9-10-2021

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Research Article

Influence of Tasking During Vestibular Testing

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Purpose: The purpose of this study was to investigate the effectiveness of different types of tasking on the measurement of peak slow phase velocity (SPV) for caloric testing and rotary chair testing.
Method: This study evaluated the peak SPV response for caloric testing and rotary chair across five conditions. Three verbal, one tactile, and one condition without tasking were used for both caloric testing and rotary chair. The subjects consisted of 20 young adults (age range: 22–33 years, *M* = 26.65, *SD* = 3.72; seven male, 13 female) with normal vestibular function and no history of ear surgery or vestibular disorder. Study participation consisted of two visits with 24 hr minimum between each, one for caloric testing and one for rotary chair testing. The test completed at each visit was counterbalanced.

Caloric Testing: The caloric irrigations were performed 5 times, with the ears randomized and tasking conditions randomized.

Rotary Chair Testing: Rotary chair sinusoidal harmonic acceleration testing was performed 5 times at 0.08 Hz with the tasking conditions randomized.
Results: Tasking of any kind resulted in significantly larger peak SPV responses when compared to the no tasking condition for rotary chair testing. When comparing each type of tasking, no significant differences were noted. No significant difference was noted when comparing the conditions with tasking to the no tasking condition for caloric testing.
Conclusions: Clinically, either mental or tactile tasking can be utilized as a method to reduce VOR suppression during rotary chair testing. As no difference was found when comparing different verbal tasks to each other, the type of tasking can be catered to the patient. If verbal tasking cannot be completed, the braiding tactile task is a valid substitution. Caloric results varied widely across subjects and did not reach statistical significance, so conclusions on the need for tasking cannot be drawn.

Accurate identification and management of vestibular disorders relies on measurements of the vestibulo-ocular reflex (VOR). The VOR is a compensatory reflex that allows for the stabilization of vision on the retina during active head movement or changes in body position. In response to the vestibular pathway stimulation created by active head movement, the VOR produces a reflexive eye movement called nystagmus. The slow phase velocity (SPV) of this eye movement is equal in magnitude and opposite in direction of the head movement. Stimulation of the VOR is regularly used to identify and quantify peripheral and central vestibular system lesions. When the VOR is induced, the intensity of the nystagmus that is produced in response can be measured.

The VOR can be induced either through active head/body rotation, such as with rotary chair testing, or induced by thermal changes within the ear canal, such as with caloric testing during videonystagmography (VNG) or electronystagmography (ENG). The peak SPV of the nystagmus is most often used clinically to assess vestibular function. When using peak SPV as a measurement of vestibular function clinically, it is important to ensure a robust response is being recorded. One method to ensure a robust response when measuring the VOR is to control for suppression. Suppression of the VOR occurs when the reflex is reduced or eliminated by extra-vestibular factors.

Common causes of VOR suppression during testing include light/visual stimuli and inadequate mental stimulation. Well-supported methods for controlling visual stimuli during testing include having the patient close their eyes or eliminating all light sources in the testing room (Baloh et al., 1977; Karlsen et al., 1980; Jacobson & Newman, 1993). This is either completed through the use of well-fitting video goggles with a cover if completing VNG or through having a patient close their eyes if completing ENG. Rotary chair testing either requires well-fitting video

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Correspondence to Kathryn Makowiec: kmakowi1@hfhs.org
Editor-in-Chief: Ryan W. McCreery
Editor: Jamie Bogle
Received December 30, 2020
Revision received March 4, 2021
Accepted May 24, 2021
https://doi.org/10.1044/2021_AJA-20-00227

Disclosure: *The authors have declared that no competing financial or nonfinancial interests existed at the time of publication.*

goggles with a cover or an enclosed surround to eliminate light sources.

A common method to provide adequate mental stimulation during testing is mental tasking, which requires the patient to perform a cognitive task while the VOR response is being measured (Collins, 1962; Collins et al., 1960). These cognitive tasks will often be performed in a question–answer format and can include listing, calculations, or be more conversationally based. Cognitive tasks completed within a clinical setting often vary depending on the examiner, the patient, and the clinic.

