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Implementation and Evaluation of Prompting Changeover System from Repetitive Behavior

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Abstract - Children with developmental disorder have more difficulty engaging in changeover behavior than children without such disorders. Since this characteristic will be more critical as they grow and become adults, prompting changeover behavior is very important. When supporting prompting changeover, reducing the load on them and their supporters is also required. We developed support equipment and verified its effectiveness to provide assistance that prompts changeover by voice and vibrations. The supporters operate our support device when a changeover is required. The changeover support is done based on the target object of the repetitive behavior. Therefore, since children with developmental disorders feel that the target object of the repetitive behavior is itself providing the support, they will respond to the prompt of the changeover support. We analyzed the effect of support in a case where changeover support was implemented continuously and verified it by continuing to prompt changeover support at the children's home with them and recording their progress. We video-recorded their emotional state with the supporter who also evaluated our device. The prompting changeover success rate improved with repeated support. However, it might decrease due to changes in their physical condition. We conclude that our proposed support provides effective changeover support for repetitive behavior.

Keywords: Children with developmental disorder, Repetitive behavior, Changeover support, Support device

1 INTRODUCTION

Children with developmental disorders have more difficulty doing changeover behavior than children without them [1]. This is a major issue for children with developmental disabilities as they become adults and join society [2]. Such children must learn changeover behaviors to live productive lives. The load on supporters during changeover support is another major issue [3]. Many supporters want to reduce their load and seek mental support. Based on this background, we reduced the changeover support load for both the benefit of children with developmental disabilities and their supporters.

This research proposes a device and support method that provides changeover support for developmental disabled children by voice and vibrations (Fig. 1). We implemented our proposed support and verified its effects. In our proposed support, a supporter operates a device when the target child must make a changeover. The device is installed on the child's tar-



Figure 1: Support system outline

get object. The device supports speech, vibrations, etc. based on its particular operation. The target child experiences the support from the target object. In other words, we provide support from within the repetitive behavior space¹.

We designed a support device and implemented a prototype to achieve our proposed support. The prototype provided three kinds of support: vibration, speech, and operation. First, vibration support gives a moving stimulation through the target object that is held or worn by the target child. Thus, the target child knows when the changeover support will begin. Second, speech support is generated from the target object and provides two types of changeover voice support: preparatory and parental voices. Third, operation support is provided so that the target child can understand the changeover support mechanism. To that end, the supporter directly manipulates the target object to overwrite the existing operation on the target object. This enables the target child to understand the support.

We verified our system to determine whether the prototype provides support. A family with a special needs child cooperated in our study and we video-recorded the child's performance with the supporter who also evaluated our system. We analyzed the difficulties of the changeover behaviors, which were conducted continuously and evaluated the effectiveness

¹Repetitive behavior space is the target child's recognition space during repetitive behavior.

of our system using the analysis data.

2 RELATED WORK

In recent years, research on developmental disorders has increased [4]–[6]. Although changeover support away from obsessive behavior is one basic type of support [7], unfortunately, few studies have addressed it. Direct support using voice and gestures is common.

However, if the changeover support does not work very well, the burden falls on the supporter [8], [9]. In addition, smooth behavior in a group might be hindered. Therefore, in the research on changeover support, effective methods that provide general direct support and ways of creating ideal environments for changeover support have been discussed [10]: in other words, making successful prompts. Little research has focused on "what to do."

In addition, prompting tools have been developed, for example, a support device that offers an auxiliary role for intentional transmission. Support devices that use visual information, which are typically represented by picture cards, and support devices that use such aural information as voice, are starting to be used in some fields.

2.1 Related Support Method

Support exists that matches the environment to the target child [11]. For example, the child's supporter waits until the environment and the target child's mindset can be switched. In this way, the supporter acts in coordination with the target child who can live based on his or her own ideal situation. Therefore, such support benefits the target child. On the contrary, forced changeover behavior increases the stress on the target child and strengthens the attachment to the obsessive behavior.

Other support prepares the target child's engagement in the activity [12]. In this support, the child must act base on a schedule. A schedule table or timetable combined with picture cards should be set in front of the target child to reduce the anxiety of the changeover behavior. The schedule also prompts self-directed changeover behavior. However, due to the support for changeover based on the situation, it is impossible to act based on the surrounding situation. Therefore, the target child cannot accomplish collective action.

