Journal of Fundamentals of Mental Health
Mashhad University of Medical Sciences
Psychiatry and Behavioral Sciences Research Center

Original Article

Comparing visual and auditory working memory in adults with stutter and normal adults

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Abstract

Introduction: Developmental stuttering is a neurological disorder commonly manifested as a motor problem. Cognitive theories, however, hold that poorly developed cognitive abilities are the origins of stuttering. This study aimed to compare the visual and auditory working memory in adults with and without stutter.

Materials and Methods: This research was performed at the Speech Therapy Clinic of Ibn-e-Sina Hospital and Psychiatry and Behavioral Sciences Research Center of in Mashhad University of Medical Sciences, Iran, in 2019-2020. In this study, Adults Who Stutter (AWS) (N= 60) and Adults Who No Stutter (AWNS) (N= 60), aged between 17-37 years, with no history of mental and sensory, lingual, hearing, articulatory, motor, and psychiatry defects, were recruited. The N-Back test evaluated the participants' visual working memory abilities. In addition, the Wechsler test (Digit span) was used to evaluate the auditory working memory abilities. Data analyzed through SPSS 25 software.

Results: The results revealed no significant difference between groups in the digit naming task ($P > 0.05$). However, a significant difference was seen between the two groups during the 2-Back task ($P = 0.02$). Analysis showed that AWS had more false alarms due anxiety while responding due to increased attentional demands. On the other hand, it could be a sign of working memory deficits during a difficult task.

Conclusion: Adults with stutter perform poorly than normal adults, even though their performance is still within the normal range.

Keywords: Hypoactive sexual desire disorder, Marriage, Qualitative research, Women

Please cite this paper as:
Hakimi E, Ghanaei Chamanabad A, Salehi Fadardi J, Hajebi S. Comparing visual and auditory working memory in adults with stutter and normal adults. Journal of Fundamentals of Mental Health 2022 Sep-Oct; 24(5): 333-340.

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Received: Aug. 18, 2021
Accepted: Jul. 14, 2022

Introduction

Stuttering is a multi-factorial communication disorder (1-3) that is mainly manifested by involuntary repetition and prolongation of sounds and syllables, as well as blocks in the flow of speech output, which impacts adversely on the social, professional, and academic life of people who stutter (2). Significant data suggest that fractions in phonological working memory may be one factor contributing to Adults Who Stutter (AWS') fluency of speech, particularly; when offered cognitively demanding tasks (4). The etiology of persistent stuttering has been debated based on many theories, including speech motor control (5,6), and psycholinguistic theories (7). Especially theories involving psycholinguistic abilities suggest that a breakdown or delay may occur during the retrieval and construction of the phonological segments of words or the phonological encoding. Regarding these theories, breakdowns or delays at the level of phonological encoding may result in speech fluency disorder (8). A recent study has presented the influence of working memory on fluency in AWS, which indicates a relation between working memory and speech fluency. Working memory is "a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as learning comprehension, language, reasoning, solving problem" (9).

The working memory model describes how memory and language are interlinked through the phonological loop. Working memory, according to Baddeley's model (2003), is comprised of the central executive and the three supporting systems: (A phonological loop, (B) visuospatial sketchpad, and (C) the episodic buffer (10). Bajaj shows that the central executive part of working memory is impaired in stuttering. The central executive or supervisory attentional working memory system manages information and regulates attention. An actual attentional problem in AWS reduced working memory performance in them (11-13).

The central executive supports the retrieval and transfer of information from long-term to short-term memory and vice versa. The phonological loop comprises two critical components: a phonological store and a subvocal rehearsal system. The phonological store facilitates the ability to hold a substance to be remembered in a phonological code. This phonological code is vulnerable to decline over time (approximately 2 seconds), hence the need for the subvocal rehearsal system. The subvocal rehearsal system is a silent verbal repetition process that illuminates the phonologically encoded material, allowing it to be retained in memory for longer (14,15). It has been formed that phonological memory recycles information between input and output components through two phonological buffers to mediate speech. The input to phonological memory is also prepared through auditory pathways, where auditory working memory plays a major role in phonological processing. Deficits in phonological working memory are shown in performance on reading rate and non-word recognition tasks (14,16,17).

