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Association of auditory processing abilities and employment in young women

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Abstract

Background This study aimed to investigate the relationship between employment status and auditory processing abilities in women, considering the cognitive impact of work-related demands. The objective was to study the influence of employment on forward -, backward -, operation span, 2n back, and speech perception in noise (SPIN) scores.

Methods Fifty-eight women aged 20 to 64 years were categorized into working and non-working groups. Auditory cognitive assessments included forward and backward digit span, auditory 2n-back, operational span, and speech perception in noise. Mental workload, listening effort, and fatigue levels were evaluated for each test using standardized scales. Handedness was assessed using the Edinburgh Handedness Inventory. Statistical analysis involved Mann–Whitney tests and effect size calculations.

Results Working women scored significantly higher in 2n-back task compared to non-working counterparts, emphasizing the positive impact of employment on working memory and cognitive control processes. The working women group perceptually rated greater mental load on the operational span task than non-working group, indicating the task-specific manifestation of group differences. When the tasks are easier (2n back) or difficult (operation span), employed women exhibited an advantage in auditory processing over their counterparts.

Conclusion This study reveals nuanced cognitive differences influenced by employment status in women. Working women demonstrated superior auditory processing abilities, specifically in working memory tasks, suggesting potential cognitive benefits associated with engagement in the workforce. The elevated mental workload for dual task working memory paradigms underscores the complexity of simultaneous processing and storage, highlighting cognitive challenges in specific occupational contexts.

Keywords Working women, Cognitive abilities, Auditory processing, Working memory, Mental workload

Background

The cognitive abilities of adults are closely linked to the job specific demands and skills [25], with gender-based influences. Women constitute half of the global population and play multiple roles in society's development. They contribute significantly to both nation-building and improving the quality of life for their families. Women in adulthood often strive to find a balance between biological changes, work-related issues, family responsibilities, financial security, and personal goals.

According to several studies [7, 15, 33, 37], employment status has been found to have a significant impact on cognitive functioning throughout life. Unemployed individuals tend to experience higher levels of mental health issues such as stress, anxiety, and depression [16]. They are also more prone to developing chronic diseases like hypertension, cardiovascular disease, diabetes, and musculoskeletal disorders, leading to poor mortality rates [32]. Unemployment often results in inadequate savings or income, creating difficulties in accessing optimal healthcare services in the long term [10]. In addition to these health concerns associated with unemployment,

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the absence of paid employment is also linked to notable cognitive effects.

Numerous studies have indicated that individuals engaged in intellectually challenging and complex occupations tend to maintain better cognitive abilities as they age, in comparison to those who do not have such occupations [7, 15, 33, 37]. Occupations characterized by cognitive complexity have been associated with a lower prevalence of cognitive decline [6], and it has been proposed that occupational demands contribute to enhancing cognitive reserves [6], with no exception to women. Specific to women, aging and employment have been found to alter the ability to process speech in noisy environments. Women may experience changes in speech perception as they age [28, 35].

In continuation with the other systems, where a strong relationship between employment and gender exists, changes in auditory processing can also be hypothesized. Several factors have been identified as influencing auditory processing and cognition, including employment status [5, 13]. Given the significance of employment and work-related demands, it is concerning that the lack of employment-related mental activities may pose a higher cognitive risk to non-working women, potentially affecting their auditory processing abilities [17, 26, 27, 29]. While there is ample evidence indicating gender disparities in employment and the role of employment in cognitive health, there is currently insufficient scientific consensus on the specific impact of unemployment status on auditory processing abilities in women. The aim of the study was to examine the relationship between employment and auditory processing abilities in women. Evidence derived from the present study is crucial to inform appropriate policy measures and ensure cognitive well-being among women.

Methods

Participants

A total of 58 female participants, within the age range of 20 to 64 years (mean age = 31.27 ± 9.76 years) took part in the study. The participants were further divided into two groups: working women and non-working women. The working group consisted of 33 participants (mean age = 31.93 ± 8.95 years), whereas the other had 25 participants (mean age = 30.40 ± 10.87 years). In selecting participants for the study, we prioritized individuals whose work primarily involved mental activity over those whose work involved primarily physical activity. The women working in sectors where mental activity is the main focus involved fields such as human resources development, schooling and education, healthcare, administration, information technology, finance, legal professions, engineering, management, public relations and journalism.

