

Title

Teaching generalized reading and spelling to children with autism

Author names and affiliations

*Takayuki Tanji (First author)

*E-mail: tanji_takayuki2000@yahoo.co.jp

*Address: University of Tsukuba, Ibaraki, Japan

1-1-1, Tennoudai, Tsukuba-shi,

305-8572, Japan

*Tel: +81 90 2027 8667

*Fax: +81 29 853 6719

**Koske Takahashi (Second author)

**E-mail: kosuket77@gmail.com

*Address: University of Tsukuba, Ibaraki, Japan

1-1-1, Tennoudai, Tsukuba-shi,

305-8572, Japan

*Tel: +81 29 853 6755

***Fumiyuki Noro (Third author)

***E-mail: noro@human.tsukuba.ac.jp

***Address: University of Tsukuba, Ibaraki, Japan

1-1-1, Tennoudai, Tsukuba-shi,

305-8572, Japan

**Tel: +81 29 853 6719

**Fax: +81 29 853 6719

Corresponding author

For additional information about the study or reprint requests, contact Takayuki Tanji, University of Tsukuba, 1-1-1 Tennoudai, Tsukuba 305-8571, Ibaraki, Japan.

Tel: +81 90 2027 8667

Fax: +81 29 853 6719

E-mail: tanji_takayuki2000@yahoo.co.jp

ABSTRACT

We examined the effects that constructed-response matching-to-sample (CRMTS) training using a series of overlapping-syllable word sets has on establishing generalized reading and spelling skills in three Japanese children with autism. All participants were proficient at reading single letter and matching picture to spoken word but had difficulties with generalized reading and spelling. We taught them to construct printed words to match printed words, spoken words, and pictures through CRMTS procedure. The results showed that all participants exhibited skills in not only spelling of trained words but also derived reading comprehension (e.g., matching pictures to printed words). In addition, two participants performed well in generalized reading and spelling of untrained words. However, one participant was needed for an additional training procedure to establish generalized reading and spelling skills. We taught her to break a word into each syllable as a differential observing response to the sample in the CRMTS task. This procedure enabled the participant to establish generalized reading and spelling skills. The present study discusses the application of the CRMTS procedures using a series of overlapping-syllable word sets and differential observing responses is effective for acquisition of generalized reading and spelling skills in children with autism.

Keywords

generalized reading; generalized spelling; constructed-response matching to sample; matching to sample; stimulus equivalence; children with autism

1. Introduction

The stimulus equivalence paradigm has been applied to teach reading and spelling to individuals with intellectual disabilities (Sidman, 1971; Mackay, 1985). Stimulus equivalence is established through the matching-to-sample (MTS) procedure. When A1 (e.g., the spoken word /dog/) is presented as a sample stimulus, the participant is required to select B1 (e.g., a picture of a dog), and when A2 (e.g., the spoken word /cat/) is the sample, the participant is required to select B2 (e.g., a picture of a cat). Furthermore, when A1 is presented as a sample, the participant is required to select C1 (e.g., the printed word *dog*), and when A2 is the sample, the participant is required to select C2 (e.g., the printed word *cat*). MTS procedures may generate derived stimulus relations. That is, when B1 is presented as a sample, the participant without training may select C1, and when B2 is presented as a sample, the participant without training may select C2. Furthermore, when C1 is the sample, the participant may select B1, and when C2 is the sample, the participant may select B2. Such derived stimulus relations have been called stimulus equivalence (Sidman & Tailby, 1982).

Mackay (1985) reported that Constructed-Response Matching-to-Sample (CRMTS) procedure is effective for acquisition of reading and spelling skills. Mackay taught students with intellectual disabilities to name color patches and construct the appropriate color words when shown color patches using movable letters. For example, if the color patch “red” was presented as the sample stimulus, and the letters “r,” “e,” and “d” were presented as the comparison stimuli, the students would be required to select “r,” “e,” and “d” from a choice pool of letters in CRMTS task. After CRMTS training, the students matched printed words to color patches and

color patches to printed words and also named printed words. The training produced equivalence classes between the colors, printed names, and spoken names. These findings suggest that equivalence relations may integrate reading and spelling skills. Dube, McDonald, McIlvane, and Mackay (1991) and Stromer, Mackay, Howell, McVay, and Flusser (1996) developed a computerized instructional version of Mackay's CRMTS procedure. Vedora and Stromer (2007) reported that computerized CRMTS instruction led to improvements in reading and spelling performances of children with developmental disabilities who had difficulty reading and spelling.

In recent studies, Mueller, Olmi, and Saunders (2000) noted that at the word level, within-word and especially within-syllable units, which are crucial to generalized reading, could be considered while making the selection of word sets for a reading program. De Souza, de Rose, Faleiros, Bortoloti, Hanna, and McIlvane (2009) sought to encourage generalized reading and spelling in Brazilian children with developmental disabilities by teaching them to match printed syllables to spoken syllables and to construct words with syllables through computerized MTS and CRMTS procedures. These procedures were designed to establish generalized reading and spelling through multiple-exemplar training with a series of word sets with overlapping within-syllable units (e.g., BO + LO = *cake*, MA + LA = *suitcase*, PA + TO = *duck*). Following this training program, most children exhibited emergent skills matching novel printed words with pictures (i.e., reading with comprehension) and vice versa and in oral reading and spelling novel printed words to match spoken words (e.g., BO + LA = *ball*, MA + PA = *map*). As the children's repertoires of the trained and emergent relations expanded through multiple-exemplar training and

stimulus equivalence, they began to read and spell novel words and were able to acquire generalized reading and spelling skills. However, very few studies have examined the effect of CRMTS training with a series of word sets on generalized reading and spelling skill in children with autism. There is evidence that some children with autism can read accurately, but even amongst these children, level of reading comprehension are poor (Frith & Snowling, 1983). Schlosser and Blischak (2004) suggested that provision of multiple-exemplar training would be needed for generalized spelling in children with autism. Thus, a training package based on stimulus equivalence and recombination of syllable-units would be effective for learning generalized reading and spelling in children with autism.

The Japanese language is well suited to the above-mentioned training program. In the Japanese language, a letter (e.g., い, か, す) is represented as a syllable (e.g., [/i/], [/ka/], [/su/]), and Japanese words are comprised of syllable combinations (e.g., い+す [/i-su/] = *chair*, か+い [/ka-i/] = *shell*, す+い+か [/su-i-ka/] = *watermelon*). Letter-sound correspondence is very simple in Japanese language; however, children with intellectual disabilities and autism often have difficulty in acquisition of generalized reading and spelling skills. Some of children with intellectual disabilities and autism cannot read novel words with comprehension despite being able to read many printed letters (Dairoku, 1995). It is important for them to teach letter-sound correspondence in a word and break the word into each syllable. Therefore, the procedures proposed by de Souza et al. could be worth applying for Japanese children with intellectual disabilities and autism who have difficulty in acquisition of generalized reading and spelling skills.

Despite the potential efficacy of these procedures for the Japanese

language, few studies have examined the effect that CRMTS training with a series of word sets has on establishing the skills in generalized reading and spelling of novel words in Japanese. Shimizu and Yamamoto (2001) examined the effect of teaching such a word set on reading and spelling in Japanese in a child with mild intellectual disabilities. However, they did not study the effectiveness of a training program that uses a series of word sets in establishing generalized reading and spelling skills.

This study examined the effect of CRMTS training using a series of word sets on establishing generalized reading and spelling skills in Japanese children with autism. We taught three children with autism to construct printed word in response to printed word, spoken word or picture with a series of word sets, and examined whether generalized reading (e.g., match picture to printed word) and spelling (e.g., construct word to match spoken word) performances are shown in untrained word sets.

2. Method

2.1. Participants and setting

Ryo (aged 11), Taku (aged 9), and Miki (aged 9) were diagnosed with autism. We used a Japanese version of the Psychoeducational Profile-Revised (PEP-R) (Schopler, & Ibaraki, 1995), which is an instrument used to assess developmental level in children with autism and other developmental disorders, and to design individualized training plans for them (Shopler, Reichler, Bashford, Lansing, & Marcus, 1990). Their developmental ages measured by using a Japanese edition of PEP-R were 4.3, 2.11, and 4.4 years, respectively. And, we used Picture Vocabulary Test

(Ueno, Nadeo, & Iinaga, 1991), which is an instrument used to assess developmental level of receptive vocabulary in Japanese children. Their vocabulary ages measured by using Picture Vocabulary Test were 4.0, 2.2, and 2.8 years, respectively. Ryo and Taku could speak one-word utterance; however, their pronunciations were inarticulate. Miki could speak two- or three-word utterance. None of children had experienced MTS tasks on a touch screen, although they had experienced such tasks on a tabletop. Therefore, they were able to match printed letter (e.g., う) to spoken syllable (e.g., /u/), match picture (e.g., うし) to spoken word (e.g., /u-shi/), name known pictures (e.g., foods, colors, animals), and read printed letters (e.g., あ, い, う, え, お) in tabletop setting. They were enrolled in a special needs education school, and all sessions were held in a quiet room at this school. Sessions were scheduled two days a week.