Hakim and Ratner administered the Children's Non-word Repetition task to children ages 4-8. They reported lower scores for children who stutter, with a significant between-group difference at the 3-syllable level. The authors concluded that there were no between-group differences for four-and five-syllable non-words (13). Also, children with stutter performed significantly less than those without stutter on the non-word repetition task used as a measure of phonological memory (18). Yang illustrated the neural deficits in AWS, regardless of memory load, suggesting that phonological working memory dysfunction is likely to be a common deficit in AWS. In addition, the significant brain activation-behavior correlation major emphasized the contribution of the hyperactivity of the right inferior frontal gyrus to the working memory leakage in AWS (19). Bakhtiar et al. investigated the phonological memory skills of 5- to 8-year-old children who stutter using 2- and 3-syllable non-words; however, no significant differences were found. Thus, the study may not have identified potential differences in phonological memory that become apparent under a larger cognitive processing load (12). People with stuttering (PWS) were less accurate in repeating non-words than people with no stuttering (PWNS), and phonological working memory could contribute to the creation or maintenance of speech fluency in PWS (20,21). The empirical evidence indicated a strong relationship between language skills, executive function, and emotion regulation. Many studies have established an association between young children's language abilities and their Executive Function (EF) capacities. Some studies have suggested that PWS are weaker than PWNS in language abilities due to weaknesses in EF or that some PWS exhibit lower capacities in EF than their normally-fluent peers because their lower language abilities negatively impact the development of EF. It is well documented that EF plays an important role in several aspects of life, such as school readiness, academic performance (22), psychosocial effects (23), and social adjustment and relations. Hence, it is unsurprising that certain components of EF (working memory and inhibitory control) have been researched in many studies as potential contributors to the onset and/ or manifestation of childhood stuttering. This hypothesis is in line with previous findings that suggest stuttering is a disorder related to deficit working memory (16), the effect of cognition tasks and improvement of executive functions (i.e., promoting working memory capacity) in PWS, and increasing fluent speech through extended working memory (21). Thus, the primary purpose was to compare AWS and AWNS in visual and auditory working memory capacities.

Materials and Methods

The ethics committee of Ferdowsi University of Mashhad approved this research proposal (IR.UM.REC.1399.100). Therefore, the participants were fully informed of the study protocol and were assured that their names and identity would not be revealed. Furthermore, the participants were informed the volunteer participation at any stage. Sixty AWNS (33% female, 67% male, aged between 17-36 years) and sixty AWS (30% female, 70% female, aged between 17-36 years) participated in this study. AWS participants were recruited from the speech therapy clinic in Ibn-e-Sina Hospital in Mashhad, Iran. Fluent speakers were recruited randomly from hospital staff. All participants were native Persian speakers without history of psychiatric/neurological disorders/diseases or medications impact on neural function (e.g., anti-depressants or anti-seizure), or hearing loss, mental and sensory deficits. At the time of evaluation, the Stuttering Severity Instrument for Adults—4th edition (SSI–4) was administered by a speech therapist to each of the AWS, and their stuttering severities were rated to be between mild to severe. Participants were reported in AWS (81.70% right hand, 18.30% left hand) and AWNS (91.70% right hand, 8.30% left hand). According to the Chi-square test, there is no significant difference between the two groups regarding laterality. Participants were selected in terms of the level of education, from diploma to doctorate.

According to the Chi-square test, there is no significant difference between the two groups regarding education level. Participants were matched on general language abilities, age, education level, sex, and laterality because these factors might affect working memory.

Research instruments

Test Battery

N-Back: It is a working memory test that would allow us to assess working memory and is not sensitive to subtle language deficits. The N-Back test was initially developed by Kirchner (24), where the age differences in short-term memory were assessed. In the classic N-Back task, an individual is presented with a series of stimuli, and the individual's task is to respond with a button press whenever a particular stimulus is the same as "n" trials before. The "n" can vary between 1 and any integer but is often increased to 3, which becomes very taxing for the individual. In addition, participants must respond to all stimuli at all stages. Therefore, this task requires updating the information and current control in the working memory. N-Back dual tasks are used where a combination of different modalities offers stimuli to evaluate two working memory inputs. Bush et al. reported the reliability of this test as 0.78. In Iran, Nejati, Taghizadeh, Mohammadzadeh, and Akbarzadeh used this test in a study and confirmed its reliability (25).

