ARTICLE

An Investigation of the Druid® Smartphone/Tablet App as a Rapid Screening Assessment for Cognitive and Psychomotor Impairment Associated with Alcohol Intoxication

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ABSTRACT

Background

Neuropsychological tests have been used for years to determine impairments in cognitive and motor functions. There have been increases in impairment related to the abuse of alcohol and/or drugs related to driving. Recently, there has been an increased use of the Smartphone/Tablet applications for neurocognitive impairment testing. The DRUID® test is intended to identify and measure impairment from alcohol and various drugs by measuring changes in divided attention, decision making, reaction time, motor tracking, and balance movements control.

We investigated the application of The DRUID® test as a potential rapid screening for cognitive and psychomotor impairment as a function of specific levels of alcohol that are known to have an effect on driving and job performance.

Methods

There were 48 volunteer drinkers, (Mean age 30[5.36])19 females -29 males who were administered a two minute DRUID® test pre and post drinking alcohol in a controlled dosage setting. Breath testing for alcohol was performed confirming absence of alcohol (Pre DRUDI®) and the when dosing exceeded the legal intoxication level for alcohol in Massachusetts (Blood Alcohol Content BAC 0.08%).

Results

DRUID® post drinking scores were significantly higher (worse) than DRUID® pre drinking. Higher scores on the BAC and DRUID® correspond to higher intoxication and associated impairment. There were no significant differences by gender for any of the central variables. A repeated measures t-test comparing DRUID® pre and post alcohol BAC scores revealed a highly significant ($t_{(47)}$ = 34.5, $p < .0001$), difference in pre- and post DRUID® scores ($t_{(47)}$ = 8.68, $p < .0001$).

Conclusions

The DRUID® test is a compelling and useful Smartphone/Tablet based candidate as a rapid screening test for identifying cognitive and psychomotor impairment associated with the intoxication level of alcohol and effects on driving.

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INTRODUCTION:

There are millions of people in the United States who will become impaired and/or disabled, annually either partially or permanently, from multiple causes. The effects may be mild to severe and range widely in nature across all ages. Such causes often include impairment from accidental/unintentional injuries, cognitive/mental changes, and from neurological and cardiovascular events.[1] In the quest to identify, diagnose and plan treatment for such impairments there is a continual need for appropriate assessment tools. In many of these cases, there is a need for neurologic and cognitive functioning testing. The aim of neurological and cognitive performance testing is detection of possible impairment in many areas of cortical functioning.[2]

This testing has a primary task to determine a decreased ability to perform basic screening skills as well as complex neurological and psychomotor tasks.

Two fundamental areas that have seen increases in neurological and cognitive impairment are the abuse of alcohol and/or drugs related to driving[3-5] and traumatic brain injuries.[6-10]

A range of neuropsychological tests have been used for years to measure and determine impairments in cognitive and motor functions. Often, specific neuropsychological and cognitive functions are known to be linked to a particular cortical structure or pathway related to the observed impairment.

Traditionally, neuropsychological assessment relied on time consuming paper and pencil based tests to assess cognitive abilities, and studies conducted with these tests have generated thousands of scholarly articles promoting their strengths and debating their weaknesses.

In the past several decades, neuropsychological assessment has undergone substantial growth and improvement in the evaluation in the abuse of alcohol and/or drugs related to driving and traumatic brain injury.[11]

These clinically helpful evaluations often are quite time consuming, costly, and may lead in delays for treatment in many situations. Lack of early identification of possible neurologic and/ or cognitive impairments can appreciably delay diagnosis and appropriate treatment and can affect the individual's quality of life.[11]

More recently, increasing numbers of researchers and clinicians have started to apply various technologies to improve the efficiency, reliability, and cost-effectiveness of neuropsychological assessment. Rapid advances in technology, including improved computer programming, have allowed many assessment measures to even be administered, scored, or interpreted without the direct interaction of a clinician.[12]

There remain numerous questions and challenges to better support measurement tools and convert these findings into meaningful recommendations and treatments. Computerized neurocognitive tests have several advantages since they can be administered relatively quickly and do not require a clinician's presence or time. They can be adapted to a specific clinical issue, e.g., traumatic brain injury, concussion, mild cognitive impairment, drug abuse impairment, and are often self-scoring and produce a report briefly after the test is finished. Another benefit is the use of the computerized test results for in quicker or more efficient decision making as the data can be stored and easily accessible for ongoing comparison of previous results. With the advent of smartphones and tablet based applications, there is an increased growth of more rapid, diverse, and accurate assessment of neuro–cognitive impairment.