Multiple studies have shown that mental tasking does matter and will reduce a person's ability to suppress the VOR response (Collins, 1962; Collins et al., 1960; McGovern & Fitzgerald 2008). Generation of the fast phase of nystagmus likely requires steady stimulation of higher-level cortical activity, and mental tasking maintains this steady stimulation (Barin, 2009). In addition to whether to task, the type of mental tasking may also matter. Some studies discussed below have compared different types of mental tasking to each other in an attempt to find an optimal type of mental tasking.

Numerous types of tasking (i.e., conversational, mathematical, active, passive, tactile, and no tasking) have been investigated with variable results. Studies by Kileny et al. (1980) and King et al. (2006) found that verbal tasking resulted in larger measured SPV responses when compared to no tasking. However, studies by Jacobson et al. (2012) and Easterday et al. (2016) found no difference in the VOR response when comparing conditions with tasking to conditions without tasking. In addition to the importance of tasking in general, the effectiveness of different types of tasking has also been investigated. For example, Kileny et al. (1980) reported conversational tasking resulted in larger amplitude responses than a mathematical task. Formby et al. (1992) found that a noninteractive quizzing task with little interaction with the examiner resulted in the largest amplitude responses. Davis and Mann (1987) examined the difference between passive and active tasking and found that active mental tasking resulted in larger amplitude SPV measurements than passive tasking, but no difference was noted between the two types of mental tasking (mathematical and answering questions).

At times within a clinical setting, verbal/aural tasking cannot be completed, such as if a patient has significant hearing loss or is not a native English language speaker. Tactile tasking is a mental alerting option that may be used in these types of situations. In addition to reporting that tasking resulted in larger measured SPV responses than no tasking, King et al. (2006) developed a vibrotactile tasking paradigm to be used during caloric testing. They found no significant difference on the peak SPV of the VOR between verbal and vibrotactile tasking.

The current study had multiple purposes to address the inconsistencies noted in prior literature. The first was to examine if there is a difference between types of mental tasking on the peak SPV response measured during caloric testing and rotary chair testing within the same population. The second, in response to Easterday et al. (2016), is to investigate the effect of tasking versus no tasking on the peak SPV response measured. The third purpose is to confirm that a tactile braiding task can be utilized in place of mental tasking.

The researchers felt this study was of value as previous literature has not compared the impact of different types of tasking on both caloric and rotary chair responses within the same population. Anecdotally within a clinical setting, the researchers have not found that one type of mental tasking works best for all patients, even when the patients have similar education levels, but have found that some sort of tasking typically results in larger responses than when no tasking is used. Additionally, the type of tactile tasking utilized in this study has been used clinically where the researchers practice but has not been validated in previous literature.

Method

Subjects

All procedures were approved by the Henry Ford Health System's Institutional Review Board (IRB # 00000253, Protocol 12721). Participants included 20 young, healthy adults (seven males, 13 females; age range: 22–33 years, M = 26.65, SD = 3.72). To be included in the study, all subjects underwent video head impulse testing (vHIT) to screen for normal lateral semicircular canal and superior vestibular nerve function in the 3–5 Hz frequency range. vHIT testing was completed using the GN Otometrics ICS Impulse equipment. Additionally, subjects with a history of ear surgeries or vestibular disorder(s) were excluded.