Digit Span: It is also frequently used in phonological memory research and can measure the capacity of a person's phonological working memory (26). Capacity measures how much phonological information can be held and accessed from the phonological store before the signal decays beyond retrieval. These tasks use numbers or other "closed set" stimuli (i.e., stimuli with a limited number of items in a set, such as letters or numbers) that are presented in a series of increasing lengths. For example, the digit span task started with strings that contained two numbers (e.g., "1-6") and became longer up to 10 digits (e.g., "4-9-6-7-3-1-8-2-6-5") (18). The participant perceives the auditory stimuli, stores and rehearses the signal in the phonological loop, and then repeats back what was heard in the exact arrangement that was given.

In the reverse repeat numbers section, the participant is asked to listen to the numbers and show them upside down. The total score is calculated by the sum of the scores of the two parts (forward and reverse repetition). In examining the validity of this test as one of the Wechsler intelligence subtests, the correlation coefficients obtained from the scores of this scale with the scores of Raven's progressive matrices is 0.38. In Iran, Nejati and Alipour used this test to evaluate psychometric properties in Iranian children (25).

The total data analysis of this study that compares the two groups of people with stuttering and people without stuttering will be done in two parts. The first part is dedicated to descriptive findings that examine frequency, mean and standard deviation indicators. In the second part, the obtained data were analyzed using parametric (multivariate analysis of variance) for between-group comparisons and non-parametric (Mann-Whitney test and Chi-square test). The criterion for statistical significance was defined as $P \leq 0.05$. Statistical analyses were conducted using SPSS 25.

Results

Groups did not differ considering sex, age, handedness, and education. Based on the results of comparing the age distribution of participants, the mean of participants in AWNS was 28.3±5.9 years, and in AWS was 26.3± 4.9 years. According to the Mann-Whitney test, there was no significant difference between the two groups regarding age (P= 0.081). The frequency of men in AWNS was 41 (68.30%), and AWS was 42 (70%). But, the frequency of women in AWNS was 19 (31.70%) and in AWS was 18 (30%). According to the Mann-Whitney test, there was no significant difference between the two groups regarding gender (P= 0.843). The frequency of right-handed participants' AWNS is 55 (91.70) and 49 (81.70%) in the AWS. At the same time, the frequency of left-handed participants in the AWNS was five people (8.30%) and 11 people (18.6%) in AWS. According to the Chi-square test, there was no significant difference between the two groups regarding handedness (P= 0.099). According to the Chi-square test, there was no significant difference between the two groups regarding education (P= 0.193) (Table 1).

The first research question examined whether people who stutter differed from people who do not stutter in working memory capacities. In the simultaneous relationship of cognitive variables with the study group (people with stuttering, people without stuttering), the variables of 2-Back visual working memory had a significant difference between the two groups ($P \leq 0.05$) (Table 2).

