



Original Article:

Assessment of Working Memory in Individuals with Stuttering in Comparison with Individuals with Normal Fluency

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Citation

Varghese AL, Nanditha JP, Bajaj G, Anil MA, Balasubramaniam RK, Kumar AS. Assessment of Working Memory in Individuals With Stuttering in Comparison With Individuals With Normal Fluency. *Online J Health Allied Scs.* 2018;17(1):2. Available at URL: <https://www.ojhas.org/issue65/2018-1-2.html>

Submitted: Mar 3, 2018; Accepted: Apr 30, 2018; Published: May 15, 2018

Abstract: It is common in literature to relate stuttering with some other deficit that interferes with communicative functions. Working memory comprises the system of human memory dedicated to both temporary storages of phonological detail and allocation of cognitive resources necessary for forming lasting memories. In this study we have analyzed the performance of individuals with stuttering on various working memory tasks. The aim of study is to compare the working memory abilities in individuals with stuttering and individuals with normal fluency on various working memory tasks. A total of 30 individuals with stuttering and 30 individuals with normal fluency in the age range of 18 – 40 years participated in the study. The Working Memory domain will be assessed using The Manipal Manual for Cognitive Linguistic Abilities (MMCLA) which consists of auditory word retrieval, auditory letter and number recall, auditory word list recall, auditory delayed sentence recall, visual practice recall, visual letter and number recall, visual word list recall and visual delayed sentence recall. Results revealed that the individuals with normal fluency had superior performance compared to the individuals with stuttering. Hence, it's helpful to understand the involvement of working memory in stuttering and incorporate working memory training along with the conventional fluency therapy.

Key Words: Working memory, Stuttering

Introduction:

Stuttering is a common fluency disorder seen in children and adults. It is a diagnostic label given to a group of syndromes that describes the atypical and most perseverant dysfluencies in speech associated by characteristic affective, behavioral, and cognitive patterns. Stuttering is usually perceived by speech ruptures, habitual repetitions or elongations of sound, syllabus and words. The prevalence of stuttering varies with

age. Stuttering is found in all age levels beginning with the onset of speech. According to Yairi & Ambrose (1), the mean age of onset of stuttering is 33 months, with over 85% of onsets prior to 42 months of age and very few onsets prior to 24 months.

Working Memory is an abstract schema within cognitive psychology that attributes for the temporary storage and manipulation of information in the structures and processes in its framework. Working memory includes these systems and processes to store and manipulate verbal and visual images, and a central executive that integrates the subsystems. The information is stored only for a limited amount of time in the working memory. Working memory tasks involves the manipulation of information to accomplish goal-directed actions in the background of any interfering processes and distractions.

Fluent speech involves certain constituents to be conjugated in synchrony, and stuttering can develop when components of the speech plan are imprecisely timed. In individuals with stuttering, Sommer et al (2) observed neuro-anatomical substantiations for cortical disconnections, approximating below the laryngeal and tongue representations in sensorimotor cortex. They estimate from their conclusions that persistent developmental stuttering develops from disrupted timing of activation in speech relevant brain areas. The findings of Salmelin et al (3) supported this interpretation.

The present study has focused about the possible relation that can exist between working memory and stuttering. Working memory comprises the system of human memory dedicated to both temporary storages of phonological detail and allocation of cognitive resources necessary for forming lasting memories.(4-6) Research on utterance planning and attention processes in stuttering have heightened the prospect of working memory involvement in the disorder (7). Studies

involving memory and dual-task performance in children and adults with stuttering has been conducted in order to establish a possible connection between them (8). Memory is intently connected to the communication process. Various authors have established in their research evidences that stuttering can be linked to memory deficits.

Working memory performances was assessed by Oyouun et al (9) on 30 children with typical normal fluency and 30 children with stuttering in order to identify if working memory deficits have a part in the advancement of stuttering. The participants were subjected to various working memory recall tests. It was concluded that children with stuttering may have reduced capacity in recalling non -words and their performance diminished in some of the other working memory tasks. The reaction time and rate of learning abilities was studied by Ali et al (10) in 2011 in 30 children who did not stutter and 30 children with stuttering based on various word set call and digit span tests. The author's findings reveal that the mean of reaction times in children with stuttering was significantly longer than that of the control group. He also reported that rate of learning non words were slower in children with stuttering when compared to their normal counterparts.

