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ORIGINAL ARTICLE

Effects of Divided Attention on Swallowing in Healthy Participants

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Abstract Swallowing impairments are treated mostly behaviorally. It is requisite to understand the relationship of cognition, specifically attention, with swallowing since so many swallowing impairments occur concomitantly with cognitive disorders. This study examined the hypothesis that attentional resources are required during swallowing. The approach involved a dual-task, reaction time (RT) paradigm in ten healthy, nonimpaired participants. Baseline measures were obtained of the duration of the anticipatory phase and of the oropharyngeal phase of swallowing and the RTs to nonword auditory stimuli. A dual-task then required participants to swallow 5 ml of water from an 8-oz. cup while listening for a target nonword presented auditorily during the anticipatory or the oropharyngeal phase. Target stimuli were randomized across baseline and dual-task trials. Duration of the anticipatory phase and of the oropharyngeal phase of swallowing and duration of the RT baseline trial and of the dual-task trial were determined. Results showed a statistically significant increase in speed of the anticipatory phase, relative to the oropharyngeal phase, for swallowing during the dual-task. RTs were slowed for both the anticipatory and the oropharyngeal phase during the dual-task, although neither of these was statistically significant. Clinical implications of these data suggest that disruptive stimuli in the environment to non-impaired individuals may alter feeding but have little effect on the oropharyngeal swallow.

Keywords Deglutition · Deglutition disorders · Attention · Reaction time · Cognition

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Swallowing is a complex, neuromuscular event. Historically, swallowing has been regarded as "reflexive" [1, 2], "vegetative" [3, 4], and "automatic" [5–7]. Implicit in the use of these descriptions of swallowing is the relative irrelevance of higher-level processes and, moreover, the view of swallowing as occurring without conscious control or attention-demanding resources. Stated differently, *cognition*, the collection of all unobservable mental processes [8], has been largely ignored in swallowing research. It is true that nearly 30 years ago new terms were introduced that potentially suggested a more cognitive involvement, namely, a "preparatory phase," the preparation of the bolus in the oral cavity, and a "lingual phase," the transit of the bolus from the oral cavity into the pharynx [9]. Researchers and clinicians have accepted and now routinely describe actions of these two phases as the "oral preparatory" and "oral" phases of swallowing, respectively.

These concessions notwithstanding, there remains something of a disconnect between the general view of swallowing as "reflexive," "vegetative," and "automatic," and the voluntary aspects of swallowing (i.e., therapeutic maneuvers and postural changes used to improve bolus flow during swallowing) that are targeted in dysphagia therapy and have been shown to influence swallow characteristics [10–15]. However, there remains a paucity of information in the literature about specific cognitive resources that may be involved and their associated demand on all aspects of swallowing. Instead, research has continued to focus largely on physical factors in the oral phase of swallowing, including bolus characteristics [16], the aerodigestive system's response to bolus characteristics [17–24], aging and age effects [12, 25–30], the coordination of mastication and respiration with swallowing [31–40], and timing of events related to swallowing [41–45].

Historically suggested and described, but without consideration in the research literature, was the concept of "prehension," i.e., those activities that are preparatory to the direct introduction of food or liquid into the mouth [46]. This concept was reintroduced over 160 years later to address aspects of swallowing that arguably involve cognitive resources as the "anticipatory phase" of swallowing [9, 47]. Described first in the now theorized five phases of swallowing (i.e., anticipatory, oral preparatory, oral, pharyngeal, and esophageal), the anticipatory phase involves all preparation of nutritional materials, including decisions and physical (fine and gross motor) control for actions, prior to and including the introduction of the materials to the oral cavity. Specifics include the speed and coordination of limb movements with which food or drink is presented to the mouth and the size of the bolus prepared for intake, all of which impact bolus coordination prior to the initiation of a swallow and meal duration.

It appears, then, that the anticipatory and oral preparatory phases of swallowing would involve some level of controlled, purposeful processing. Relative to these phases of swallowing, the pharyngeal and esophageal phases of swallowing would seem less likely to be subjected to such cognitive influences. However, the role of cognition in the more susceptible anticipatory and oral preparatory phases, or any phase of swallow, has not been explored.

In sum, the primary intervention modality for swallowing impairments is behavioral and ultimately rests on some level of cognitive–physical manipulation. However, research exploring the presence and nature of cognitive influences in swallowing is virtually absent. The present study addresses this paucity of evidence by exploring the possible role of cognition, specifically attention, in swallowing. Using a dual-task reaction time (RT) approach in healthy individuals, this study explores (1) whether evidence of attentional resource utilization can be shown in any phase of swallowing and (2) whether there may be differences in attentional demands across phases of swallowing. Hypotheses are that (a) RTs to secondary auditory stimuli presented during both anticipatory and oropharyngeal phases of swallowing will be significantly longer than baseline/single-task RTs, and (b) RTs to secondary auditory stimuli will be significantly longer during the anticipatory phase than during the oropharyngeal phase of swallowing. This pattern of results would suggest a role of attention in both anticipatory and oropharyngeal phases of swallowing, and, moreover, greater resource demands during the anticipatory phase. The study lays the groundwork and point of reference for other studies examining similar questions in individuals with dysphagia with cognitive or motor dysfunction or both.