Table 1. The demographic variables

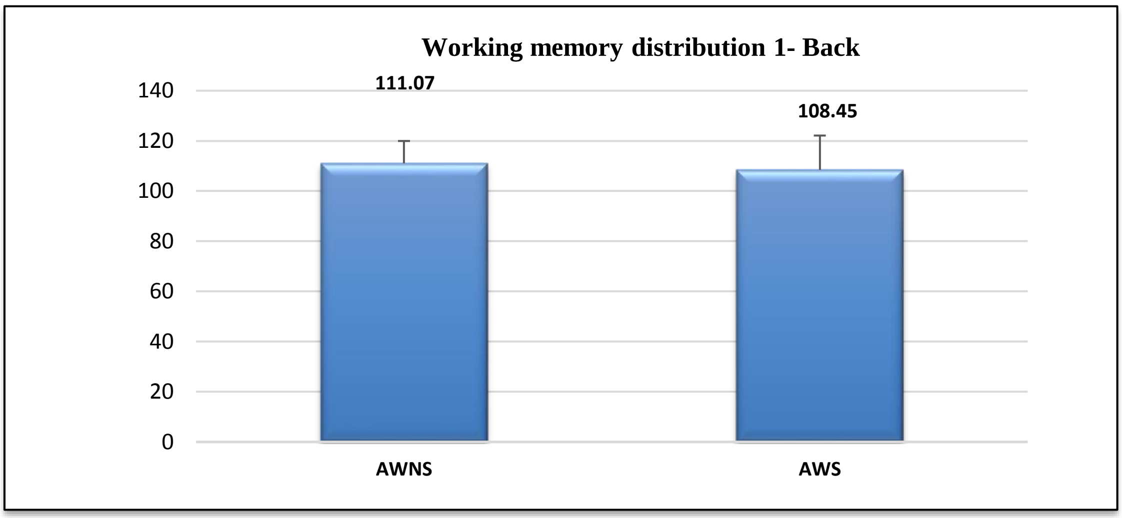
		AWNS	AWS	P
Sex	Male	41 (68.30%)	42 (70%	0.843
	Female	19 (31.70%)	18 (30%)	
Age (years)		28.3±5.9	26.3± 4.9	0.081
Education	Diploma	8(13.30%)	16(26.7%)	0.193
	BA	43(71.7%)	32(53.3%)	
	MA	7(11.7%)	9(15.0%)	
	PhD	2(3.3%)	3(5.0%)	
Handedness	Right hand	55 (91.7%)	48(81.4%)	0.099
	Left hand	5(8.3%)	11(18.6%)	

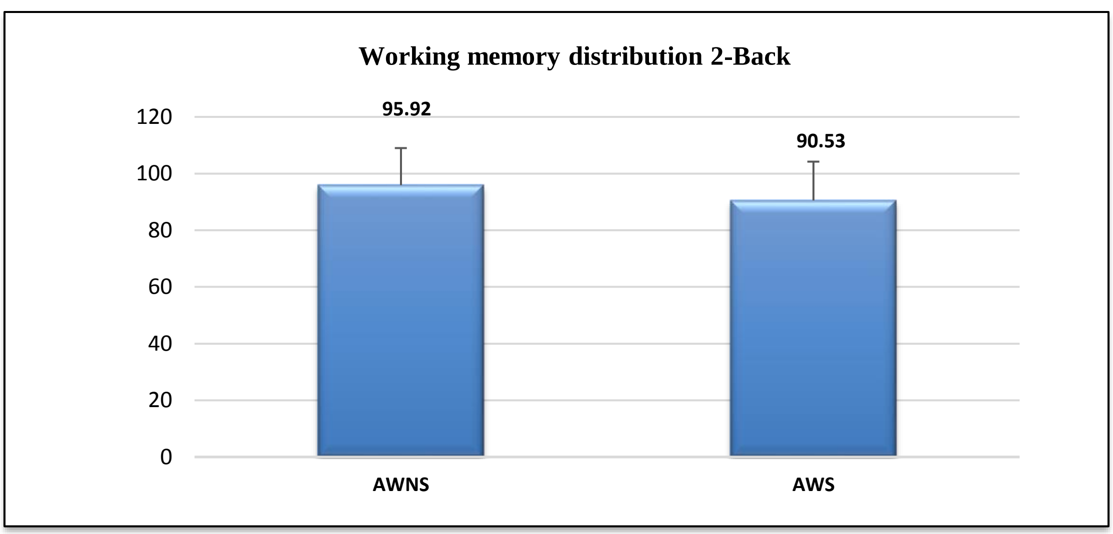
Table 2. Multivariate comparison of linguistic-cognitive variables between two groups based on Multivariate Analysis of Variance (MANOVA)

	Type III Sum of Squares	df	Mean Square	F	P	Partial Eta Square
1-Back	205.408	1	205.408	1.202	0.275	0.01
2-Back	869.408	1	869.408	4.848	0.03*	0.039
Digit span 1	1.20	1	1.20	1.202	0.639	0.002
Digit span 2	1.408	1	1.408	0.21	0.647	0.002

*$P \leq 0.05$

Based on Figure 1, the mean visual working memory (1-Back) was not significantly different between people with stuttering and those without. However, the mean visual working memory (2-Back) was significantly different in people with and without stuttering. The mean auditory working memory (forward and reverse numbers) was not significantly different in people with and without stuttering.