Procedure

Study participation consisted of two visits with 24 hr minimum between each, one for caloric testing and one for rotary chair testing. Each visit was 1 hr in duration. The study was conducted within the Henry Ford Hospital Vestibular Lab. The test completed at each visit (i.e., rotary chair or caloric testing) was counterbalanced across subjects. The same clinician performed the testing and tasking for all visits. Five tasking conditions were investigated for both caloric testing and rotary chair testing. These conditions included (a) spatial awareness, such as "describe your home from when you first enter your front door as you walk through"; (b) alphabet/listing, such as "tell me an animal that begins with the letter A, the letter B, etc."; (c) counting/numerical, such as "beginning at 100, count backwards by 3"; (d) tactile, where the subject was provided with three cords and was told to begin braiding the cords together at a certain time and not stop braiding until instructed to do so; and (e) no tasking. Different tasking methods within each condition were used for caloric testing and rotary chair testing to reduce any learning effect. For example, subjects were asked to list female names with a specific letter A–Z during the caloric test and asked to list male names with a specific letter A–Z during the rotary chair test. The tasking prompts for each condition were consistent across subjects; they were all given the same prompts for the caloric tasking conditions and were all given the same prompts for the rotary chair tasking conditions. Table 1 shows the tasking prompts used for each condition for caloric irrigations and rotary chair. The order of tasking condition was randomized for each subject and each test. There was no payment provided to subjects for participation.

Caloric Testing

GN Otometrics Chartr VNG goggles were comfortably placed on the subject and calibration was completed prior to air caloric irrigations. Additionally, otoscopic examination was completed to ensure no obstructing cerumen in the external ear canals prior to irrigation. The subject was placed in the standard 30° supine position and a total of five warm air caloric irrigations were performed, using a different tasking condition for each irrigation. The caloric irrigations were completed in both the right (R) and left (L) ear, and the order was randomized (for example, one subject underwent R, L, R, R, L, and another subject underwent L, L, R, R, L). The tasking condition assigned to each irrigation was additionally randomized. Randomization of ear and tasking condition ensured habituation would not impact the obtained results. The irrigation temperature was set to 50 °C and the length of each irrigation was 60 s.

All five irrigations were completed within a 1 hr session. The subject was given 4 min between each irrigation with the VNG goggles open to allow the ear to return to body temperature and to allow the caloric response to dissipate before completing the next irrigation. The subjects were instructed to inform the examiner if the caloric irrigations became uncomfortable or if they wished to stop prior to the completion of all five conditions. No subject reported discomfort and all were able to undergo all five caloric irrigations without difficulty. For each condition with tasking, the subject was engaged by the examiner immediately upon the completion of the 60-s irrigation, and the tasking was continued until after the peak SPV amplitude was observed and the response subsided. A minimum of 60 s of recording was completed after the completion of the 60-s irrigation to ensure the peak SPV was recorded. For the condition without tasking, the subject was only instructed to keep their eyes open and the response was recorded until it subsided. Reminders to keep eyes open were provided as needed for each subject. The peak SPV was calculated for each tasking method by the Otometrics VNG software and the experienced clinician reviewed, confirmed, and agreed with the calculated peak.

Rotary Chair Testing

Micromedical System 2000 Rotational Chair goggles were comfortably placed on the subject and calibration was completed prior to rotary chair testing. Rotary chair sinusoidal harmonic acceleration testing was completed 5 times at 0.08 Hz with a 2-min break with the goggles open in between each to allow the response to dissipate prior to continuing. For each condition with tasking, the subject was engaged by the examiner as soon as the chair began moving and tasking was continued the entire time the chair was moving. The condition without tasking only involved instruction and reminders to maintain eyes open throughout. Three cycles were completed for each condition (first cycle dropped automatically by software, analysis completed on second and third cycles). Peak SPV was calculated for each tasking method by the Micromedical Spectrum software and the experienced clinician reviewed, confirmed, and agreed with the calculated peak.

Data analysis

Data analysis was completed using SigmaPlot. The means and standard deviations for peak SPV response were calculated for each tasking condition for both caloric testing and rotary chair testing. Repeated-measures analyses of variance (ANOVAs) were conducted to analyze for significant difference between conditions. Additionally, the first caloric SPV response was compared to the last caloric SPV response for each subject to ensure that the first caloric irrigation did not result in an inaccurately large response due to the novel stimulus and to ensure there was no evidence of habituation to the caloric stimulus and caloric response by the fifth irrigation.