Methods

Demographics

This study was approved by the Institutional Review Board at the participating institution. Ten healthy, nonimpaired individuals participated in the experimental study. Participants who reported histories of swallowing difficulties, the use of illicit drugs, or the use of prescribed medications having known effects on swallowing (e.g., benzodiazepines, botulinum toxin, antipsychotics), or currently experienced gross visual impairment (e.g., cataracts, blindness) were excluded from this investigation.

Screening

A hearing screening using pure tones for each participant was completed at 35 dB HL for 500 Hz and 1, 2, and 4 kHz in a quiet, distraction-free room. To insure that participants could hear the test stimuli above ambient noise levels during experimental conditions, test stimuli were presented at 85 dB SPL in free field as measured by a portable sound-level meter with an A-weighted scale at ear level and a distance of 1 m from the speakers. Because the test stimuli were single-syllable nonwords, sound-level calibration took place using continuous, prerecorded white noise normalized based on 100% peak level prior to beginning the experimental conditions for each participant.

Participants were screened for cognitive impairment using Cognistat (Novatek Medical Data Systems) [48]. Participants with two or more impaired ability domains on the Cognistat exam were excluded from the investigation [49].

Participants were also screened for depression using the Beck Depression Inventory (BDI) [50] because of the known effects of depression on reaction times [51]. Participants scoring greater than 16, indicating borderline depression, were excluded from the investigation.

Experimental Design

This study used a within-subjects design. The independent variables for this study were the auditory stimuli presented for single- and dual-task discrimination and the anticipatory and oropharyngeal phases of swallowing. The dependent variables for this study were durations of the anticipatory and oropharyngeal phases of swallowing and reaction time.

Procedures

After participants had completed informed consent and screening procedures, they initiated the experiment proper. The investigation took place in a distraction-free environment. The participant testing area was split between a table setup and a floor setup. For the table setup (Fig. 1a), the participant sat approximately 18 in. in front of a 17-in. computer monitor at eye level on the table. On the table between the seated participant and the monitor were one hand-lift sensor, one cup-lift sensor, and the disposable drinking cup containing the cup module. The hand-lift sensor was placed flush with the front edge of the table. The cup-lift sensor was placed 12 in. from the front edge of the table centered in line with the hand-lift sensor, with both secured to the table with clear packaging tape for the duration of the investigation. Finally, each of the two satellite computer speakers was placed on either side of the computer monitor at a distance of approximately 36 in. from the participant's ear to the front of the speaker and connected to the data computer's audio output.

The floor setup (Fig. 1b) was adjusted for each participant. On the floor immediately in front of the participant's dominant (based on self-report) lower extremity was a foot sensor and a foot pedal used to measure RT. With the participant seated at the table and able to comfortably reach the cup containing water, the participant's lower leg was placed at an approximate 90° angle of flexion to determine placement of the foot sensor. The foot sensor was placed under the participant's foot with a distance of 6 in. from the tip of the participant's shoe to the front edge of the foot pedal. Both the foot sensor and the foot pedal were securely taped to the floor.

Finally, the participant's submandibular area was prepared with an alcohol swab, and electrode gel was placed on the electrode surfaces of a self-adhering patch containing three electrode disks for surface electromyography (sEMG). The prepared patch then was placed over the digastric-mylohyoid-geniohyoid muscle complex.

Two experimental conditions were used in this study: baseline and dual-task. Within the baseline condition were two sets of 19 trials each: (1) nonword discrimination trials and (2) swallowing trials. The dual-task condition contained one set of 19 trials. Thus, there was a total of three sets of 19 trials each (i.e., 57 trials) for each participant. For each trial type (two baseline trials and one dual-task trial), the initial three trials were expected to contribute to an extinction of learning for the task [8] and were planned to