Inclusion criteria

To be included in the study, participants in both groups had to meet the following criteria:

a. Normal hearing sensitivity, confirmed using an online AIISH hearing screening app (AIISH Hearing Screening App—Apps on Google Play,) [1] for a quick and convenient assessment of hearing abilities without the need for specialized equipment. Using the app facilitated hearing screening even in the remotest areas where data collection was done and where no equipment was available.
b. Normal functioning of the middle ear, determined through a detailed case history and screening tympanometry test.
c. No history of speech, language, otological, or neurological problems was ascertained through thorough case history and medical reports provided by the individuals.
d. No reported history of significant noise exposure.
e. Right-handed individuals, as determined by the Edinburgh Handedness Inventory by Oldfield [30]
f. Normal cognitive abilities were screened using the Neurobehavioral Evaluation System Test [12].
g. Proficiency in Hindi and English either as a primary or secondary language acquired during formal education, as they are one of the official languages of India.

Procedure

Cognitive allocation was measured through assessments of mental load and working memory (WM) tasks, including forward span, backward span, operation span, and 2n-back, using the Smriti Sharavan 3.0 Software [39]. Speech perception in noise was assessed using SPIN-Indian English [38]. While listening fatigue levels and effort were evaluated using the Fatigue Assessing Scale [23] and Effort Assessment Scale [18], task specific mental load was measured with the NASA Task Load Index (TLX) [11]. Other than these tests, handedness was also obtained using the Edinburgh Handedness Inventory [30]. Through this inventory, details were gathered regarding individuals' preferences for specific activities, including writing, drawing, and using a spoon. Only individuals identified as right-handed were included in the selection process.

The cognitive abilities were screened using the Neuropsychological Evaluation Screening Tool (NEST) [12], a quick cognitive screening tool which covers evaluation of attention, memory, perception, verbal and language skills, constructional ability, and executive functioning.

The optimum cutoff for NEST is ≥ 3 for categorizing as cognitive impairment.

All the tests were administered in a quiet room with noise level below 35 dB(A). In order to monitor the environmental noise, an android-based application Sound Meter developed by Smart Tools Company [19] was used at the participants' end.

Cognitive assessment

- *Forward and backward digit spans*: In the forward digit span test, participants listened to a series of random numbers (1–9) through headphones with a 1000 ms gap between each number. The test ranged from simple (2 digits) to complex (9 digits), with three practice rounds. Participants had to repeat the digits in the same order within 5000 ms. The backward span test was similar but required participants to type the digits in reverse order. Scores were based on the maximum correct digits repeated in the correct or reverse order, displayed by the software.
- *Auditory 2n back:* The auditory 2n-back task required participants to repeat the second-to-last number heard in a series via headphones. There were 15 trials, each with a 1000 ms interval, a 5000 ms time limit, and varying string lengths from 4 to 10 numbers. Scoring depended on correct responses by participants.
- *Operation span*: In the operation span task, the participant's ability to remember the target stimuli was assessed. The stimulus was presented along with a secondary task involving solving an arithmetic problem, followed by recalling a bi-syllabic English target word.
- *Speech perception in noise—Indian–English (SPIN-IE)*: Speech perception in noise (SPIN-IE) involved phonemically balanced words spoken in Indian–English, presented alongside background noise generated by eight Indian–English speakers at a signal-to-noise ratio of 0 dB [38]. The test consisted of 25 carefully selected words presented in the presence of 8 talker speech babble noise with strategically positioned interruptions to avoid overlap with word stimuli.

