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The Impact of Working Memory on Text Composition in Hearing Impaired Adults

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Introduction

Working memory involves the temporary storage and manipulation of information that is assumed to be necessary for a wide range of complex cognitive activities. Baddeley and Hitch (1974) proposed that it could be divided into three subsystems: One, the phonological loop providing verbal and acoustic information; a second, the visuo-spatial sketchpad providing its visual equivalent, while both are dependent upon a third attentionally-limited control system, the central executive.

Text production is a complex activity composed of various processes, which tax the storage and processing capacities of working memory in different ways. According to Kellogg (1996), it is possible to predict which writing processes will be hindered when central executive, phonological loop or visuo-spatial capacities are heavily or overloaded. These predictions have been tested in hearing adults (Ransdell & Levy, 1996) and in children (Swanson & Berninger, 1996). The results confirm that the respective capacities of the three registers do indeed bring about specific variations in compositional fluency and/or text quality and length.

Kellogg's Model

The relationship between text production and working memory is explained by Kellogg (1996). Kellogg formalizes the relationships between the various processes involved in text production and the registers of working memory (as defined by Baddeley, 1992).

Kellogg's model postulates the existence of six basic writing processes, paired together to form three different components : Formulation ('Planning' and 'Translating'), 'Execution' ('Programming' and 'Executing') and 'Monitoring' (Reading and Editing).

Three kinds of relationships between these processes and working memory registers are described.

First of all, the processing capacity of the central executive constrains the course of every controlled process (i.e. planning, translating, programming, reading and editing). In the case of beginning writers, the executing process is not sufficiently automatized. It, too, draws on the resources of the central executive.

Secondly, the storage capacity of the phonological loop constrains the linguistic processing involved in sentence production (translating at the lexical and grammatical levels) and in reading the text produced so far.

Thirdly, the storage capacity of the visuo-spatial sketchpad constrains conceptual processing (planning of text content), especially when the text content is concrete and contains figurative language.

Two Consequences

Writing processes and components are implemented iteratively and recursively throughout text production. If their storage and processing capacities are too limited and/or overloaded, the most costly controlled writing processes cease to operate in parallel (Flower and Hayes, 1980). The resulting sequentialization has at least two consequences (Ransdell, Levy, 1996 & Kellogg, 2002): (i) by increasing the length and frequency of the writing pauses, it brings about a general reduction in compositional fluency; (ii) by limiting interactivity between the controlled processes, it reduces opportunities for monitoring the processes as a whole, thereby diminishing the text's conceptual and linguistic quality.

Difficulties in Mastering Text Production Among Pre-lingual Deaf Children

There exists a great deal of evidence to show that pre-lingually deaf children and adults encounter serious difficulties in acquiring and mastering text production. It suggests that the deaf may have difficulty using a speech-based code for processing linguistic units (Leybaert, Alegria, Hage, & Charlier, 1998). These difficulties have been extensively described from an educational perspective, both by classifying the errors recorded in whole texts (Marschark, Mouradian, & Halas, 1994) and by conducting more controlled experiments, where participants carry out single word production tasks (Transler, Gombert, & Leybaert, 2001).

On the basis of studies involving hearing students, it can be argued that the compositional difficulties experienced by deaf people are partly attributable to a particular mode of processing information in working memory adopted in response to the lack of auditory input. Research into the influence of working memory on the way texts are processed by deaf people has mainly focused either on reading and comprehension (Garrisson, Long, &Dowaliby, 1997) or on the production of isolated words (Leybaert & Alegria, 1995). Studies of text production remain few and far between (Lichtenstein, 1998; Mozzer-Mather, 1990) and it would be well worth taking them a step further.

Objective of the Study

The aim of this study is to highlight and compare the relationships between the working memory capacities of hearing impaired and hearing writers and the efficiency of the conceptual and linguistic processes involved in text production.

Need of the Study

- To assess and compare the conceptual and linguistic qualities of a descriptive text
- To determine how variations in these performances can be associated with variations in phonological and executive capacities.