With this technology change, there has been an increase in use of the smartphone and Tablet applications for neurocognitive impairment in numerous conditions e.g., hearing and vision loss, addiction, neurological diseases, mental illness, brain injury /concussion, and alcohol and drug impairment.[13-18] It allows people to use some of the newer Internet-based tests at home, using a tablet or a smartphone, for screening for impairment and monitoring treatment.

Abuse and adverse effects of alcohol and its impact on driving continues to be a national concern causing multiple injuries and impairment. The role of alcohol in affecting neurological and cognitive functions and a person's the ability to safely operate a motor vehicle has been fully documented and acknowledged.[20]

Over the years, there have been numerous studies related to alcohol impairment. These have ranged from the examination of simple sensory, perceptual, and motor behaviors to more complex measures of cognitive functioning, such as divided attention and mental workload.[19]

Computer based tests of neurocognitive performance were used to test subjects under the influence of alcohol and a battery of mental tests and standardized roadside field sobriety tests. The abilities evaluated and included were divided attention, focused selective attention, reaction time, balance, critical visual tracking, and visual motor control. These are identified as sensitive functional biomarkers i.e., a characteristic of a physiological and/or psychological ability that is objectively measured and evaluated as an indicator of pharmacological responses. Numerous studies[21,24-26] demonstrated that these select cognitive abilities were very good predictors of impaired performance relative to changes in alcohol concentration.

Impaired driving deterrence from alcohol abuse remains a major priority of law enforcement and industry fitness for work programs nationwide.[27-29]

Unfortunately, the recognized cognitive and psychomotor tests used in clinic or laboratory settings to assess alcohol impairment are not readily applicable for use by of law enforcement and industry in the field.

At present, the most widespread suitable and reliable field test method used by law enforcement to determine if a driver exhibits brief behavioral and physical signs of alcohol impairment is the Standardized Field Sobriety Test (SFST).[30] During these SFST procedures, the officers require a subject to listen and follow instructions while performing simple physical movements. Impaired persons have difficulty with tasks requiring their attention be divided between simple mental and physical tasks.

In the United States, Blood Alcohol Concentration (BAC) refers to the percent of alcohol (ethyl alcohol or ethanol) in a person's blood stream. Legal impairment of driving under the influence of alcohol is applicable when a BAC level of 0.08% or higher is determined to be present . Officers trained to conduct SFSTs, were able to correctly identify alcohol-impaired drivers over 90% of the time who had BAC levels above the legal limit of 0.08%. However, in plenty of these cases, the BAC is often discovered to be well above the 0.08% level allowing for more obvious identification of impairment on the SFST.[30-31] The SFST may not be sufficiently sensitive to observe impairment behavior to lower BAC levels or causes other than alcohol, e.g., cannabis.[32]

Other studies have reported impairment from alcohol not be uniform across different areas of cognitive processing and that both the size of the alcohol effect and the extent of effect change across different dose levels, Low and moderate doses of alcohol may not compromise cognitive ability in non-problem drinkers under certain task conditions nor yet be evident in SFST results.[33-34]

Though the use of computer based tests of cognitive and psychomotor functions to measure impairment related to alcohol is quite valid and possibly more sensitive to impairment, it is unfortunately not practical for use in the field at this time. Conceivably, the potential use of Smartphones and/or tablet based applications, e.g., iPads, for detecting impairment from alcohol intoxication, as well as other drugs, may offer be a supplemental, practical, accurate, and efficient method to measure cognitive and psychomotor impairment.

