), a total of 67 out of 101 (66%) undergraduate and graduate students reported to have used a strategy of creating stories or imagery during the RST. In McNamara and Scott (p. 14), a total of 38 out of 60 (63%) university students reported using a semantic strategy or a rehearsal-and-semantic strategy. In stark contrast, a majority of the PWS employed the verbal "rehearsal" strategy, which may well stem from their habitual and often anxious focus on speech motor behavior during oral reading and speaking (Iimura et al., 2016; Kamhi & McOsker, 1982; Vanryckeghem et al., 2004). However, the exact reason(s) for the greater tendency toward this unintuitive, less effective choice of strategy among PWS remain to be explored, especially because it limits WM capacity and yet is not a mandatory choice in the RST, as discussed below.

The type of strategies employed was shown to have influenced the RST score as in Figure 3, which is essentially a replication of the previous finding that those who used the "imagery" strategy performed better than those who used the "rehearsal" strategy in the RST (Bailey et al., 2009; Endo & Osaka, 2012; Friedman & Miyake, 2004; Kaakinen & Hyönä, 2007; McNamara & Scott, 2001; Osaka & Nishizaki, 2000; Osaka et al., 2012). This study confirmed that it also applies to PWS. The reason for the higher RST scores when using the "imagery" strategy can be explained by Baddeley's model. Since the "imagery" strategy for storing target words resorts to the visuospatial sketchpad, it would not be interfered by the sentences reading subtask during the RST. However, the "rehearsal" strategy would be interfered by the sentences reading subtask, since it resorts to the same phonological loop.

The new finding of this study is that the RST score depends on the strategy even in the same individuals. All participants who had used the "rehearsal" strategy in the first RST session obtained a higher score in the second session when they were instructed to employ the "imagery" strategy (see Figure 5). The scores of the second session increased whether performed on the same day or performed a few months later, which likely excludes the possibility of the practice effect on the second RST session. Those results indicate that the strategies for the RST can be changed at will by individuals and that the "imagery" strategy is more efficient than the "rehearsal" strategy for the RST, whether one stutters or not. The increased WM capacity could be used to enhance the quality of communication in daily situations.

WM Capacity and Disfluencies

Because the rate of SLD during the RST was not affected significantly either by the difference between the strategy groups (see Figure 4) or by the different strategies in the same individuals (see Figure 6), it is now unlikely that the difference in WM capacity, as measured with the RST, plays a major role in stuttering frequency (Sasisekaran, 2013; Smith et al., 2010). Eichorn et al. (2019) similarly found nondifferent rates of disfluencies between two different dual tasks (spatial and mathematical tasks during spontaneous speech), which were still significantly lower than that of spontaneous speech without a simultaneous, attention-depriving task. The present results reaffirm the hypothesis that the level of conscious attention on speech motor control contributes significantly to disfluencies, as discussed above. The result that some of the PWS retained more than 3% of SLD in the RST (see Figure 2) may also be explained by their insufficient attentional shift away from speech motor control. However, this assumption needs verification with the independent measure or estimate of the individual's attention allotment on speech motor control.

Clinical Implications

The findings of this study have several clinical implications. The attentional shift away from speech control results in improved fluency or even near-complete fluency in the majority of the PWS, as shown in Figure 2. Although the current experimental setting required an artificial target of attention, existing evidence indicates that it can be of any kind, as long as it "distracts" sufficient attention from speech control (Bloodstein & Bernstein Ratner, 2008, pp. 267–273; Eichorn et al., 2019). Such mechanism should also mediate the treatment efficacy of emphasizing prosodic focus (Dahm, 2010) and speech shadowing (Andrews et al., 1982; Arongna et al., 2015, 2018) to a certain degree. Direct intervention on attentional control using mindfulness meditation may be a useful addition to therapy (Silverman, 2012). Since traditional speech therapies, such as fluency shaping and stuttering modification, ask the client to focus on speech motor control at least during the introduction phase (Guitar, 2013), they might deter the automatization of speech motor control and, thus, the transfer outside the clinic. A combination of the dual-task paradigm and speech therapy could be beneficial, for a smoother transition to daily life situations (Metten et al., 2011).

Because simple distractors are habituated easily and become less effective in reducing disfluencies (Bloodstein & Bernstein Ratner, 2008), especially when tension and anxiety are high, more persistent and useful "distractors" should be sought in therapy. As such, the contents and manner of delivery of messages could be emphasized, which are unlikely to be habituated easily because they are always fluid. Since they would improve the quality of communication as well, they make ideal "distractors" of attention from stuttering. However, many PWS attend to speech motor control because they are insecure about the stuttering, which makes a vicious cycle. In order to break the cycle, PWS have to learn how attentional focus actually affects fluency against their experiential belief.