2.2. Apparatus and Stimuli

A touch-sensitive screen presented the stimuli and detected the participants' responses. Experimental operations on the computer were controlled by a program developed by using Visual Basic.Net. Visual stimuli and auditory stimuli were presented on the screen. Three types of visual stimuli were presented: color pictures, printed words, and printed single letters. Two types of auditory stimuli were presented: spoken words and spoken single syllables. Three types of procedures were used: MTS, CRMTS and Naming. In all tasks, visual sample stimulus was centered at the top of the screen. In MTS and CRMTS tasks, four comparison stimuli were presented in a row at the bottom of the screen after a sample stimulus was presented. In CRMTS task, when the comparison stimuli (i.e., printed

single letters) moved to a construction area below the visual sample stimulus, the computer presented the corresponding spoken syllable. In Naming task, the experimenter recorded them using the computer keyboard when vocal responses were required.

Stimuli: We used common Japanese words that could be easily represented by pictures. Ten word sets were used: six 2-letter word sets and four 3-letter word sets. Each word set consisted of four words. All printed words comprised of known-letter combinations for the participants. Word sets were different for each participant because the vocabulary prior to the experiment differed for each participant. An example of word sets is presented in Table 1.

2.3. Procedure

2.3.1. General MTS, CRMTS, and Naming procedure

MTS: The top of Fig.1 illustrates five MTS tasks in this study. First, a visual sample stimulus or an image of a speaker was presented at the top of the screen. When a participant touched the visual sample stimulus (e.g., a printed word, or a picture), four comparisons (e.g., pictures, or printed words) were presented at the bottom of the screen. When a participant touched the image of a speaker, an auditory sample stimulus (e.g., a spoken word, or a spoken syllable) was presented, which was followed by the presentation of four comparisons (e.g., printed words, pictures, or printed letters). The sample and position of the comparisons changed randomly from trial to trial. The computer coded a response correct if the selected the comparison matched the sample. A response was coded incorrect if the selected comparison did not match the sample. When a correct response was

made, the participant's favorite picture and a fanfare sound were presented for 2 s as a reinforcer. After the reinforcement ended, the next trial began after a 1-s intertrial interval. When incorrect responses were made, a retrieval was done with a 1-s intertrial interval.

CRMTS: The middle of Fig.1 illustrates the three CRMTS tasks. When a visual sample (e.g., a printed word, or a picture) was touched, four comparisons (e.g., printed letters) were presented. When an image of a speaker was touched, an auditory sample was presented in the following manner: First, a spoken first syllable (e.g., /u/) in a spoken word (e.g., /u-shi/) was presented with a blank square slot in the construction area, and then a spoken second syllable (e.g., /shi/) in the spoken word (e.g., /u-shi/) was presented with a blank square slot next to the first slot. After the presentation of auditory sample was complete, four comparisons were presented. A response was coded correct if the order of the selected comparisons (e.g., う>>し) matched that of the presented sample (e.g., a printed word うし, a spoken word /u-shi/, or a picture of cow), and it was coded incorrect if the order of the selected comparisons (e.g., う>>ま) did not match that of the sample (e.g., a printed word うし, a spoken word /u-shi/, or a picture of cow). The reinforcement contingencies for correct or incorrect responses were the same as those in the MTS procedure.

Naming: The bottom of Fig.1 illustrates the three naming tasks. When a visual stimulus (e.g., a printed letter, a printed word, or a picture) was presented, the participant was required to name the stimulus. If the vocal response was correct, then the reinforcement contingencies were the same as those in the MTS procedure. For incorrect vocal responses, they were required to imitate the experimenter's naming of the stimulus, and if they correctly imitated the naming, then a reinforcer was presented.

2.3.2. CRMTS with differential observing response (DOR) procedure

In reference to the procedures of Gutowski, Geren, Stromer, and Mackay (1995), we developed a computerized CRMTS procedure with differential observing responses to help the participant attend to each syllable in a word. This procedure was used for Miki. All aspects of the procedure were the same as CRMTS showed in Fig.1 except that differential observing responses (DOR) to the sample were introduced. Fig.2 illustrates the three CRMTS tasks with DOR. For example, as the top of Fig.2 illustrates, when a printed word was presented as the sample (e.g., あお [/a-o/]), the participant was required to name the first syllable (e.g., あ [/a/]) of the sample while touching a blank slot. As the middle of Fig.2 illustrates, when a spoken word was presented as the sample, following the presentation of the sample, the participant was required to imitate the first syllable while touching a blank slot. As the bottom of Fig.2 illustrates, when a picture was presented as the sample, the participant was required to name the first syllable of the sample while touching a blank slot. If the response was correct, the blank slot moved to the construction area. If, however, the response was incorrect, the participant was required to imitate the experimenter's naming. If the participant then made a correct imitation, the blank slot moved to the construction area. Following this, the participant was required to name or imitate the next syllable (e.g., お [/o/]) of the sample while touching the other slot. When 3-syllables word was presented as sample, the participant was required to name or imitate three syllables in a word as DOR. For example, when a spoken word was presented as a sample (e.g., すいか [/su-i-ka/]), the participant was required to imitate the first syllable (e.g., す [/su/]) of the sample while touching the blank

slot on the left. Next, she was required to imitate the middle syllable (e.g., い [/i/]) while touching the middle blank slot, and then imitate the last syllable (e.g., か [/ka/]) while touching the right blank slot on the right. Feedback for correct and incorrect responses was the same as that for the previous syllable. That is, if the participant made a correct response to each syllable, all blank slots were moved to the construction area, and then the comparisons were presented. After the comparisons were shown, the participant was required to construct the printed word that corresponded to the sample. The reinforcement contingencies for correct or incorrect responses were the same as those in the general CRMTS procedure.

2.3.3 Assessment

Before pre-test, the participants were assessed two MTS tasks with fourteen 2-letter word sets (e.g., word sets 1-6 in Table 1) in order to select the word sets to be used in this study. Receptive letter-naming and listening comprehension skills were assessed by MTS tasks: Match printed letter (e.g., う) to spoken syllable (e.g., /u/), and match picture (e.g., a picture of cow) to spoken word (e.g., /u-shi/). We used all printed letters included each word in a word set. For example, in Ryo's word set 1, the printed letters う, し, く, and せ were assessed. There were four trials on each of the two MTS tasks, with each stimulus in a set appearing once. The assessment ended after each task occurred three times with each stimulus set. Each participant's favorite pictures (e.g., animated character, animal, or train) were presented as a reinforcer when they responded correctly, and retrials were conducted when they responded incorrectly. Only for Miki, the experimenter gave her a seal when a trial ended.

2.3.4. Pre-test

The program was comprised of a pre-test phase, 6 training phases and 6 post-test phases distributed in the sequence shown in Table 2. In the pre- and post-test, 11 tasks were performed: five MTS, three CRMTS and three Naming tasks. Table 3 lists all the tasks that were employed in the pre-test, training, post-test, follow-up and generalization test. In a pre-test phase, the participants were assessed the following behavioral relations: (1) Read printed letter; (2) Match printed letter to spoken syllable; (3) Read printed word; (4) Name picture; (5) Construct printed word to match printed word; (6) Construct printed word to match spoken word; (7) Construct printed word to match picture; (8) Match picture to spoken word; (9) Match printed word to picture; (10) Match picture to printed word; and (11) Match printed word to spoken word. In each task, each stimulus of a word set was presented once. Each of the 11 tasks included four trials. A test block had 44 trials in total, and one to two test blocks were conducted in one session. In the (1), (2), (4), and (8) tasks, a reinforcer was presented when the participants responded correctly; however, when responses were incorrect, a retrieval was conducted in the (2) and (8) tasks, and the participants were required to imitate the experimenter's naming in the (1) and (4) tasks. On the other hand, in the (3), (5), (6), (7), (9), (10) and (11) tasks, a reinforcer was not presented regarding the correct responses; however, the participants were praised for the compliance with tasks (e.g., Good, OK).

2.3.6. Training

In a training phase, the participants were taught to construct printed word to sample by three CRMTS tasks: construct printed word to match printed word, spoken word, and picture. A word set was used for training during a

phase. For example, in training phase 1, set 1 was used for training. Three CRMTS tasks were taught in the following order in each training phase. First, construct printed word to match printed word task was taught. The participants were required to construct printed word corresponding to sample printed word. A training block included four trials, with each word in a set appearing once. For a correct trial, a reinforcer was presented, and for an incorrect trial, retrials were conducted until the participants provided correct responses. The training blocks continued until the participants responded correctly in at least three out of four trials for three consecutive blocks. Second, construct printed word to match spoken word task was taught. The participants were required to construct printed word corresponding to spoken word. The number of trials in a training block, reinforcement contingencies and criterion were the same as those in the previous task. Finally, construct printed word to match picture task was taught. The participants were required to construct printed word corresponding to picture. The number of trials in a training block, reinforcement contingencies and criterion were the same as those in the previous task.

In a session, one to five training blocks were implemented depending on the participant's achievement. When the criterion was met in training phase, post-test was conducted with the trained set and untrained sets.

2.3.7. Additional training

We applied an additional training procedure for only Miki after training 3 phase. As additional training procedures, three CRMTS tasks with DOR were taught. Pre-training was conducted to establish DOR to the sample before training 4 phase started. The participant was required to name or

imitate each syllable in a word as DOR to the sample. Set 3 was used for pre-training. A training block had four trials in each task. The criterion for each successful task was that the observation and construction were correct in at least three out of four trials for three consecutive blocks. After the criterion was met, post-test 3 were assessed again. After post-test 3 was reassessed, training 4 phase started. In training 4, 5, and 6, post-test 4, 5, and 6, three CRMTS tasks with DOR were conducted for Miki. The number of trials in a training block, reinforcement contingencies and criterion were the same as those in the CRMTS task of training phase.