Method

Subject: Two groups of population were tested. 10 normal subjects with age range of 18 to 21 years and 10 prelingually profound hearing impaired with age range of 18- 21 yrs.

Test environment: All the tasks were carried out in a room with permissible ambient noise levels.

Material

Working memory tasks (production and phonological span tasks) were presented using a laptop computer operating software designed specifically for the experiment. The central executive capacities involved in verbal production were assessed by using adapted versions of the speaking span test designed by Daneman and Green (1986). The signed words were taken from The Signed English School book (Bornstein, H. and Saulnier K. L, 1987). The phonological span was assessed using an adapted version of Conrad's short-term memory task (1964, 1967).

Tasks

Participants were required to perform two written and two memory tasks. The written tasks comprised a grapho-motor automatization test and the production of a descriptive task. The memory tasks comprised of verbal production and the phonological span.

Written Tasks

Grapho-motor task**:** Participants were required to write the alphabet as many times as they could in the space of 1 min (Abbott & Berninger, 1993). This task was performed in two speed conditions ('normal speed' vs. 'as fast as you can').

Text production task: Participants were asked to write a text in the form of a word about their classroom showing all the furniture and personal possessions. Prior to the written task, in order to facilitate content generation as well as to obtain a reference for scoring the text content, participants were required to draw the layout of their classroom. When they had finished, their plans were collected by the experimenter so that the subjects could not refer to them during the written task. The assignment was read by all participants and then recalled orally (or by signs) by the experimenter before the task began. For both the drawing and text production tasks, participants were required to note the exact times when they started and finished. Each task was given 5 minutes time for completion.

Working Memory Tasks

Two kinds of working memory tasks (production, phonological tasks) were presented using a laptop computer operating software designed specifically for the experiment. Participants were given a notebook in which they were asked to write sentences or series of letters, which are necessary for the test.

Production Span

The central executive capacities involved in verbal production were assessed by using adapted versions of the speaking span test designed by Daneman and Green (1986) (This consisted of presenting a series of written, oral or signed words to participants, who then had to remember as many words as they could and build a sentence around each one (written, oral or signed sentences). The number of words per series was gradually increased (from 2 to 6 words). The oral and written words were prepared in Telugu language.

The signed words, extracted from an ISL text books (used in lessons by deaf students), were all familiar and composed of a single gesture. The oral/written words were dictated/displayed by the computer. For the signed words, a sign language expert was made to sign the words. At the end of each set, participants had to produce a sentence containing all the words in that set. For the written version of the test, the deaf and hearing participants wrote sentences down in the notebook. For the oral/ISL version, the deaf participants signed sentences based on the signed words (the message was interpreted by a sign language expert), while the hearing participants produced spoken sentences containing the words they had heard.

Phonological Span

This span was assessed using an adapted version of Conrad's short-term memory task (Leybaert et al., 1998; Lichtenstein, 1998). A series of 6 letters from Telugu language were presented, one letter at a time, in the centre of the screen and participants were asked to write down the letters in their strict order of presentation, leaving blank spaces if they forgot any of them. The 10 6-letter series were composed, so that they would not evoke any word or acronym. The score corresponded to the proportion of correctly recalled letters (an error was a wrong, omitted or misplaced letter in a series).

Procedure

The whole experiment was divided into two individual sessions in which, in the first session two written tasks were carried out and in the second session two working memory tasks were carried out in a separate room for the two different groups. Each session lasted for around 45 min.

Results

Comparisons were made, using paired sample t-tests to find the relationship between these writing performances and working memory capacities. The analyses were carried out in two steps.

Analysis 1: Compositional Performances

Graphomotor Task

The number of alphabetical letters produced in the space of one minute by hearing impaired students in normal speed condition (M = 57.1; S.D. = 7.80) & very fast condition (M=70.2; S.D =4.46) did not differ from that produced by hearing students in normal speed condition (M = 62.3; S.D. =10.14) & very fast condition (M=84.7; S.D = 7.8) t = 2.118 (p>0.05).