In a study done by Barbosa(11), the verbal memory abilities of 15 children with stuttering were compared to that of 15 children with typical normal fluency and they were matched in terms of their age and gender. Results established that the difficulties presented by children with stuttering were related to more of the pre- motor level of speech processing deficits along with difficulties to select and adopt effective cognitive strategies and their verbal abilities were affected because of their incompetent working memory abilities.

There are evidences which suggest that working memory plays a major role in individuals with stuttering. Through this study we have analyzed the performance of these individuals in various working memory tasks to have clarity on how it affects their ability for dual task performances.

Aim: To study the working memory abilities in individuals with stuttering in comparison with individuals with normal fluency on various auditory working memory and visual working memory tasks.

Method

The present study aimed at comparing the performance on both auditory and visual working memory abilities in individuals with stuttering and individuals with normal individuals.

Participants

A total of 30 individuals with stuttering (29 males and 1 female) and 30 individuals with normal fluency (18 males and 12 females) in the age range of 18 – 40 years (young adults) according to the Erikson's Psychosocial Classification (1968) participated in the study. The participant selection criterion was adhered to during their recruitment. An informed consent was obtained from all the participants prior to their inclusion in the study.

Procedure

All the tests were performed in a quiet room setup devoid of any distractions. The administration of test items took a total of 1.5 hours and was completed within two sessions for each subject.

The test procedure was carried out in two phases. The first phase included the pre-assessment, to determine eligibility criteria of participants based on the inclusion and exclusion criteria mentioned above. The second phase consisted of the administration of the experimental tasks.

Phase 1: Pre-assessment

A detailed case history was taken This was followed by screening of participants using the Mini mental state examination (MMSE) and Quick Neurological Screening test (QNST) to rule out the presence of any cognitive and neurological deficits respectively.

The Stuttering Severity Instrument Fourth Edition (SSI-4) by Riley (12) was administered on the participants and the frequency, duration and physical concomitants exhibited were noted down. Speech samples (Reading, Narration, Monologue and General conversation) were elicited from each participant to assess the severity of stuttering.

The Overall Assessment of the speaker's experience of Stuttering (OASES) by Yaruss & Quesal (13) was used to evaluate the quality of life of the participants.

At the end of the initial procedures of assessment of stuttering the participants who met the criteria for the study were selected for further evaluation to assess the working memory abilities.

Phase 2: Experimental tasks

The auditory working memory tasks and visual working memory tasks from The Manual for cognitive linguistics abilities by Mathew et al (14) was used to evaluate the working memory abilities in individuals with stuttering and individuals with normal fluency.

Auditory and visual working memory tasks were assessed in both the groups equally. The participants were assessed for standard auditory and visual working memory tasks which consists of auditory word retrieval, auditory letter and number recall, auditory word list recall, auditory delayed sentence recall, visual practice recall, visual letter and number recall, visual word list recall and visual delayed sentence recall. Each task was presented in an increasing order of complexity. The stimuli for auditory working memory tasks were presented verbally to all the participants and the stimuli for the visual working memory tasks were presented visually on a laptop at a distance of 1 meter away from the laptop screen in a room with relatively low ambient noise levels to avoid distractions. The participants were given instructions at the beginning of each task and the instructions were repeated and explained if required.

Practice trials were given prior to the commencement of each task in order to familiarize them with the tasks. Once the participants were familiarized, the visual mode tasks and auditory mode tasks were presented in a sequential manner. The response pattern of these tasks was verbal. The verbal responses of each participant were noted down.

Auditory word retrieval: In this task, the participants were presented with lists of words at progressively increasing length, beginning with a sequence of 3 words. They were instructed to repeat the sequence aloud.

Auditory letter and number recall: Series of alphabets and numbers were presented in randomized order and the participants were instructed to repeat alphabets and numbers in the correct order as presented by the examiner

Auditory word list recall: In this task, the participants were presented with two lists of words. They were instructed to remember and repeat each list aloud as it is read one after the other. Following this the participant was asked to retell the first list of words.

Auditory Delayed Sentence Recall: In this task, the participants were presented with sentences from one list and were asked related questions about those sentences. Later the participants were presented with sentences from a second list and were instructed to indicate if those sentences were present or absent in the first list.

Visual Picture Recall: In this task, the participants were shown pictures and they were instructed to recall and tell aloud the object or the action which was depicted in the picture in the correct order. The stimulus items to be remembered were presented for 10 seconds.

