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Effects of instructions on optokinetic nystagmus (OKN)

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EFFECTS OF INSTRUCTIONS ON OPTOKINETIC NYSTAGMUS (OKN)

by

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Abstract: The primary objective of this research study is to determine the effects of instructions on optokinetic nystagmus (OKN).

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

ABBREVIATIONS

OKN	Optokinetic Nystagmus
VOR	Vestibulo-ocular reflex
OKAN	Optokinetic After-Nystagmus
ANOVA	Analysis of Variance

INTRODUCTION

Optokinetic Nystagmus (OKN) is an involuntary reflexive eye movement that occurs in response to visual field movement. The normal OKN response involves a slow phase, which moves in the direction toward the stimulus, followed by a quick recovery fast phase in the opposite direction, also known as a saccade (Ter Braak, 1936). OKN is closely related to smooth pursuit. It is distinguished from smooth pursuit in that the movement of the eye is elicited by tracking a field instead of a distinct target (Jacobson & Shephard, 2008). In addition, the optokinetic system and smooth pursuit system differ in the type of retinal detection. The smooth pursuit system is induced by foveal stimulation, while the optokinetic system is induced by full-field peripheral stimulation of the retina. This makes the OKN a more reflexive eye movement (Goebel, 2008). The goal of OKN is to stabilize the whole visual field while the head is in motion (Cyr & Harker, 1993). In contrast, the purpose of smooth pursuit is to preserve the location of a single target on the fovea (Jacobson & Shephard, 2008). The optokinetic system contributes when the vestibular system is unable to "keep up" throughout continuous rotation of the head. The fluid movement of the vestibular system is unable to maintain cupula stimulation throughout continuous rotation of more than 10 to 15 seconds (Leigh & Zee, 2006).

OKN and smooth pursuit are often opposed when elicited in isolation. For example, OKN elicited by a moving visual field is often opposed when a patient tries to fixate. However, with normal movement of the head, smooth pursuit and OKN usually have synergistic effects (Jacobson & Shephard, 2008). The OKN response and smooth pursuit are produced by similar brainstem and cortical anatomical structures; however, good vision is not a necessity for OKN, resulting in a more robust response when compared to smooth pursuit (Jacobson & Shephard, 2008). Like the vestibulo-ocular reflex (VOR) and saccades, OKN is present at birth (Gorman, Cogan, & Gellis, 1957). In contrast, smooth pursuit develops post-natally (Aslin, 1981).

OKN occurs throughout continuous self-rotation in the light. In a clinic setting, OKN is typically elicited by a patterned drum that rotates around the patient, while the patient remains stationary (Leigh & Zee, 2006). Although there is no vestibular stimulation peripherally, the patient perceives a sensation that they are rotating, which is known as circularvection. In order to stimulate the OKN reflex in humans, the drum rotates at 60 degrees per second for 60 seconds (Leigh & Zee, 2006). The OKN test is completed by the individual visually fixating on a moving stimulus. This stimulus usually consists of moving stripes or objects (Cyr & Harker, 1993).

Throughout OKN stimulation in humans, the smooth pursuit and optokinetic systems are instrumental in the resulting response (Leigh & Zee, 2006). Full-field visual stimuli are defined as covering 90% or more of the visual field. During sustained rotation of full-field visual stimuli, the induction of nystagmus is primarily a result of smooth pursuit tracking, with the addition of the OKN element. The response requires seconds of continuous rotation to completely develop and then continues as a mixture of both optokinetics and smooth pursuit tracking (Jacobson & Shephard, 2008).

