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Influence of Attention Resource Allocation on Sequential Swallow in Healthy Young Adults

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Abstract Despite the role of central pattern generator in swallowing, till date, there exists a contributing opinion on involvement of cortical structures. This has lead few researchers to contemplate cortical function involvement while swallowing using behavioral experiments. Hence, the primary focus of the study was to investigate if sharing attention resources affects swallow performance in healthy young adults. A cross sectional study design was adopted involving 30 gender matched healthy adults within 18-23 years of age. 100 ml water swallow test was administered on each subject across two conditions. In the baseline condition, subjects continuously ingested 100 ml luke warm water directly from the rim of 120 ml capacity cup. Based on which, volume/swallow (V/S), time/swallow (T/S) and swallow capacity (SC) indices were obtained. This task was compared with Concurrent Cognitive Task (CCT), which involved performing a cognitive task, namely Visual Feature Scan, simultaneously with 100 ml water swallow test. On comparison, between the two conditions, results revealed decreased V/S with longer T/S and decreased S/C for CCT condition. Statistically significant difference was noted at 95% confidence level when one way ANOVA was applied between the two groups. Collectively the results observed sheds light that allocating attention resources elsewhere hampers swallow performance. Thereby, highlights the existence of overlap between cognitive control and central pattern generator during swallowing.

Keywords 100 ml, Thin Liquids, Divided Attention, Cognitive Task, Swallow

1. Introduction

Deglutition involves series of complex, co-ordinated neuromuscular process controlled by the brainstem. Despite researchers supporting swallow as a reflexive and/ or automatic behavior, the overlap between higher level processing, like cognition, and central pattern generator is addressed recently ([1]). To define, cognition is an unobservable mental process ([2]). The potential influence of cognition in swallowing was conceived nearly 30 years back, when concepts of oral preparatory phase and lingual-bolus propulsion were rigorously explored ([3]). Owing to this, a newly theorized anticipatory phase was proposed that precedes the traditional four phases of swallowing ([4]). Anticipatory phase explicitly deals with how cognition controls our fine and gross motor neural commands before initiation of oral phase of swallow. To specify the role of anticipatory phase, it imparts selection of food size, type and positioning of food into the oral cavity, all critical to trigger sequential oral preparatory and oral phase of swallowing ([3], [4]). Since this corresponds to voluntary aspects of swallow, that are channelled by cortical and basal ganglia neural activity, one can arrive at the conclusion that its neural control may not completely reside at the central pattern generator ([5]). Apparently, the efficiency of anticipatory phase is dependent upon the amount of attention resources allocated by an individual, thereby making it sensitive to interference.

Over the years several researchers have addressed that, during swallow, cortical areas get activated along with central pattern generator. Collectively, numerous neuro-imaging studies evidences activation of cortical areas that associates with control over attention resources ([1], [6], [7]). Though each technique has its boon, disadvantages like lack of temporal sensitivity, lack of resolution, radiation exposure and risk of seizures has led to many clinical modifications ([8-11]). Following these evidences, but overcoming the banes, researchers have explored with the focus of finding an answer to the research question 'How cognition influences swallow?' using behavioral tasks. This steered the genesis of behavioral experiment "Dual Task Paradigm" and/ or "Concurrent Cognitive Task" ([12-14]). The primary assumption of these tasks is the shared neural substrates, if any, will lead to decrease in either and/ or both the tasks performance. Typically, this is monitored by comparing isolated swallow performance with CCT. To observe swallowing aspects, typically, one continuously ingests a pre-determined quantity of thin liquids. This format is followed to monitor the sequential swallow or one's

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natural swallow style.