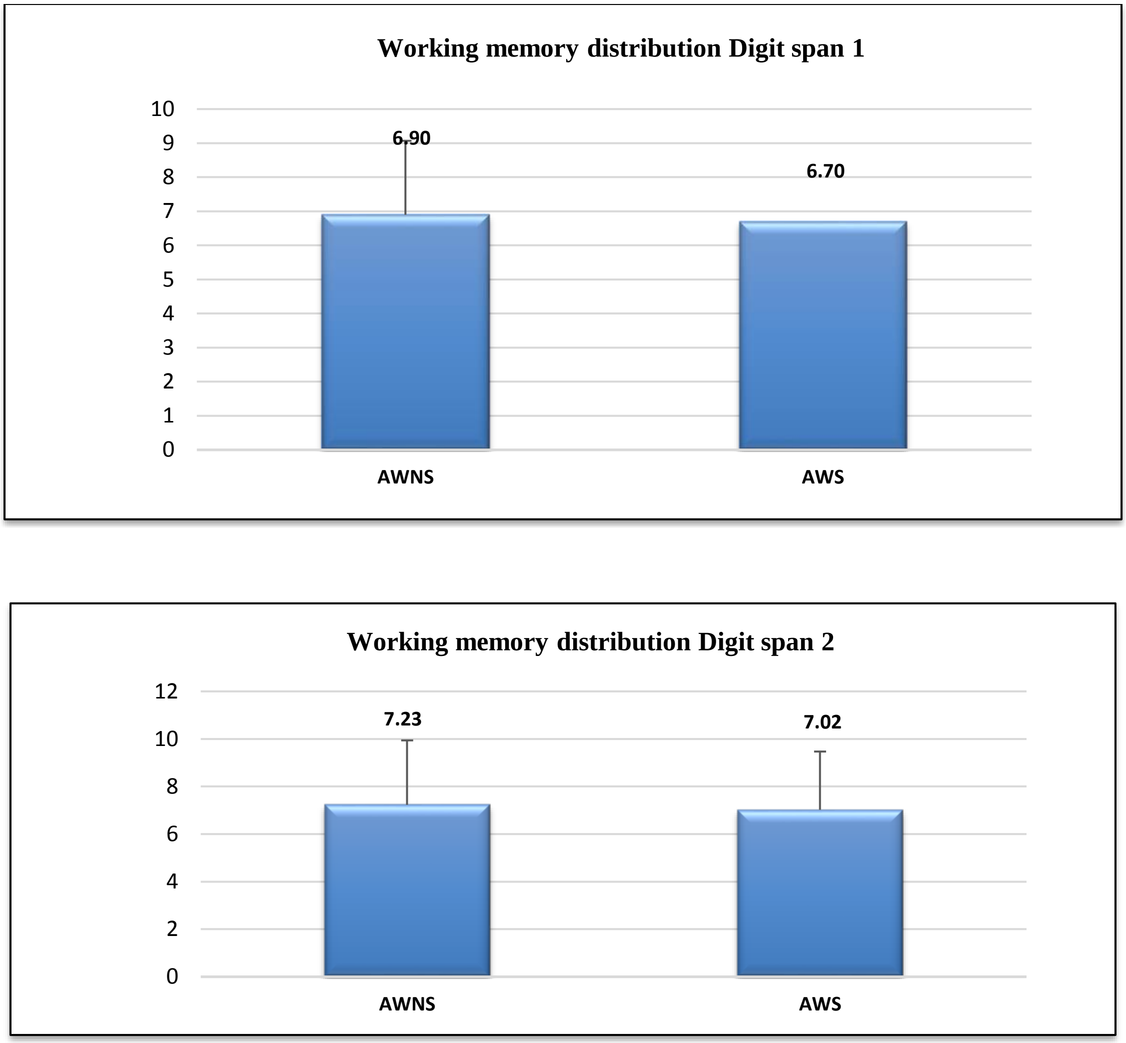


Figure 1. Distribution of working memory (Visual and Auditory) in AWNS and AWS

According to Table 3, there is no significant difference between the two groups of AWNS and AWS in the visual working memory test (1-Back). However, the significance level of the Mann-Whitney test (*P*= 0.02) in the visual working memory test (2-Back) indicates a significant difference between the two groups of AWNS and AWS.

Table 3. Univariate comparison of visual working memory (1-Back, 2-Back) variables between two groups based on the Mann-Whitney test

	Groups	Mean Rank	Wilcoxon W	Test statistic	P
1-Back	AWNS	61.85	3695	1735	0.732
	AWS	59.42	3565		
2-Back	AWNS	67.90	4074	1356	0.02*
	AWS	53.10	3186		

*$P \leq 0.05$

According to the Mann-Whitney test (*P*= 0.382), there is no significant difference between AWNS and AWS in the auditory working memory test digit span one. Also, the Mann-Whitney test (*P*= 0.632) in the auditory working memory test digit span two indicates there was no significant difference between the AWNS and AWS (Table 4).

Table 4. Univariate comparison of visual Auditory working memory (Digit span 1, Digit span 2) variables between two groups based on the Mann-Whitney test

	Groups	Mean Rank	Wilcoxon W	Test statistic	P
Digit span 1	AWNS	63.24	3794.5	1635.5	0.382
	AWS	57.76	3465.5		
Digit span 2	AWNS	62.01	3720.5	1709.5	0.632
	AWS	58.99	3539.5		

Discussion

The adults who stutter were intently matched to adults who do not stutter according to factors that have previously been expressed (i.e., age, sex, handedness, and education level). While some of the results concerning visual working memory are consistent with the results of several studies assessing visual and auditory working memory, AWS has been shown equal or higher performances in visual working memory in low level (1-Back) that could be a compensatory mechanism (27). On the other hand, in high-level cognitive tasks (2-Back), AWS has been shown fewer capacities than people who do not stutter. The poorer performance in AWS might be due to deficits in phonological working memory capacities as phonological coding along with visual information storage. However, the underlying language disturbances may affect performance on reading rate and non-word recognition tasks in AWS. All these previously-examined tasks need appropriate language processing skills, which AWS lacks (28).