Results

Caloric data was unable to be analyzed from three subjects due to small ear canal size leading to poor irrigations ($n = 17$). Rotational chair testing was unable to be completed for one subject due to scheduling conflicts ($n = 19$).

Caloric Testing

Table 2 displays the mean, standard deviation, and range of the peak caloric SPV response for each condition

Table 1. Tasking prompts used for each condition for caloric irrigations and rotary chair.

Tasking condition	Calorics	Rotary chair
Spatial	Directions to today's appointment	Describe home, beginning at front door
Alphabet	Girls names A–Z	Boys names A–Z
Counting/numerical	Beginning at 100, count backwards by 3	Beginning at 0, count upwards by 3
Tactile	Braiding 3 cords together	Braiding 3 cords together
No tasking	N/A – reminders to keep eyes open only	N/A – reminders to keep eyes open only

Note. N/A = not applicable.

Table 2. Mean, *SD*, and range of the peak SPV response for caloric testing for each condition.

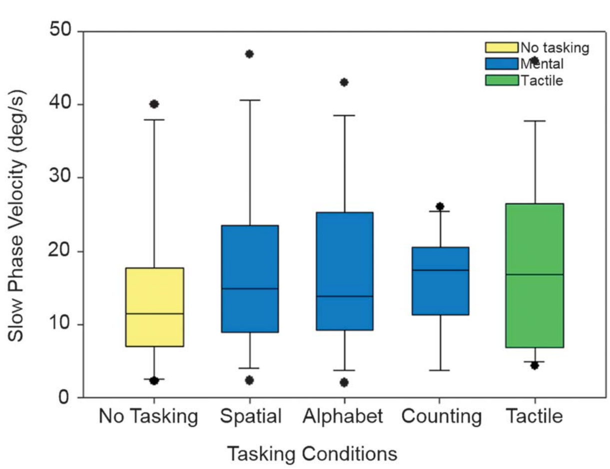
Caloric peak SPV	No tasking	Spatial	Alphabet	Counting/Numerical	Tactile
MEAN	14.47	16.94	17.82	16.47	18.53
ST DEV	10.18	10.19	11.06	9.08	11.60
Range	2–40	2–48	2–43	4–29	5–47

(no tasking, spatial, alphabetic, counting/numerical, tactile). On average, the condition without tasking produced the lowest SPV response; however, a repeated-measures ANOVA revealed no significant differences between the tasking and no tasking methods, $F(4, 64) = 0.78$, $p = .544$. Figure 1 shows the data from Table 2 in graph form; the box-and-whisker plot shows each caloric condition across the *x*-axis and the SPV in deg/s is shown on the *y*-axis. Each box indicates the first, median, and third quartiles with the whiskers showing the range from 10th to 90th percentiles. The outliers are plotted above or below the whiskers. No significant difference in SPV response was noted, $F(1,11) = 2.763$, $p = .125$, when comparing the first caloric response to the last caloric response within each subject, indicating that the data was not inaccurately influenced by which tasking condition was completed with the first irrigation and the last irrigation.

Rotary Chair Testing

Table 3 displays the mean, standard deviation, and range of the peak rotary chair SPV response for each condition (no tasking, spatial, alphabetic, counting/numerical, tactile). A repeated-measures ANOVA revealed a significant effect of tasking on rotary chair results, $F(4,12) = 11.906$, $p = < .001$. Post hoc comparisons using a Bonferroni *t* test indicated that the mean SPV for the condition without tasking was significantly lower than the remaining four tasking conditions ($p < .001$). Figure 2 shows the data from Table 3 in graph form; the box-and-whisker plot shows each rotary chair condition across the *x*-axis and the SPV in deg/s is shown on the *y*-axis. Each box indicates the first, median, and third quartiles with the whiskers showing the range from 10th to 90th percentiles. The outliers are plotted above or below whiskers. No significant difference was noted between the other four tasking conditions (spatial, alphabet, counting/numerical, tactile) when compared to each other.