Mental workload, listening effort and fatigue levels assessment

The mental workload for each WM and SPIN task was assessed using the NASA TLX [11] across six domains: mental demand, physical demand, temporal demand, effort, performance, and frustration level. Participants rated their workload using a visual analog scale ranging from 0 to 10 where 0 indicates less load and 10 indicates maximum load. The factor weights corresponding to each domain were added to the ratings. Thus, obtained weighted average for each domain was obtained by dividing the sum of adjusted ratings by 15. The difference in mental load between the two groups was compared based on the weighted rating. The higher the score, the greater the mental load.

Listening effort and fatigue were assessed at the end of all the tests for each participant. Assessing these two perceptual ratings, in addition to mental load, helps to screen out challenges in extended periods of auditory stimulation in everyday listening environments. Listening effort was evaluated utilizing the Effort Assessment Scale (EAS), a six-question tool developed by Alhanbali et al. [4]. This scale incorporates the three effort-related inquiries from the Speech, Spatial Quality (SSQ) Hearing Scale [18], such as "How much do you have to concentrate when listening to someone?" rated on a 10-point visual analog scale where 0 signifies no effort and 10 indicates a lot of effort.

Fatigue level was appraised using the 10-question Fatigue Assessment Scale (FAS) [23]. The FAS serves as a standardized generic scale for fatigue, demonstrating commendable internal consistency, reliability, and validity [23]. Participants were prompted to assess their daily fatigue by responding to statements like "I get tired very quickly" on a 5-point Likert scale ranging from never to always.

Statistical analysis

The collected data were analyzed using the statistical package for Social Sciences (SPSS) version 25.0 (IBM Corp., Armonk, NY, USA). The Shapiro–Wilk test was administered to assess the normality of data. Mann–Whitney test was performed to identify group differences in WM scores, SPIN Scores, NASA task force ratings, Fatigue ratings, and listening effort ratings. Whenever there was a statistically significant difference between the groups, the effect size was calculated based on the Rosenthal formula $r_e = /Z// \sqrt{N}$ [34].

Results

Comparison of the working memory and SPIN scores between the two groups

Based on the Shapiro–Wilk test results, the data in both working and non-working groups deviates from a normal distribution ($p < 0.05$). The median scores of working group were comparatively higher than the non-working group on all WM tasks except operational span and SPIN-IE, as shown in Fig. 1. However, only 2n back withstood statistical testing. Mann–Whitney U tests confirmed that the 2n-back scores of working women were significantly greater than the non-working group