Voice support establishes changeover behavior by a repeated voice, for example, providing preliminary preparation for an imminent changeover. Voice support does not just denote that such sound is required. Timing and voice strength are also important.

2.2 Related Support Device

Support devices for communication using voice also exist [13]. Speech recognition can be achieved using such a support device for children who can't speak very well [14].

Such recognition enables the voice-based indication of the intention of the target children who want to communicate but can't speak well. The target child operates a device in which the supporter's voice was recorded in advance and emits audio that transmits the target child's intention to the supporter

Table 1	1:	Hearing	and o	bservation	survey
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Location	Repetitive behavior	
Home	Watching on DVD player	
	Watching on a mobile DVD player	
	Reading a magazine	
Outing	Watching on mobile DVD player	
	Supporter sings	
Support facility A	Listen to CD player	
	Reading a magazine	
Support facility A	Supporter sings	
Outing		
Support facility B	Reading magazine	
Support facility C	Listening to CD player	

by voice. The supporter can also communicate through the hand of the target child who holds the device. In other words, the support device can actively communicate the supporter's intention 2 .

For digital devices, systems have been proposed that extend conventional support using tablets and PCs [15]. Using digital devices can significantly reduce the cost of producing individual tools, which is a problem with conventional support. This step will also reduce the burden on supporters. Unfortunately, many target children can't use digital devices because they have difficulty correctly inputting commands or they don't know which icons to touch. Supporters might also not be familiar with advanced technology. They might also have trouble making settings.

3 REPETITIVE BEHAVIOR FOR CHILDLEN WITH DEVELOMENTAL DISORDER

The repetitive behaviors of children with developmental disorders are significantly different from those of children without them, especially in the time, period, and attachment force that occur. Children with developmental disorders show a marked attachment to certain items or situations. They never want to relinquish them, which causes repetitive behavior.

Repetitive behavior is associated with place. However, the target child only changes the repetitive behavior based on the place. In other words, the essence of repetitive behavior does not change. Table 1 shows the results of interviews with collaborators in this study. From interview surveys, we identified behaviors where children repeatedly looked at a particular scene in a video or listened to a particular piece of the music. Repetitive behavior changes depending on the place. However, the behavior of playing videos, listening to music, and reading does not change. In other words, some acoustic or visual stimuli are repetitive behaviors.

Since the changeover from repetitive behavior is stressful for children with developmental disorders, they have difficulty changing. One major obstacle has been identified in the performance of children with developmental disorders and those without them. In addition, the group life of children

²Current support includes a type that allows children to choose cards and intentional communication by pointing.

with developmental disabilities is extremely difficult due to their repetitive behavior. Therefore, since they can't cope with their environment because it fails to match their feelings, they can't digest sudden schedule changes. Compulsory changeover to adjust to the surrounding situation causes a great deal of stress on the target child. As a result, he may engage in self-harm or hurt others. Forced changeover supports counterproductive effects. To reduce such stress, it is important to spontaneously prompt the child to make the changeover.

The following are supports that promote conventional changeover action: using picture cards; using timers and watches; using voice overs. Such support is provided at homes and schools for children with developmental disabilities and afterschool services. In the support by picture cards, a picture card shows the next action. By focusing on the target child before the action or the changeover, we can make image the action after the changeover and promote changeover behavior. A timer or a clock can provide support by announcing the changeover time. The target child can imagine how much of their own behavior they can do later to promote changeover behavior. Before a switch is made, the voice support announces: "It will soon be time to make a changeover." We can immediately create an image that changes the child's target and encourage the changeover behavior. Critically, these types of support should be used to gradually increase actions that the target child can do but dislikes. In other words, our method avoids compelling responses from target children and making them feel bad. Such behaviors must only be increased with activities the target child wants to do but can't.

However, children with developmental disorders only concentrate on objects of interest. Therefore, often support from the surrounding people is not transmitted. The following support is provided, but it is stressful for children with developmental disorders. One example is support between the objects of interest and children with developmental disorders: physically separate the objects and children with developmental disorders. Stop the operation. In addition, attachment to a supporter may occur. Such attachment to a supporter might turn him/her into a favorite, and they decide they prefer support from that supporter and not from the others. Hence, they only accept support from their favorite supporter.