In this study, we investigated the application of a rapid Smartphone/Tablet based test protocol ability to identify cognitive and psychomotor impairment as a function of specific levels of alcohol that are known to have an effect on driving and job performance. The DRUID® app[16] is such a new Smartphone/Tablet application. The DRUID® test is designed to identify and measure impairment from alcohol and various drugs by measuring changes in divided attention, decision making, reaction time, motor tracking, and balance movements control. Using this method, we sought to determine if subjects differed in their performance in DRUID® scores from a baseline sober condition with an intoxicated condition where the alcohol level was considered to be legally above the level for safe driving. Further examination would be carried out to determine if there was a significant difference and correlation between pre and post alcohol levels and the DRUID® app scores.

METHODS

Alcohol Impairment Workshops

In order to obtain alcohol drinking subjects for this study, we obtained permission to use data acquired in testing alcohol workshop subjects as part of the training of police recruits during the Standardized Field Sobriety Test (SFST) 3-day program established by the International Association of Chiefs of Police and the National Highway traffic and Safety Administration.[30] These alcohol workshops were located at two police academies in Massachusetts operated under the administration of the Municipal Police Training Committee (MPTC).[35] The MPTC is responsible for establishing training standards for and delivering police training in Massachusetts. They follow and incorporate the national protocols established by the International Association of Chiefs of Police and the National Highway traffic and Safety Administration.[30] These sessions recruit and use volunteers to drink measured doses of alcoholic beverages under controlled conditions usually for about 4 hours. Blood alcohol concentration (BAC), also known as blood alcohol level, is measured on a breath testing device. BAC is commonly reported as a percentage of alcohol weight per volume of blood. Each subject is dosed with alcohol at established intervals and their blood alcohol content (BAC) is carefully monitored throughout the workshop by certified Massachusetts Municipal Police Training Committee instructors. Certified Standardized Field Sobriety instructors performed measurements using the Drager Alcotest 6510 instrument, a breath-based alcohol testing device. The Draeger 6510 is a Breathalyzer used widely by the Police around the world to measure Breath Alcohol Content (BAC) at an accuracy of ± 0.005%BAC at 0.100%BAC (Figure 1).[36]

Figure 1. Drager Alcotest 6510 Portable Breath Tester

Baseline breath alcohol test evaluations confirming the absence of alcohol were performed at the beginning of the workshop, before the subject's first drink using a calibrated Drager Alcotest 6510 Portable Breath tester. When dosing reached or exceeded the legal impairment level of alcohol as defined by the legal limit or Massachusetts (BAC 0.08%), drinking was suspended and a final BAC level was recorded.

Subjects

Forty-eight volunteer drinkers, 19 females and 29 males, participated in the study. Subjects were recruited from police academy resources. Each subject signed an informed consent form[a] explaining the purpose of this workshop to assist in training police officers to recognize persons impaired by alcohol or drugs.

They were encouraged to ask any questions and could refuse at any time to participate. Subjects were recruited solely on the basis of their availability, and not on their age, gender, weight, or ethnicity. All subjects were of legal drinking age. None of the subjects reported fatigue, presence of any health conditions, or use of any medications that excluded participation in the study.[30] Subject demographic data are summarized in Table 1.

Table 1. Characteristics of Subjects[a]

Participants N=48	
Mean Age (yrs)	30.00 (5.36)
Age Range (yrs)	21-40
Male, N, (%)	(n=29) 60%
Female N, (%)	(n=19) 40%

DRUID® Tasks and Testing Procedures

DRUID® is an application designed to capture measures of cognitive and motor impairment in divided attention, decision making, reaction time, motor tracking, and balance movements, following the intake of drugs such as alcohol or cannabis.[16] DRUID® testing consist of four tasks to measure cognitive and psychomotor performance. The tasks were consistent with those identified in research on the effects of alcohol and driving impairment.[19,21,37]

Specifically, the DRUID® tasks are:

Task 1—Reaction Time/Decision Making

Shapes flash on the screen for ½ second, either a square or a circle, one shape being the Target-shape and the other being the Control-shape. The user is instructed to touch the screen where the Target shape appeared, and to touch the oval shape at the top of the screen when the Control-shape appears. Users must first make a decision about what type of shape appeared (square or circle) and perform a different action (where to touch the screen) depending on that decision. DRUID® measures reaction time in touching the screen, and errors in choosing the correct action based on each stimulus shape. DRUID® Task 1 is shown in Figure 2.