Visual letter and number recall: In this task, the participants were shown pictures of letters and numbers in a random order and was instructed to remember and tell aloud those sequence of letters and numbers in the correct order. The standardized stimulus item used in MMCLA was presented increased as the

test advanced. The stimulus items to be remembered were presented for 10 seconds.

Visual word list recall: In this task, the participants were shown two lists of words. They were instructed to remember and tell aloud each list as it is shown one after the other. Following this, the participants were instructed to retell the first list of words. The standardized stimulus items used in MMCLA were presented for 10 seconds. Only the second repetition of the first list was considered for scoring.

Visual delayed sentence recall: In this task, the participants were shown sentences from one list and were asked related questions about those sentences. Later the participants were shown sentences from a second list and were instructed to indicate if those sentences were present or absent in the first list. The standardized stimulus items used in MMCLA were presented for 10 seconds. Each correct and incorrect response was awarded 1 and 0 respectively.

A practice item was presented before the initiation of assessment. The overall score for all the tasks were obtained by adding all the correct responses of the participant. Scores from all the above tasks were documented and the overall score was calculated to evaluate the working memory abilities of all the participants. The same protocol was followed for each participant in both the groups, which included 30 individuals with stuttering and 30 individuals with normal fluency.

Results

The aim of the current study was to assess the working memory abilities in individuals with stuttering and to compare them to individuals with normal fluency. The participants of this study were divided into two groups, individuals with stuttering (18-40 yrs.) and individuals with normal fluency (18-40yrs).

The scores obtained for each task were then subjected to statistical analysis using the SPSS software version 16.0. The scores obtained for all the participants were analyzed and their mean and standard deviation was obtained. The student's independent 't' test was applied to analyze precisely the significance of performance for each task between the groups. The results obtained after statistical analysis are reported below.

Working Memory Tasks

Auditory working memory tasks: For the present study, the performance of both the groups on tasks such as Auditory word recall (AWR), Auditory letter and number recall (ALNR), Auditory word list recall (AWLR) and Auditory delayed sentence recall (ADSR) are represented in Figure 1.

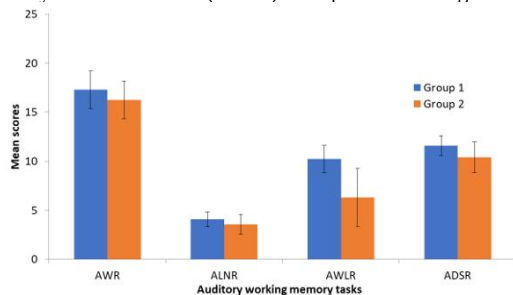


Figure 1: Mean score and SD for Group 1 and Group 2 on auditory working memory tasks.

Auditory word recall: The mean and standard deviation of both the groups on auditory word recall task is presented in figure 1. The bar chart shows the numerical mean of auditory word recall task for both the groups. The arithmetical mean of Group 2 (individuals with stuttering) was poorer than that of Group 1 (individuals with normal fluency). In the auditory word recall task, the Group 1 outperformed Group 2. Further, to assess and compare the auditory word recall performance in both the groups, the student's independent 't' test was used.

The test revealed that, the mean values of this task was significantly different between the groups with the $p < 0.05$. The mean score of auditory word recall task ($p = 0.006$), differed significantly between the groups.

Auditory letter and number recall: In figure 1, the mean and standard deviation of both the groups on auditory letter and number recall task is depicted. The bar chart indicates the numerical mean and standard deviation of auditory letter and number recall task for both Group 1 and Group 2. The arithmetical mean of Group 2 was poorer than that of Group 1 and it revealed that the Group 1 outperformed Group 2. Further analysis and comparison of the auditory letter and number recall performance in both the groups was done using the student's independent 't' test. The test indicated that, the mean score of this task ($p = 0.113$) did not exhibit a statistically significant difference between the groups. The higher standard deviation of auditory letter and number recall task indicates the responses to be highly variable between the participants.

Auditory word list recall: Both the groups mean and standard deviation on the auditory word list recall task is shown in figure 1. The bar chart depicts the numerical mean of auditory word list recall task for both the groups. The arithmetical mean of Group 2 was poorer than that of Group 1, that is the Group 1 showed superior performance compared to Group 2. Additional analysis and comparison of the auditory word list recall performance in both the groups revealed that, the mean values of this task was significantly different between the groups with $p < 0.05$. The mean score of auditory word list recall task ($p = 0.000$) differed significantly between the groups.