For more than three decades, experimental literature on swallow rehabilitation was built on the premise that there exists some overlap between voluntary and automatic aspects of swallow. Evidence for these assumptions is positive outcome of safe swallow upon postural changes with maneuvers, which have successfully proven to rehabilitate individuals with dysphagia ([15]). In addition to these, the traditional behavioral swallow therapy approach indirectly addresses manipulation of cognition, especially attention, that aid in swallow recovery and/ or promote safe swallow at some level. Knowing the importance of cognition in dysphagia rehabilitation it is very alarming that there is continued one sided research support dealing with manipulation of traditional approaches like altering bolus characteristics, respiratory swallow co-ordination with mastication and temporal aspects of swallow ([16-18]). Moreover, the concept of possible overlap between cognition and swallow is gaining lot of exposure and evidence in the era where consumption of food is negatively influenced because of distracters like television ([19, 20]). Apparently, lack of clinical data and research evidence, both in normal individuals and dysphagic population, has lead to paucity in our understanding of how cognition influences safe swallow. Hence, the study was undertaken to investigate effect of sharing attention resources on swallow performance in healthy young adults.

2. Method

2.1. Participants

30 age and gender matched subjects were involved in this cross sectional study design. 15 Males and 15 Females within the age range of 18-23 years (mean age=20.3 years) participated. History of speech, language, hearing, neuro-logical deficits and / or history of surgery done to oro-pharyngeal apparatus were ruled out, ascertained by case history. Cognitive functioning was estimated to be intact as per Mini Mental Status Examination ([21]). Only the participants who passed the Four Finger Test ([22]) and trial feeds were subjected to further swallow investigations. Subjects were categorized as pass if there was timely hyo-laryngeal elevation and subsequent depression, monitored by fingers placed on neck region. Ingestion of five ml thin liquid consistency without aspiration was deemed as green signal for detailed swallow investigation.

2.2. Stimuli

Swallow abilities were tested using thin liquids in form of luke warm water. A 120 ml capacity disposable cup was filled with 100 ml water to perform 100 ml water swallow test. To test the CCT condition, a cognitive task was incorporated, namely Visual Feature Scan, a sub-section under the attention domain put forth in Manipal Manual for Cognitive Linguistic Abilities ([23]). To ensure complexity of the cognitive task was well balanced five Speech Language Pathologists performed the cognitive task as per manual instructions. Following which, each graded the task for level of difficulty using a 1-10 rating scale, with 1 indicating very easy and 10 representing most difficult. The stimuli with mean rating of 5 were only considered for CCT. This was done to ensure the results must not be influenced by the complexity of the CTT. After finalizing the stimuli, high resolution photographs in .jpeg format were uploaded on Microsoft PowerPoint template for visual presentation. Prior to popping of the target screen, instructions to perform the cognitive task, this was, “Count the animal that has fur” were presented on Times New Roman 16 font size black imprint on a white background. Change from instruction screen to target screen was controlled by the clinician, who duly performed this once the participant verbally consented to proceed. Figure 1 below depicts the order of presentation of CCT, in which instruction for cognitive task is followed by the target picture.

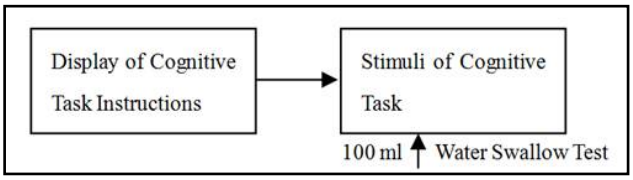


Figure 1. Sequential presentation of cognitive task stimuli for CCT

2.3. Procedure

Each participant was seated comfortably erect on a chair with back rest. Participants underwent swallow testing across two different conditions in a single setting. In the first baseline condition, subjects were directed to ingest 100 ml water directly from the rim of the cup continuously without oral spillage. No further instructions were given so as to obtain participants natural sequential swallow style ([24], [25]). Participants were given the chance to decide choice of hand over holding of the cup. In the second condition of CCT, subjects were presented with high resolution picture of Visual Feature Scan on a 14 inch laptop screen using Microsoft PowerPoint. Specific instructions were given to perform the cognitive task simultaneously with 100 ml water swallow test. To prevent bias over one of tasks we did not provide them with further instructions ([26]).

During this course, simultaneously the clinician monitored number of hyo-laryngeal movements and total time taken to swallow. One hyo-laryngeal elevation and its subsequent depression, as observed visually, were considered as one hyo-laryngeal movement. To calculate the total swallow time, a digital stopwatch was used with commencement of timing as the rim of the cup touched the upper lip and ended with withdrawal of the cup. These directives were put forth as a standardized method to evaluate Timed Test of Swallow ([27]), based on which 100 ml water swallow was conceived.