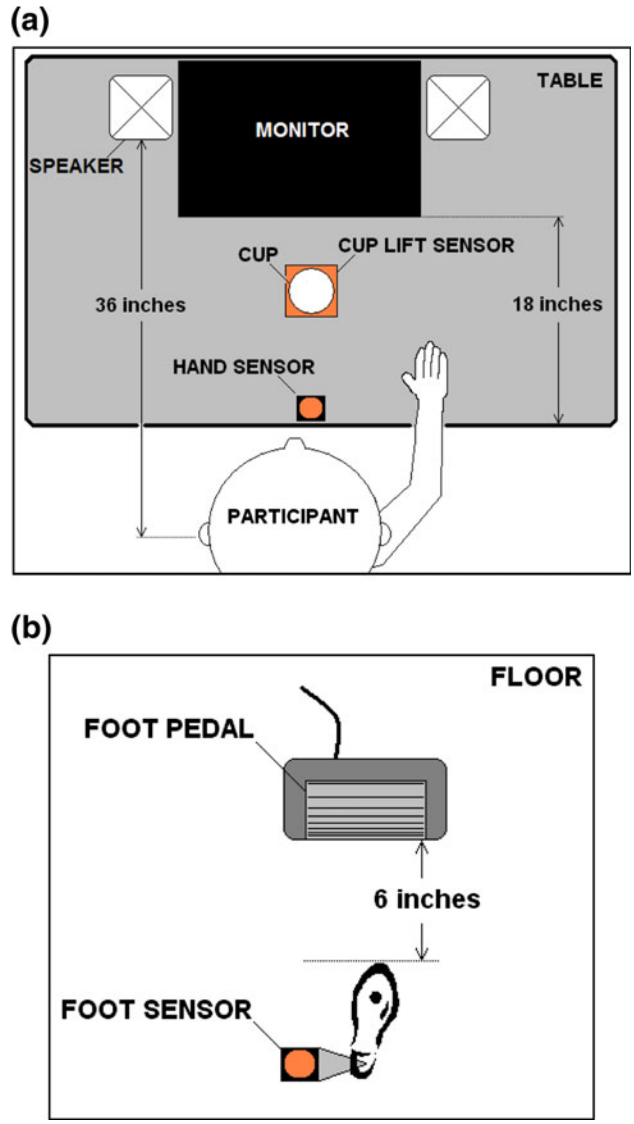

Fig. 1 Physical setup of the investigation: **a** table and **b** floor

be eliminated from analyses, leaving 16 trials for analyses from each data set. Baseline (single-task) and dual-task trials were not counterbalanced across participants. Baseline trials were presented only prior to the dual-task trials so that participants were able to learn the single tasks for the dual-task condition.

Auditory Stimuli

Auditory stimuli used for the nonword single-task discrimination and dual-task trials were validated using digitally recorded, phonotactically legal, monosyllabic nonwords that were created by the principal investigator. All nonwords, distracters and target words, were in the form of consonant-vowel-consonant (CVC) with the same lead (CV–) but different codas (–C). Two randomized lists, each containing 11 *distracter* stimuli and one *target* stimulus were presented to each participant. The lists were randomized and counterbalanced across baseline and dual-task trials and between participants.

Baseline (Single-Task) Trials

Swallow baseline trials consisted of each participant removing his or her hand from the hand sensor, reaching for and bringing the cup containing 5 ml of water to his or her mouth, and swallowing the water with a visual "go" cue from the computer. Nonword discrimination baseline trials consisted of an auditorily presented nonword. Upon hearing the target word, participants were instructed to tap the foot pedal with their dominant foot as quickly as possible; participants were instructed to ignore nontarget words, with the participant's foot never leaving the foot sensor on the floor. The same target nonword was presented with 25% incidence (4 target trials randomized within the 16 trials analyzed) relative to the 11 distracter nonwords. Distractor words were randomly presented across the remaining 12 trials. A similar paradigm was used in prior studies [52, 53]. The order of baseline trials types (i.e., swallowing, RT) was counterbalanced across participants.

Dual-Task Trials

The dual-task condition combined the single tasks of swallowing and nonword discrimination into one task. That is, participants were again asked to tap the foot pedal as quickly as possible with his or her dominant foot when the *target* nonword was heard during the sequence of bringing the water to the mouth and swallowing it. The four target trials were divided into two target stimuli presented during the anticipatory phase of swallowing and two target stimuli presented during the oropharyngeal phase of swallowing. These target trials were randomized within and between participants and manually presented by the principal investigator using the data computer.

Measures and Instrumentation

The measurements made during this study were based on various points in time during each of the baseline and dual-task trials. Each of these is illustrated in Fig. 2 which shows a screenshot of the signal acquisition windows using the Digital Swallowing Workstation^{TM} model 7100 (KayPENTAX, Lincoln Park, NJ) and the Workstation's Swallowing Signals Lab model 7120. The top window depicts a sample sEMG trace, with t_s marking the duration