Groups	Grapho motor task			
	Mean	S D	t value	p value
Normal adults	62.3	10.14	2.118	0.28
H.I impaired adults	57.1	7.80		

Table-1 Mean S D, t value and p value for the grapho motor task of the two groups

Text Composition

Conceptual characteristics

Text content richness was assessed by counting (i) the number of objects described minus the number of objects drawn, such as chairs, desks, black board (the walls, doors and windows were not regarded as objects) Results showed no significant difference between the two group regarding total number of objects drawn, (Hearing impaired M = 6.20; S.D. = 2.04) and (Hearing students M = 5.1; S.D. =2.23); t (-1.029) (p= 0.330.);

While calculating the total number of words produced in the text compositional task, a significant difference between the two groups, (Hearing group (M = 19.7 words; S.D. = 4.4) and the Hearing impaired group (M = 11.40 words; S.D 6.62) (p=0.02) were observed.

Linguistics Characteristics

The hearing impaired students produced significantly more linguistic (spelling) errors per word (M = .129; S.D. = .075) than their hearing counterparts (M = .075; S.D. = .038; t=2.54; p = .02). Results are shown in the table given below

Groups	Conceptual characteristics				Linguistic characteristics			
	Mean	S D	t value	p value	Mean	S D	t value	p value
Normal adults	5.1	2.23	- 1.029	0.33	.075	.038	2.54	.02
H.I impaired adults	6.20	2.04			.129	.075		

Table -2 Mean S D, t value and p value for the text composition task of the two groups

Analysis II: Working memory capacities and their relationship with compositional performances

Working Memory Capacities

Verbal Production Span

This span was assessed according to the percentage of presented words that were correctly inserted into sentences. Because of the linguistic difficulties encountered by the deaf students, a sentence was regarded as correct if its meaning was clear and the target word was used in its proper context. We did not take syntactic and spelling errors into account for either the deaf or the hearing students. The results showed significant difference between the hearing impaired students (M =23.1; S.D. = 7.1) and the hearing students (M = 40; S.D. = 0.0) for the production span task. (t = 7.517) (p = 0.00). Results are shown in the table given below

Groups	Verbal production span			
	Mean	S D	t value	p value

Normal adults	40	0.0	7.517	0.00
H.I impaired adults	23.1	7.1		

Table-3: Mean, S D, t value and p values for the verbal production task of the two groups

Phonological Span

The percentage of items recalled in their correct position was subjected to paired sample t test for the comparison. The results showed significant difference between the hearing students (M = 57.2; S.D = 1.9) and the hearing impaired students (M = 40.8; S.D = 9.6) for the phonological span task. (t = 5.78) (p = 0.00). Results are shown in the table given below.

Groups	Phonological span			
	Mean	S D	t value	p value
Normal adults	57.2	1.9	5.78	0.00
H.I impaired adults	40.8	9.6		

Table- 4: Mean, S D, t value and p values for the Phonological span task of the two groups

Discussion

The primary results of this experiment revealed that the hearing impaired students are relatively poorer to the hearing adults in most of the tasks conducted.

a) Text Production

An analysis of text production performances provided three main findings. Hearing impaired students (i) displayed lower compositional fluency and (ii) made more spelling errors but (iii) produced very similar text content, regarding the number of objects described and attributes used. The latter result is consistent with the findings of Marschark et al. (1994), who did not find any difference between hearing impaired and hearing children in terms of text content organization.

b) Working Memory

An analysis of working memory performances revealed that hearing impaired students had lower phonological (memorizing letter series) and executive (written production span) capacities than hearing students. An analysis of the various correlations points a coherent picture of how these working memory capacities in hearing impaired and hearing students can be linked to their text production, especially in-terms of fluency and linguistic quality.

In the hearing students, however, there was no significant correlation between writing span and fluency (r=.17). This leads us to assume that the implementation of compositional processes in hearing students did not rely on the capacity of the central executive. This explanation is based on several arguments.