Auditory delayed sentence recall task: The mean and standard deviation of both the groups on auditory delayed sentence recall task is presented in figure 1. The bar chart represents the numerical mean of auditory delayed sentence recall task for both the groups. The arithmetical mean of Group 2 was poorer than Group 1 and it revealed that the Group 1 exhibited a superior performance compared to Group 2. Further analysis and comparison of the auditory delayed sentence recall performance in both the groups revealed that, the mean values of this task was significantly different between the groups with $p < 0.05$. The mean score of auditory delayed sentence recall task ($p = 0.008$), differed significantly between the groups.

Visual working memory tasks: For the present study, the performance of both the groups on tasks such as Visual Picture Recall (VPR), Visual letter and number recall (VLNR), Visual word list recall (VWLR) and Visual delayed sentence recall (VDSR) are represented in figure 2.

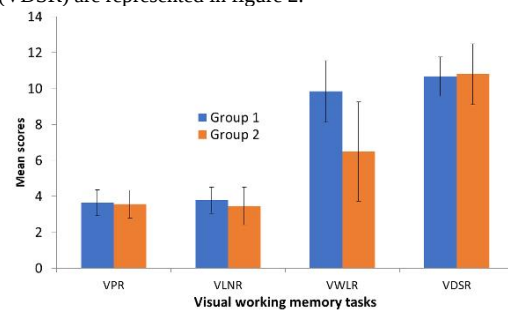


Figure 2: Mean score and SD for Group 1 and Group 2 on visual working memory tasks.

Visual picture recall: The mean of both the groups on visual picture recall tasks are presented in Figure 2. The bar chart shows that the numerical mean of visual picture recall task was higher in Group 1 compared to Group 2. Further analysis and comparison of the visual picture recall performance in both the groups was done using the student's independent 't' test. The test results revealed that, the mean score of this task ($p = 0.287$)

did not exhibit a statistically significant difference between the groups. The higher standard deviation of visual picture recall task indicates the responses being highly variable between the participants.

Visual letter and number recall: The mean and standard deviation of both the groups on visual letter and number recall task is presented in figure 2. The bar chart shows the numerical mean and standard deviation of visual letter and number recall task for both the groups. The arithmetical mean of Group 2 was poorer than that of Group 1, which indicates that the Group 1 outperformed Group 2. Additional analysis and comparison of the visual letter and number recall performance in both the groups revealed that, the mean score of this task ($p=0.006$) was significantly different between the groups.

Visual word list recall: The figure 2 represents the mean and standard deviation of both the groups on visual word list recall task. The bar chart depicts the numerical mean of visual word list recall task for both the groups. In this task, the arithmetical mean of Group 2 was poorer than that of Group 1, which indicates that the Group 1 showed superior performance compared to Group 2. The analysis and comparison of the visual word list recall performance in both the groups revealed that, the mean values of this task was significantly different between the groups with the $p<0.05$. The mean score of visual word list recall task ($p=0.002$), differed significantly between the groups.

Visual delayed sentence recall: For both the groups, the mean and standard deviation on the visual delayed sentence recall task is depicted in figure 1. The bar chart represents the numerical mean of visual delayed sentence recall task for both the groups. The arithmetical mean of Group 2 was poorer than that of Group 1, which revealed that the Group 1 exhibited a superior performance compared to Group 2. Advanced analysis and comparison of the visual delayed sentence recall performance in both the groups revealed that, the mean values of this task was significantly different between the groups with the $p<0.05$. The mean score of visual delayed sentence recall task ($p=0.007$) differed significantly between the groups.

Discussion

Present study aimed to assess and compare working memory abilities in individuals with stuttering and normal fluency under two types of tasks that is auditory working memory and visual working memory. Both the tasks required immediate recall of presented stimuli, along with an operation or manipulation of stored information. The auditory working memory tasks include auditory word recall (AWR), auditory letter and number recall (ALNR), auditory word list recall (AWLR) and auditory delayed sentence recall (ADSR). The visual working memory tasks include visual picture recall (VPR), visual letter and number recall (VLNR), visual word list recall (VWLR) and visual delayed sentence recall (VDSR). The results are discussed below under the two headings of working memory; auditory working memory (AWM) and visual working memory (VWM).