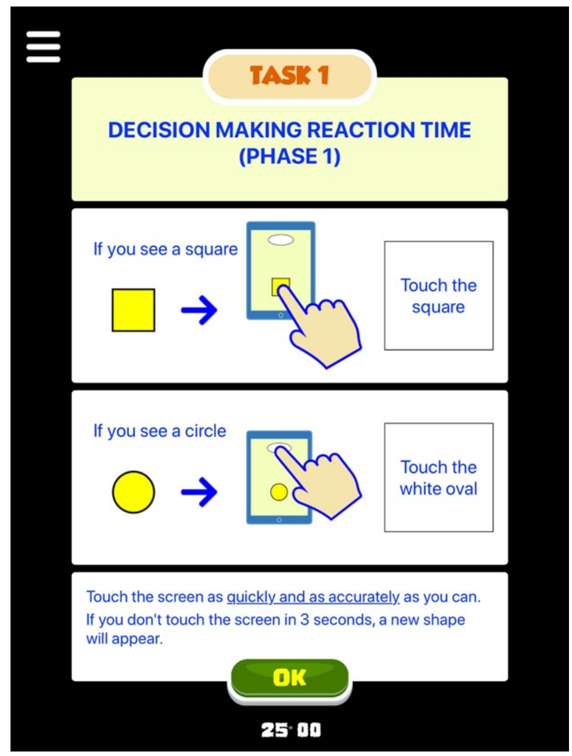

Figure 2. Task 1—Decision Making Reaction Time

Task 2—Reaction Time

This task requires users to press a "START" button to begin internally counting for a minute and to press a "STOP" button when they estimate 30 seconds has passed. In addition, circles are flashed on the screen for ½ second, and the user is required to touch the screen where they appeared. Users thus need to count time passing as well as reacting to stimuli on the screen, a Divided Attention Test (DAT). DRUID® Task 2 is shown in Figure 3.

a The standard informed consent form for alcohol workshops approved by the Massachusetts Municipal Police Training Committee is available upon request.