The nonsignificant effect of WM capacity on fluency implies that the reported smaller WM capacity may not contribute much to the disfluencies. However, enhancing WM capacity by switching strategies could lead to a better understanding of the reading material without noise masking (Iimura et al., 2016). It also may help improve the communicative effectiveness of speech if the increased WM capacity can be allocated to the processing of the pragmatics and eloquence of speech.

Limitations

This study does not directly assess WM during spontaneous speech due to the use of the RST. Thus, the applicability of this study to spontaneous speech is unknown. However, the influence of attention on spontaneous speech is shown by Eichorn et al. (2019).

The strategies during the RST were taken as declared by the participants. The consistent change in the RST scores with the strategy switching may be considered as verification of the overall accuracy of their introspection.

The focus of attention of the participants was not measured but inferred. For the reading aloud task, no instruction was given to or not to attend to the contents of reading text, which may have contributed to the large variance of the disfluency rate (see Figure 2). Although the participants were instructed to maximize the number of correctly remembered words in the RST, the exact amount of attention directed to speech motor control is not known. However, it is reasonable to assume that at least some amount of attention was diverted from speech motor control in order to meet the requirement of the dual task, compared to the simple oral reading task. The comparison of the oral reading task and the RST does not reveal the reason for the high proportion of PWS using the less efficient strategy in the RST, which warrants future study.

Conclusions

We found that PWS reduced their SLD in the RST compared to the simple oral reading task. Our study also found that 31% of the PWS used an "imagery" strategy, which was significantly smaller than the percentage for the PWNS (67%). The users of the "imagery" strategy scored higher than the users of the "rehearsal" strategy in both groups. Switching from the "rehearsal" strategy to the "imagery" strategy was shown to be possible for the same individuals, and it enhanced the WM capacity for both the PWS and the PWNS. However, the frequency of SLD of the PWS did not change by switching strategies. These results imply that the major contributor to the rate change of disfluencies in oral reading is not WM capacity but attentional focus on speech motor control.

For those who tend to limit themselves to the "rehearsal" strategy, the overall quality of communication may be enhanced without sacrificing fluency, by holding the contents of speech in imagery or in the semantic domain. It would then increase the total amount of available WM, which, in turn, may be taken advantage of for better pragmatics and manner of speech.

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Appendix

Reading Material for the Reading Aloud Task

The Text for the Reading Aloud Task (in Japanese)

私の家は，駅と学校の近くにあります.学生が多いところです.

私には弟が一人います.妹はいません.とても元気な弟で，去年，父のカップを割って怒られていました.今年は，私が学校で使っているテキストにペンで落書きをしました.言葉では大人しくならないので，困っています.父は八百屋で働いています.だから，ネクタイをつけません.風邪をひいた時には，おいしい果物を持って帰ってくれます.休みにはラジオを聴きながら，眼鏡をかけて本を読んでいます.弟と顔がよく似ています.

母は，いつも色のきれいなハンカチを持っています. 甘いものが大好きで，ケーキなら三つは食べます.私は一つで満足です.コーヒーにもスプーンで砂糖をたくさん入れます. 玄関と部屋の中では声が違います.私は変だなと思いますが，皆さんのお母さんはどうですか?

一昨日，私は友達と一緒に，地下鉄に乗って街へ遊びに行きました.私は電車の切符を集めることが好きです.手のひらからズボンのポケットへ，大切にしまいます.集めた数は， 二十枚ぐらいです.街には一昨年も行きました.でも，とても広いので，一日や二日だけでは充分な観光ができません.建物がいっいあって，迷子になりそうです.だから，来月の一日にも，またみんなと行く予定です.

English Translation of the Japanese Text for the Reading Aloud Task

My home is close to the station and the school. There we see many students. I have a younger brother. I do not have a sister. He is a very energetic boy. Last year, he got yelled at by our dad when he broke his cup. This year, he scribbled graffiti with a pen on one of my textbooks I used at school. He annoys me, because he does not behave as I tell him.

As my dad works in a greengrocer, he does not wear a tie. When I catch a cold, he brings home delicious fruits for me. On holidays, he reads books with glasses while listening to the radio. My brother resembles him in the face very much.

My mom always has a beautifully colorful handkerchief with her. She loves sweets, so much that she eats at least three pieces of cake at once. I get satisfied with only one. She puts many spoonful of sugar in coffee, too. She talks in a very different tone of voice inside the house and at the entrance. I think it is weird, but how about your mom?

The day before yesterday, I went to the city with my friends by subway. I like collecting train tickets. I put them from my palm to my pants' pocket with caution. I have collected as many as 20 tickets. I went to the city two years ago, too. It is too large to do enough sightseeing in a day or two. There are so many buildings that we could almost get lost. So, we plan to go there together again on the first day of the next month.