King-Devick Test for Neurological Function

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Residency Training: The King-Devick test and sleep deprivation: Study in pre- and post-call neurology residents

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OBJECTIVE: The current study investigates the effect of sleep deprivation on the speed and accuracy of eye movements as measured by the King-Devick (K-D) test, a 1-minute test that involves rapid number naming.
METHODS: In this cohort study, neurology residents and staff from the University of Pennsylvania Health System underwent baseline followed by postcall K-D testing (n = 25); those not taking call (n = 10) also completed baseline and follow-up K-D testing. Differences in the times and errors between baseline and follow-up K-D scores were compared between the 2 groups.
RESULTS: Residents taking call had less improvement from baseline K-D times when compared to participants not taking call ($p < 0.0001$, Wilcoxon rank sum test). For both groups, the change in K-D time from baseline was correlated to amount of sleep obtained ($r_s = -0.50$, $p = 0.002$) and subjective evaluation of level of alertness ($r_s = 0.33$, $p = 0.05$) but had no correlation to time since last caffeine consumption ($r_s = -0.13$, $p = 0.52$). For those residents on their actual call night, the duration of sleep obtained did not correlate with change in K-D scores from baseline ($r_s = 0.13$, $p = 0.54$).
CONCLUSIONS: The K-D test is sensitive to the effects of sleep deprivation on cognitive functioning, including rapid eye movements, concentration, and language function. As with other measures of sleep deprivation, K-D performance demonstrated significant interindividual variability in vulnerability to sleep deprivation. Severe fatigue appears to reduce the degree of improvement typically observed in K-D testing.

AEROSPACE MEDICAL ASSOCIATION

Panel Presentation at the 84th Annual Meeting of the Aerospace Medical Association

Hypoxia, Cognition, Capnic State and TUC (Time of Useful Consciousness): Early Detection of Hypoxic Cognitive Impairment Using the King-Devick Test

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Introduction: Training in a hypobaric chamber or a normobaric hypoxic gas exposure are common methods for aviators to experience signs and symptoms of hypoxia. The presence of significant signs and symptoms represents an advanced stage of hypoxic incapacitation. The purpose of this study was to evaluate the potential role of a standardized cognitive test, "The King-Devick (K-D)", as an early detector of cognitive impairment in a pre-symptomatic phase of experimental hypoxia. The K-D test is in clinical use for the recognition of cognitive changes associated with concussive events in team sports.
Methods: Twenty-five subjects (mean age 32.4 ± 9.8 years) performed the K-D test at baseline normoxic, hypoxic and post-baseline normoxic conditions. Normoxia was induced by breathing room air. The hypoxic condition was induced by breathing a gas mixture of 8% O2 + balance N2 for 3 minutes. Subjects were asked to quickly read a sequence of numbers on three K-D test cards. K-D completion time and numbers of errors made were analyzed and compared by using one-way ANOVA. Any signs and symptoms of hypoxia were collected by taking a history of the subjects.
Results: K-D completion time in hypoxia (54.5 ± 12.4s) was significantly higher (worse) than baseline (46.3 ± 10.4s) (p=0.016). Completion time in post-baseline (47.6 ± 10.4s) testing was significantly improved (lower) compared to hypoxia (54.5 ± 12.4s) (p=0.04). The total number of errors was significantly higher in hypoxia (40 errors [1.6±1.5 errors per subject (eps)]) than at baseline (10 errors [0.4±0.8eps]) (p=0.015). No major signs or symptoms of hypoxia were reported by the subjects.
Discussion: Hypoxia induced a clinically and statistically significant change on K-D test performance that represents an early phase preceding hypoxic incapacitation. We propose further study of the K-D test as a standardized, portable, easily administered and rapid testing tool to detect early cognitive impairment due to hypoxia.

Panel Presentation at the 84th Annual Meeting of the Aerospace Medical Association

Hypoxia, Cognition, Capnic State and TUC (Time of Useful Consciousness): Assessing Eye Tracking Features in Hypoxic and Isocapnic Hypoxia

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Introduction: Military aircrew and pilots have reported visual performance impairment due to hypoxia. The aims of this study were: 1) assess the role of eye-tracking features related to blink metrics, pupillary dynamics, fixations and saccades as cognitive biomarkers to detect early signs of hypoxia; 2) analyze the impact of different conditions of hypoxia ("Hypoxic hypoxia (HH)" and "Isocapnic Hypoxia (IH)") on these oculometrics during mental workloads.