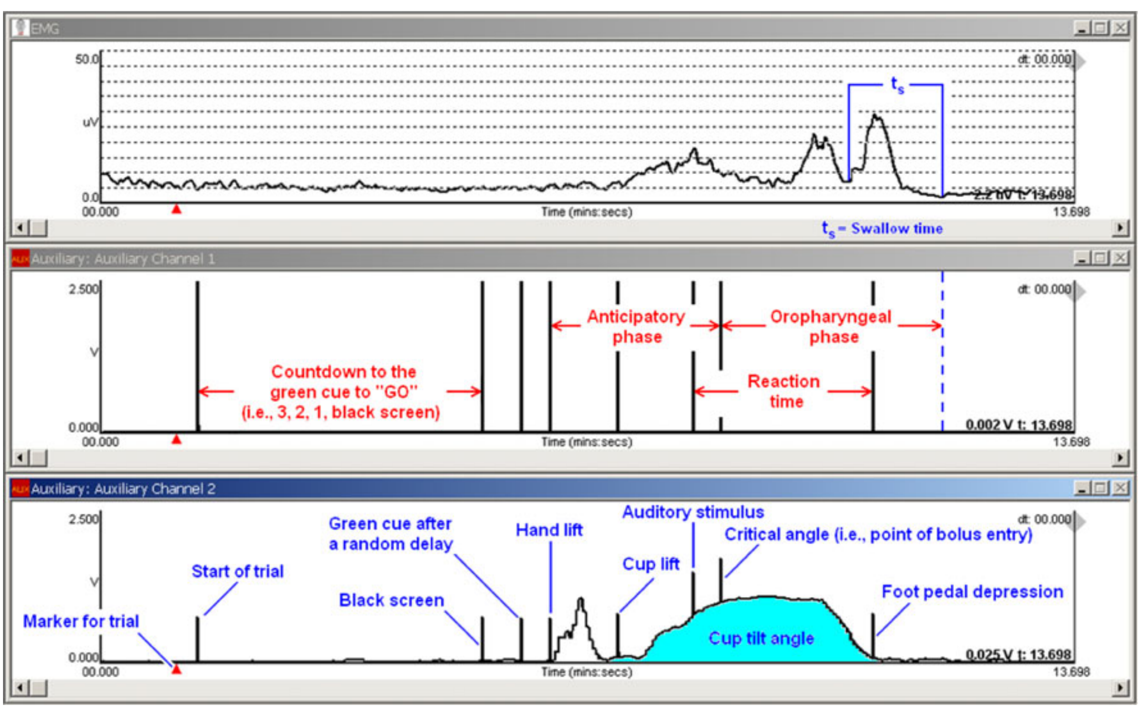

Fig. 2 Sample screenshot of the Digital Swallowing Workstation's time-linked, composite, signals screen. The *top window* (labeled *EMG*) is the sEMG signal collected without interference from other signals in a dedicated channel through the Swallowing Signals Lab. The *middle window* (*Auxiliary Channel 1*) captured all input sensors as 5-ms square wave pulses. The *bottom window* (*Auxiliary Channel 2*) captured all input sensors in addition to the cup tilt trace. The auditory stimulus, for purposes of this screenshot, was presented during the anticipatory phase of swallowing

of swallowing between initiation of the pharyngeal swallow and completion of the swallow. Skipping the middle window (i.e., Auxiliary Channel 1) for the moment, the bottom window, Auxiliary Channel 2, depicts the various measures as pulses during the study, all of which are redundantly recorded in Channel 1 for data integrity purposes. There was a maximum of eight pulses, each recorded as follows.

The start of the experimental trials was noted using an initial pulse (pulse 1) that began a 3-s countdown. The countdown, displayed on the participant's monitor, proceeded with the word "Ready," followed by the characters "3," "2," and "1" in 72-point, white, Times New Roman font on a black background. A randomly imposed delay between 500 and 2,000 ms following this countdown occurred, during which time the computer monitor was completely black (pulse 2). After this delay, a green circle 3 in. in diameter appeared in the center of the computer monitor (pulse 3), prompting the participant to begin his or her response to drink the water in the cup. The participant lifted his/her hand from the table (pulse 4) to take hold of the round, 8-oz. (237 ml), disposable cup (Solo® Hot Drink Cups, No. 378). The cup was lifted from a sensor (pulse 5) and the participant began to bring the cup containing 5 ml of filtered water (measured using a graduated syringe) to his/her mouth. A cup tilt circuit was placed in the bottom recess of the cup and was used to calculate the absolute tilt in degrees, and the calculated value was transmitted to the Swallowing Signals Lab. The cup tilt, calculated from the combination of the accelerometer roll and pitch signals, was used to determine the angle at which the cup delivers its liquid contents over the rim operationally defined as the critical angle, i.e., the angle between the side of the cup facing the table when it was tilted immediately before 5 ml of water flowed over the rim and the table surface (pulse 6). The auditory stimulus (pulse 7) and foot pedal depression (pulse 8) were used for the baseline RT and dual-task portions of this study only. They recorded the time of presentation of the auditory stimulus and the moment the food pedal was depressed by the participant.

A notebook computer (data computer), responsible for the management of a timer, commencement cue, presentation of auditory stimuli, and real-time data acquisition, served as the primary control device for this study. The KayPENTAX Digital Swallowing Workstation was used to record all pulses, the cup tilt angle, and submental sEMG tracings. A custom interface box was constructed to control the presentation of stimuli and collect data from all sensors and from the Workstation's Swallowing Signals Lab. The experiment was performed using Presentation® software ver. 0.50 (Neurobehavioral Systems, Inc., Albany, CA) to allow for simultaneous experimenter-delivered stimuli, data acquisition, and voltage pulse generation captured by the Workstation. Sampling rate was 1,000 Hz.

Data Reduction

Following the completion of data collection, the database was inspected. Nineteen trials for each of three conditions (i.e., baseline swallowing, baseline RT, and dual-task) for a total of 57 trials were completed per participant. The first three trials were immediately removed from all analyses to control for any practice effects [8]. The data were then inspected for outliers using box plots and stem-and-leaf plots. Based on group data, outliers greater than 2 standard deviations (SD) were removed from the data set for final analyses.