Figure 1. Box plot of the peak slow phase velocity in deg/s for caloric testing for each condition. Shown are the median (black line) and the range of the 75th to 25th percentile (i.e., first and third quartiles). Outliers that fall outside the whiskers are shown as black dots.



Discussion

The purpose of this study was to assess if the type of mental tasking impacts the peak VOR measurement for caloric and rotary chair testing, if there was a significant difference between conditions with tasking and with no tasking, and if the braiding tactile tasking method utilized is an acceptable mental alerting task replacement. This study compared different forms of mental tasking to analyze if one type of tasking was notably better than the others. No significant difference was noted across the mean peak SPV measurements using the three verbal types of mental tasking (alphabet listing, spatial, and counting/numerical) for both caloric and rotary chair testing. All three of these forms of tasking resulted in robust peak SPV responses for both caloric and rotary chair tests and none were significantly better than the other. This is in disagreement with the research completed by Formby et al. and Kileny et al. Formby et al. (1992) found a significant difference in the peak SPV measurement across types of tasking, with counting/numerical tasking resulting in the lowest measured SPV responses. Kileny et al. (1980) also found a significant difference in types of mental tasking; their study showed that mathematical tasking resulted in significantly lower amplitude caloric responses than conversational based tasking. Our findings are, however, in agreement with what was found by Davis and Mann (1987), who did not note a significant difference between types of active mental alerting tasks.

When comparing the tasking and no tasking conditions within our study, there was a significant difference noted on the peak SPV response for rotary chair testing, where all of the tasking conditions resulted in significantly larger responses than the no tasking condition. This finding is contradictory to the results found by Jacobson et al. (2012), which investigated how visual and nonvisual stimuli could induce VOR suppression, causing a reduction in the responses measured. While it was not the purpose of their study, review of the data showed there was no significant difference in the measured peak response for rotary chair

Table 3. Mean, standard deviation, and range of the peak slow phase velocity (SPV) response for rotary chair testing for each condition.

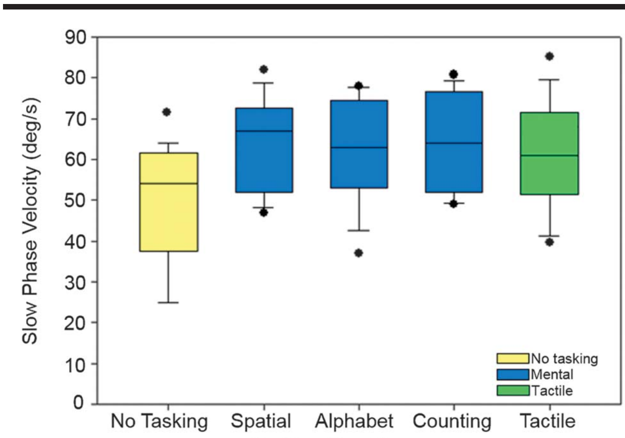
Rotary chair peak SPV	No tasking	Spatial	Alphabet	Counting/numerical	Tactile
M	49.42	62.47	60.58	60.89	62.79
SD	13.82	13.32	12.65	14.50	14.09
Range	25–72	47–84	35–78	48–80	40–88

when comparing mental tasking to no tasking conditions. For the purposes of their study, this indicated that mental tasking did not adequately suppress the VOR.

No significant difference on the measured SPV response for caloric testing was noted when comparing conditions with tasking to the no tasking condition. When looking at individual subject data across all five irrigations, the SPV response for the no tasking condition was the smallest of the responses measured across the five irrigations in seven out of 17 participants. Two of the 17 participants had their largest SPV response in the no tasking condition. The SPV response for the no tasking condition fell somewhere in the middle for the eight remaining subjects, where some mental tasking conditions resulted in a larger response than the no tasking condition and other mental tasking conditions resulted in a smaller response than the no tasking condition.