2.3.8. Post-test

Trained set: After each training phase was completed, 11 tasks were assessed. In the post-test of the trained set, the reinforcement contingencies in each task were the same as those in the pre-test; however, in three CRMTS tasks that were taught directly, a reinforcer was presented when correct responses were made (See Table 3). This was done to maintain the trained stimulus control (e.g., the relations between spoken syllables and letters in a word). Post-test was conducted two or three times in each trained word set. If more than 75% the correct responses were recorded for all tasks on two consecutive tests, it was assumed that the criterion was met.

Untrained set: After each training phase was completed, 11 tasks were assessed not in the trained set but also in untrained sets. In the post-test of untrained sets, the reinforcement contingencies in each task were the same as those in the pre-test. After a post-test in the trained and untrained set was completed, a training phase in the next word set begun. If more than 75% correct responses in all tasks were recorded on two consecutive post-test in the untrained set, it was assumed that the criterion for each task was met

and the word set was not taught. If the participant did not meet the criterion in all word sets, then those word sets were taught later.

2.3.9. Follow-up

Trained set: A follow-up was implemented three-four weeks after the post-test in each trained set. The reinforcement contingencies for each task were the same as those in the post-test phase in the trained set.

Untrained set: If the criterion was met in the untrained set, a follow-up phase was implemented three-four weeks after the post-test in untrained set. The reinforcement contingencies for each task were the same as those in the post-test phase in the untrained set.

2.3.10. Generalization test

Generalization test was started after follow-up phase in word set 6 was completed. We assessed whether reading and spelling skills were generalized to 3-letter words that included the known letters. We used four stimulus sets, of which three were designed so that novel words were composed through new combinations of previously taught letter-sound relations (see Table 1). For example, あいす [/a-i-su/] in set 7 was composed of three taught letters, とけい [/to-ke-i/] in set 8 was composed of two taught letters, and かえる [/ka-e-ru/] in set 9 was composed of one taught letter. However, in set 10, きりん [/ki-ri-n/] was composed of three untaught letters. All nine tasks except the (1) read printed letter and (2) match printed letter to spoken syllable tasks were the same as those in the pre-test. However, the number of comparisons was not four but three in the (5) construct printed word to match printed word, (6) construct printed word to match spoken word, and (7) construct printed word to match picture tasks

as only positive comparisons were presented. Furthermore, the (1) and (2) tasks were omitted because the participants already knew letters that were included in the word sets, having heard them from their teachers. The reinforcement contingencies on each task were the same as those in the pre-test. Each stimulus was presented once in each task, and each task included four trials. This test had 36 trials in total and was assessed once in each set.

2.4. Experimental design

We used a non-concurrent multiple probe design between stimulus sets. To assess generalized reading and spelling skills, post-test in untrained sets were introduced with successive applications of the training condition with sets 1-6.

2.5. Reliability

The first author of the present study and two independent observers evaluated whether the participants' responses were correct or incorrect. One-third total trials in the all tasks were scored by three independent observers. Ratings were made from the video recordings of the responses. The interobserver agreement score was 93% for Ryo, 92% for Taku, and 97% for Miki.

3. Results

3.1. Assessment

All participants achieved accuracy scores of 75% (three trials out of four) or better on the matching tasks for each word set. They were able to match

picture to spoken word and printed letter to spoken syllable in each word set. Before the pre-test, their ratio of correct responses was high for stimulus relations between spoken word and picture (e.g., the relation between the spoken Japanese word for cow [/u-shi/] and a picture of *cow*), and individual sound and letter relations (e.g., the relation between the sound [/u/] and the printed letter う)

3.2. Pre-test

Fig.3 and 4, Fig.5 and 6, and Fig.7 and 8 show the percentage of correct responses in Ryo's, Taku's and Miki's reading (MTS) and spelling (CRMTS) test, respectively. However, we drop all (1) read printed letter, (2) match printed letter to spoken syllable, (8) match picture to spoken word, and (5) construct printed word to match printed word tasks data from the figure because they were at almost 100% across the phases. In addition, we also drop all (3) read printed word and (4) name picture tasks data from the figure because of the indistinctness of their articulation. Thus, the figure shows (9) match printed word to picture, (10) match picture to printed word, and (11) match printed word to spoken word tasks data for tests about the reading, and (6) construct printed word to spoken word and (7) construct printed word to picture tasks data for tests about the spelling.

Ryo was assessed MTS and CRMTS performances across set 1, 2, and 3 in the pre-test phase (Fig.3 and 4). Ryo showed a high percentage of correct responses in the match picture to printed word and match printed word to spoken word tasks with set 1, while he showed a low percentage of correct responses in the three MTS and two CRMTS tasks with set 2 and 3. Taku was assessed MTS and CRMTS performances with set 1 (Fig.5 and 6). Taku's correct responses in MTS and CRMTS tasks were lower than 50%.

Miki was assessed MTS and CRMTS performances across set 1, 2, and 5 (Fig.7 and 8). Miki's correct responses in MTS and CRMTS tasks also were lower than 50% across the all sets.

3.3. Training

As training advanced in all participants, the number of the training blocks decreased although the data were not shown in the figure. Ryo was needed 25 training blocks for meeting the criterion in set 1, 12 blocks in set 2, 10 blocks in set 3, 8 blocks in set 4, and 5 blocks in set 5. Taku was needed 15 training blocks for meeting the criterion in set 1, 9 blocks in set 2, 4 blocks in set 3, and 2 blocks in set 5 and 6. Miki was trained by the general CRMTS procedure to set 3. Miki was needed 19 training blocks for meeting the criterion in set 1, 17 blocks in set 2, and 13 blocks in set 3.

3.4. Additional training

Miki was trained by the additional CRMTS procedure (i.e., CRMTS with DOR) from set 4 to 6. Pre-training was introduced with set 3 before training phase 4. Miki was needed 15 training blocks for meeting the criterion in pre-training, 4 blocks in set 4, and 3 blocks in set 5 and 6.

3.5. Post-test

Trained set: All participants showed a high percentage of correct responses in the three MTS and two CRMTS tasks in each trained set after each CRMTS training was completed (See each post-test of the trained sets in Fig.4 to 8). Their correct responses in the three MTS and two CRMTS tasks were higher than 75% on two consecutive post-test. The criterion was met in the all sets. Thus, all participants exhibited high performances in not only

spelling of taught words but also derived reading (i.e., three MTS performances).

Untrained set: As CRMTS training advanced with some sets, all participants came to show a high reading and spelling performances in the untrained sets. Ryo's correct responses in the three MTS tasks came to be higher than 75% with set 4 (except match printed to spoken word task) and 6 during post-test 2 (See Fig.3). Furthermore, his correct responses in the three MTS tasks were higher than 75% with set 5 during post-test 3. In the two CRMTS tasks, Ryo's spelling performances came to be improved slowly in the untrained sets (See Fig.4). His correct responses in the two CRMTS tasks were 75% with set 4 during post-test 2. In addition, his CRMTS performances were higher than 75% with set 6 during post-test 5 to 6. The criterion was met in the set 6 before CRMTS training was implemented. Similar to Ryo, Taku's correct responses in the both MTS and CRMTS tasks came to be higher than 75% with set 4, 5, and 6 during post-test 3 (See Fig.5 and 6). In set 4, the criterion was met before CRMTS training was implemented.

On the other hand, Miki's MTS correct responses in the untrained sets were almost lower than 50% during post-test 1 to 3; however, Miki scored more than 75% in the match picture to printed word task with set 5 during post-test 2 to 3 (See Fig.7). In the CRMTS tasks, Miki showed no increasing trend in the all untrained sets during post-test 2 to 3 (See Fig.8). On the whole, the main spelling error pattern in the CRMTS tasks was one of the following two: error responses in constructing trained words to match untrained words samples (e.g., Constructing trained printed word あお [/a-o/] to match untrained spoken word あめ [/a-me/] in set 4 during post-test 2), or error responses in selecting the last letter of the words first

(e.g., Selecting the letter し [/shi/] first for the spoken word はし [/ha-shi/]). However, after the additional procedure was introduced (i.e., after the pre-training), Miki's MTS and CRMTS performances improved in the untrained sets. Her MTS performances in set 5 were more than 75% during post-test 4, and the MTS performances in set 6 were 75% during post-test 5. Miki scored more than 75% in the CRMTS tasks with set 4-6 during post-test 3-6. Thus, all participants showed high reading and spelling performances in the untrained sets through the CRMTS training using a series of overlapping-syllable word sets. In particular, Miki improved MTS and CRMTS performances in the untrained sets after CRMTS procedure with DOR was introduced.

3.6. Follow-up

All participants maintained MTS and CRMTS performances in the both trained and untrained sets during follow-up phases. Ryo scored more than 75% in the both MTS and CRMTS tasks with set 2-6. Taku also scored more than 75% in the both MTS and CRMTS tasks with set 2, 3, 5, and 6. Miki showed stable maintenance of the MTS and CRMTS performances. Across the all sets, she scored 100% in the both MTS and CRMTS tasks.

3.7. Generalization test

Table 4 shows results of the Generalization test. Ryo's performances show a high level accuracy in the both MTS and CRMTS tasks. Except for the construct printed word to match picture task with set 8, Ryo scored 75% or higher for all sets. In construct, Taku's performances were different across sets. With sets 7 and 9, Taku scored 75% or higher except for the construct printed word to match picture task with set 7. However, he scored above

75% on the construct printed word to match spoken word and match printed word to picture tasks with set 10, and the construct printed word to match spoken word, match picture to printed word, and match printed word to spoken word tasks with set 8. Except for the construct printed word to match spoken word task with set 10, Miki scored 75% or higher for all sets.