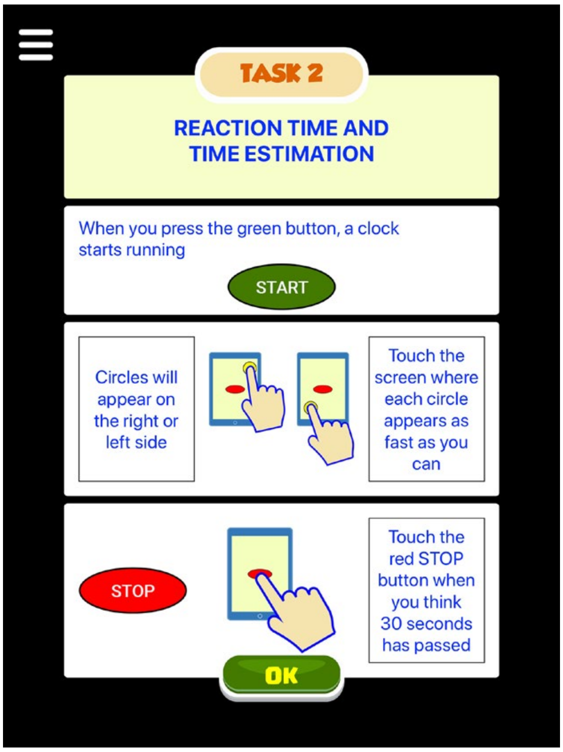

Figure 3. Task 2 – Reaction Time

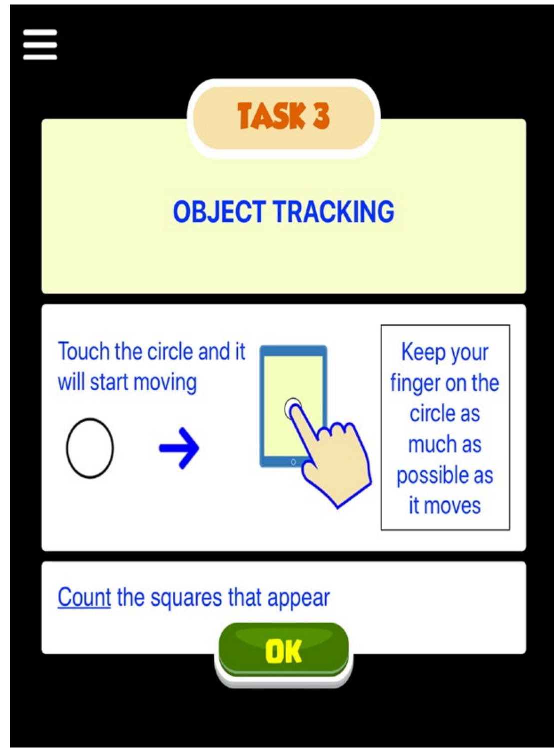

Figure 4. Task 3 – Motor Tracking

Task 3 — Motor Tracking

This task presents a circle that moves around the screen, sometimes jumping a distance, and the user is required to keep their finger on the circle as much as they can. In addition to keeping track of the moving circle, users are required to count the number of squares that flash on the screen for ½ second, incorporating a DAT. DRUID® Task 3 Object Motor Tracking Directions screen is shown in Figure 4.

Task 4 — Balance

DRUID® uses the accelerometer to test stability and balance performance. Users are instructed to stand on their right leg for 15 seconds, holding the device in their opposite hand, trying to keep the device as still as possible, then to switch the device to the opposite hand and stand on the left leg for 15 seconds. DRUID® Task 4 Balance Directions screen is shown in Figure 5.

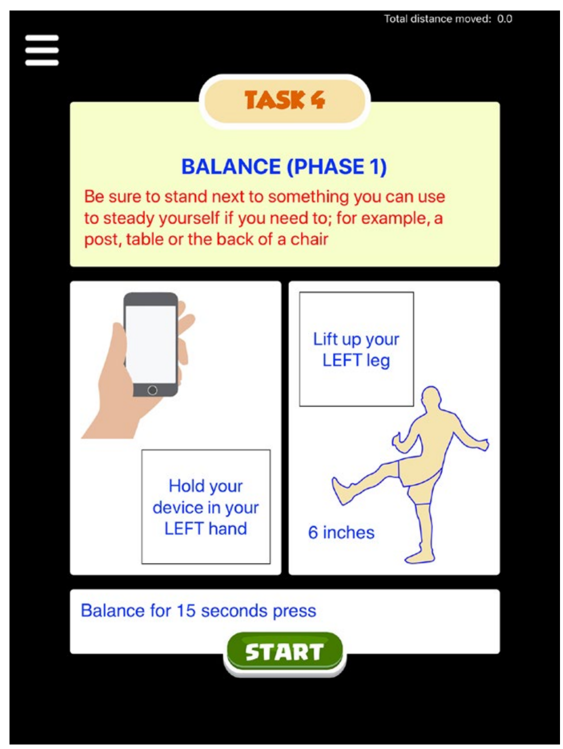

Figure 5. Task 4 – Balance

DRUID® Test Protocol and Output

The DRUID® tasks requires approximately two minutes to complete following the instructional phase. The testing was performed on iPad Tablets with the DRUID® Research application installed and administered by independent examiners from the DRUIDapp, Inc. Each subject is assigned an identification number to protect identity. All the data from the testing is transmitted for analysis via Wi-Fi using the algorithm by the DRUID® designer. There is a pre-test practice trial period for each of the four tasks to ensure the subject understands the test and becomes familiar with the iPad tablet.