A characteristic of the optokinetic system is that the response lingers after the stimulus has extinguished (Leigh & Zee, 2006). Throughout the period of stimulation, the optokinetic system effectively acts through an area in the brainstem known as the velocity storage system (Tijssen, Straathof, Hain, & Zee, 1989). After turning the lights off, the nystagmus persists in the same direction for some seconds, with a decreasing slow-phase velocity. This phenomenon is known as optokinetic after-nystagmus (OKAN) (Leigh & Zee, 2006). In order to assess the function of OKN in isolation from smooth pursuit, it is useful to look at OKAN (Jacobson & Shephard, 2008). Immediately after the stimulus has been removed for 1 second, the smooth pursuit system no longer has an impact and the OKAN is a direct result of the optokinetic system's activity revealed through the velocity storage system (Tijessen, Straathof, Hain, & Zee, 1989).

OKN is a cortical response in humans. In many animals, there is a direct OKN pathway from the retina to the nucleus of the optic tract; however, in humans this pathway does not exist or is weak (Buttner & Buttner- Ennever, 2006). The OKN pathway in humans is similar to the smooth pursuit pathway. It includes the primary visual cortex and extrastriate visual cortex located in the occipital lobe, with descending connections through the internal capsule to the brainstem pontine nuclei, flocculus of the cerebellum, vestibular nuclei, and the oculomotor nuclei (Buttner & Buttner-Ennever, 2006). OKN pathways utilize VOR pathways to access the oculomotor nuclei (Goldberg, Wilson, & Cullen, 2012). Information about visual motion arrives at the oculomotor neurons through 2 pathways. These pathways include a direct pathway with fast dynamics and an indirect pathway with slower dynamics. A crucial characteristic of the indirect pathway is the velocity storage component shared with the VOR. OKN stimulates both the direct and indirect pathways, while smooth pursuit activates only the direct pathway (Robinson, 1981). The velocity storage component explains the slow buildup in OKN and OKAN. The instant rise initially in OKN and the instant drop off after turning the lights off is accounted for by the direct pathway (Baloh & Honrubia, 2001). The direct (pursuit) pathway is congruent with the cortical pathway, while the indirect (velocity storage) pathway is congruent with the subcortical pathway (Robinson, 1981).

In order to create the OKN response through retinal stimulation and signals transmitted by the accessory optic track, it is necessary for the stimulus to cover at least 90% of the visual field and be able to create a circularvection effect (Leigh & Zee, 2006). Light bars do not activate the optokinetic system because the size of the stimulus does not fill the visual field with its movements. Light bars create a nystagmus that appears to be OKN; however, it is produced mainly by the smooth pursuit system. In addition, the stimuli produced from light bars do not create OKAN, which would be evidence of stimulation of the optokinetic system and the manner by which it can be assessed directly. The most effective way to supply stimulation of the optokinetic system is to have the patient seated in a full-field stimulus configuration. Two examples of this configuration include a rotary chair environment, with a projection light system in the ceiling or a patterned cloth enclosure that surrounds the patient and is set into motion (Jacobson & Shephard, 2008).

The instructions provided to the patient are crucial when testing for OKN as the response of the nystagmus can be variable. There are two main types of nystagmus elicited from different instructions. These are known as "look" and "stare" nystagmus (Jacobson & Shephard, 2008). "Look" nystagmus, also known as pursuit OKN, is described as a smooth pursuit task attending to a small visual target. If the patient follows a single target out of the optokinetic visual presentation or actively tracks the moving stimulus, "look" nystagmus will be elicited (Lott & Post, 1993). "Look" nystagmus is composed of a large excursion for the slow component, which gives a coarse appearance to the jerk nystagmus. "Look" nystagmus accentuates the smooth pursuit element (Jacobson & Shephard, 2008).

"Stare" nystagmus is similar to attending to a region at a fixed distance from the patient (Newsome, Wurtz, & Komatsu, 1988). If the patient is instructed to stare or gaze in the middle of the arrangement, a "stare" nystagmus is produced (Jacobson & Shephard, 2008). Additionally, "stare" nystagmus is a reflex and occurs when individuals do not actively follow the moving stimulus (Lott & Post, 1993). "Stare" nystagmus is composed of nystagmus with a low-amplitude slow component. "Stare" nystagmus intensifies the optokinetic element with full field stimuli (Jacobson & Shephard, 2008).