Results from all trials were electronically recorded and categorized from the programmed code as "good," "bad," or "void," based on sensor signals and their consequent data recording. A *good* trial was defined as a trial in which all sensors were successfully triggered and the sEMG data were successfully recorded. A *bad* trial was one in which a participant made an error (i.e., did not react to a target trial or anticipated the response to a target with an RT less than 100 ms). A *void* trial was defined as a trial in which at least one electronic sensor was not triggered or the sEMG signal was not recorded. In addition to reporting the status for each trial, "repeat" trials were labeled in the database; they were trials that were presented to the participant following a bad or void trial. Although no feedback was provided to the participant at any time, immediate feedback for the trial's status type was presented to the researcher following each trial. Bad and void trials were immediately repeated without informing the participant.

Statistical Analysis

The completion of the oropharyngeal swallow was operationally defined as the offset of the submental sEMG signal and was manually determined using the Workstation's software. Measurement reliability was calculated on a randomly chosen 25% of the total number of sEMG tracings from each participant. A repeated-measures analysis of variance (RMANOVA) was conducted to detect statistically significant differences between trials within participants and between conditions, controlling for trials. A Mauchly test of sphericity was used with all analyses, applying the Greenhouse-Geisser correction when applicable. Significance was set to $\alpha \leq 0.05$ for all comparisons. Statistics were computed using SPSS 16.0 for Windows (release 16.0.2) (SPSS, Inc., Chicago, IL, USA).

Results

Demographics

Ten nonimpaired adults participated in the study. All ten participants were Caucasian (9 non-Hispanic and 1 of unknown ethnicity). Within this sample of seven males and three females, one male was left-handed; all other participants were right-handed. The average age was 61.9 years (SD = 9.7 years, range = 45–76 years).

Screening Results

Participants either passed a hearing screening in both ears with pure-tone stimuli through headphones at 35 dB HL for 500 Hz and 1, 2, and 4 kHz in a quiet distraction-free room ($n = 6$) or had the sound level adjusted relative to their pure-tone average with no less than 35 dB SL to compensate for external noises (e.g., computer fan, room noise) ($n = 4$).

Scores from the BDI suggested that there was no depression in any participant (mean = 4.2, SD = 4.1, range = 0–13). Composite score results from Cognistat were within normal limits for all participants. In sum, no participant showed evidence of a depressive, neurological, or cognitive disorder.

Data Used in Analyses

Briefly, this study involved three arms: (1) baseline (single-task) swallow, (2) baseline (single-task) RT trials to auditory stimuli, and (3) dual-task trials combining swallowing with RT trials. There were 16 baseline swallow trials involving single swallows of 5 ml of water, 16 baseline RT trials containing 4 randomly delivered auditory target trials among 12 distracter trials, and 16 dual-task trials containing 4 randomly delivered auditory target trials among 12 distracter trials while the participant completed drinking a single 5-ml volume of water per trial.

Ten of the 16 possible trials during the baseline swallowing condition had complete data for each participant. Three of the four possible target trials during the baseline RT trials had complete data. The dual-task condition contained four trials as well: two sets of two trials for each of the two phases of swallowing in which they were presented. Data from the dual-task condition yielded one trial from each of the two phases of swallowing, with complete data for each participant. Table 1 provides a summary of these data. Data loss was due to a sensor malfunction or unreadable sEMG tracing discovered after all of the data were collected.

Table 1 Summary of valid trials used for analyses

	Valid trials	Possible trials
Baseline (single-task) swallowing	10	16
Baseline (single-task) RT		
Anticipatory phase	2	2
Oropharyngeal phase	2	2
Dual-task		
Anticipatory phase	1	2
Oropharyngeal phase	1	2

Baseline (Single-Task) Data

Swallowing

The average time for the anticipatory phase of swallowing was 2,543 ms (SD = 437 ms, range = 1,690–3,597 ms). There was no significant difference between trials ($F = 0.759$, df = 3.267, $P = 0.536$) for anticipatory phase time, suggesting that participants repeated their performance in a stable fashion across trials during the baseline phase. The average time for the oropharyngeal phase of swallowing was 2,177 ms (SD = 663 ms, range = 746–3,830 ms). There was no significant difference between trials ($F = 0.545$, df = 3.805, $P = 0.696$), again suggesting that participants repeated their performance in a stable fashion across trials during the baseline phase. Mean times for phase durations by trial are presented in Fig. 3.

Nonword Discrimination Reaction Time

The average RT in target trials (those trials requiring a RT response) for the participants was 777 ms (SD = 288 ms, range = 406–1468 ms). There was no significant difference between trials ($F = 0.954$, df = 3, $P = 0.440$), suggesting that participants repeated their performance in a stable fashion across trials during the baseline phase. Mean times for phase durations by trial are presented in Fig. 4.

Dual-Task Data

Swallowing

For target trials during the dual-task, participants demonstrated an average anticipatory phase duration of 2,354 ms (SD = 488 ms, range = 1,729–3,416 ms) and an average oropharyngeal phase duration of 2,198 ms (SD = 1,218 ms, range = 515–4,462 ms). There was no significant difference between dual-task anticipatory phase time trials ($F = 0.115$, df = 1, $P = 0.746$) or oropharyngeal phase time trials ($F = .305$, df = 1, $P = 0.596$).