The DRUID® Baseline evaluations were performed after the initial breath testing and before the subject's first drink. Once drinking commenced and the blood alcohol levels (BAC) increased to be above a 0.08% BAC, the DRUID® procedures were administered again.

DRUID® Output

For each of the four tasks, subject response data was collected. The specific measures were each DRUID® were as follow:

- Task 1, Reaction Time/Decision Making, there are three measures of the data output. These are Average Reaction Time, Average Error Distance (in inches), and Percentage of wrong shapes selected.
- Task 2, Reaction Time, there are four measures of the data output. These are average Error Distance (inches), number of errors counted, average reaction time (seconds), and difference in time from 30 seconds.
- Task 3, the Motor Tracking, there are two measures. These are the percentage of time the finger is not on the moving circle target and error count in counting squares.
- Task 4 Balance, there are two measures. These are in inches of sway for movement while standing on left leg and inches of sway for movement while standing on right leg.

Each of the tasks will have an output to a screen of the responses following each assessment. At the conclusion of the testing, the DRUID® app integrates hundreds of data points into a smaller set of variables which is transmitted for analysis via Wi-Fi to the DRUID® designer. An algorithm then integrates these variables into an overall measure score of impairment, using a formula based on analyses of all the data collected. Impairment scores range from 0-100, and generally range between 30-70. The pre and post alcohol drinking scores were then made available to the investigators for analysis.

RESULTS

A statistical analysis was performed using the SPSS v19 statistics package on the data from the study. Characteristics of the subjects for the study sample (n = 48) were displayed in Table 1.

Summary statistics for the major variables in the study (pre/post Blood Alcohol Content (BAC) and pre/post DRUID® scores are presented in Table 2.

Higher (more errors) scores on the BAC and DRUID® represent higher intoxication and associated impairment. There were no

Table 2. BAC and DRUID® Total Impairment Scores

	All Participants (n=47)	Males (n=28)	Females (n=19)
BAC, pre-alcohol % Mean [SD]/Median	0.00[0]/0.00	0.00[0]/0.00	0.00[0]/0.00
BAC, post-alcohol % Mean[SD]/ Median $t_{(47)}$ = .82, *n.s.*	0.113[.023]/0.111	0.111 [.025]/.107	0.117[.020]/0.111
BAC post-alcohol BAC % range	(0.08 - 0.17)	(0.08 - 0.16)	(0.09 - (0.17)
DRUID® Pre-alcohol Mean [SD]/Median $t_{(47)}$ = 1.30, *n.s.*	44.3[4.9]/43.6	45[5.3]/43.0	43.2[4.0]/43. 7
DRUID® Pre-alcohol (range)	(36.0 - 60.0)	(37 .0 - 60.0)	(36.0 - 51.2)
DRUID® Post-alcohol Mean [SD]/ Median $t_{(47)}$ = .14, *n.s.*	57.1 [11.3]/54.4	56.9[9.65]/55	57.4[9.57]/53
DRUID® Post-alcohol (range)	(42.5 - 99.0)	(44.0 - 80.0)	(42.5 - 99.0)