4 CHANGEOVER PROMOTION SYSTEM FROM REPETITIVE BEHAVIOR

Our proposed system provides the following support, as shown in Fig. 1. The target child concentrates on his target object. Perhaps the assistance from the surrounding supporters will not be accepted. In this research, the target child's recognition range is defined as the Repetitive Behavior Space. This space is conceptual and varies in scope and size depending on the target child. A support device is attached the child's target device to provide support to the objects of choice. The supporters benefit the target child using remote control equipment outside of the Repetitive Behavior Space. Our changeover promotion system generates voice and vibrations to support the target child who can recognize whether the target 51

object itself is vibrating or speaking. This enables support from inside the Repetitive Behavior Space that is expected to encourage changeover behavior. Even if the support person changes, the voice support from the object of attention does not change. This resolves the issue of attachment to a particular supporter.

The following is the support order of our proposed system that promotes changeover behavior. The vibration support device is activated, and it notifies the target child at the beginning of the changeover behavior. The voice support device is activated to prompt the child to prepare for a changeover. The operation support device is activated to orally state the action. Actions can be associated with states. To realize this kind of support, we designed a device as shown in the Fig. 2.

4.1 Vibration Support Device

The vibration support device generates vibrations on the target object of interest to inform the target child of the support. Since this support uses vibrations, the target child must be touching the target object to receive support. When not making contact, an object must be used that is in contact with an item that is related to repetitive behaviors.

The supporter starts the device before beginning the support. After activation, the vibration motor attached to the vibration support device is turned on, and the object of interest or the related object to which the device is attached vibrates. This vibration stimulates the target child's skin because we expect an action that simplifies responding to the stimuli due to poor hearing.

4.2 Voice Support Device

The speech support system provides support using speech from the target object. The audio attached to the object of interest plays back a sound that can facilitate the changeover. We chose the same voice used at homes and educational settings based on our assumptions that it would be effective.

When the target child is notified by vibration support, support is provided using this device. The assistant starts the voice support device, which reproduces a voice registered in advance. Since the sound is reproduced from the target object, the target child recognizes that target object itself is speaking. Support is provided from the target object enjoyed by the target child. We believe that this support will have the same effect as support provided by a favorite supporter.

4.3 Operation Support Device

The operation support device enhances the effect of our proposed system by controlling the target object's power so that operational control cannot be relinquished to the target child. This device is not intended to be used continuously. In other words, we only assumed its use at the initial stage of support. This device is only effective when the object of interest runs on electricity.

It controls the actual operation with the voice support device. Since the changes in the target might simplify the target child's understanding, changeover actions are only promoted by voice support.

4.4 Implementations for Home Applications

Three devices are controlled by a remote-control device, which wirelessly controls the device. Its operation must be simple so that the supporter who uses the support device can do so easily. For practical operation of our proposed system, the devices are linked by the implementation and home environments.

We conducted interview surveys and observed the home environments of the families from whom we obtained prior consent for cooperation with our research. Based on the information obtained from the household environment, the interview surveys, and home observations, we tailored our equipment to the living environment of the target child. Since target of the basic commitment at home was watching DVDs, we installed our equipment on a DVD and attached our equipment to it.

Based on a preliminary survey, the child's attention behavior was performed for the following period: 1) from waking up to going to school and 2) from returning home to taking a bath.

At home, in addition to watching a DVD, viewing on a mobile DVD player was also possible. Changeover behavior is classified as not continuable or continuable. Not continuable changeover is defined as changeover behavior that can't continue the repetitive behavior after the changeover (Fig. 3). Such changeover behavior is completely separated from the target object. Continuable changeover is defined as changeover behavior where the repetitive behavior can continue after changeover (Fig. 4).

One item that the target child must have during the selective actions is the DVD remote control. We attached a vibration support device to the remote control so that it could always be used during playback. We attached a small device to the remote control to reduce the risk of inconvenience when using it. Figure5 shows the remote control to which we attached our mounted device. The vibration support device was attached to the back of the remote control for the target object. Since the device is controlled by an infrared signal, we designed it so that the light receiver can't be hidden when the target child carries it.