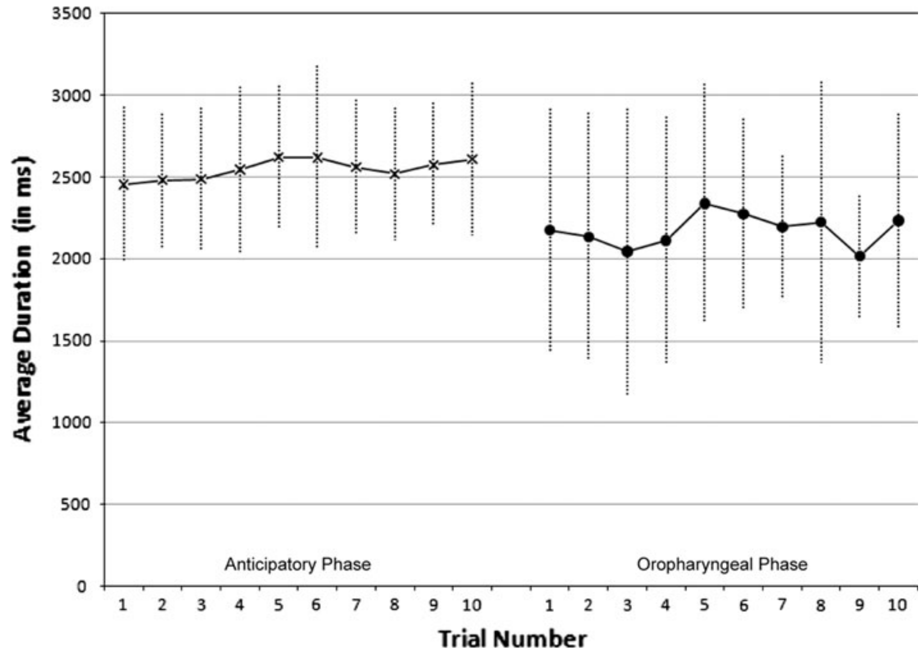

Fig. 3 Baseline average anticipatory phase and oropharyngeal phase swallowing times

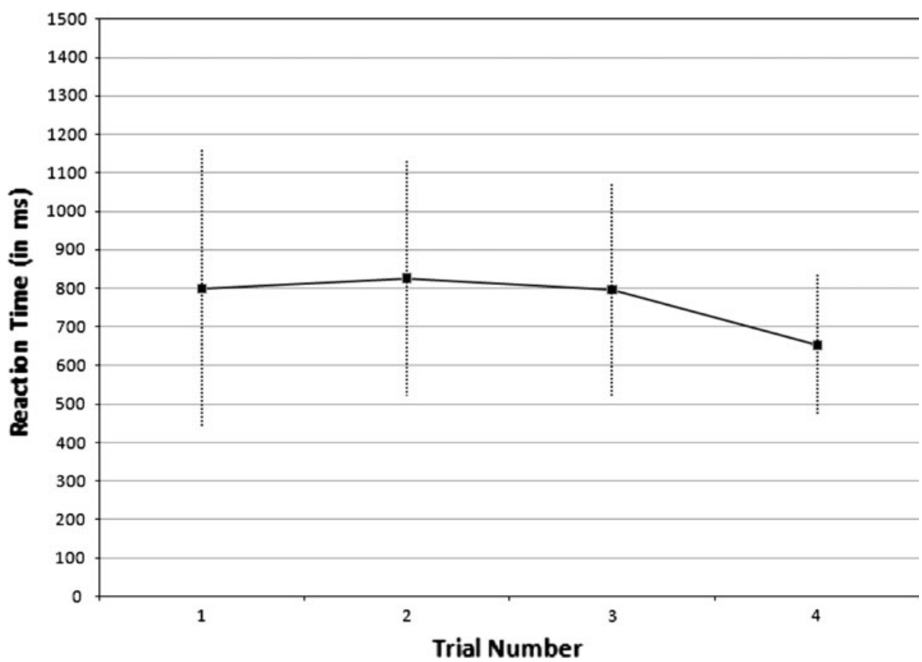

Fig. 4 Baseline average reaction times to auditory stimuli

Nonword Discrimination Reaction Time

The average RT for targets presented in the anticipatory phase of swallowing was 892 ms (SD = 338 ms, range = 463–1,672 ms). The average RT for targets presented in the oropharyngeal phase of swallowing was 911 ms (SD = 273 ms, range = 583–1678 ms). There was no significant difference in RT between phases of swallowing during the dual-task ($F = 0.576$, df = 1, $P = 0.467$).