4. Discussion

In this study, we examined the effects that CRMTS training using a series of overlapping-syllable word sets has on establishing generalized reading and spelling skills in three Japanese children with autism. As the CRMTS training advanced, the participants' MTS and CRMTS performances in the untrained sets came to be improved. This result suggested that the application of the CRMTS procedures using such a series of word sets was effective for acquisition of generalized reading and spelling skills in children with autism. The present study extended the analysis of Shimizu and Yamamoto (2001) by showing that computer-based CRMTS procedures with such a series of word sets may be used to establish generalized reading and spelling skills in children with autism. However, one participant was needed for an additional teaching procedure to establish generalized reading and spelling skills. We taught her to break a word into each syllable as a differential observing response to the sample in the CRMTS task. This additional procedure enabled the participant to establish generalized reading and spelling skills. In the following sections, the effectiveness of the CRMTS training procedure and some issues to be considered in applying this procedure for children who have difficulty in reading and spelling are discussed.

The present data supports the idea that training with a series of word sets based on recombinative syllable-units is effective for children with intellectual disabilities (Melchiori, de Souza, & de Rose, 2000). Melchiori et al. (2000) suggested that a training package based on stimulus equivalence and recombination of units has generality across participants with reading difficulties. Without explicit training, many of the participants showed the generalized reading via recombinative generalization. Recombinative generalization has been defined as “differential responding to novel combinations of stimulus components that have been included previously in other stimulus contexts” (Goldstein, 1983). All words used in this study were comprised the known syllables for the participants. They have known the letter-sound correspondence (e.g., printed letter *あ* and sound /a/) in many Japanese letters before this study; however, they have not known the correspondence within 2-letter words. Therefore, they showed generalized reading and spelling skills in untrained words that included known letters through multiple-exemplar training in the CRMTS task. Surprisingly, reading and spelling skills with trained 2-letter words were generalized to novel 3-letter words. The participants learned to match relations between syllables and letters in 3-letter as well as 2-letter words. These results suggest that a history of multiple-exemplar training for relating instructional stimuli in specific manners promotes responses that generalize across a range of novel stimuli and tasks (de Souza, de Rose, & Domeniconi, 2009; Hayes, Barnes-Homes, & Roche, 2001).

However, in this study, there was a case the generalized reading and spelling scores never reached the accuracy levels achieved on the trained words by CRMTS procedure. In the previous studies, a similar research question was suggested. De Souza et al. (2009) reported that some of the

participants did not improve spelling performance in the novel words. Melchiori et al. (2000) also reported that some of the participants did not show generalized reading performance. Saunders, O'Donnell, Vaidya, and Williams (2003) reported that to establish generalized reading, it is important to attend to each single syllable in a word, that is to break a word into each syllable. We assumed that Miki had difficulty in attending to each syllable in a word from the analysis of her error pattern in the CRMTS tasks. Therefore, we employed an additional procedure that required the participant to observe each syllable in a word (i.e., CRMTS procedure with DOR). Miki's data suggested that the CRMTS procedure with DOR facilitates the acquisition of generalized reading and spelling skills to a child who have difficulty in acquiring those skills by general CRMTS procedure. De Souza et al. (2009) and Melchiori et al. (2000) examined no additional procedure for the participants who did not show generalized reading and spelling of novel untrained words. Miki's data suggested a solution for the research question. Thus, the present study suggested that we developed a new training protocol for children who have difficulty in generalized reading and spelling skills.

The present study also had some issues that must be considered. First, further research is needed to examine that this training package is effective for children of what kind of profile. The developmental and vocabulary age of the participants in this study were lower than that of the participants in the previous studies (e.g., de Souza et al., 2009; Melchiori et al., 2000; Saunders et al., 2003). In particular, Taku succeeded in acquiring generalized reading and spelling skill by this training package in spite of his developmental and vocabulary age under 3 years old. However, we cannot clarify the reason why this training package succeeded in him. The

reason may be caused by the difference of the type of disability (e.g., intellectual disability and autism), or the difference of language (e.g., English, Portuguese, and Japanese). In considering the research base on reading development of students with autism spectrum disorders (Calhoon, 2001; Nation, Clarke, Wright, & Williams, 2006), this population of learners appear to have relative strengths in the area of phonics or decoding. Children with autism may develop and understand the phonemic structure of words, despite having significant language and communication deficits frequently associated with autism (Gabig, 2010). The present data may be shown by such relative strengths in the area of phoneme skill in children with autism. As other possibility, a good result may be occurred because the Japanese has higher consistency of letter-sound rule than the other language (e.g., English). Second, one question concerning the positive training outcomes obtained in this study is the extent to which these outcomes were due to the training program and not some other influences. All participants also received reading instruction in the classroom, which may have contributed to their improved performances. We should have employed an experimental design in which extra-experimental variables are ruled out. Finally, further research is needed to develop a revised procedure for cases in which this training package for generalized reading and spelling cannot be applied. We assumed that Miki's scores on novel untrained sets did not improve because of a lack of attending to each syllable in a word. CRMTS procedure with DOR was applied for Miki to promote the breaking of a word into each syllable and lead to generalized reading and spelling. Such a revised training procedure will prove to be broadly effective in promoting functional reading and spelling skills in children.

Acknowledgements

This study was conducted by the first author as part of his doctoral studies in disability sciences at the University of Tsukuba, Japan. We appreciate the help of many teachers from Special Needs Education School for Children with Autism at the University of Tsukuba.

References

- Calhoon, J. A. (2001). Factors affecting the reading of rimes in words and nonwords in beginning readers with cognitive disabilities and typically developing readers. *Journal of Autism and Developmental Disorders*, 31, 491-504.
- Dairoku, H. (1995). Is awareness of morae a requisite for acquisition of kana reading? *The Japanese Journal of Psychology*, 66(4), 253-260.
- De Souza, D. G., de Rose, J. C., Domeniconi, C. (2009). Applying relational operants to reading and spelling. In Rehfeldt, R. A., Barnes-Holmes, Y., & Hayes, C. S. (Eds.), *Derived relational responding: Applications for learners with autism and other developmental disabilities* (pp. 173-207). Oakland: New Harbinger Publications, Inc.
- De Souza, D. G., de Rose, J. C., Faleiros, T. C., Bortoloti, R., Hanna, E. S., & MacIlvane, W. J. (2009). Teaching generative reading via recombination of minimal textual units: A legacy of Verbal Behavior to children in Brazil. *International Journal of Psychology and Psychological Therapy*, 9(1), 19-44.
- Dube, W. V., McDonald, S. J., McIlvane, W. J., & Mackay, H. A. (1991). Constructed response matching to sample and spelling instruction. *Journal of Applied Behavior Analysis*, 24, 305-317.
- Frith, U., & Snowling, M. (1983). Reading for meaning and reading for sound in autistic and dyslexia children. *British Journal of Developmental Psychology*, 1, 329-342.
- Gabig, C. S. (2010). Phonological awareness and word recognition in reading by children with autism. *Communication Disorders Quarterly*, 31(2), 67-85.

- Goldstein, H. (1983). Recombinative generalization: Relationship between environmental conditions and the linguistic repertoires of language learners. *Analysis and Intervention in Developmental Disabilities*, 3, 279-293.
- Gutowski, S. J., Geren, M., Stromer, R., & Mackay, H. A. (1995). Restricted stimulus control in delayed matching to complex samples: A preliminary analysis of the role of naming. *Experimental Analysis of Human Behavior Bulletin*, 13, 18-24.
- Hayes, S. C., Fox, E., Gifford, E. V., Wilson, K. G., Barnes-Holmes, D., & Healy, O. (2001). Derived relational responding as learned behavior. In S. C. Hayes, D. Barnes-Holmes, & B. Roche (Eds.), *Relational frame theory: A functional approach to verbal events* (pp. 21-49). New York: Kluwer Academic / Plenum.
- Mackay, H. A. (1985). Stimulus equivalence in rudimentary reading and spelling. *Analysis and Intervention in Developmental Disabilities*, 5, 373-387.
- Melchiori, L. E., de Souza, D. G., & de Rose, J. C. (2000). Reading, equivalence, and recombination of units: A replication with students with different learning histories. *Journal of Applied Behavior Analysis*, 33, 97-100.
- Mueller, M. M., Olmi, D. J., & Saunders, K. J. (2000). Recobinative generalization of within-syllable units in prereading children. *Journal of Applied Behavior Analysis*, 33, 512-531.
- Nation, K., Clarke, P., & Wright, B. (2006). Patterns of reading ability in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 36, 911-919.
- Saunders, K. J., O'Donnell, J., Vaidya, M., & Williams, D. C. (2003).