Instructions vary from clinician to clinician and institution to institution. A common instruction across testing facilities during OKN testing is to "count the stripes like train cars going by." At other times, the individual is instructed to "watch the stripes go by." By giving pointed directions such as in the first example related to how to track the stripes, it is hypothesized that the task results in a smooth pursuit and refixation saccade test as opposed to a true OKN reflex. The goal of this study was to determine the effects of instructions on optokinetic nystagmus. The specific research question is stated as follows: What are the effects of two different types of patient instructions upon parameters measured in that patient's OKN response?

METHODS

Participants

Twenty-two healthy subjects participated in the study ranging in age from 22 to 66 years (16 females and 6 males; mean age= 34.95 years, SD=15.49). This study was approved by the Institutional Review Board at Washington University School of Medicine in St. Louis, Missouri. Each subject was given a written explanation of the study and signed a consent form before participating in the study. All participants were screened and determined to have no history of a balance disorder, surgery involving the eye muscles, or blindness.

Experimental Procedure

Participants visited the Dizziness and Balance Center located at the Center for Advanced Medicine in St. Louis, MO on one occasion for approximately 30 minutes. Micromedical ™ Technologies System 2000 Rotational Vestibular Chair equipment was utilized. Figure 1 illustrates the rotational chair equipment utilized in this study. The participants were asked to sit in a rotational chair enclosure and a headband with infrared cameras was placed on the participant. Next, to ensure appropriate tracking of the patient's eye movements, calibration of the cameras was performed by asking the participant to follow a light with their eyes. Spontaneous nystagmus was evaluated prior to testing with and without fixation.

Testing involved administering three subtests, which included smooth pursuit, saccades, and optokinetic nystagmus. All three of these subtests were randomized. During the smooth pursuit subtest, participants were asked to follow a dot as it floats back and forth horizontally across the enclosure wall. The saccades subtest required the participant to follow the dot with their eyes as it jumped back and forth horizontally across the enclosure wall. During the optokinetic nystagmus subtest stripes were projected on the wall inside the rotational enclosure. The optokinetic nystagmus subtest was administered 8 times. Each of 2 sets of instructions ("watch the stripes go by" and "count the stripes like train cars") were tested in both the clockwise and counterclockwise directions. Each combination was randomized and administered twice to ensure repeatability.

Data Analysis

This study is a repeated measures design with two data collection time points (one for each time the test is completed with one of two different sets of instructions). The order of condition and the order of testing was not included in the statistical model. For continuous variables, paired t-tests were used to determine whether the difference between the two conditions is significantly different from zero. McNemar's test was used to compare dichotomous variables between the two conditions. For all analyses, careful attention was given to whether the data satisfy the distributional and model-specific assumptions of the procedures used. Appropriate data transformations or non-parametric methods were used as appropriate.

Since estimates of variability are not available, statistical power is expressed in terms of an effect size (i.e., the ratio of the standard deviation to the mean difference). Effect sizes are unitless and can be interpreted using Cohen's conventions for effect sizes where 0.2 is a small, 0.5 is a medium, and 0.8 is a large effect (Cohen, 1988). A sample size of 33 participants will have 80% power to detect a medium effect size of at least 0.5 at alpha=0.05 with a two-tailed paired t-test. In order to have adequate statistical power to detect a smaller effect, a sample size of 51 is needed to detect an effect size of 0.4 at 80% power at alpha=0.05 with a two-tailed paired t-test.

RESULTS

Of the 22 participants tested, 21 participants were included in the data analysis. Participant number 19 was excluded from the data analysis due to experimenter error. Participant demographic information is summarized in Table 1. Statistical analyses of all data was completed using a repeated measures ANOVA.

Smooth Pursuit Conditions

Statistical analyses were completed to determine the differences among the 3 different smooth pursuit frequencies. Table 2 summarizes the means and standard deviations of the gain of the response for the 3 smooth pursuit conditions. These 3 smooth pursuit conditions revealed all participants had normal smooth pursuit function.