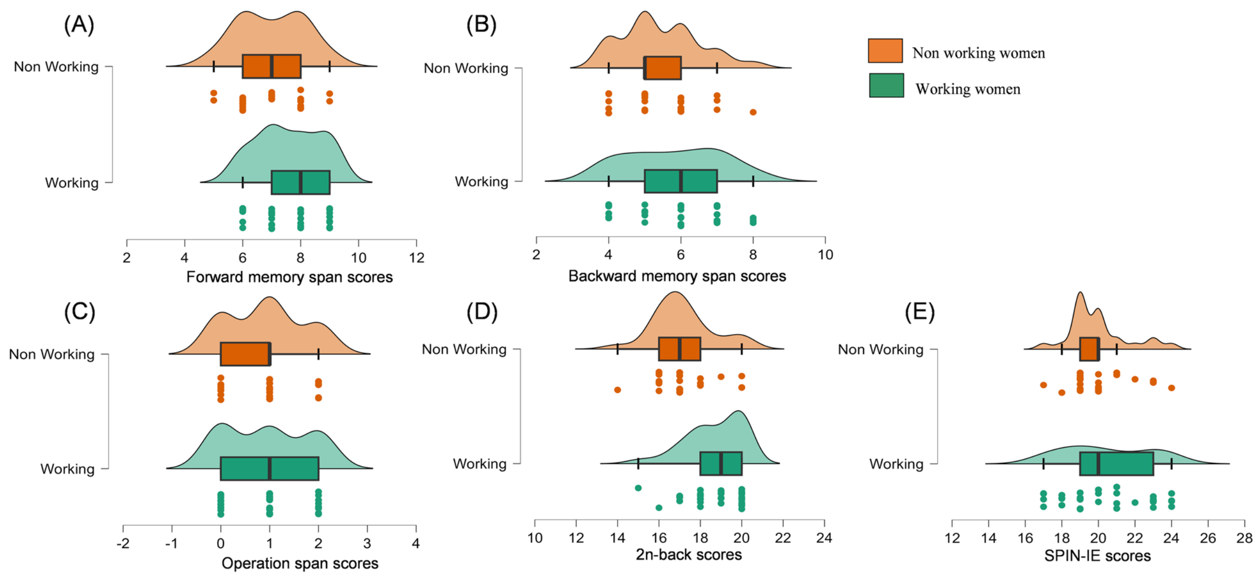

Fig. 1 Comparison of performance of the two groups for forward digit span (**A**), backward digit span (**B**), operation span (**C**), 2n-back scores (**D**), and SPIN-IE (**E**). Individual data points along with box plots (median, interquartile range—IQR) are given representing the scatteredness of data

(/Z/ = 3.78, $p < 0.001$). However, the performance of the non-working group was similar to the working group on all other tests including the forward span (/Z/ = 1.88, $p > 0.05$), backward span test (/Z/ = 1.12, $p > 0.05$), operational span task (/Z/ = 0.06, $p > 0.05$), and SPIN test (/Z/ = 0.59, $p > 0.05$) compared to the non-working group.

Comparison of the perceptual ratings (mental load, listening effort, and fatigue) scores between the two groups

Similarly, the results of the Mann–Whitney U test found no statistically significant group differences in the NASA task force scores ($p > 0.05$) across the tests (forward span: /Z/ = 0.53, $p > 0.05$; backward span test: /Z/ = 1.14, $p > 0.05$; 2n back: /Z/ = 1.65, $p > 0.05$, and SPIN test: /Z/ = 1.38, $p > 0.05$), except for operation span task wherein the working group women rated (NASA task force scores) the items of operational span test to have significantly greater mental load (/Z/ = 3.44, $p = 0.001$, $r_e = 0.45$) compared to the non-working group, as shown in Table 1. Also, on comparison of within group scores, the median ratings of the 2n back was lower than the other tests, while the highest mental load was on the Operation span tasks in both the groups. The results of the Mann–Whitney U test found no statistically significant group differences in the overall scores of the fatigue scale (/Z/ = 1.45, $p > 0.05$) and listening effort scale (/Z/ = 0.71, $p > 0.05$).

Discussion

The results of the present study highlight the relationship between employment status and various cognitive tasks and SPIN. Though not statistically significant, the results of descriptive analyses showed that working women exhibited better WM scores (Fig. 1) compared to non-working group. This finding aligns with the broader literature emphasizing the positive impact of intellectually challenging occupations on cognitive abilities [7, 15]. Madhavan et al. [22] found that middle-aged women who

Table 1 Median, interquartile range, /Z/, and *p* value for the mental load ratings from the NASA TLX for each test performed on the participants

	Working group		Non-working group		/Z/	*p* value
	Median	**Interquartile range**	**Median**	**Interquartile range**		
Forward span	3	2	3	2.5	0.53	0.59
Backward span	7	2	7	3	1.14	0.25
Operational task	9	1	9	5.5	3.44	< 0.001
N-Back	2	2	2	4	1.65	0.09
SPIN	3	3	3	5.5	1.38	0.16

are employed demonstrate better cognitive abilities, suggesting a positive impact of employment on cognitive functioning. This is supported by Miller et al. [24], who highlighted the psychological impact of job conditions on cognitive functioning in women.

Similar to the advantages enjoyed by working women in terms of WM, women who were employed also had higher SPIN scores (Fig. 1) compared to those who did not have employment. Research has shown a complex relationship between employment status and auditory processing abilities in women. Akeroyd [2] found that cognitive abilities, particularly working memory, can influence speech recognition in noise. Lunner [20] further supported this finding by demonstrating that high cognitive performance is associated with better speech recognition, even with hearing aids. Beaman [9] highlighted the impact of auditory distraction on cognitive performance in the workplace, suggesting that employment status may influence auditory processing abilities. Lastly, [21] demonstrated that working memory capacity, which can be influenced by employment demands, is related to speech understanding in noisy environments.