The target child's repetitive behavior is watching DVDs. In this experiment, we defined the obsessed object as the object of repetitive behaviors. Therefore, the target object in this example is the TV screen. The voice support device needs to be installed around it so that the sound can be heard. The home appliance control support device needs to be installed around the output cable of the DVD player. We integrated the voice support device and the home appliance control support device next to the TV display. The target object's power is drawn to the device, and control is done using an infrared signal. The voice support device also incorporates an independent control mechanism using a commercially available system and controls from a smartphone application. Figure6 shows the attached device, and Figure7 shows its installation.

The supporter operates each device at each changeover behavior. Basic operations are done using the infrared remote control (Fig. 8) that was implemented in an easy-to-understand manner using large operation instructions and colored but-

Table 2:	Classi	fication	of c	hangeover	beł	navior	in c	hil	d
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	Not continuable	Continuable
Favorable		Message
Unfriendly	Meal	Brushing teeth
	Going out	
	Doing homework	
	Taking a bath	
Voluntary	Going to the bathroom	

tons. By pressing the button, the infrared signal is emitted to control the target device. The voice support device can record, register new assistance, and so on. Each operation is performed using a smartphone application. Figure9 shows the positional relationship introduced into an actual environment. The vibration support device is held by the target child.

5 VERIFICATION OF EFFECT BY SUPPORT FROM THE TARGET OBJECT

Our proposed system provided continuous support with the cooperation of a female junior high school special support school, a first grader, and her family. This child does not talk with others. However, she can understand the voices of her supporters to some extent. Communication from her is based on gestures or pointing. When the child is engaged in repetitive behavior, she tends to prioritize the repetitive behavior over the voices of the surrounding supporters. Therefore, in many situations she cannot transition to the changeover behavior.

We recorded from March to September 2018. Spring and summer breaks were included. The recording was mainly done by the mother who was also a supporter at home, and we did video recording on our visitation days. We observed the changeover behaviors that occurred at home and classified them with the supporters. The classifications are shown in Table 2. We predicted and classified the situations we observed and determined whether the target child liked or disliked the changeover behaviors itself. Since the changeover behavior for going to the bathroom is a voluntary changeover, we did not analyze it.

As shown in Table 2, we made two major classifications based on the content of the changeover behavior. Not continuable changeover behavior is defined as changeover behavior that cannot be continued after the changeover. Since repetitive behavior can't be continued after a changeover, we can't changeover a behavior even with such support such as the direct voice of supporters and gestures. Continuable changeover behavior is defined as repetitive behavior that can continue after a changeover. In many cases, changeover behavior can also be done by summoning the supporters. In addition, the target child performs a changeover behavior based on the information of the sound of the voice support. However, there was also a case where the changeover behavior differed from the content of the support. Therefore, the target child probably performed the changeover behavior by observing the surrounding situation based on the assistance of the voice support.

We propose support based on the timing of the occurrence



Figure 2: Support system detailed overview



Figure 3: Example of not continuable behavior (Dinner)

of the daily changeover behaviors. The supporter operates the support device based on the procedure. The supporter observes and records the target child's behavior. In the procedure, the voice support for the preparation of the target child's changeover is implemented just before the occurrence timing of the changeover behavior. Here is an example of a voice support: "Please finish soon." The voice's content was decided in consultation with the support person based on the voice usually heard at home.

At the early stage, the content was based on the usual practices at home. As the talking time increased, the child's cooperation became more effective. In other words, by increasing the number of sentences per utterance, we more effectively prompted changeover behaviors. In the second half, the same



Figure 4: Example of continuable behavior (brushing teeth)

word is repeated twice or the name of the target child is spoken.

Commitment behavior in the home is performed intermittently from the time of getting up for school on weekdays, going out (weekends and holidays), and returning home for a bath. The target child watches his favorite DVD (Fig. 10). In some cases, he watched on a mobile DVD player (Fig. 11).