Saccade Conditions

Statistical analyses were completed to determine if the 2 saccade conditions, to the left and the right, were different from each other. Table 3 summarizes the means and standard deviations of the 2 saccade conditions. The results from the saccade conditions indicate all participants had normal saccade function. In addition, there was no difference found between the left and the right direction of the saccade.

OKN Conditions

Statistical analyses were completed to determine the significance of 3 possible effects. These effects included a verbal subject instructions main effect, a direction main effect, and an instructions and direction interaction, which tests whether the magnitude of the verbal subject instruction effect depends on the direction the stimulus moves. The only significant effect found was the instructions main effect. The lack of a significant interaction reveals the instructions effect is the same for both clockwise and counterclockwise directions. Table 4 summarizes the means and standard deviations of the 4 OKN conditions.

DISCUSSION

In the current study, it was hypothesized that different verbal instructions, "count the stripes like train cars" and "watch the stripes go by" would result in varied OKN responses. Furthermore, it was hypothesized that the "count the stripes like train cars" task would result in a smooth pursuit and refixation saccade test as opposed to a true OKN reflex. Results from the current study revealed that verbal subject instruction for OKN resulted in varied responses. More specifically, we found that the OKN gain was larger for the verbal instructions "count the stripes like train cars," when compared to "watch the stripes go by." These results indicate the importance of reliable and uniform verbal subject instruction across different institutions. These differences were observed in both the individual and group levels.

There are a number of possible explanations for the larger OKN gain with the verbal subject instructions "count the stripes like train cars". One explanation could be that the smooth pursuit system was engaged during the OKN stimulation. Another explanation could be the participants had to actively pursue the stripes in order to count them. In addition, many participants reported the verbal instructions "watch the stripes go by" allowed suppression to occur more easily. This phenomenon could explain why the gain of the nystagmus was larger for the verbal instructions "count the stripes like train cars" because it was more difficult to suppress.

Previous research has described two different types of OKN response, referred to as "look" and "stare" nystagmus (Ter Brak, 1936) & (Lotts & Post, 1993). This study revealed the verbal instructions "count the stripes like train cars" produced an OKN response similar to "look" nystagmus, while the verbal instructions "watch the stripes go by" produced an OKN response similar to "stare" nystagmus. Figure 3 illustrates the two types of OKN responses found in this study. The large amplitude nystagmus tracing reveals how the individual follows one stripe all the way across and then picks up another stripe to follow. This task is similar to the verbal instructions "count the stripes like train cars" and represents a similar tracing. In contrast, the small amplitude nystagmus shown in Figure 3 represents a tracing similar to the OKN response produced from the verbal instructions "watch the stripes go by."

A limitation of this study was the small number of participants. A larger number of participants would be necessary to obtain a large effect size. Additionally, the participants consisted of a majority number of females. In the future, research in this area should contain a larger number of participants that are equally distributed between males and females.

A true OKN response is a reflex and test administration should not include a task requiring the individual to count or track the stripes. However, many of the participants reported the task "watch the stripes go by" was easier to suppress. Due to suppression of the OKN response, a direction for future research should involve tasking individuals. Tasking may decrease suppression and still allow a true reflexive OKN response.

CONCLUSION

The current study revealed statistically significant differences between the OKN response based on verbal subject instructions, which consisted of either "count the stripes like train cars" or "watch the stripes go by." Results demonstrated a larger gain of nystagmus for the verbal subject instructions of "count the stripes like train cars," when compared to the verbal subject instructions of "watch the stripes go by." Further research is needed with a larger number of participants. Additionally, future research is necessary to determine the effects of tasking on suppression of the OKN response.

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Table 1: Individual demographic information of each participant is summarized below.

Participant ID	Sex	Age
1	Male	24
2	Male	66
3	Female	63
4	Female	24
5	Female	22
6	Female	24
7	Female	25
8	Female	22
9	Female	55
10	Female	62
11	Female	42
12	Female	56
13	Male	29
14	Male	26
15	Male	25
16	Male	38
17	Female	24
18	Female	27
20	Female	24
21	Female	26
22	Female	30

Table 2: Mean and standard deviation differences among the smooth pursuit conditions at each tested frequency are summarized in the following table.