Auditory working memory (AWM)

The numerical means of auditory working memory tasks revealed that, the performance of Group 2 was poorer than Group 1 for all the tasks, indicating an existence of working memory deficits in Group 2.

On the auditory word recall task, the results were statistically significant between Group 1 and Group 2. This signifies that Group 1 showed a superior performance compared to Group 2 indicating clear existence of impairment in working memory in Group 2. These results are consistent with the other studies which stated that individuals with stuttering had a lesser ability to accurately recall long word sets compared to individuals with normal fluency as the complexity of the task increased (9). Similarly, in this study, the participants in Group 2 found it more difficult to accurately recall all the longer word sets as

the complexity of the task increased compared to the shorter word sets. This can be attributed to the fact that long word sets require more articulatory duration and is of higher phonological complexity and that long articulatory duration does not allow spoken words to be rehearsed more frequently. Words that are not rehearsed more frequently are more likely to decay before an entire sequence of them can be recalled (15). This finding can also be explained by the fact that the phonological complexity of words hinders the speech planning abilities, thereby deteriorating their abilities to recall words of increasing phonological complexity (16).

The overall performance shown by both the groups in auditory letter and number recall task indicated that there were no statistically significant differences between the groups even though there were differences in the mean scores. These findings suggested that the performance of both the groups on this task is almost similar in nature. The present finding shows that the recall of the presented string of letters and numbers are relatively simpler because numbers and letters are more familiar. Hence, a more complex task of ordering of the presented string of letters and numbers in ascending or descending order would have yielded a statistically significant difference. This is supported by the evidence of the involvement of working memory and attention in individuals with stuttering in dual task performances. Bosshardt (17) stated that in dual tasks, the attention needs have to be split between two demanding tasks which would thereby increase the cognitive load, thus effecting individuals with stuttering to maintain task relevant information in working memory. Therefore, it is indicative of a probable cause of people with stuttering forgetting to use the techniques which are taught during the therapy for reducing the dysfluencies.

The results shown by both the groups on auditory word list recall task revealed an involvement of working memory deficits in stuttering. The Group 2 performed poorly compared to Group 1. The comparison of results showed that there is a significant difference in the performance of Group 1 and Group 2 in the auditory word list recall task. These results can be supported by stating that this particular task increased the cognitive load of the participants by requiring them to recall all the words from two lists which were presented to them. As mentioned earlier, as the complexity of the task enhances, there is a rise in cognitive load, thus, disabling individuals with stuttering to effectively maintain information in working memory (17). In this particular task, there was a substantial increase in the cognitive load due to the requirement of recall of both the lists of words. This increase in cognitive load would have probably caused a deficit in rehearsing the presented stimuli and thereby ultimately disabling to recall the words accurately.

Further, the results of auditory delayed sentence recall task have shown a similar trend of working memory deficits in stuttering. In this task, significantly poorer performance was shown by Group 2 compared to Group 1. The Group 2 exhibited a highly significant decline in their ability to recall the presence or absence of a sentence after a distracter was presented immediately after the presentation of stimuli. The probable reason for this could be that individuals with stuttering are more vulnerable to distractions due to their impairment in attention processes. The presence of attention deficits in individuals with stuttering are supported by many authors. Heitmann et al (18) stated that individuals with stuttering have significant impairment in their skills of focused attention. Anderson et al (7), assessed the attention processes of individuals with stuttering and reported that they exhibited a reduced attention flexibility and control of attention. In this study, the participants exhibited deficits in focused attention to the presented stimuli and an inability to split attention between the stimuli and distracter. Therefore, the impairment in attention control would be the probable cause for the low

scores obtained by Group 2 in this task. This indicates that the presence of stuttering will be due to deficits in the working memory.

Visual working memory (VWM)

The numerical means of visual working memory tasks revealed that, the performance of Group 2 was poorer than Group 1 for all the tasks, indicating an existence of working memory deficits in Group 2.