5.1 Experiment Setting

In this experiment, we calculated the success rate of the prompting of the changeover behavior using our proposed support. Then we analyzed its effectiveness. The success rate was based on situations where the target child did the changeover behavior just based on reminders from the sup-



Figure 5: Vibration support device



Figure 6: Integrated voice and operation support devices

port device. First, the support person operated the support device for the changeover. Next the support person called out to promote the changeover behavior. At this stage, the supporter was aware of and pretended to ignore the target child so that we can analyze the effect of the summoning support from the support device. If no changeover behavior is seen in this state, the strength of the support from the support person is sequentially increased to promote changeover behaviors. We increased the strength of the support in the following order: direct support from the supporter, gestures, stopping the object of interest, and taking arms and guiding.

We recorded the extent of the increase of the support intensity in a five-step evaluation. Table 3 shows the success criteria for the changeover behaviors. In the not continuable behavior, a case where the behavior shown in the table 3 is performed after the intention to end or end the sticking action by itself is regarded as success. In the continuable behavior, the continuable behavior is performed while continuing the repetitive behavior. Therefore, even if the repetitive behavior is ongoing, if the behavior shown in the table 3 is performed, it is successful. In addition to the changeover behavior results, the target child's daily situation was recorded and analyzed. Figure12 shows an actual paper record of a target child. Our analysis used these aggregated weekly data for Fig. 12.

5.2 Success Rate of Changeover Behavior by Proposed Support

The graph obtained by aggregating the weekly changeover behavior success rate based on our proposed support is shown in Fig. 13. The success rate varies greatly in a short time due to factors such as physical condition. Therefore, analysis is



Figure 7: Support device installation diagram



Figure 8: Infrared remote control for basic operation

performed using the average of the success rates for one week. Each element represents a not continuable behavior and an continuable behavior, respectively. Each of the changeover behaviors was also grouped and averaged.

The not continuable changeover behaviors can't continue the repetitive behavior after the changeovers. Therefore, the changeover success rate is low. On the other hand, Continuable changeover behavior can continue the repetitive behavior after the changeover. So the target child easily made the changeover. The data from March 25 and April 8 are missing because the subject was sick and the proposed support was not implemented. The success rate of the changeover behaviors between the not continuable and continuable changeover behaviors fluctuated. For example, since the target child's physical condition did not improve in the week of May 27th, the tabulation end date where the changeover behavior success rate was significantly reduced for both the not continuable and continuable changeover behaviors.

We focused on such changes in the physical condition and the environment and analyzed their occurrence rates, the changes in the environment, and the changes in the continuation of support. Section 5.3 describes the transition of the changeover behavior success rate, Section 5.4 describes the changes in the environment, and Section 5.5 describes the changes due to continuous support.

5.3 Transition of Changeover Behavior Success Rate

The success rates of the changeover behavior between the not continuable and continuable changeover behaviors changed depending on the physical condition of the target child. In the week where the changeover behavior success rate decreased, both the not continuable and the continuable changeover be-



Figure 9: Positional relationship among support system, supporters, and target child



Figure 10: Target child who watched DVDs

haviors decreased, and the rate increased in subsequent weeks. The decrease factor is sensitive not only to the child's physical condition but also to her environmental changes.

In the continuable changeover behavior, almost 100% was maintained in the week when the child had a good physical condition and a good environment. Therefore, for the continuable changeover behavior, we continue to propose support and establish the changeover behavior. However, if the support person fails to show the toothbrush at the changeover behavior for brushing the teeth ³, the target child may exhibit this behavior (the changeover behavior to the massage) and direct her foot to the supporter (Fig. 14).

5.4 Change in Changeover Behavior Success Rate due to Environmental Changes

A major change in the environment revolved around whether to go to school. The experimental period included spring vacation from March 18 to April 8 and summer vacation from July 22 to September 2. We confirmed a decrease in the changeover behavior success rate during both holidays.

The child's waking-up time and bedtime changed because the routine of going to school was interrupted. In addition,



Figure 11: Target child who watch DVDs by mobile DVD player



Figure 12: Support situation record sheet

the decrease in the changeover behavior success rate that occurred early in the first semester was probably affected by the change in the support method at school due to a new teacher. The changeover behavior success rate decreased based on such environmental changes, and the changeover behavior success rate and changes in the living environment have a large relationship.