Comparison between Baseline (Single-Task) and Dual-Task

Swallowing

The durations for each of the two phases of swallowing were analyzed for differences, with the results depicted in Fig. 5. There was a significant decrease in anticipatory phase duration from baseline to dual-task trials ($F = 7.505$,

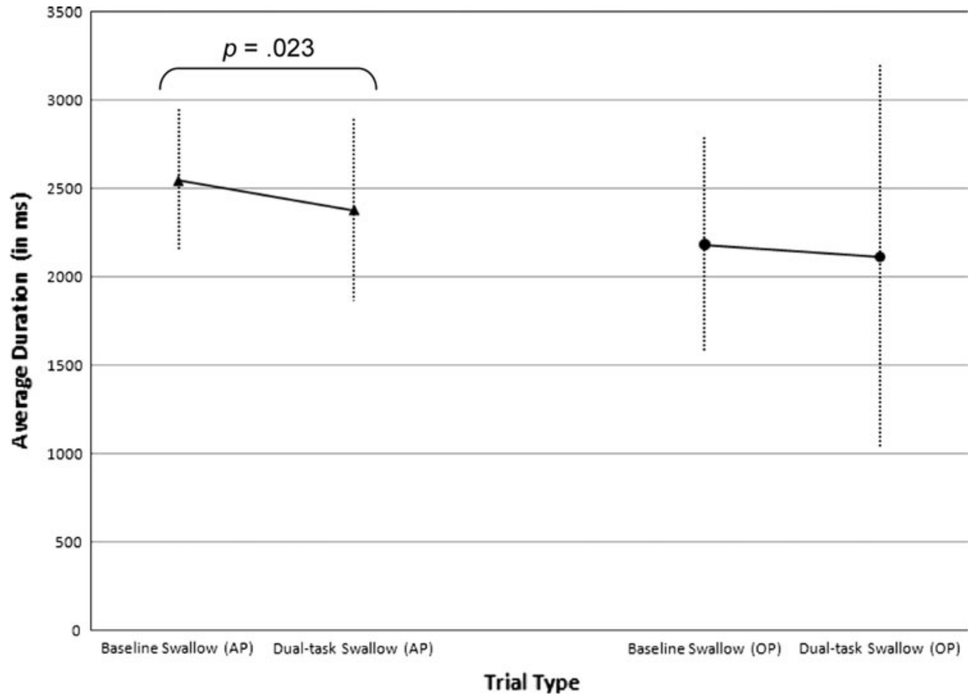

Fig. 5 Average duration of anticipatory and oropharyngeal phases of swallowing between baseline and dual-task

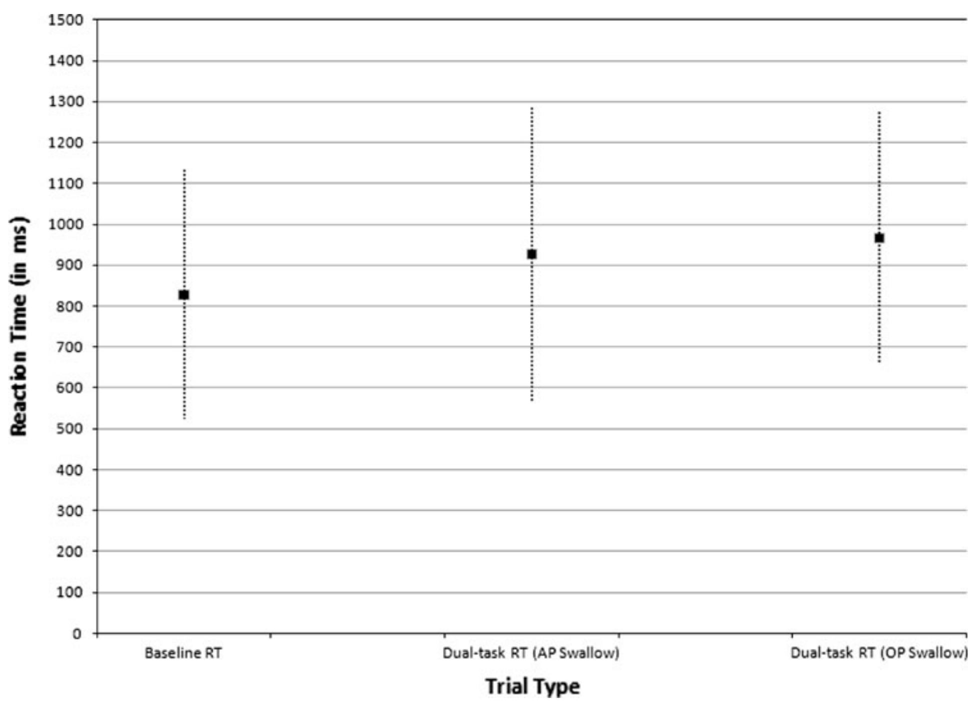

Fig. 6 Average reaction times during baseline trials and dual-task target trials during the anticipatory and oropharyngeal phases of swallowing

df = 1, $P = 0.023$), with an average difference of 167 ms. However, there was no significant difference from baseline to dual-task for oropharyngeal swallow duration ($F = 0.001$, df = 1, $P = 0.977$), with an average difference of 68 ms.

Nonword Discrimination Reaction Time

RTs were analyzed for differences between baseline and the dual-task within the same phase, with the results depicted in Fig. 6. There was no significant difference in

RTs between tasks during the anticipatory phase of swallowing ($F = 0.711$, df = 1, $P = 0.421$) or during the oropharyngeal phase of swallowing ($F = 2.307$, df = 1, $P = 0.163$).