Methods: The eye-tracking data was collected on twenty-five subjects (mean age 32.4 ± 9.8 years) in three different conditions (subjects and operators were blinded to gas mixtures): Normoxia, HH(8% O2 +balance N2) and IH (7% O2 + 5% CO2 + balance N2). The mental workload in each condition consisted of reading the numbers on an eye-tracking screen for one minute after three minutes of breathing the respective gases. The oxygen saturation level (SpO2) and end tidal CO2 were also measured.

Results: The blink rate was significantly increased in both hypoxia conditions (100.7%) in HH and 92.8% in IH compared to Normoxia). However, a faster recovery of the blink rate was observed in transitioning from IH (23.6% vs. 76.3% after 3 minutes, $p<0.05$) to transitioning from IH (23.6% vs. 76.3% after 3 minutes, $p<0.05$) to normoxia. The percentage change in the fluctuation in pupil diameter compared to Normoxia was increased in HH more so than IH (29% vs. 4.4%, $p<0.05$). The average fixation time and size in HH was significantly higher than in IH ($p=0.03$ and $p=0.04$). The total saccadic times in both hypoxic conditions were significantly increased from normoxia ($p<0.05$). The SpO2 decreased from 98±0.9% to 75.8±8.3% in HH and 81.1±5.5% in IH.

Discussion: These results show that eye-tracking features are biomarkers, which can be monitored through portable, non-invasive eye-tracking devices in a cockpit analogous environment to detect hypoxic changes in aircrew. Comparative results between hypoxic and isocapnic hypoxia might suggest the potential role of CO2 in modulating the response during hypoxia by altered cerebral perfusion.

Panel Presentation at the 84th Annual Meeting of the Aerospace Medical Association

Hypoxia, Cognition, Capnic State and TUC (Time of Useful Consciousness): Influence of Adding 5% CO2 to Inhaled Air on Time of Useful Consciousness, Motor Coordination and Cognitive Function during Hypobaric Hypoxia

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Introduction: The blinded study was designed to show the progression and effect of hypobaric hypoxia (HH) during TUC (time of useful consciousness) on motor coordination and vigilance. We also examined the effect of adding 5% CO2 (carbon dioxide) to the breathing gas.

Methods: 11 healthy male Swiss Air Force pilots were exposed in a hypobaric chamber to 24,600 ft (7,500m). They first carried out a psychomotor multiple task test (PMA). PMA entails a motor tracking task combined with a test of attention. The subjects also performed the King-Devick test for an assessment of their neurocognitive function. A GCS (Glasgow Coma Scale) value of <15 was the abort criteria. Each subject carried out these tests twice, once with gas A (21% O2, 79% N2) and once with the gas B (21% O2, 5% CO2, 74% N2), the subjects were blinded to what gas mixture was used.

Results: Joystick task performance with gas A deteriorated significantly from the second to the third minute and become significantly worse in the fourth minute compared to gas B ($p = 0.005$). Petal task performance deteriorated in both gas mixtures and became significantly worse in the fourth minute compared to gas B ($p<0.05$). With gas mixture A the GCS values fell below 15 prior to completing the King-Devick test in all 11 cases and the experiment was aborted. With gas B the test could be completed in 9 of 11 cases.

Discussion: This study presents the effects of hypobaric hypoxia in empirical tests over the entire TUC at 24,600 ft (7,500m). The addition of 5% CO2 has a positive influence on vigilance and parts of motor coordination during the first four minutes and extends the TUC. This is of potential interest to terrestrial and aerospace altitude operations.

Panel Presentation at the 84th Annual Meeting of the Aerospace Medical Association

Hypoxia, Cognition, Capnic State and TUC (Time of Useful Consciousness): Blink Rate and Pupil Size Changes as Biomarkers for Hypoxic Incapacitation

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Introduction: Hypoxia at altitude is well known to cause visual performance alterations. The aim of this study was to evaluate the effect of hypoxia on blink rate and pupil size while performing combined cognitive and scanning tasks during an acute hypoxic exposure to a simulated altitude of 22000 ft (6705m).
Methods: The data was collected on twenty-five subjects (mean age 32.4±9.8 years) in two different sessions: 1) breathing room air; and 2) breathing a gas mixture with 8% O2 with balance N2 provided through an aviator mask. In each session, the subject was seated in front of the eye-tracking computer screen that recorded blinking and pupil size as they read multiple sequences of numbers (cognitive task) displayed on the screen from left to right and top to bottom (scanning task). The duration of each session was 2 minutes with 120 numbers spatially arranged in increased levels of difficultly. The oxygen saturation level (SpO2) was measured using pulse oximetry at the finger.
Results: In normoxia, the blink rate (mean ± SD) was 11.9 ± 11.1 blinks per minute. During hypoxia, the blink rate increased to 22.5 ± 28.2 blinks per minute (p=0.04, repeated measures ANOVA). Hypoxia during cognitive and scanning tasks significantly increased the blink rate by 100.7% in comparison to normoxia. The fluctuation of the size of the pupil was significantly greater (0.15 ± 0.05 mm) in hypoxia than decreased to 75.8± 8.3% during hypoxia.
Discussion: The significant increase in blink rate and fluctuation of the pupil size while performing cognitive and scanning tasks are associated with hypoxia. The detection of these changes in safety critical operators (pilots, mountaineers, etc.) could be useful as an early sign of impending hypoxia incapacitation.