5.5 Change in Changeover Success Rate due to Continuation of Support

Although the changeover behavior success rate fluctuates based on environmental changes and physical conditions, the appearance tendency tends to improve as a whole. This improvement trend shows better use of our continuous proposed support. The decrease in the success rate due to environmental and physical condition factors can be judged by a comparison with the continuable changeover behavior, which is the success rate at a normal 100%. In other words, except for

 $^{^{3}\}mbox{The supporter}$ has a toothbrush in his hand but does not show it to the target child.



Figure 13: Graph of changeover behavior success rate



Figure 14: Failure to brush teeth changeover behavior

the week when the changeover success rate of the continuable changeover behavior decreased, the general tendency showed an increase. The assistance with our continuous proposed support is effective for successful changeover behaviors.

Before summer vacation, the changeover behaviors were successful with a 60% probability. The incidence rate improved by about 40% in three months. Due to the environmental change of summer vacation, the emergence rate de-

Table 3: Achievement standard of goals				
Changeover behavior	Achievement standard			
Breakfast	Moving to the table and eating			
Dinner	Moving to the table and eating			
Go out	Moving to the door			
Homework	Doing homework			
Taking a bath	Moving to the bathroom			
Massage	Putting feet on the supporters			
Toothpaste	Turning head to supporter and			
	lie down			

creased. If we can incorporate such environmental changes, we expect a more stable changeover behavior success rate. If our proposed support is used continuously and assistance is done as such, the target child can expect better growth. We believe that our support device is effective. The supporters themselves also commented that the target children's reactions improved.

5.6 Change in Supporter Burden

After the experiment, we investigated the burden on supporter. For this reason, supporter were interviewed. From the results of interviews with supporters, the following are the factors that reduce and increase the burden. The burden reduction factors are as follows: I can help when I am away from my child. Even at a position where my voice could not normally be heard by the target child, support was provided through the device. (However, it took about a year to be fully responsive.) For the same reason, the same effect was felt even when the supporter could not speak due to a cold or the like. The device changed the supporter's feelings for support. As a result, we were able to provide continuous support. Changeover is now successful even if the supporter changes. (Can change over with the support of her brother.) At first, they did not respond without assistance from the subject. With continuous support, I became responsive when I heard the sound.

The factors that increase the burden are as follows: Immediately after I started support, she responded with a rejection. I bit myself and me.(About 2 to 3 months) The operation support device has reduced the number of DVD viewings. She began to watch mobile DVDs that could not be controlled by the device. She started watching DVDs in her favorite room, and I could no longer monitor her. (However, watching mobile DVDs has increased her mobility. We think that her stress was reduced by this.) I make a mistake in operation the device. There is a bias in the devices that can be controlled. Therefore, the target child can escape to another repetitive behavior. For example, she changed from a DVD player to a mobile DVD player.

6 CONCLUSION

We reduced the burden on both the target child and the supporters during changeover behavior from obsessive behavior and obtained spontaneous changeover behavior. The early stage not continuable changeover behavior is not practical because the changeover behavior success rate is low. However, continuous support was maintained, and we eventually achieved an emergence rate of 60%, proving that this support is effective. On the other hand, a 100% success rate can be maintained in continuable changeover behaviors. We believe that our process has advanced to a practical stage.

In the future, we will provide more continuous support and investigate how long it can improve the success rate in accordance with environmental changes and physical conditions. We must also analyze the problems of our proposed support based on the situation and changes of the target child and investigate whether a significant adverse effect exists.

We haven't considered the burden on supporters yet. Therefore, we must implement a new support device that can automate operations and support with a low load. However, we received the following comments from a supporter. "Using the device as a trigger for changeover behavior allowed smooth changeover behavior." "Although at times using the device was burdensome, it switched my feelings. ""The child asked to use the device." In other words, using the device itself is a burden. However, the support environment was improved by the device. Currently, control is done by a smartphone. We can achieve operation with less burden by implementing control with physical buttons that can be operated immediately, automatic voice call support based on the situation of the target child, and semi-automatic trigger call support, etc. We must also devise equivalent support in multiple places to cope with the target child's movement in the room and a smaller device that can cope with changes in the target object.

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