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An fMRI study on the effectiveness of self-modeling treatment for stuttering

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A home-based video self-modeling (VSM) treatment was developed and implemented in 10 adults who stutter (AWS). This VSM treatment provides an opportunity for adults who stutter to recognize their ability to speak fluently. Findings showed that the VSM treatment affects their thoughts and beliefs about stuttering, their communication attitudes, and reactions to different speech situations toward a more positive manner. Second findings from this study showed that AWS and controls showed different brain activation areas during word reading aloud. ASW showed lack of activation in Broca's area and superior temporal gyri, and an increased activation of the cerebellum area. This additional recruitment of the cerebellum may act as a "compensatory" way to produce fluent speech.

fMRI

As many as 67 million people in the world suffer from developmental stuttering that impact their communication and social interaction life (The Stuttering Foundation, 2009). Yet, its effective and lasting treatment has not yet been forthcoming. Relapse (or failure to maintain treatment effects) is commonly seen with traditional training in people who stutter (PWS), especially adults. Despite the efforts of researchers and clinicians to develop interventions for stuttering, there is still limited information about different procedures that may be efficacious as part of the relapse management plan.

(1) Video Self-Modeling (VSM)
The VSM intervention involves people watching images of themselves free of problem target behaviors (Bellini & McConnell, 2010). Because PWS show avoidance behaviors in certain situations, the VSM treatment could provide opportunities for the PWS to recognize their abilities to perform stutter-free speech, hence, promoting fluent speech in daily life environment. There is evidence suggesting that the VSM is effective in reducing stuttering in children, adolescents (Bray & Kehle, 1998), and adults who stutter (Chu, Sakai, Mori & 2012). Bray and Kehle (1998) provided three 5-minute videos for each participant (3 boys, 13-17 years old) showing their stutter-free response to teacher questions during an academic lesson situation. Subjects watched these videos for 6 times in the clinic during a 5-week treatment period. All participants showed a decrease in their average percentage of syllable stuttered (%SS) at the end of the intervention period.

(2) Neuroplasticity of the brain
Stuttering has been reported to be associated with widespread over activation in right cortical and left cerebellar motor regions and often with deactivations in left hemisphere language and auditory areas (Sommer et al, 2002, Fox et al., 2000). To test the cortical plasticity associated with fluency shaping therapy, one fMRI study showed that post-treatment activation increases in the left-sided speech related regions such as the frontal and temporal areas, the insula, and the anterior cingulate cortex (Neuman, 2005). These findings suggest

that fluency shaping techniques reorganize neuronal connections among left-sided speech motor planning, motor execution, and temporal auditory feedback areas. To date, none of the speech clinics provides evidence-based treatment outcomes using the VSM and fMRI techniques. Therefore, the main objective of this research is to test the efficacy of the VSM treatment in PWS by providing concrete evidence of the neural substrates changes within- and between-group comparison.

There were two aims in this study:
(1) To determine the effectiveness of the VSM treatment in PWS using clinical objective and subjective measurements.
(2) To examine the underlying neural substrates changes in relation to VSM pre-post treatment conditions in PWS and normal control speakers using fMRI techniques.

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(1) Method for Aim 1:
Subjects: A total of 10 PWS were recruited into the study [N=10, Age= 35.8 (SD=11.2), Male=7].
Procedure: Subjects were asked to watch their own 5-minute stuttered-free video at home every day for 1-month. The following clinical objective and subjective assessment tools were used to examine for the effect of the VSM pre-post treatment.

Objective test:
1. *The Stuttering Test-Revised Version* (Hara, et al., 2010): This test is Japanese standardized clinical assessment tool designed to evaluate the patient's stuttering severity level. This test includes asking the subject to read a series of words, phrases, passages, and a 5-minute conversation to judge his/her stuttering severity.

Subjective tests:
1. **Modified Erickson Scale of Communication Attitudes (S-24)** (Andrews & Cutler, 1974): To obtain information about a subject's communication attitudes.

2. **Self-rating of Reactions to Speech Situations (SR)** (Sakata, *Stuttering Association Meeting Proceedings*, 2003): This test is used to assess the reactions

to different speech situations before-and-after VSM treatment.

3. Unhelpful Thoughts and Beliefs about Stuttering Scales (UTBAS) (Iverach, et al., 2010): This is a self-report measure of the frequency of unhelpful cognitions associated with social anxiety for PWS.

4. Overall Assessment of the Speaker's Experience (OASES) (Yaruss & Quesal, 2006): This test aims to describe the experience and impact of stuttering from the perspective of PWS and serves as a monitoring tool in the evaluation of stuttering treatment outcomes.

5. Liebowitz Social Anxiety Scale Japanese (LSAS-J) (Liebowitz, 1987): To assess the way that social phobia plays a role in a subject's life across a variety of situations.

6. Self-rated Stuttering Severity (SRSS) (O Brian et al., 2004): This test is a 9-point severity rating scale commonly used in clinical setting (1-no stuttering, 9-extremely severe stuttering).

(2) Method for Aim 2:
10 normal adults and 10 adults who stutter were scanned in 1.5T Toshiba MRI. Subjects were asked to read the words presented to them inside the scanner. Five categories of stimuli were presented: Japanese 40 Familiar (F), 40 Unfamiliar (U), 40 Pseudowords (P), 5 prolonged Vowels (V), 5 Cyrillic letters (visual control, R). The fMRI data were analyzed with 2-way-ANOVA in SPM8: Subject (C-group/S-group) x Word (F/U/P/V/R).