2.4. Data Analysis

The data was subjected to further analysis only if the

subject's answer to the cognitive task was correct. We followed this protocol to ensure that the subjects had performed the cognitive task while swallowing. This in turn evidences active participation while performing CCT. Post validating, we obtained V/S, T/S and SC parameters using the mathematical formula ([27]).

V/S = 100 ml/ No. of hyo-laryngeal movement

T/S = Total time taken in sec / No. of hyo-laryngeal movement

SC = 100 ml/ Total time taken in sec

Inter session time i.e., between baseline and CCT condition was 5 minutes. Total time involved for each participant was 10 minutes. On an offline basis, 180 tokens [(1 Baseline condition x 30 subjects x 3 parameters) + (1 CCT x 30 subjects x 3 parameters)] were tabulated and subjected to statistical package SPSS (Version 17) computed on Windows XP.

3. Results

All participants completed the 100 ml water swallow test in one attempt with no oral spillage or residue in the cup. Audible aspiration and / or cough were not observed. Moreover, all thirty subjects were able to perform the cognitive task and answer the question correctly. Hence, all the data was further analyzed without any drop-out.

Results of descriptive statistics revealed that in baseline condition the 100 ml water swallow test performance was better compared to CCT condition. Specifically, we observed increased V/S with lesser T/S and consequently increased S/C in baseline condition. On the contrary, in CCT condition, swallow behavior was characterized as decreased V/S with longer T/S and decreased S/C. Mean values with standard deviation of each condition are tabulated in Table 1.

Table 1. Results of descriptive statistics

		V/S	T/S	SC
Baseline	Male	21.13(±11)	1.17(±0.26)	18.17(±6.62)
	Female	18.29(±5.9)	1.31(±0.22)	13.68(±3.69)
CCT	Male	13.53(±4.1)	1.51(±3.89)	8.9(±3.41)
	Female	15.13(±5.9)	1.71(±0.65)	9.1(±2.53)

On administering one way ANOVA, we obtained statistically significant difference between baseline and CCT condition across V/S, T/S and SC parameters at 95% confidence level. Statistical values obtained was [F (1, 58) = 8.346; p = 0.005, η=0.126], [F (1, 58) = 11.367; p = 0.001, η=0.164] and [F (1, 58) = 33.849; p = 0.000, η = 0.369] for V/S, T/S and SC respectively. Effect size analysis was performed for each condition. We obtained Cohens *d* value of 0.74, -0.87 and 1.50 for V/S, T/S and SC respectively. These are interpreted as large practical significance for V/S and SC with small practical significance for T/S.

Repeated measures of ANOVA were applied with gender as one factor. In the baseline condition, results of Mauchly's Test of Sphericity showed assumption of sphericity to be violated [$x^2(2)$ = 18.181, p=0.000]. Results of Greenhouse-Geisser revealed statistical significant difference with values [F (1.342, 37.584) = 128.522; p=0.000]. Therefore, the null hypothesis is rejected. Results of Bonferroni Post-hoc analysis with gender as the variable show significant difference at 95% confidence level. The values are described below in Table 2.

On the same note, for CCT condition repeated measure of ANOVA with gender as a factor, results of Mauchly's Test of Sphericity showed assumption of sphericity not to be violated [$x^2(2)$=5.465, p=0.065]. Statistical significant difference for gender was observed for CCT condition as [F (2, 56) = 132.309; p=0.000]. Hence, the null hypothesis is rejected. Results of Bonferroni Post-hoc analysis for gender as the variable under CCT condition were statistically significant and the values are depicted in Table 3.