Smooth Pursuit Frequency	Mean	Standard Deviation
.1 Hz	1.11	.11
.2 Hz	1.02	.11
.4 Hz	1.01	.06

Table 3: Mean and standard deviation differences between the saccade conditions are summarized in the following table.

Saccade Direction	Mean	Standard Deviation
Left	154.15	51.92
Right	154.21	47.88

Table 4: Mean and standard deviation differences among the OKN conditions are summarized in the following table.

OKN Condition	Mean	Standard Deviation
Clockwise: Watch the Stripes go by	.72	.19
Counterclockwise: Watch the Stripes go by	.66	.19
Clockwise: Count the Stripes Like Train Cars	.81	.16
Counterclockwise: Count the Stripes Like Train Cars	.76	.15

Figure 1: Displays the Micromedical ™ Technologies System 2000 Rotational Vestibular chair equipment utilized for this study. The participant's eye movements were monitored on a computer screen as shown below. Used with permission from Belinda Sinks, Au.D. from Washington University School of Medicine in St. Louis, 2014.

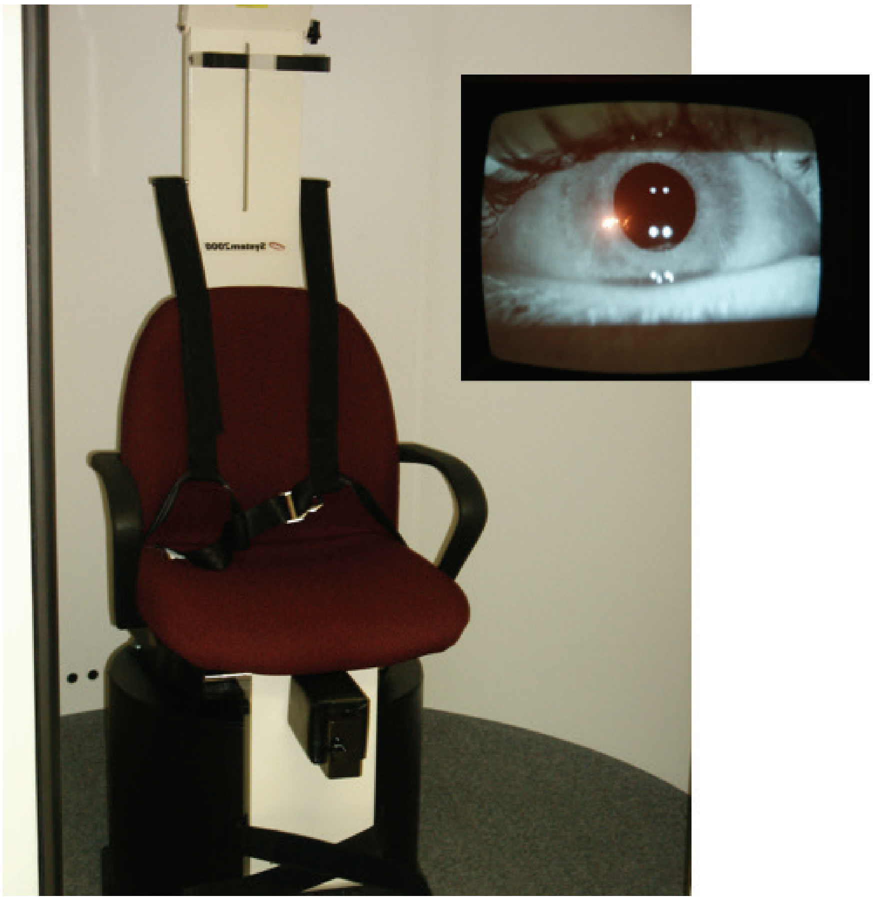


Figure 2: The relevant means of the two OKN verbal subject instructions "Watch the stripes go by" and "Count the stripes like train cars." Error bars represent the lower and upper bound of the 95% confidence interval.