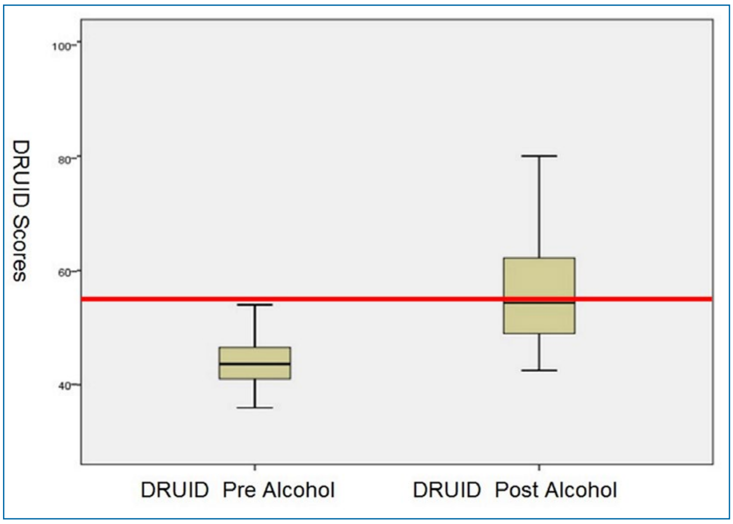

Figure 6. Boxplot of the medians for the DRUID® Baseline scores vs. DRUID® intoxicated scores beyond BAC 0.08%

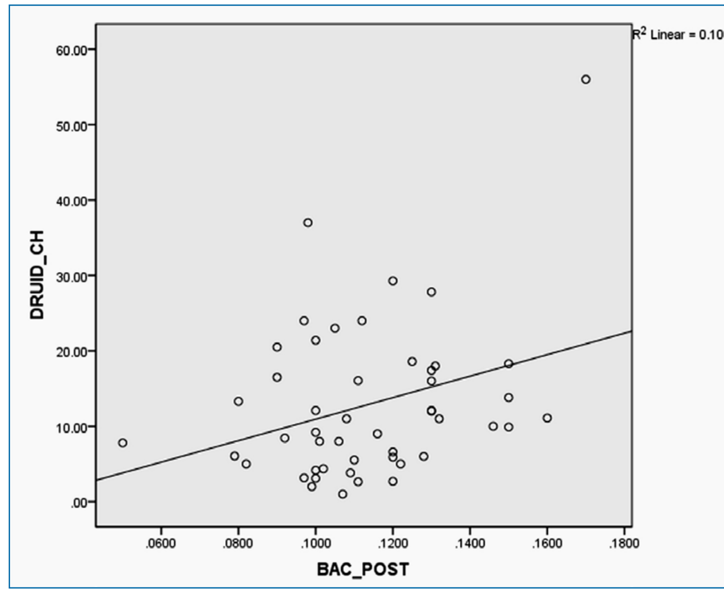

Figure 7. Scatterplot of change in BAC vs DRUID scores. The higher the BAC, the greater was the increase in their impairment score.

significant differences by gender for any of the pre and post alcohol level and DRUID® scores.

As displayed in Table 2, each mean/ median pair is very close in value, therefore the median values were computed since the median is inclined to be more robust to both skewness as well as outliers to measure central tendency than the mean. There was no significant difference between genders in their Post-BAC scores and the Pre and Post DRUID scores.

A repeated measures t-test comparing pre- and post-alcohol BAC scores was highly significant ($t_{(47)} = 34.5$, $p < .0001$), as was the difference in or change between the pre- and post-DRUID® scores ($t_{(47)} = 8.68$, $p < .0001$). The distributions of the Pre- and Post-DRUID® scores as a function of the pre- and post-alcohol consumption is shown in a box plot. (Figure 6) This displays a boxplot around the medians for the DRUID® Baseline (non-intoxicated) scores and the same individuals' DRUID® scores when they were alcohol-impaired beyond the legal limit of BAC > 0.08%.

Since the box plot of the full sample identified an isolated high outlier (score of 99) in the post-DRUID® scores that could affect the test of means, the paired sample t-test was rerun, excluding the high outlier. The resulting test statistic was larger than with the outlier ($t_{(46)} = 10.1$, $p < .0001$), indicating that the outlier had increased the variability in the denominator of the t-test, producing no bias.

No subjects' DRUID® scores decreased between the sober vs. intoxicated measurements. Using the mean of the intoxicated participants' DRUID® scores as a limit identifying intoxication (solid horizontal red line in Figure 6), there were no false positives identified by DRUID® in the participants before they started drinking alcohol.