On the visual picture recall task, the overall performance shown by both the groups indicated that there were no statistically significant differences between the groups even though there were differences in the mean scores. These findings suggested that the performance of both the groups on this task is almost similar in nature. The present finding shows that the recall of the visually presented set of pictures of common objects and events are relatively simple and more familiar. Hence, a more complex task would have generated a statistically significant difference. This is supported by an event related potential study assessing the visual working memory capacity in individuals with stuttering. Maria et al (19) stated that the visual working memory capacity in individuals with stuttering is significantly lower for the recall of complex geometric figures than compared to the recall of simple figures as well as the event related potential amplitude differed significantly for complex figures than compared to the visually presented simple figures. Therefore, in this study we would have got a significant difference in this particular task, as the images to be recalled were more complex in nature. The increase in the complexity of the task would clearly show a substantial difference in the performance of both the groups.

The overall performance showed by both the groups in visual letter and number recall task indicates that the results were statistically significant between Group 1 and Group 2. This signifies that Group 1 showed a superior performance compared to Group 2 and indicates clear existence of impairment in working memory deficits in Group 2. These results can be supported by the fact that individuals with stuttering may have had disruptions in the rehearsal and recall of strings of visually presented letters and numbers due to attention deficits. The attention processes of individuals with stuttering were found to have deficits in attention flexibility and attention control (7). Hence, these findings can be attributed to deficits in the focused attention which would have led to poor recall of strings of letters and numbers in this study. The results shown by both the groups on visual word list recall task were also found to have an involvement of working memory deficits in stuttering. The Group 2 performed poorly compared to Group 1. The comparison of results showed that there is a significant difference in the performance of Group 1 and Group 2 in the visual word list recall task. These results can be supported by stating that this particular task increased the cognitive load of the participants by requiring them to recall all the words from two lists which were presented to them. As noted earlier, the complexity of the task enhances cognitive load, thus, disabling individuals with stuttering to effectively maintain information in working memory (17). Additionally, this can also be explained on the basis of deficits in phonological processing in individuals with stuttering. Alvarez (20) stated that individuals with stuttering have deficits in phonological processing in visual word recognition. Further, the results of visual delayed sentence recall task have shown a similar trend of working memory deficits in stuttering. In this task, significantly poorer performance was shown by Group 2 compared to Group 1. The Group 2 exhibited a highly significant decline in their ability to recall the presence or absence of visually presented sentences after a distracter was presented immediately after the presentation of stimuli. The probable reason for this could be that individuals with stuttering are more vulnerable to distractions due to deficits in attention processes and phonological word

encoding during visual word recognition while reading sentences. Heitmann et al (18), stated that individuals with stuttering have significant impairment in their skills of focused attention. McGill et al (21), noted that individuals with stuttering have deficits in phonological processing including vision to sound conversions and lexical access. Therefore, in this study these deficits in individuals with stuttering would have in turn lead to deficits in visual working memory capacity in individuals with stuttering thus leading to a poor recall of the visually presented sentences.

This study clearly reveals that the performance on visual working memory tasks were superior to auditory working memory tasks in individuals with stuttering. This shows that even the modality of presentation of stimuli has an effect on the working memory abilities in individuals with stuttering. Powell & Hiatt (22) assessed the performance of normal adults on both the modalities: auditory and visual, by using various recall tasks, and the authors stated that the recall for visual presentation was significantly stronger than for auditory presentation of various recall tasks. This fact can also be generalized to individuals with stuttering and the probable cause for better performance of visual working memory can be attributed to the fact that the visual modality would be providing a higher level of processing than auditory modality which would be enabling them in better rehearsal and recall of the presented stimuli. Hence, in this study the individuals have shown a superior performance on visual working memory tasks compared to auditory working memory tasks.

Summary and Conclusions

The present study was designed to investigate the auditory and visual working memory abilities in individuals with stuttering and normal age matched peer group. The study was carried out using eight working memory tasks. We found that except for auditory letter and number recall and visual picture recall tasks, the individuals with stuttering scored lower than normal individuals in all other working memory tasks. The results can be attributed to inferior working memory abilities and limited capacity of the attention processes and manipulation of the stored information in individuals with stuttering. An important outcome of this research might be to enlighten Speech language pathologists about the potential involvement of working memory in individuals with stuttering and to encourage them to plan to incorporate intervention strategies to improve working memory. It would be of interest to further study, whether individuals with stuttering possess inferior abilities in other executive functions and if they have an impact on their disability.

Conflict of Interest

We Nanditha JP, Gagan Bajaj, Aiswarya L Varghese, Malavika A Anil, Radish K Balasubramaniam and Arya S Kumar declare that there is no conflict of interest regarding the publication of this paper.

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