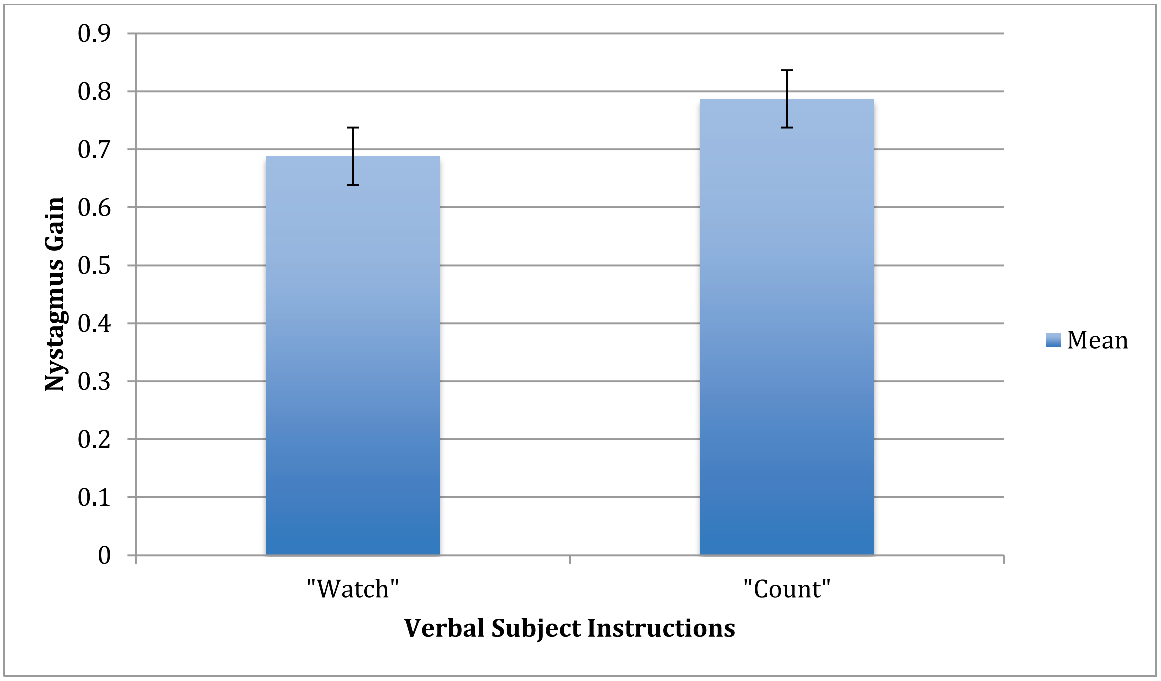
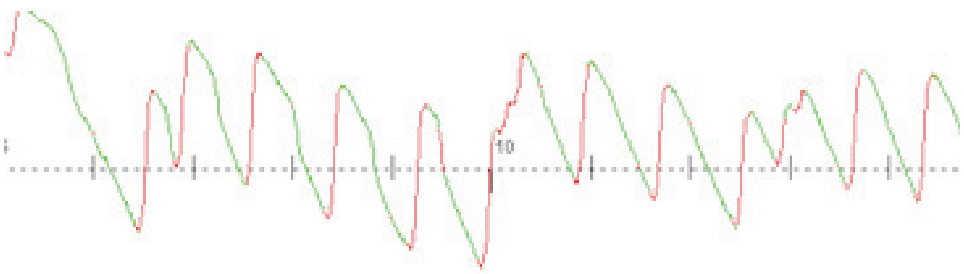


Figure 3: Displays tracings that represent the OKN differences between the verbal instructions "count the stripes like train cars" (part A) and "watch the stripes go by" (part B). The following tracings were provided by Micromedical ™ Technologies.

A.



B.