Discussion

The fundamental question posed in this research was whether attentional resources are utilized during swallowing. The question directly addresses the historically pervasive view that swallowing is a reflexive, vegetative, and/or automatic physiological function, the implications of which relate to behavioral therapeutic interventions and may relate to neuroplasticity. Through the use of the terms "reflexive," "vegetative," and "automatic," it may be suggested that attentional resources have little or no role in swallowing, especially in the "reflexive" oropharyngeal phase. The goal of the present study was to assess the validity of this belief by evaluating the potential involvement of attention in swallowing.

The data from this study do not suggest a limitation of attentional resources during either phase of swallowing for these normal-functioning individuals. Despite the "voluntary" nature of motor control during the anticipatory phase, dual-task RTs were not significantly increased compared to baseline RTs. Interestingly, there was a statistically significant decrease in duration of the anticipatory phase of the swallow during the dual-task trials. This suggests that attentional resources were available and allocated during the dual-task condition. It also is consistent with the resource model of attention that view it as limited, sharable across tasks, and as differentially able to be allocated [54–58]. Capacity-sharing theory suggests that simultaneous tasks share a limited pool of available attentional resources; if one task requires a great amount of those resources, resources will be limited for processing in a second simultaneous task. A typical result would be a reduction in the quality of performance for the second task. The finding of a reduced swallow duration in the anticipatory phase under the dual-task condition is interpreted as being consistent with the resource allocation model in that resources were available and allocated under the condition when more was required.

No instructions were given to the participants as to how they were to allocate their attention to this task. However, our result was unanticipated. From this finding, it can be argued that the anticipatory phase of swallowing is cognitively demanding, requiring fine motor control to bring the cup to the participant's lips and orient (i.e., tilt) the cup for delivery of the water to the oral cavity. In this light, the anticipatory phase of swallowing seems to have robbed the RT task of the needed resources it required to complete the task as timely as baseline. The RT did increase, although the results were not statistically significant, as the anticipatory phase of swallowing decreased. In effect, these data support the capacity-sharing model of cognition for the anticipatory phase of swallowing only [54–58].

A second experimental question investigated whether there is a disparity in the demand for attention between different phases of swallowing (i.e., anticipatory versus oropharyngeal). As stated, greater involvement of attention was expected in the anticipatory phase due to its complexity and perhaps its voluntary nature. There was, in fact, a significant difference in duration of the anticipatory phase of swallowing under the dual-task compared to that of the baseline, but no such difference was present in the oropharyngeal phase. This finding suggests the resistance of the anticipatory phase to external distracters, while the oropharyngeal phase appears unaffected by this manipulation of competition. Introduction of the dual-task during the anticipatory phase of swallowing was enough to perturb the attentional resources required to complete the dual-task; however, this perturbation may not be clinically meaningful, especially when the increase in speed is outside of the swallowing system.

Limitations

As noted, data from the present investigation suggest that the anticipatory phase of swallowing may be changed under conditions where attentional resources are shared. However, the oropharyngeal swallow was not affected by the dual-task manipulation used in this study with these healthy, normal individuals. Whether this reflects a fundamental difference in the cognitive control of the two stages of swallowing has not been resolved with this study. Perhaps the oropharyngeal phase of swallowing is more "reflexive" or "overlearned" and less reliant on and available to attentional modulation. Alternatively, the dual-task may not have taxed a shared attentional system sufficiently to reveal a resource-dependent process. However, the data do suggest that this phase of swallowing was unaffected in its maintenance of the temporal factors measured in this investigation. Broader conclusions about such homeostasis may be premature. The present task did demand enough attention to show a trade-off in resources between baseline RTs and those during the dual-task during the anticipatory phase, yet it may not have been as powerful during the oropharyngeal phase. Other, perhaps more demanding tasks will need to be investigated to estimate the generalizability of this finding.

Another limitation is that the present study did not allow for a fine-grained examination of cognitive influences related to the individual physiologic events of swallowing, such as breathing coordination with swallowing, bolus collection, bolus propulsion, oral transit time, initiation of the pharyngeal swallow, or pharyngeal transit time. Although some of this work has already been completed [34, 59, 60], such issues should be pursued with more detailed approaches to the evaluation of swallowing, such as videofluoroscopy, endoscopy, and hook wire or surface EMG sampling of specific muscle regions. These more fine-grained indices of swallowing may reveal attentional influences on swallowing which in turn could have implications for detection, diagnosis, and management of dysphagia across different patient populations.

The present findings suggest that attention has some influence in the anticipatory stage of swallowing, at least in healthy, normal individuals. This paradigm should be extended to individuals with motor impairments, absent of cognitive impairments, in order to provide evidence for the "resource" model in the sharing of the motor acts of swallowing and limb (upper and lower extremity) movements [54–58]. In a subsequent study we address this model in patients with idiopathic Parkinson's disease.

The data from the present investigation support clinical observations—in the absence of data in the literature—that intact cognitive skills allow patients the ability to modulate and modify the failing system of swallowing. That is, swallowing maneuvers that are given to patients to address the physiologic impairments of swallowing, such as the Mendelsohn maneuver [11, 13, 15], supraglottic swallow, and effortful swallow [10, 12, 14, 15, 61], demand the cognitive resources needed to understand how to perform the task, how to organize and coordinate efforts motorically, and do all of this while swallowing a bolus of food or drink.

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