On Inferential statistics using the Mann–Whitney U test, the superiority of working women in the auditory 2n-back task over their non-working counterparts was established. The 2n-back task, a measure of working memory and cognitive control processes [31], demonstrated statistically significant differences between working and non-working women, with the former group exhibiting significantly superior performance (Fig. 1). The use of 2n-back in the study might be sensitive for employment induced changes in auditory WM. In an experiment, Alain et al. [3], focused on auditory spatial working memory using an n-back task design. The results of their study showed that the hit rate was lower and response time was slower in the 2-back condition compared to the 1-back condition. While false alarms were slightly higher in the 2-back condition, the difference was not statistically significant.

The study found no differences in EAS and FAS scores among groups, indicating that listening effort and fatigue did not impose limitations on auditory processing tasks during extended periods. This screening effectively ruled out any effects of fatigue or effort on task performance over time. The significantly enhanced performance in the 2n-back task suggests that engagement in the workforce may specifically influence working memory and cognitive control processes, contributing to the maintenance of these cognitive functions among employed women. Working memory, a crucial component of cognitive functioning, involves the temporary storage and manipulation of information for ongoing tasks [8]. The 2n-back task, requiring participants to recall the second-to-last item in a sequence, taps into both short-term memory storage and the ability to update information in real-time working memory [31]. On analysis of the NASA TLX mental effort (Table 1), the median scores of 2n-back in both working and non-working women groups were found to be the lowest compared to other tasks. In contrast, the operational span task, a measure of complex WM assessed in the study, showed the highest mental workload scores (Table 1). This indicates that participants perceived the operational span task as the most demanding among the cognitive assessments. The operational span task involves simultaneous performance of an arithmetic problem while remembering a target stimulus, reflecting the dual-task nature of WM [36]. The higher mental workload scores in both groups for the operational span task are consistent with the literature on WM tasks, indicating that tasks requiring simultaneous processing and storage impose greater cognitive demands [14]. Also, the perceptual ratings of mental load of the working group were significantly higher in working group than non working group. By coagulating the findings that working women had the advantage in both 2n-back scores (Fig. 1) and perceptual mental load (NASA TLX), it can be understood that when the perceptual difficulty of the tasks is either easy or difficult, the benefits derived from cognitive demands of work are manifested. In addition, the emergence of group differences is also regulated by the task complexity. When the tasks involve a distracter or a dual task paradigm, the groups differences are readily observable. In case of operation span, the cognitive load of dual tasks may be particularly taxing. As observed, the mental workload scores were high (Table 1), as the cognitive effort required to simultaneously engage in arithmetic operations and maintain target stimuli in memory. However in 2n-back task, ignoring the last-but-two numeral was easy on mental load. Despite the mental load aspect, due to its inherent nature of real-time updating of memory process, 2n back was sensitive to employment induced changes in WM.

Conclusions

In conclusion, the study provides valuable insights into the specific cognitive domains influenced by employment status in women. The superior performance on the 2n-back task suggests that working women may experience cognitive benefits, particularly in working memory and cognitive control processes. Moreover, the elevated mental workload scores for the operational span task emphasize the intricate nature of dual task working memory paradigms, shedding light on the cognitive challenges associated with simultaneous processing and storage.

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Authors' contributions
YS contributed to the design, data collection, and processing, analyzing the data, reviewing the literature, and writing. NK supervised, analyzed, and interpreted the data along with writing and critically reviewing. Both authors read and approved the final manuscript.

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Availability of data and materials
No data are available.

Declarations

Ethics approval and consent to participate
The study strictly adhered to ethical guidelines established for bio-behavioral research, as outlined by Basavaraj and Venkatesan (2009) with the reference number SH/AUD/2022-23/UR on 22/12/22 by Institutional review board (IRB). Before participating in the study, informed consent was obtained from each participant.

Consent for publication
Not applicable

Competing interests
The authors declare that they have no competing interests.

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