- Recombinative generalization of within-syllable units in nonreading adults with mental retardation. *Journal of Applied Behavior Analysis*, 36, 95-99.
- Schlosser, R. W., & Blischak, D. M. (2004). Effects of speech and print feedback on spelling by children with autism. *Journal of Speech, Language, and Hearing Research*, 47, 848-862.
- Shimizu, H., & Yamamoto, J. (2001). The acquisition of Hiragana letter: Decoding and encoding of syllable. In T. Asano, & J. Yamamoto (Eds.), *Language and behavior* (pp.75-96). Tokyo: Brain Press.
- Shopler, E., & Ibaraki, T. (1995). A Japanese edition of *Individual assessment and treatment for autistic and developmental disabled children: Vol. 1. Psychoeducational Profile-Revised (PEP-R)*. Tokyo: Kawashima Shoten.
- Shopler, E., Reichler, R. J., Bashford, A., Lansing, M. D., & Marcus, L. M. (1990). *Individual assessment and treatment for autistic and developmental disabled children: Vol. 1. Psychoeducational Profile-Revised (PEP-R)*. Austin: Pro-Ed.
- Sidman, M. (1971). Reading and auditory-visual equivalences. *Journal of Speech and Hearing Research*, 14, 5-13.
- Sidman, M., & Tailby, W. (1982). Conditional discrimination vs. matching-to-sample: An expansion of testing paradigm. *Journal of the Experimental Analysis of Behavior*, 37, 5-22.
- Stromer, R., Mackay, H. A., Howell, S. R., McVay, A. A., & Flusser, D. (1996). Teaching computer-based spelling to individuals with developmental and hearing disabilities: Transfer of stimulus control to writing tasks. *Journal of Applied Behavior Analysis*, 29, 25-42.
- Ueno, K., Nadeo, T., & Iinaga, K. (1991). *Picture vocabulary test*. Tokyo:

Nihon Bunka Kagakusha.

Vedora, J., & Stromer, R. (2007). Computer-based spelling instruction for students with developmental disabilities. *Research in Developmental Disabilities*, 28, 489-505.

Table 1 An Example of word sets.

Word Sets					
2-letter words	1	うし /u-shi/ (cow)	うま /u-ma/ (horse)	くし /ku-shi/ (comb)	くま /ku-ma/ (bear)
	2	はし /ha-shi/ (chopstick)	はな /ha-na/ (flower)	すし /su-shi/ (sushi)	すな /su-na/ (sand)
	3	いと /i-to/ (thread)	いし /i-shi/ (stone)	はと /ha-to/ (pigeon)	はし /ha-shi/ (chopstick)
	4	さい /sa-i/ (rhinoceros)	さめ /sa-me/ (shark)	かい /ka-i/ (shell)	かめ /ka-me/ (turtle)
	5	かね /ka-ne/ (bell)	かた /ka-ta/ (shoulder)	ふね /hu-ne/ (ship)	ふた /hu-ta/ (lid)
	6	あめ /a-me/ (rain)	あお /a-o/ (blue)	かめ /ka-me/ (turtle)	かお /ka-o/ (face)
3-letter words	7	あيس /a-i-su/ (ice cream)	すいか /su-i-ka/ (watermelon)	マスク /ma-su-ku/ (mask)	とまと /to-ma-to/ (tomato)
	8	とけい /to-ke-i/ (clock)	カメラ /ka-me-ra/ (camera)	はさみ /ha-sa-mi/ (scissors)	くるま /ku-ru-ma/ (car)
	9	かえる /ka-e-ru/ (frog)	おもち /o-mo-chi/ (rice cake)	きつね /ki-tu-ne/ (fox)	こあら /ko-a-ra/ (koala)
	10	きりん /ki-ri-n/ (giraffe)	つみき /tu-mi-ki/ (block)	ひよこ /hi-yo-ko/ (chick)	れもん /re-mo-n/ (lemon)

Table 2 Sequence of training and test phases for Ryo, Taku and Miki

Ryo Taku	Pre-test	Training 1		Post-test 1		Training 2		Post-test 2		Training 3		Post-test 3		Training 4		Post-test 4		Training 5		Post-test 5		Training 6		Post-test 6	
		Trained set	Untrained set																						
Set 1	*	*	*																						
Set 2				*	*	*																			
Set 3				*			*	*	*																
Set 4				*			*				*	*	*												
Set 5				*			*				*				*	*	*								
Set 6				*			*				*			*						*	*	*			

Miki	Pre-test	Training 1		Post-test 1		Training 2		Post-test 2		Training 3		Post-test 3		Pre- training (set 3)	Re Post-test 3		Training 4		Post-test 4		Training 5		Post-test 5		Training 6		Post-test 6	
		Trained set	Untrained set		Trained set	Untrained set																						
Set 1	*	*	*																									
Set 2				*	*	*																						
Set 3				*			*	*	*		*	*																
Set 4				*			*			*			*	*	*													
Set 5				*			*			*		*			*	*	*											
Set 6				*			*			*		*		*			*				*	*	*		*	*	*	

Table 3 Task types implemented in Pre-test, Training, Post-test, Follow-up, and Generalization test

Type	Task	Pre-test	Training	Post-test		Follow-up		Generalization test
				Trained set	Untrained set	Trained set	Untrained set	
Naming	(1) Read printed letter	●		●	●	●	●	
MTS	(2) Match spoken syllable to printed letter	●		●	●	●	●	
Naming	(3) Read printed word	○		○	○	○	○	○
Naming	(4) Name picture	●		●	●	●	●	●
CRMTS	(5) Construct printed word to match printed word	○	●	●	○	●	○	○
CRMTS	(6) Construct printed word to match spoken word	○	●	●	○	●	○	○
CRMTS	(7) Construct printed word to match picture	○	●	●	○	●	○	○
MTS	(8) Match picture to spoken word	●		●	●	●	●	●
MTS	(9) Match printed word to picture	○		○	○	○	○	○
MTS	(10) Match picture to printed word	○		○	○	○	○	○
MTS	(11) Match printed word to spoken word	○		○	○	○	○	○

Note. The circles represent that the task was implemented. The open circles represent that a reinforcer was not given, and closed circles represent that a reinforcer was given.

Table 4 Results of generalization test.

Type	Task	Set 7			Set 8			Set 9			Set 10		
		Ryo	Taku	Miki	Ryo	Taku	Miki	Ryo	Taku	Miki	Ryo	Taku	Miki
CRMTS	Construct printed word to match spoken word	100%	100%	100%	100%	100%	75%	100%	100%	100%	100%	75%	50%
	Construct printed word to match picture	75%	50%	100%	50%	50%	75%	75%	100%	100%	75%	50%	75%
MTS	Match picture to printed word	100%	100%	100%	100%	75%	100%	100%	100%	100%	100%	50%	100%
	Match printed word to picture	100%	100%	100%	100%	50%	100%	100%	100%	100%	100%	100%	100%
	Match printed word to spoken word	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	50%	100%

Note. The tasks used are listed along the ordinate in the order in which they were given. The columns of correct responses (%) in each participant are arranged in groups of test blocks devoted to each set.

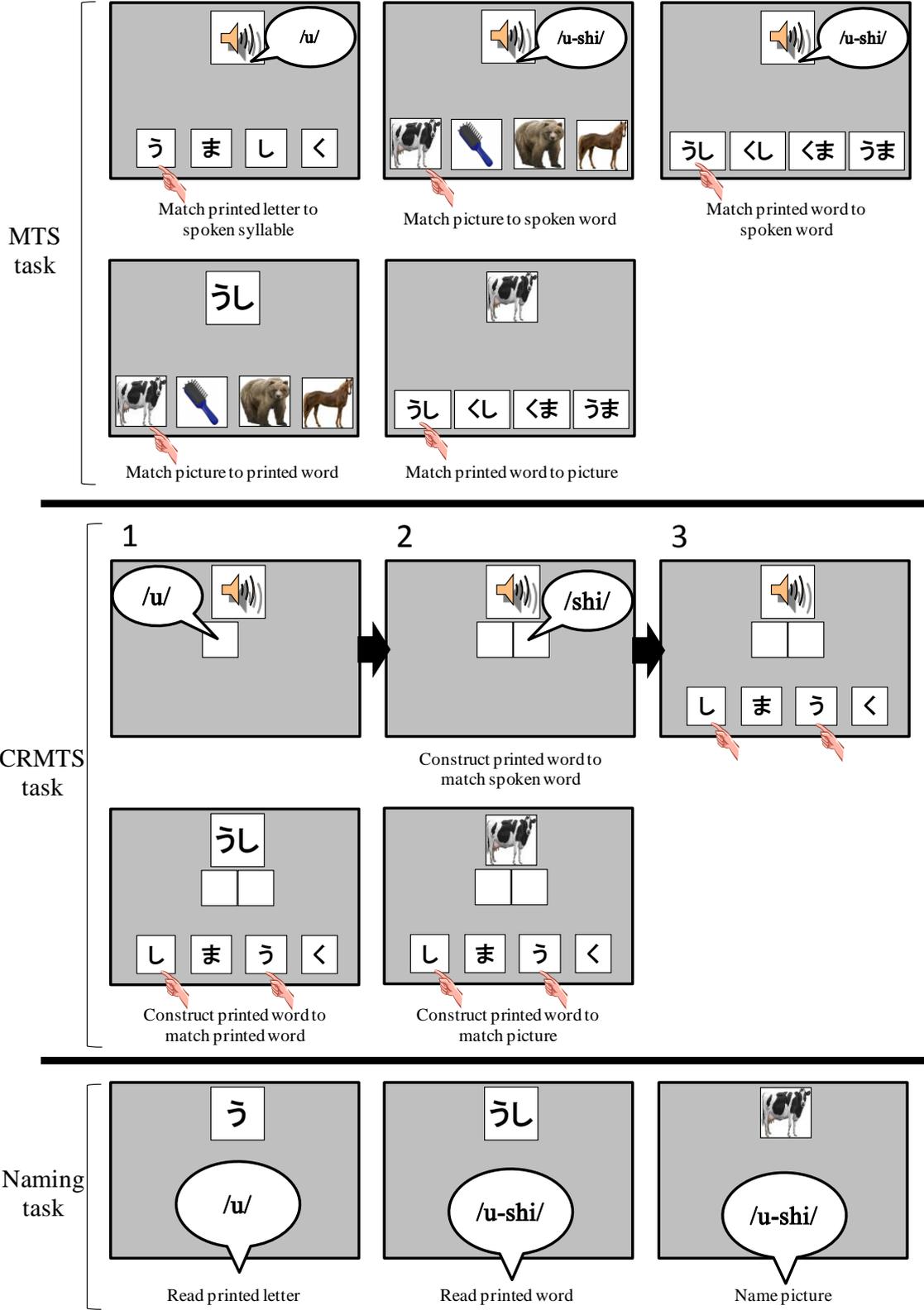


Fig.1 Examples of the trial display presented in the MTS, CRMTS and Naming tasks.