Poster Presentation at the American Academy of Neurology 2013 Annual Meeting

Slowing of King-Devick Test Rapid Number Naming in Parkinson's Disease

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OBJECTIVE: To establish the utility of the King-Devick test in Parkinson's disease (PD).
BACKGROUND: The King-Devick (K-D) test measures the speed of rapid number naming, and is postulated to be sensitive in capturing impairment of eye movements, attention, language, and possibly other aspects of cognitive function. While used in multiple sports concussion studies, it has not been applied to the field of movement disorders.
DESIGN/METHODS: A total of 25 PD and 71 controls were enrolled in the study. All were participants in the Arizona PD Consortium/Banner Sun Health Research Institute Brain and Body Donation Program. Participants read aloud a series of single-digit numbers from left to right on 3 different test cards with the sum time from all 3 cards being the test score. Two trials were performed and the total faster score was recorded. The mean K-D score for the PD group was compared to the Control group by using the two-sample t test. Adjusted means were compared by using a general linear model with terms for PD, age, and sex.
RESULTS: The mean age was younger in PD (73.8 ± 7.4 years) vs. Control (80.9 ± 6.2 years) and there were more males in the PD group (68% PD; 34% Control). The mean K-D score for the PD group (61 ± 20 seconds) was statistically higher compared to the control group (50 ± 10 seconds) with p = 0.001. After adjusting for age and sex, the mean K-D scores for the two groups remained higher in the PD group (n=64) compared to controls (n=49), p < 0.001.
CONCLUSIONS: This is the first study of the King-Devick test in patients with PD. PD patients were found to have a slower speed in rapid number naming compared to controls. Therefore, the King-Devick test may be a rapid tool for quantifying visual and cognitive function in Parkinson's disease.

Poster Presentation at the American Academy of Neurology 2013 Annual Meeting

Abnormal High and Low Visual Contrast Sensitivity in Parkinson's Disease

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OBJECTIVE: To establish the utility of the Sloan contrast sensitivity test in Parkinson's disease (PD) using the iPad.
BACKGROUND: Previous studies showed that visual contrast sensitivity is reduced in PD due to loss of dopamine in amacrine-containing retina cells. An iPad version of Sloan contrast sensitivity test recently became available and is easy to use. It has not been tested in PD patients.
DESIGN/METHODS: Twelve PD and 46 controls were enrolled in the study. All were participants in the Arizona PD Consortium/Banner Sun Health Research Institute Brain and Body Donation Program. Participants viewed the Sloan eye chart on an iPad at distances of 40cm and 2m under 100% and 2.5% contrast. Visual acuity at each condition was converted into a numeric contrast sensitivity (CS) score using a predetermined scale. Mean scores of the PD and control groups adjusted for age and sex were compared using a general linear model.
RESULTS: The mean age was younger in PD (74.3±8.1 years) vs. Control (82.8±7.2 years). More men were in the PD group (75% PD; 24% Control). The mean PD duration was 10.1±5.2 years (range 1.9-17 years). Adjusting for age and sex, PD patients had statistically lower scores (worse vision) than controls in two test conditions: 100% contrast at 40cm (CS mean score = 78 for PD vs. 84 for controls, p=0.02) and 2.5% contrast at 2m (16 vs. 28, p=0.001), with a trend in the other two conditions: 100% contrast at 2m (53 vs. 58, p=0.14) and 2.5% contrast at 40cm (42 vs. 52, p=0.06).
CONCLUSIONS: In this preliminary study, PD patients were found to have more difficulty in reading an eye chart compared to controls. Therefore, the iPad version of the Sloan contrast sensitivity test adjustable for distances and contrast levels may be a rapid tool for quantifying visual changes in Parkinson's disease.