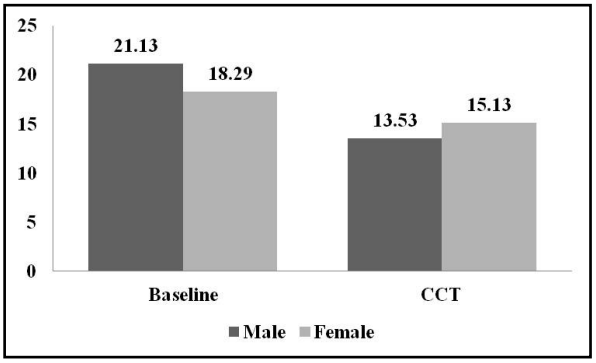


Figure 2. V/S in ml for baseline and CCT

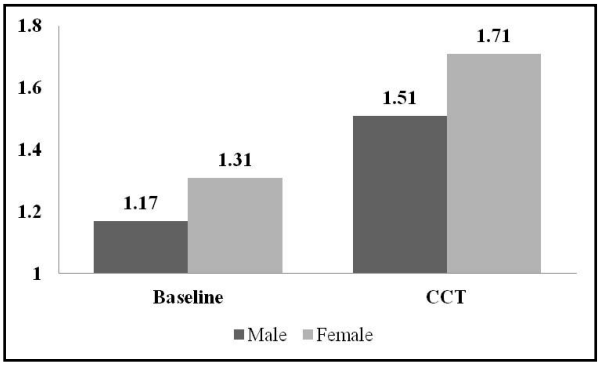


Figure 3. T/S in sec for baseline and CCT

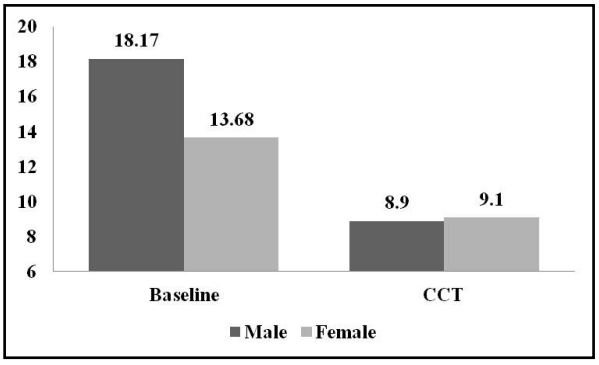


Figure 4. SC in ml/sec for baseline and CCT

Table 2. Bonferroni Post-Hoc results for gender as variable for Baseline condition

(I) Parameter	(J) Parameter	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
V/S	T/S	18.467*	1.586	.000	14.427	22.507
	SC	3.784*	.995	.002	1.251	6.317
T/S	V/S	-18.467*	1.586	.000	-22.507	-14.427
	SC	-14.683*	.967	.000	-17.146	-12.219
SC	V/S	-3.784*	.995	.002	-6.317	-1.251
	T/S	14.683*	.967	.000	12.219	17.146

*Mean difference is significant at 0.05 level

Table 3. Bonferroni Post-Hoc results with gender as variable for CCT condition

(I) Parameter	(J) Parameter	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
V/S	T/S	12.723*	.896	.000	10.442	15.004
	SC	5.268*	.830	.000	3.154	7.383
T/S	V/S	-12.72*	.896	.000	-15.01	-10.442
	SC	-7.455*	.601	.000	-8.986	-5.924
SC	V/S	-5.268*	.830	.000	-7.383	-3.154
	T/S	7.455*	.601	.000	5.924	8.986

*Mean difference is significant at 0.05 level

4. Discussion

The present study focused to investigate if sharing cognitive resources leads to change in swallow performance. CCT was compared with baseline condition performed by healthy young adults. Overall, the results revealed decreased swallow performance in CCT condition. The observed difference in the study can be explained using the well accepted "Capacity Sharing Model". It postulates that attention is a set of limited resource, which can be shared and allocated differentially ([28]). Therefore, in presence of a dual task condition, like CCT, the subjects in the study would have allocated more attention to cognitive task greater than what is required when it is done at isolation. This in turn would have resulted in a limited set of resource pool in the second task i.e., 100 water swallow test that was being done concurrently. The "Bottleneck Effect" can also be asserted to below par performance during CCT due to bottleneck resulting from competition between shared cognitive resources ([29]). As a consequence of this we observed smaller ingestion of quantity as well as decreased speed of swallow ([30]). These possibilities would have been the reason for the study to evidence decreased V/S in longer T/S and decreased SC under CCT. The results are supportive of literature findings that evidence allocating attention resources concurrently hampers swallow performance ([12-14]).