(1) Results for Aim 1:
Table 1 summarizes all the objective and subjective clinical measurements of 10 PWS after a 1-month period of VSM home-based intervention. These results showed that after the VSM treatment, PWS showed the following improvements:
(1) **S-24:** PWS change their communication attitudes to a more positive manner
(2) **Self-rating of Reactions to Speech Situations:** PWS reactions to speech situations towards a more positive manner
(3) **UTBAS:** changed the views of PWS on unhelpful thoughts and beliefs about stuttering towards a more positive manner.

(4-6) However, the VSM treatment did not improve their **percentage of stuttered phrases,** overall experience and impact of stuttering (**OASES**), social anxiety levels (**LSAS-J**), and **self-rated stuttering severity scale.**

Table 1. Summary of the pre-post VSM treatment results

Assessment tools	Pre-VSM (Mean, SD)	Post-VSM (Mean, SD)	p Wilcoxon test
Percent of stuttered	10.7 (25.8)	10.4 (24.3)	0.695
S-24	16 (4.3)	12.6 (4.8)	0.020*
SR	56.7 (14.5)	50.3 (10.5)	0.020*
UTBAS	367.1 (90.0)	286.1 (38.0)	0.006*
OASES	54.2 (10.6)	49.8 (6.1)	0.193
LSAS-J	35.8 (9.4)	31.5 (11.5)	0.203
SRSS	4.4 (1.4)	3.7 (1.1)	0.053

*indicates significance at <0.05

Conclusions: The VSM treatment provides an opportunity for the PWS to recognize their ability to produce fluent speech. Indeed, the VSM treatment affects their thoughts and beliefs about stuttering, their communication attitudes and reactions to different speech situations toward a more positive manner. This home-based treatment can be used as a self-manage program for PWS to control their speech after being discharge from clinics (Chu et al., IEICE Technical Report, 2013). Based upon feedback from subjects and their objective and subjective clinical measurement results, it is important to note that approximately 50-70% of them benefited the most from this program (Chu et al., , 2015). Like any other speech treatment programs, the reasons why the VSM treatment did not have an impact on some PWS need to be determined. There may be due to percentage of stutter level before the VSM begins, personality effects, subject's time contribution when watching the DVD, age, sex, and impact of previous speech therapy treatment. With multilevel regression model, these factors may be able to examine in the future.

(2) Results for Aim 2:
This aim has been changed because two

different word lists were used at pre-post treatment testing. Hence, direct comparison of brain activation within subjects to determine the VSM treatment effect cannot be achieved. Instead, 10 adults who stutter (S-group) were scanned and their brain activation was compared with 10 controls (C-group). This aim has been revised to following:

To determine whether there are differences in brain activation patterns between visually familiar words, unfamiliar words, pseudowords, and vowels during overt reading, and a secondary comparison between control subjects and adults who stutter.

From the fMRI analysis, the following findings were found:

Greater activations were seen in C-group in left premotor cortex (BA6), suggesting that reduced activity in BA6 is likely to interfere with the integration of sensory and motor information necessary for fluent speech production (Figure 1).

Figure 1 Group main effect
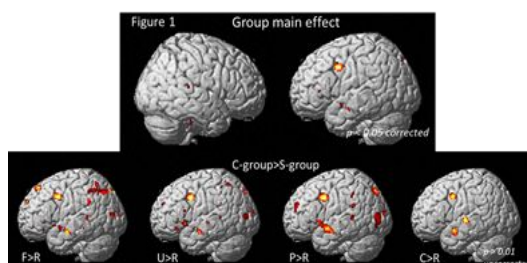
Activation in the bilateral superior temporal gyrus (BA22/BA41) and middle temporal gyrus (BA21) is clearly visible in controls but was absent in the S-group (Figure 2, black arrow). Cerebellar activation was absent in the C-group while apparent in the S-group (Figure 2, white circle).
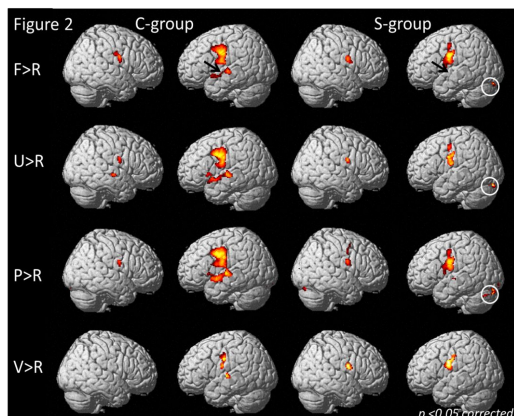
Figure 2

C-group showed activation in the Broca's area (BA44) for unfamiliar and pseudowords (U>V, P>V) conditions, this activation was not shown in the S-group (Figure 3, blue circle).

Figure 3
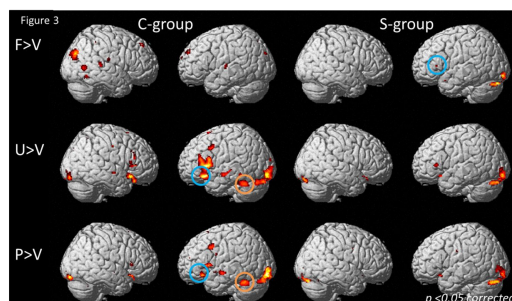
Conclusions: In addition to the Broca's area, superior temporal gyri and fusiform gyrus may play a role when reading aloud unfamiliar words and pseudowords. Due to the lack of activation in these areas in the S-group, additional recruitment of the cerebellum may act as a "compensatory" way to produce fluent speech.

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