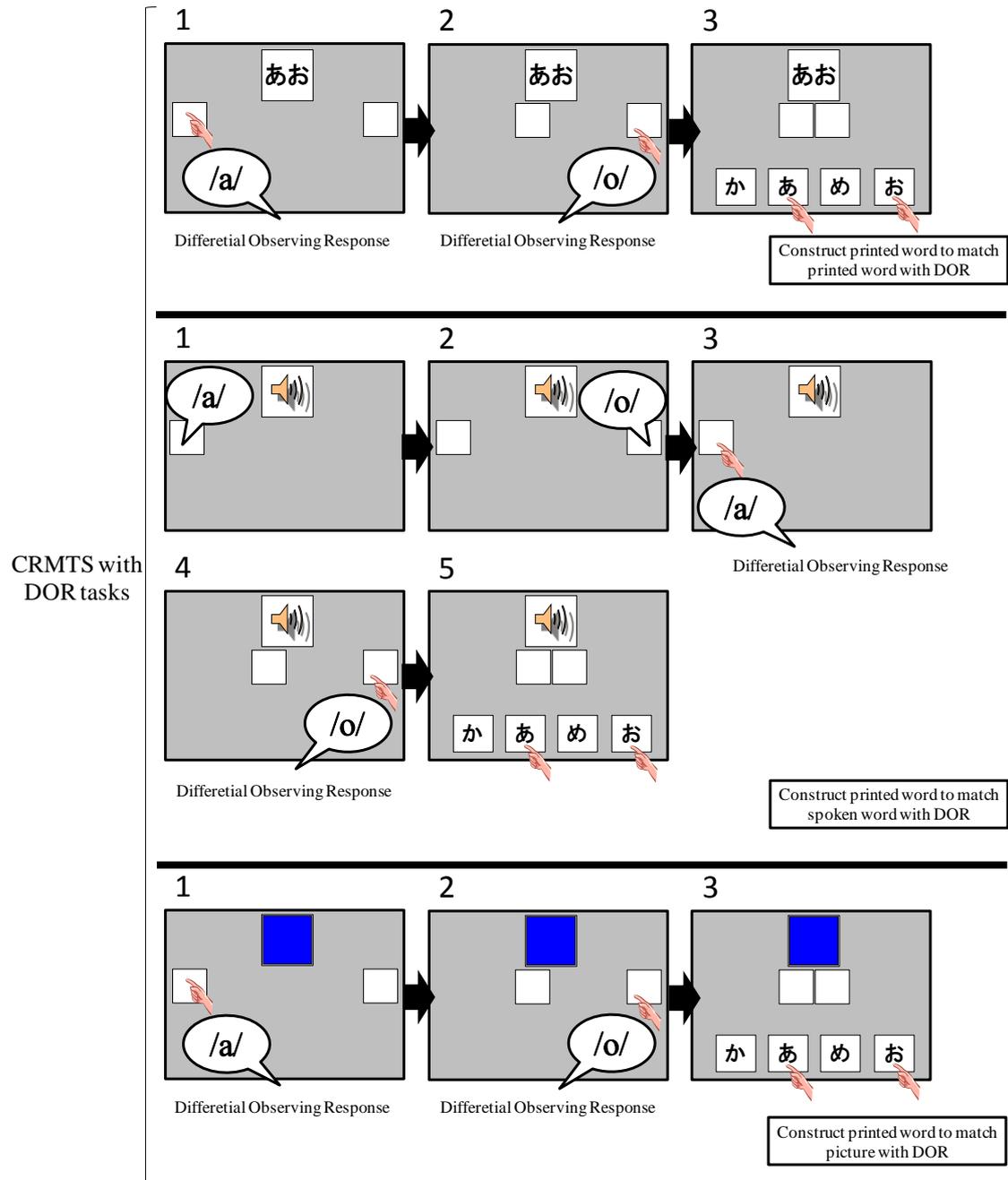


Fig.2 Examples of trial display presented in the CRMTS with DOR tasks.