Reduced performance in dual tasks could be due to shared neural substrates for two functions. Applying these possibilities, we can comment that swallow and attention must have overlapping neural activity, at the level of brainstem and cognition, consequently leading to competition during the dual tasks ([31]). Supportive evidence for these statements dates back to 1980's when the widely acknowledged "Functional Cerebral Space Model" posited that simultaneous performance of overlapping functional neural activity yields poorer performance in either one of the concurrent tasks ([32]). Other researchers supporting these views put forth the concepts "Hemispheric Overload" and "Competition of Resources" ([33] [34]). Collectively, these theoretical explanations dictates that if swallow is reflexive and / automatic in nature then it should have not been affected during CCT. Contrastingly, we noticed poorer performance in CCT condition, thereby providing evidence that there may be some overlap between swallow and cognitive resource like attention. Apparently, as per the method adopted in the present study, results throw light upon the anticipatory phase of swallow. This phase contributes maximally in deciding size of the bolus intake, positioning of the bolus and its subsequent triggering of oral phase of swallowing ([3], [4]). Thereby the difference in results was noted in the study.

Notably, till date, how much attention resource is allocated for each task remains unanswered, but cues that it may be pliable to individual preferences. Having said this, we had specifically directed the subjects to perform both the task simultaneously. Thereby preventing and/ or reducing subject's bias to give more importance to any one of the tasks.

Possible role of anticipatory phase of swallow must also be taken into account. Researchers have provided evidence that anticipatory phase and oral phase are decided based on cognitive aspects ([4]). This sheds light that during CCT the role of automatic swallowing would have been minimal or nil as the subjects had to allocate the attention to both the tasks, thereby altering bolus size, placement into oral cavity and propulsion into pharynx via lingual movements. Hence, the decrease in 100 ml water swallow test was evidenced. Clinical importance of this aspect revolves around the risk of aspirating. Remarkably, Leder and colleagues reported 31% higher risk to aspirate in patients with less orientation ([35]). Moreover, it was also brought to light that aspiration risk is as high as 57% for individuals unable to follow single step commands, thereby deeming them unfit for oral feeds ([35]).

Statistically significant difference was evident on testing between male and female participants across the two conditions. Overall, in baseline condition, males had better swallow status compared to females. This viewpoint is a universally accepted phenomenon due to difference in morphological status involving size of oral cavity and length of the vocal tract that dictates physiology of swallowing ([36]). Interesting yet contradicting findings were noted in CCT condition i.e., females performed better than males in swallowing parameters. This can be reasoned to better pre-wired cognitive skills that lends consistent upper hand by females over males ([37]). Thereby, given the circumstances, females would have performed the cognitive task quicker. Hence, allowing them conveniently more time to focus on completion of the swallow task. Apparently, this won't hold true as the time taken to swallow was longer than males. One may overlook this phenomenon as the Cohens value for T/S parameter indicated small practical significance. Another possible theoretical reason for gender difference would be equal sharing of resources between the two tasks. Considering this possibility, the upper hand held by males may be turned down in females when a cognitive task is performed. This in turn is reflected in SC parameter, that shows swallow performance between male and female to be almost same. Interestingly, these views also converge that females are better dual task performers compared to their male counterparts. These statements must be seconded by objective type cognitive tasks.

5. Conclusions

The study was taken up to investigate if swallow performance changes under the influence of CCT in healthy young adults. 100 ml water swallow test results revealed decreased sensory-motor act of swallow in CCT condition. Specifically, decreased V/S with increased T/S and decreased SC was obtained in CCT condition compared to baseline condition. This was statistically significant for V/S, T/S and SC parameters, as determined by ANOVA. The results provide empirical evidence that there exists some relationship between swallow physiology and cognitive resources. This sheds light that controlling cognitive resources during daily act of swallowing may reduce the risk of hampering intake of food. The study also provides much needed scope to administer the experiment on healthy geriatrics who have equal chance of acquiring presbyphagia along with age related cognitive deficits. On the conclusive note, further investigations must be carried out monitoring the cognitive task in an objective way, more likely adopting a reaction time paradigm.

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