Our finding of no significant difference in the measured SPV response for caloric testing when comparing the no tasking condition to the conditions with tasking are in agreement with the findings of Easterday et al. (2016). The lack of statistical significance found between the tasking and no tasking conditions on the measured caloric response in our study may be attributed to the large variability seen on the caloric responses within individual subjects and across all subjects within each condition. This can be seen in Figure 1, with both large error bars and outliers plotted. Within individual subjects, caloric responses ranged widely, for example, from 17 deg/s for the smallest response to 47 deg/s for the largest response for one individual, whereas a few subjects had much tighter response ranges, for example from 5 deg/s for the smallest response to 10 deg/s for the largest response.

Figure 2. Box plot of the peak slow phase velocity in deg/s for rotational chair testing for each condition. Shown are the median (black line) and the range of the 75th to 25th percentile (i.e., first and third quartiles). Outliers that fall outside the whiskers are shown as black dots.



The outliers for each condition were further investigated to see if there was an impact of gender or age. The age range for the subjects who represented outliers in any condition was 22–33 years and the mean was 25.86 years. The age range for the study group as a whole was the same (22–33 years) and the mean across all subjects was 26.65 years, so age was not found to be an indicator of why an outlier was an outlier. Of the outliers across conditions, the male to female ratio was 2:5. When looking at all participants, the male to female ratio was 6:11, so gender did not appear to have an impact as to why an outlier was an outlier either. Additionally no one subject was found to be a source of outlier data points across all conditions.

To ensure that the first caloric did not result in an inaccurately large response, as is often noted in clinical settings due to the novel nature of the stimulus/task, and to ensure there was no habituation by the last caloric irrigation, we compared the peak SPV measured for the first irrigation to the peak SPV measured for the last irrigation for each subject. No significant change was noted when comparing the first to the last irrigations across subjects. This allowed us to be confident that the wide range of caloric responses seen within many of our subjects was not due to the first irrigation resulting in a significantly larger response and was not due to habituation to the caloric stimulus and response by the last irrigation.

Within each condition, the caloric responses could also widely range, for example within the alphabet tasking condition, the caloric response ranged from 2 deg/s for one participant to 43 deg/s for another participant. This information is shown in Table 2; all of the conditions, no tasking included, had wide ranges of responses. The counting/numerical task had the smallest range when comparing the smallest to the largest response; 4 deg/s for the smallest response to 29 deg/s for the largest response, which is still a large range across subjects for the same condition. Due to the large variability on the measured caloric responses within this data set, it is difficult to draw conclusions whether tasking had a significant impact on the caloric response.

Our study found no significant difference between the verbal mental tasking exercises (alphabet listing, spatial, and counting/numerical) and tactile tasking within both the caloric and the rotary chair data sets. This is in agreement with King et al. (2006) who reported no significant difference in the peak SPV of the VOR between verbal and vibrotactile tasking methods. This indicates that the braiding tactile task utilized in this study is an appropriate replacement if verbal mental tasking cannot be utilized. Our data on rotary chair additionally agrees with what was found by King et al., who noted that both verbal and vibrotactile tasking resulted in significantly larger measured responses than the no tasking condition.

Based on the results of our study, we recommend that, in a clinical setting, either mental tasking or tactile tasking be utilized minimally when completing rotary chair testing to reduce suppression and allow for accurate and robust SPV measurements. Given the inconsistencies in the literature regarding whether to task, with some studies showing that tasking results in larger responses and others showing tasking is equivalent to no tasking, and as only two of the subjects had the largest response for calorics in the no tasking condition, we additionally recommend that some method of tasking is utilized during caloric testing, despite the data not reaching statistical significance. This recommendation differs from the recommendation made by Easterday et al. Like us, they found tasking did result in larger amplitude responses on calorics when looking at some individual data, but they recommended that tasking did not need to be used based on the group mean results and due to the increase in eye blink artifact noted when tasking.

As no difference was found when comparing the different verbal tasks to each other, the tasking type can be catered to the patient. Additionally, if verbal tasking is unable to be completed, for example if the patient has significant hearing loss or does not speak English, the braiding task described above can be used as a valid substitution for a verbal task.