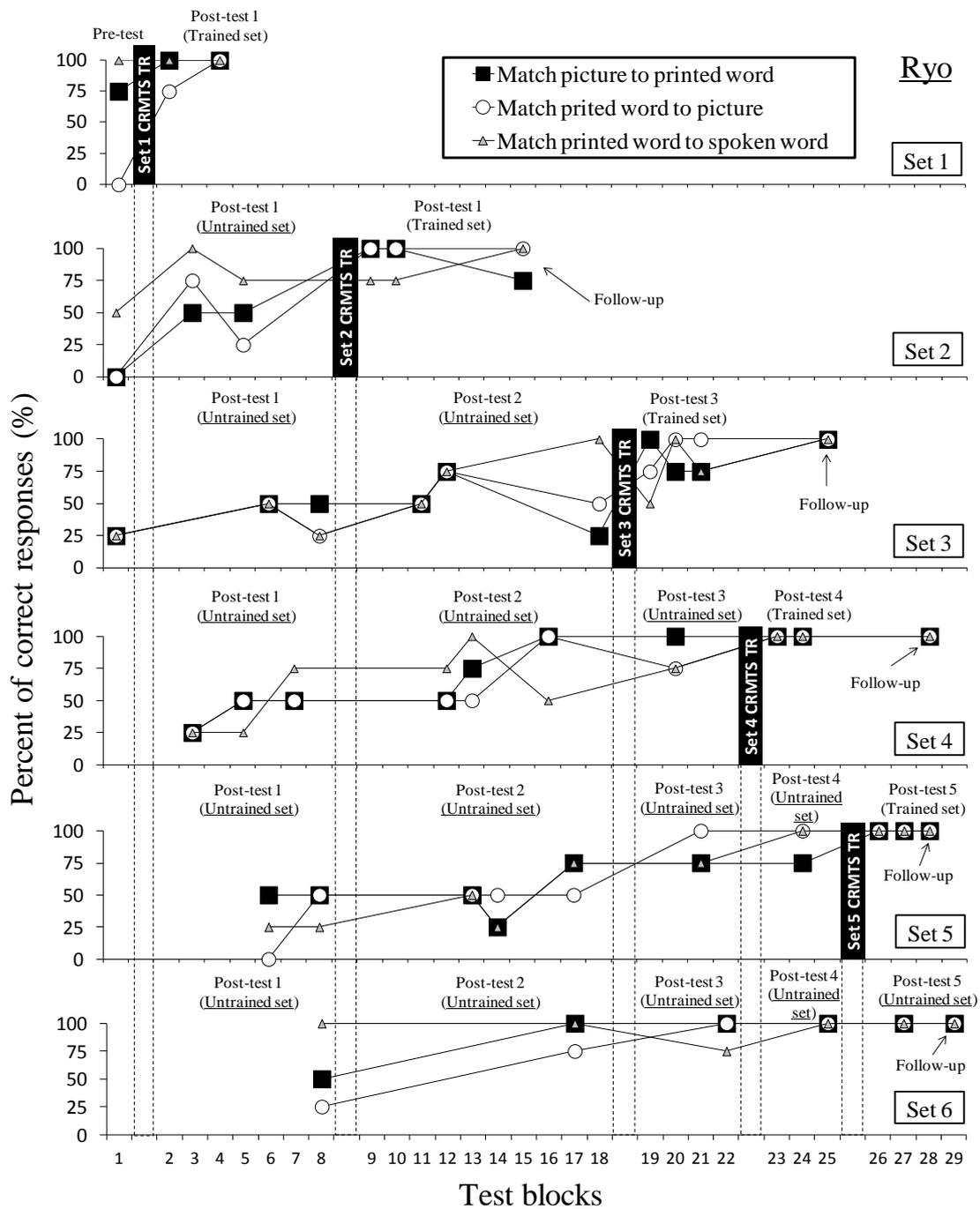


Fig.3 Ryo's reading test performances

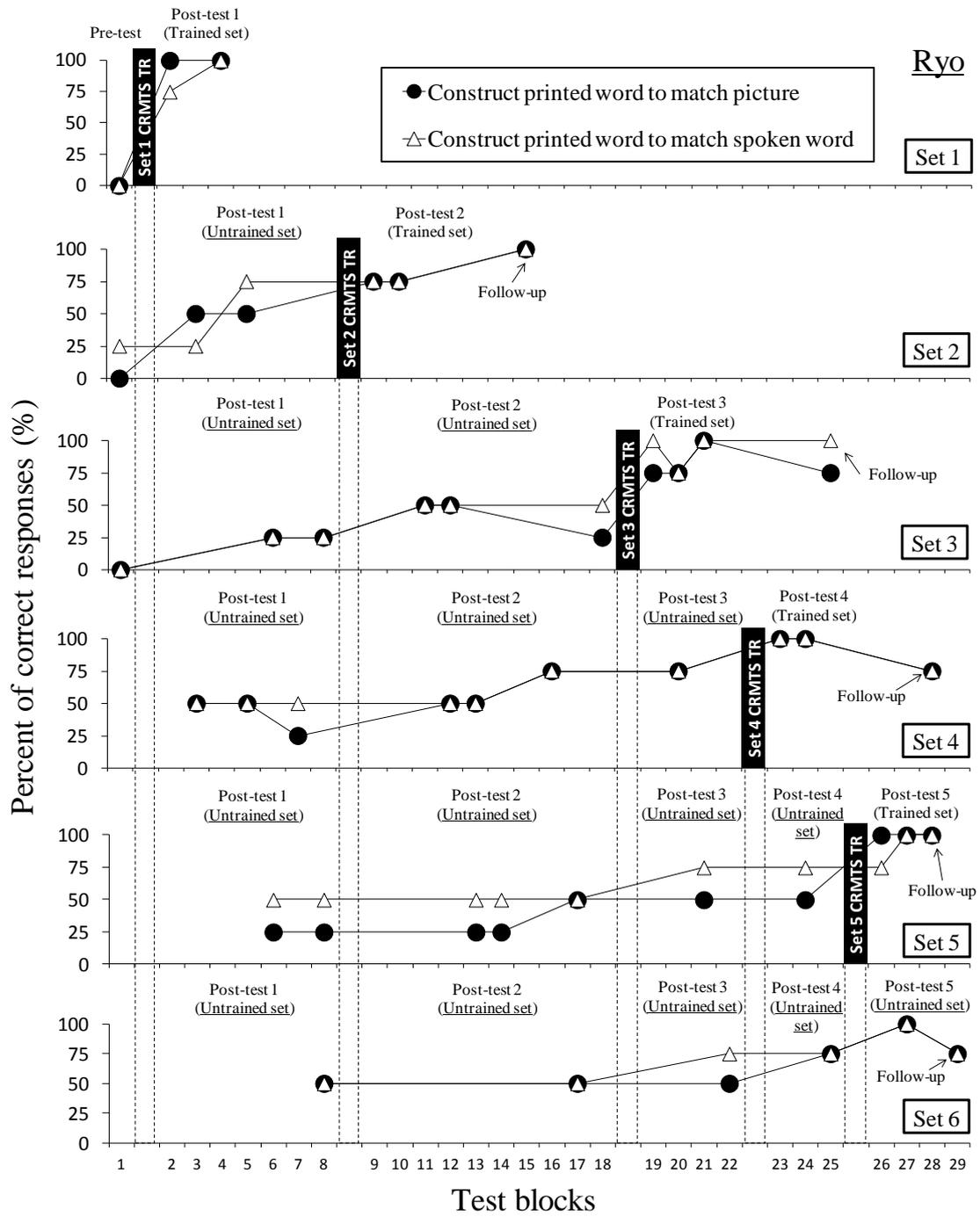


Fig.4 Ryo's spelling test performances

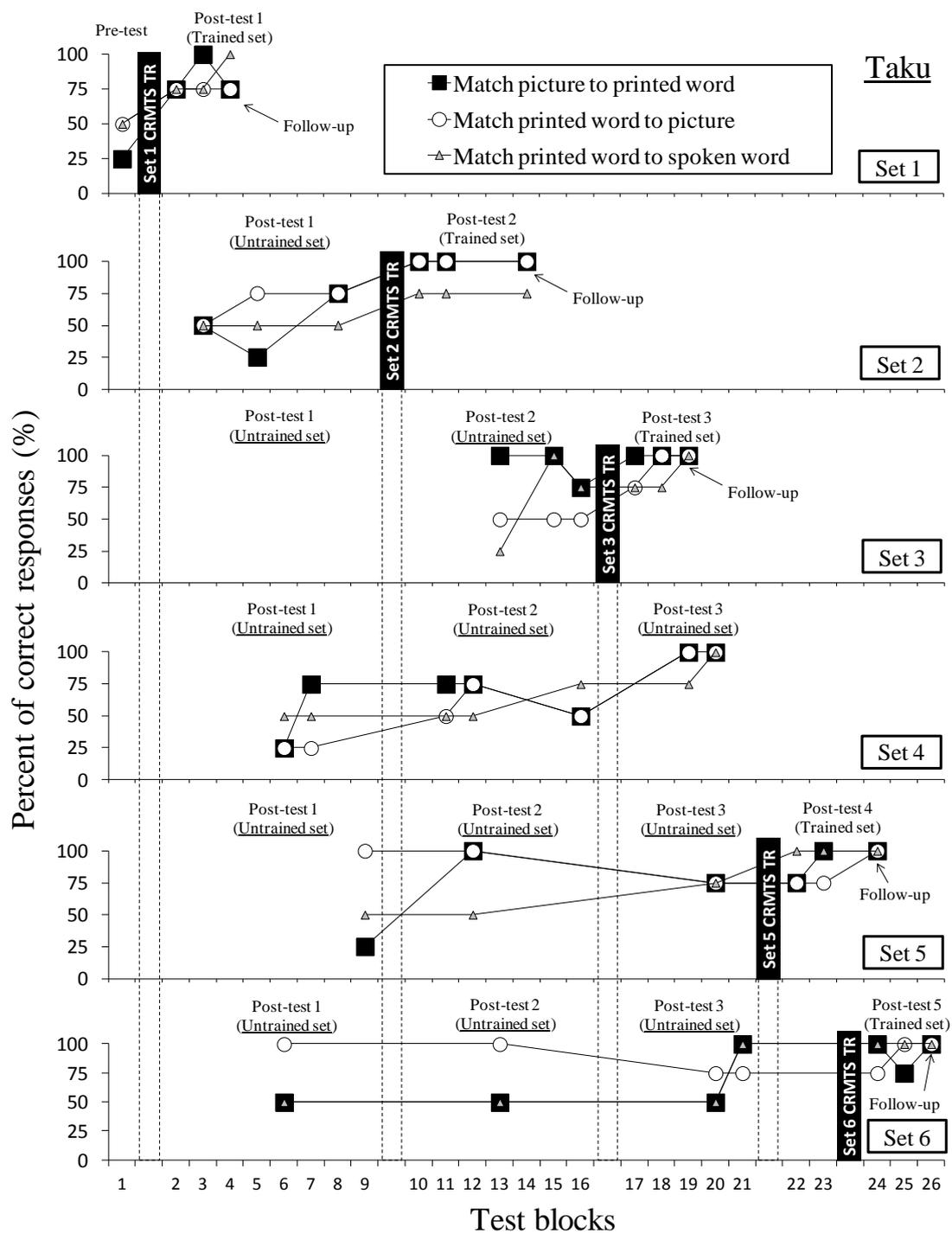


Fig.5 Taku's reading test performances

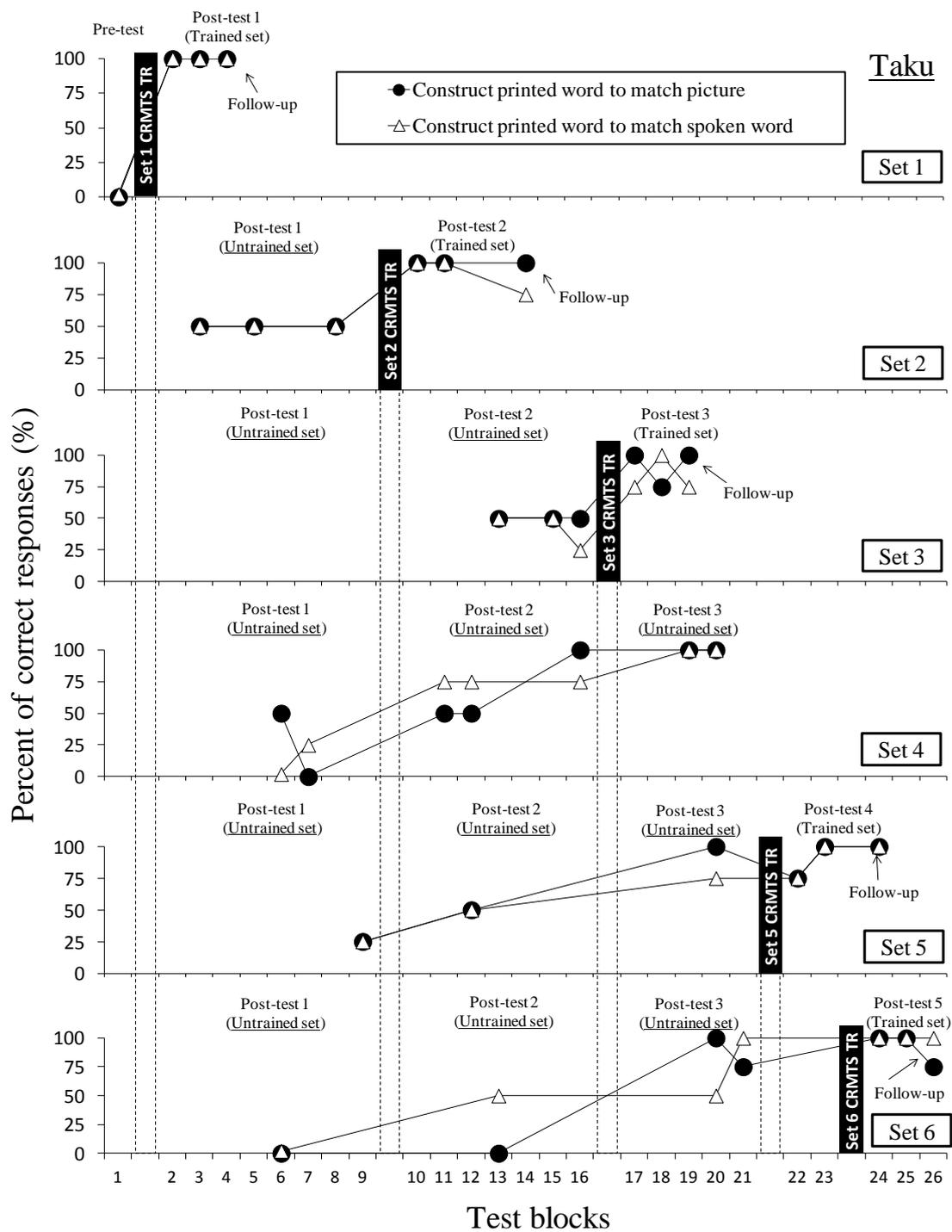


Fig.6 Taku's spelling test performances

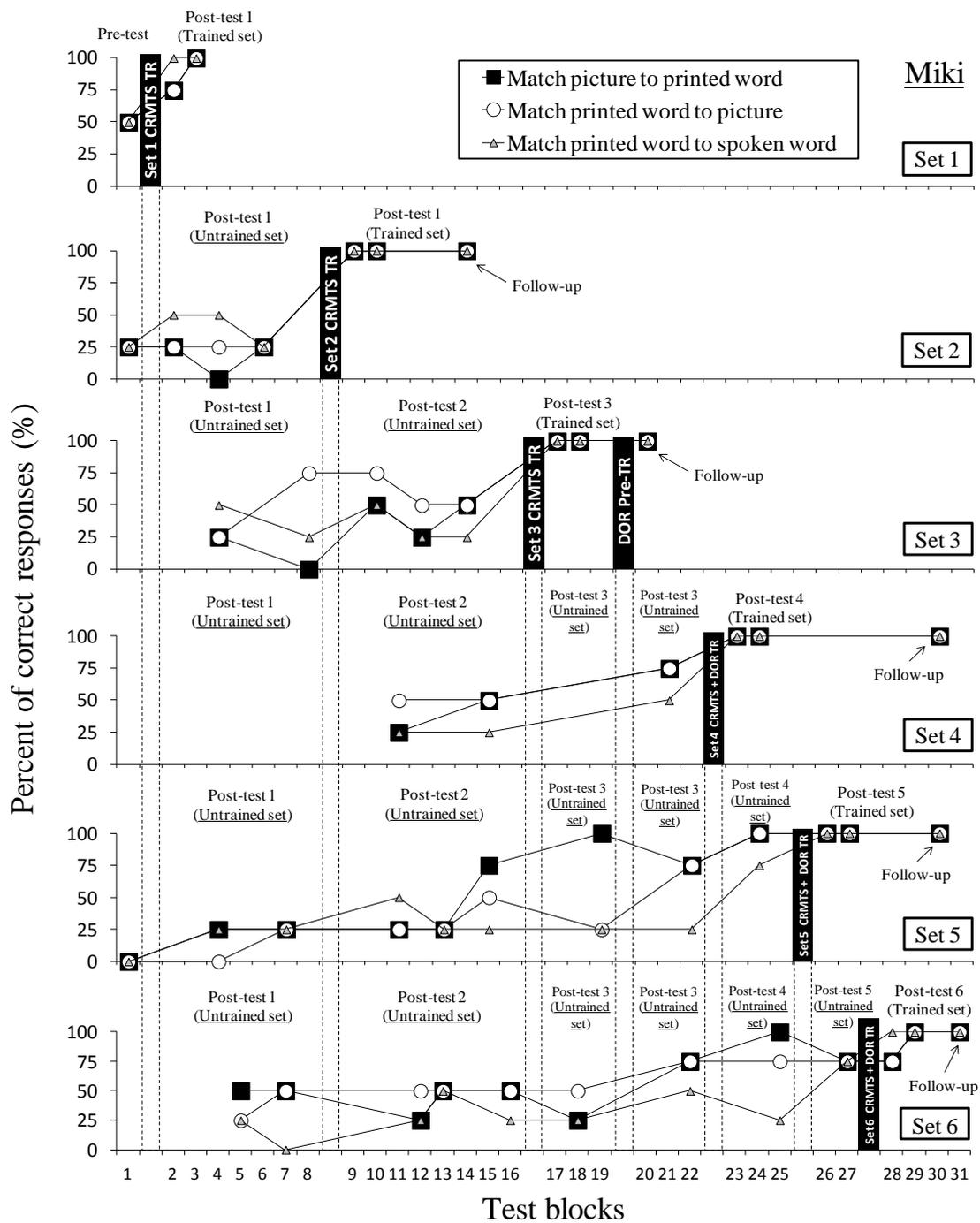


Fig.7 Miki's reading test performances

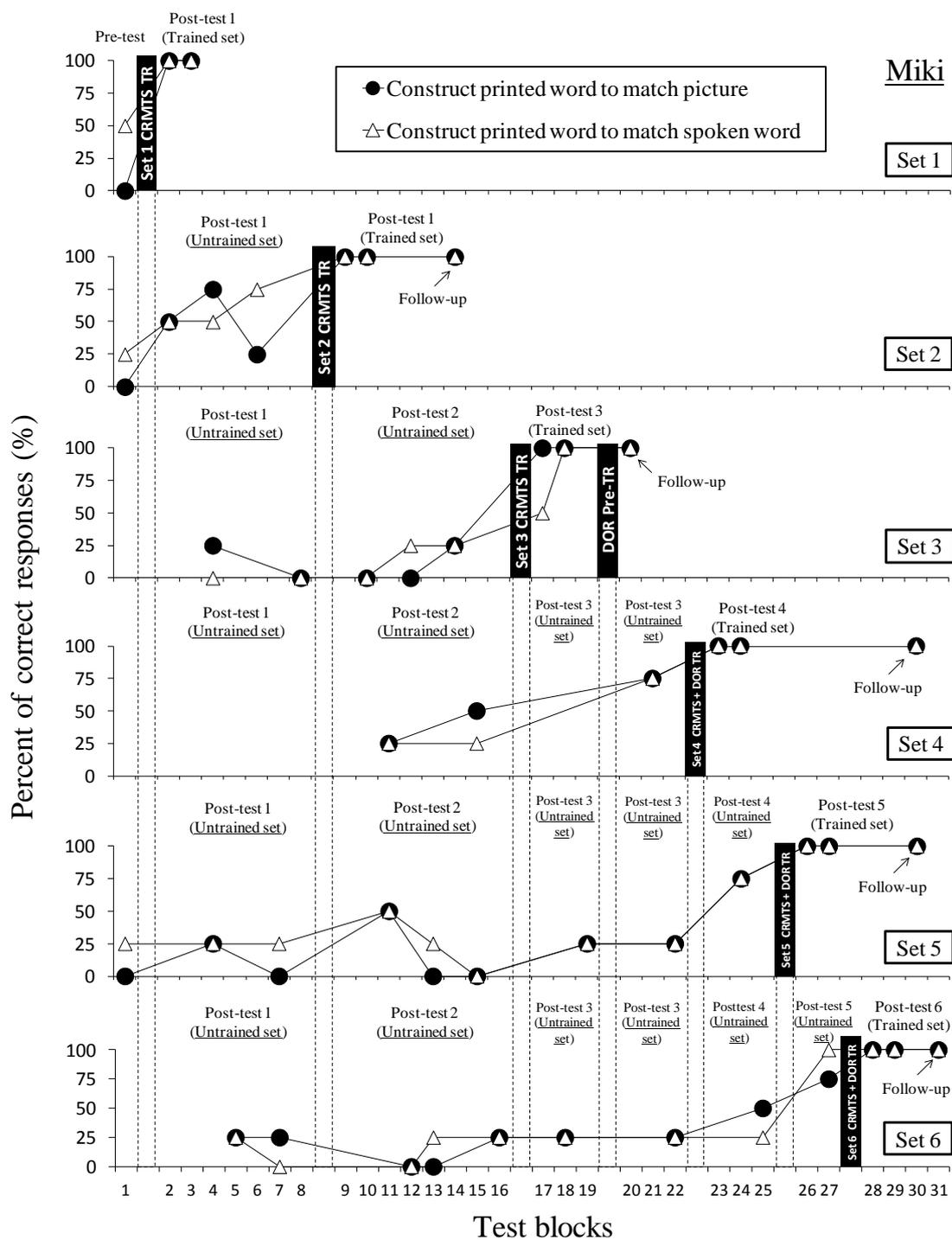


Fig.8 Miki's spelling test performances

Highlights

- Constructed-response matching to sample (CRMTS) was used for 3 children with autism
- We examined the effects of CRMTS training on generalized reading and spelling skills
- Two children with autism showed generalized reading and spelling by CRMTS training
- CRMTS with differential observing response (DOR) was developed for a special case
- She showed generalized reading and spelling after CRMTS with DOR training