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The relationship between verbal working memory, auditory processing and speech perception in noise abilities in normal hearing adults

Chandrakant Bangre[1], Saransh Jain[2]

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I. INTRODUCTION:

Auditory cognitive science is an emerging field of interdisciplinary research concerning the interactions between human hearing and cognition. Auditory working memory, an important aspect of cognition, is the process of keeping sounds in mind for short periods of time when the sounds are no longer present in the environment. The working memory helps in processing the highly complex auditory stimuli in the central auditory system. Different auditory processes are influenced by the working memory abilities. Some common auditory processes related to working memory capacity are auditory closure[1], auditory localization and lateralization[2], spatial resolution[3], temporal processing[4], dichotic processing[5], etc. But the extent to which these processes are associated with working memory is still unclear.

Studies shows that working memory also play important role in speech-in-noise[6–8]. However, the results of some studies are not in agreement. Fullgrabe and Rosen[9] had found that working memory is not an important aspect of speech-in-noise processing in listeners with normal hearing. The difference in the findings may be due to different measures of working memory used in these studies to evaluate its effect on speech-in-noise.

Need of the Study:

In previous studies, researchers measured working memory through different tests and attempted to establish their relationship with various auditory processing abilities and speech-in-noise perception. The results of these studies are not in agreement with each other. It is still under investigation that which auditory process is maximally associated with working memory.

Aim of the Study:

The aim of the present study was to find out the relationship between some widely used measures to assess working memory, auditory processing and speech-in-noiseperception in normal hearing adults.

II. METHODS:

30 participants (18-30 years) with normal hearing and no associated pathology volunteered for the study. All the participant were native Kannada speakers and were assessed for with normal cognition (using mini mental state examination) and normal auditory processing (using Screening Checklist for Auditory Processing in Adults) abilities. The study was approved from institutional ethical board and informed written consent was obtained.

The working memory was assessed using forward (FDS) and backward digit span (BDS), operation span (OS), reading span (RS), ascending span (AS) and descending span (DS). In digit-span test, cluster of digits were presented, and participants were asked to repeat the sequence in either the same order of presentation (FDS) or in reverse order (BDS).In the operation span, the target stimuli (bisyllabicKannada words with number varying from two to five) were presented along with a mathematical operation. Participant's had to solve the mathematical problem and label it as correct and incorrect and subsequently say the word in the order of presentation.In the reading span, participant's ability to remember the target stimuli (syllable) which was presented along with a secondary task was evaluated. The secondary task was to identify the correctness of a Kannada sentence.In auditory number sequencing, the participants were presented with cluster of numbers and asked to repeat them in an increasing (AS) or decreasing (DS) order. The entire working memory test battery was administered using Smriti-Shravan software[10].

Auditory processing abilities were measured to assess auditory closure, binaural processing, sound localization and lateralization, temporal resolution, temporal ordering and dichotic processing. Time compressed speech test (TCST) using standard Kannada sentences at different

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compression ratio (40%,50%,60%,70% and 80%)measured auditory closure. Binaural processing was assessed through auditory fusion test using standardized paired Kannada words. Sound localization and lateralization were measured using interaural time and level difference (ITD and ILD) through MLP toolbox[11] in Matlab. Temporal resolution was measured using gap in noise (GIN) test, temporal ordering using duration pattern test (DPT) and dichotic processing using dichotic digit test(DDT) by adapting staircase procedure implemented in Matlab[11].All these test procedures followed standard protocol for administration.

Speech perception ability in noise (SPIN) was measured using standardized Kannada sentences degraded using speech-shaped noise at +3,0,-3,-6 and -9dB SNR. The entire stimulus was constructed using matlab. SNR-50 was obtained by logistic regression with non-linear interpolation of the 50% point on the psychometric function.
The entire testing was carried out in a sound treated room. The stimuli were presented binaurally using headphones (Sennheiser HD202) connected to the personal computer at the participants most comfortable level. The output of the headphones was calibrated using sound level meter (B&K2238-mediator).The testing took at least 2-2.5 hours for each participant and conducted in two sittings.

III. RESULTS AND DISCUSSION

The data was normally distributed (Shapiro-Wilk p>0.05) across groups. A structured equation partial least square regression model was created to establish a relation between working memory, auditory processing and speech perception in noise abilities. A reflexive model was designed where working memory was considered as the first latent variable and the scores of the measures to assess working memory (digit span, operation span, reading span and auditory number sequencing) were the observed variables. The auditory processing ability was considered as the second latent variable and the scores obtained from the measures to assess auditory processing i.e., auditory closure, binaural processing, sound localization and lateralization, temporal resolution, temporal ordering and dichotic processing, were considered as the observed variable. The speech perception in noise was the third latent variable of the model with SNR-50 scores being the observed variables. The model had good fit with standardized root mean residual of 0.036[12].For each latent variable in the model, Cronbach's-alpha was measured which indicated whether the indicators of the latent variables, i.e. the observed variables, displayed convergent validity. The values for first latent variable, i.e. working memory was 0.640 indicating acceptable observations; for second latent variable, i.e. auditory processing was 0.746, indicating good observation. The Cronbach's-alpha findings showed that the tests to assess working memory and auditory processing reliably measured these processes.

The results of regression analysis showed significant associationbetween all the measures of auditory processing and cognition except DPT.The working memory accounts for 72.8% variance in the auditory processing abilities (adjusted Rsquare=0.728), whereas speech perception in noise accounts only for 11.2% variance in the auditory processing abilities (adjusted Rsquare=0.112). The working memory also accounts for 54.9% variance in the speech perception in noise (adjusted Rsquare=0.549). Among the working memory tests, the forward span (adjusted Rsquare=0.873) and descending span (adjusted Rsquare=0.658)represented the working memory skills maximally. Similarly, TCST (adjusted Rsquare=0.824)was found to be a more reliable measure to assess auditory processing. The temporal processing abilities were better represented by gap in noise (adjusted Rsquare=0.760).

An account of the individual effect of each working memory measure on each auditory processing ability, individual regression models assessing the effect of one observed variable on other were designed. The working memory maximally influences the auditory closure abilities and accounts for 62.5% variance in it (adjusted Rsquare=0.625), followed by temporal resolution abilities (adjusted Rsquare=0.556). On the other hand, operation span causes maximum variation in the auditory processing (adjusted Rsquare=0.450), whereas forward span causes maximum variation in the speech perception in noise (adjusted Rsquare=0.527).

IV. CONCLUSION:

In the present study, a clear relationship between working memory, auditory processing and speech perception in noise was established. Working memory maximally influence auditory processing which suggested the top-down influence on peripheral auditory processing.These findings may be useful in understanding auditory processing abilities and speech perception in noise and for designing appropriate speech and language intervention techniques.

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