Poster Presentation at the Association for Research in Vision and Ophthalmology 2013 Annual Meeting

The King-Devick (K-D) test of rapid eye movements: a bedside correlate of disability and quality of life in multiple sclerosis

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PURPOSE: The King-Devick (K-D) test, a rapid number naming test, captures impaired eye movements and saccades, findings correlated with suboptimal brain function. This test has been used to screen athletes for concussions, with worse time scores in athletes following concussion, consistent with widely distributed visual pathways. We examined the K-D test as a measure of vision and eye movements in multiple sclerosis (MS) and determined the relation of K-D scores to visual function, vision-specific quality of life (QoL), work disability, and history of optic neuritis (ON).
METHODS: Patients with MS and disease-free controls completed the test at a single visit. Scores represent time needed to read single-digit numbers on 3 test cards. Patients had testing of monocular and binocular low-contrast acuity (2.5%, 1.25%), high-contrast acuity (VA), spectral-domain OCT, NEI-VFQ-25, 10-Item Neuro Ophthalmic Supplement, and MS Functional Composite.
RESULTS: In the MS cohort (n=81), K-D scores were worse compared to controls (54.7±15.7 vs. 41.2±7.2 seconds, p=0.003, least squares means, adjusting for age). Higher scores in MS were associated with worse scores for vision-specific QoL (p<0.001 for NEI-VFQ-25, p<0.001 for 10-Item Supplement), binocular low-contrast acuity at 2.5%, 1.25% (p<0.001), binocular VA (p=0.003), timed 25-foot walk (p<0.001), 9-hole peg test (p=0.001), and 3-second PASAT3 (p=0.03, linear regression). Patients with history of acute ON (p=0.003) or binocular low-contrast acuities below the control group average (p=0.009 for 2.5%, logistic regression) had worse K-D scores. Correspondingly, monocular vision (p=0.001-0.009) and RNFL thickness (p=0.001) were reduced in eyes of patients with worse K-D (adjusting for age and within-patient, inter-eye correlations). Disabled patients (receiving disability pension) did worse on the K-D test compared to those working full-time, accounting for age (p<0.001).
CONCLUSIONS: The K-D test captures visual dysfunction, vision specific quality of life and neurologic impairment in MS. Scores reflect work disability as well as structural changes as measured by OCT. History of ON and abnormal binocular acuities were associated with worse scores, suggesting that the K-D captures both afferent and efferent components of vision. The K-D test should be considered for future MS trials as a rapid global visual performance measure.

Poster Presentation at the North American Neuro-ophthalmology Society 2011 Annual Meeting

The King-Devick (K-D) Test of Rapid Eye Movements: A Bedside Correlate of Disability and Quality of Life in Multiple Sclerosis

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OBJECTIVE: To examine the potential role for the K-D test as a measure of eye movements in multiple sclerosis (MS). We evaluated the relationship of rapid eye movements, visual function, retinal structure, and vision-specific quality of life status in multiple sclerosis patients.

METHODS: Design: Cross-sectional study; Participants: Patients with MS and disease-free controls at the University of Pennsylvania; Eye Movements: K-D composite timed-score of 3 test cards; Visual Function: High-contrast visual acuity (VA, ETDRS charts), low-contrast letter acuity (Sloan charts, 2.5% and 1.25% contrast); Multiple Sclerosis Functional Composite (MSFC): Timed 25-foot walk, 9-hole peg test, PASAT-2 and 3; Optical Coherence Tomography (OCT): OCT-3 was used to measure retinal nerve fiber layer (RNFL) thickness; Data Analysis: Linear regression models, accounting for age; GEE models, accounting for age and within-patient, inter-eye correlations.

RESULTS: MS cohort K-D scores were significantly higher (worse) compared to disease-free controls ($P<0.001$, accounting for age). Higher K-D scores in MS were associated with worse scores NEI-VFQ-25 composite ($P=0.001$), 10-item Neuro-Ophthalmic Supplement ($P=0.001$), binocular low-contrast acuity (2.5%, $P=0.02$), timed 25-foot walk ($P<0.001$), 9-hole peg test ($P<0.001$), and 2-second PASAT ($P=0.02$). While correlations of OCT RNFL thickness did not reach significance ($P=0.13$ accounting for age and within-patient, inter-eye correlations), monocular low-contrast acuity (2.5%) correlated with K-D scores ($P<0.007$).

CONCLUSIONS: The K-D test, a <1 minute bedside assessment of rapid number naming, correlates well with binocular visual function, disability, and vision-specific quality of life in MS. Although also affected by attention and language function, the K-D test should be considered for inclusion in MS trials as a rapid efferent visual function test.