These results are consistent with Dhatri et al. study in digit span tasks. Weaknesses in working memory may not be limited to the storage and/or manipulation of phonemes but also to other types of verbal and nonverbal information, such as commands. These commands are usually longer and carry meaningful syntactic and semantic information, which increases the cognitive load in high-level cognitive tasks that require continuous attention, which is affected in AWS (28). An obvious limitation when investigating cognitive tasks in children who stutter is the difficulty in fully separating the influence of the motoric system from the linguistic system. Research indicates that the speech motor systems in people who stutter differ from those in non-stuttering people. The multi-factorial nature of stuttering suggests that these differences in phonological memory may contribute to or exacerbate other deficits or delays in speech motor planning and execution (18). Another limitation of the study was the participants' fatigue due to the long time needed to perform the tasks.

Conclusions

This research presented that auditory and visual working memory is not significantly different in adults with stutter and adults with no stutter. However, people with stuttering are weaker than those without stuttering in high cognitive tasks (1-Back, 2-Back).

In addition, there seems to be a relationship between executive functions such as working memory and stuttering. Further studies suggest that research on this subject and cognitive rehabilitation skills such as working memory or attention training can also be added to the therapy goals of stutter treatment in the future. We suggest that future studies may benefit from cognitive therapy as a potential approach to evaluating and treating stuttering.

Acknowledgments

The authors thank the participants and the Psychiatry and Behavioral Sciences Research Center of Mashhad University of Medical Sciences. The authors declare any conflict of interest.

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