Planning was easier, because familiar knowledge facilitates content generation and the vocabulary associated with the classroom is simple, concrete, familiar and easily accessible. However, we then need to find out why the hearing impaired students failed to benefit from the same familiarization effects, even though they were enrolled in the same schools, confronted with a writing task and matched with hearing students according their compositional skills.

The fact that the writing span of hearing impaired students is shorter than their signed span leads us to think that it is the processes specific to writing that exhaust all their available resources (Mozzer-Mather, 1990).).

Compositional fluency reflects the overall operation of controlled writing processes (planning, formulation and revision - plus grapho-motor execution when it is not sufficiently automatized). The hearing impaired students' reduced fluency probably reflects the sequentialization of writing processes, resulting in more frequent and/or longer writing pauses (Ransdell, et.al, 2002).

This distribution of processes over time occurs when the processing and storage capacities of working memory are overwhelmed and can no longer allow the processes to operate simultaneously (Kellogg, 1996). In the hearing impaired students, this interpretation is supported by the strong correlation (r=.77) between compositional fluency and writing span; confirming the existence of a relationship between the time course of the processes and the amount of resources in the central executive available to operate these processes.

Two specific writing processes are involved in the writing span task grapho-motor execution and spelling and grammatical processes. As there was no difference between hearing impaired and hearing students on the alphabetic test, it is reasonable to assume that the reduced fluency was due to high-cost linguistic operations within the formulation process. In all likelihood, hearing impaired students carry out the formulation process more slowly due to difficulties in calculating grapheme-phoneme correspondences. This interpretation is supported by the higher number of spelling errors made by hearing impaired students, proving the problematic nature of linguistic processing.

Spelling errors were far more frequent in texts written by deaf students than in ones written by their hearing counter parts. This is one more replication of a result frequently observed in studies of deafness (Marscharkm 1994; Padden, 1993). In this experiment, the difference between deaf and hearing students revolved around spelling (lexical) mistakes.

Both groups made the same number of grammatical errors, but the hearing impaired students made approximately three times as many lexical errors than the hearing students. Mastering grammatical morphology clearly involves a type of linguistic knowledge that is not yet available at middle-school level, for either deaf or hearing students.

When examining the phonological consequence of spelling and grammatical errors, the main difference between the two groups was the higher frequency of phonologically inaccurate errors made by hearing impaired students. This result is consistent with the study conducted by Leybaert and Alegria (1995), who found that when deaf students produce isolated words, they make 5 to 6 times more phonologically inaccurate errors than their hearing counter parts.

The massive presence of phonologically inaccurate errors highlights the difficulty encountered by deaf writers in using grapheme-phoneme correspondences to spell words. Due to less efficient phonological coding, the monitoring of verbal output fails to curb errors, even in the case of regular words (Hanson et al. 1983; Padden, 1993).

Hearing impaired students make more phonologically inaccurate errors because they cannot use either phonological representations (at the lexical level) or morphosyntactic and morphogrammatical combinations and flexion rules (at the grammatical level) to spell words.

This interpretation is supported by the performances on the serial recall task. [Dodd, Hobson, Brasher, & Campbell (1983) and Leybaert et al. (1998)]

Conclusion

The main purpose of this study was to compare the compositional performances of deaf and hearing students and to investigate the relationships between these performances and the different capacities of working memory. Three main results can be reported. (1) For *Composition* no difference arose between the two groups in terms of planning and grapho-motor execution. However, when it comes to formulation, hearing impaired students made more phonologically inaccurate errors than their hearing counterparts.

These difficulties in processing spelling units would appear to diminish compositional fluency. (2) As regards *working memory capacities*, differences were observed in writing and phonological spans (indicating reduced capacities for hearing impaired students on both) (3) Concerning the relationships between *working memory capacities and compositional performances*, main finding reported was: (a) central executive capacity (assessed by the text production task) is associated with compositional fluency in hearing impaired students

This study is an attempt to check the impact on the working memory on the writing skills of hearing and hearing impaired adolescents. In future a large study on the same aspect will provide more light on the impact of working memory in the same population.

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