It should be taken into consideration that this study and other studies examining the same topic are typically completed on young, normal subjects rather than the average clinical population seen within a vestibular clinic setting. Future research is needed to examine if there is any interaction of age, socioeconomic status, educational level, and underlying vestibular dysfunction on the best tasking method and whether or not tasking changes the peak SPV response that is able to be measured.

References

Baloh, R. W., Solingen, L., Sills, A. W., & Honrubia, V. (1977) Caloric testing. 1. Effect of different conditions on ocular fixation. *Annals of Otology, Rhinology, and Laryngology, 86*(5, Suppl. 3), 1–6. https://doi.org/10.1177/00034894770865s301

Barin, K. (2009). Clinical neurophysiology of the vestibular system. In J. Katz, L. Medwetsky, R. Burkhart, & L. Hood (Eds.), *Handbook of clinical audiology* (pp. 431–466). Lippincott, Williams & Wilkins.

Collins, W. E. (1962). Effects of mental set upon vestibular nystagmus. *Journal of Experimental Psychology, 63,* 191–197. https://doi.org/10.1037/h0039941

Collins, W. E., Crampton, G. H., Posner, J. B., & Warburton, S., III. (1960). The effect of mental set upon vestibular nystagmus and the electroencephalogram. *US Army Medical Research Laboratory, 12,* 1–15.

Davis, R., & Mann, R. (1987). The effects of alerting tasks on caloric induced vestibular nystagmus. *Ear and Hearing, 8*(1), 58–60. https://doi.org/10.1097/00003446-198702000-00011

Easterday, M. K., Plyler, P. N., & Doettl, S. M. (2016). Mental tasking and caloric-induced vestibular nystagmus utilizing Videonystagmography. *American Journal of Audiology, 25*(3), 177–183. https://doi.org/10.1044/2016_AJA-15-0070

Formby, C., Kuntz, L. A., Rivera-Taylor, I. M., Rivera-Mraz, N., Weesner, D. R., Butler-Young, N. E., & Ahlers, A. E. (1992). Measurement, analysis, and modelling of the caloric response. 2. Evaluation of mental alerting tasks for measurement of caloric-induced nystagmus. *Acta Oto-Laryngologica, 498,* 19–29. https://doi.org/10.3109/00016489209136855

Jacobson, G. P., & Newman, C. W. (1993). Background and technique of caloric testing. In G. P. Jacobson, C. W. Newman, & J. M. Kartush (Eds.), *Handbook of balance function testing* (pp. 156–192). Mosby.

Jacobson, G. P., Piker, E. G., Do, C., McCaslin, D. L., & Hood, L. (2012). Suppression of the vestibulo-ocular reflex using visual and nonvisual stimuli. *American Journal of Audiology, 21*(2), 226–231. https://doi.org/10.1044/1059-0889(2012/12-0021)

Karlsen, E. A., Goetzinger, C. P., & Hassanein, R. (1980). Effects of six conditions of ocular fixation on caloric nystagmus. *Archives of Otolaryngology—Head & Neck Surgery, 106*(8), 474–476. https://doi.org/10.1001/archotol.1980.00790320026007

Kileny, P., McCabe, B., & Ryu, J. (1980). Effects of attention requiring tasks on vestibular nystagmus. *Annals of Otology, Rhinology & Laryngology, 89,* 9–12. https://doi.org/10.1177/000348948008900104

King, J. E., Gonzalez, J. E., & Fuller, M. I. (2006). Development of a vibrotactile tasking device for use in vestibular assessment. *Journal of Vestibular Research, 16*(1–2), 57–67.

McGovern, T. N., & Fitzgerald, J. E. (2008). The effect of mental alerting on peripheral vestibular nystagmus during spontaneous, gaze (30 left, 30 right), and body positional (left & right lateral lying) testing using electronystagmography (ENG). *International Journal of Audiology, 47*(10), 601–606. https://doi.org/10.1080/14992020802123579