Increases in the subjects' DRUID® scores from their baseline scores following alcohol consumption are strongly correlated to their increased BAC ($r= 0.430$, $p<0.003$). DRUID® impairment scores were calculated subtracting each subject's pre-alcohol DRUID® score from their post-alcohol DRUID® score. A regression analysis of BAC predicting DRUID® change scores was statistically significant ($\beta = .32$, $t_{(47)} = 2.26$, $p = .029$), showing that the higher the individual's BAC, the greater was the increase in their DRUID® score. This is shown in a scatterplot in Figure 7.

A further analysis of the difference between the pre alcohol vs. post alcohol DRUID® score was performed. The mean difference or change in the pre alcohol vs. post alcohol DRUID® scores was 11.95 [SD 8.15]. This large value for the standard deviation indicates that the

DRUID® values are spread over a large range. The range of changes in DRUID® scores was from a minimum of 1.00 to a high of 37.00. The higher the score became, the greater was the impairment from the alcohol on the testing.

DISCUSSION

Alcohol abuse has clearly been demonstrated to have an effect on driving and job performance.[19,21,37] In this study, our goal was to investigate the use of a convenient and efficient application of a quick Smartphone/Tablet based protocol's ability to identify cognitive and psychomotor impairment as a function of specific levels of alcohol. Higher scores on the BAC and DRUID® represent higher intoxication and associated impairment. The results indicate there is a positive relationship between elevated Blood Alcohol Content (BAC) levels and increased impairment on the The DRUID® test scores. There were no significant differences by gender for any of the central variables.

For years, computer based applications tests of neurocognitive performance have been applied in the assessment of in neurological and cognitive impairment. As technology improved, the personal computer features would merge with cell phone capabilities into the smartphones. The smartphone and tablet became available and in widespread use less than 12 years ago.[38,39]

It was only a matter of time to see similar assessment protocols applied to newer technologies to measure impairment related to alcohol and drug abuse and traumatic brain injuries. Today, few people worldwide can imagine life without their smartphones and tablets for a myriad of daily applications. Currently, there are many tests that can be administered at home, on the playing field, in the workplace, and in the clinical setting using a tablet or a smartphone, for screening for impairment and monitoring treatment. Unfortunately, the recognized cognitive and psychomotor tests used in clinic or laboratory settings to assess alcohol impairment are not readily applicable for use by of law enforcement and industry in the field. This study was an endeavor to assess the applicability of the use of the DRUID® app for measuring changes in divided attention, focused selective attention, reaction time, balance , critical tracking tasks, and visual motor control as it applies to alcohol induced impairment.

Our findings and the use of the DRUID® protocol are similar to other smartphone applications associated with concussion and mild traumatic brain injury assessment tools. For example, HitCheck®[15] is a smartphone based cognitive assessment application that can take baseline measurements of normal performance and then be applied to screen for changes from a possible brain injury . HitCheck® assesses cognitive and psychomotor changes in performance in nine areas associated with brain injuries, e.g., balance, reaction time, coordination, short-term memory, long-term memory, color recognition, impulse control, pattern recognition and problem solving. The HitCheck® test takes approximately 7-10 minutes to complete, which is a fraction of the time of established computer based programs.

Specific to alcohol impairment and driving, the design and use of the DRUID® set of four tasks is supported by similar though more extensive neurocognitive test batteries of cognitive and psychomotor testing of alcohol and driving. Computer based tests measuring skills related to test driving and alcohol are often more complex yet are similar in construct to the DRUID® app's use of divided attention, psychomotor vigilance test, and a balance test. These areas of testing were reported to be most sensitive to the impairing effects of alcohol and being considerably valid in assessing potential driving impairment.[25,40]

There are some limitations and observations regarding the DRUID® test battery as used in this study. For it to be used effectively over time and to be administered by different testers, the interrater and test-retest reliability of its outcomes measures should be investigated. Presently, the test is used as a pre and post screening tool that will often reflect variations in the subject's skill and experience. This was observed in the results in the study. The mean change or difference between the pre and post drinking alcohol in the DRUID® score was 11.95 [SD=8.15]. A high standard deviation is a indication that the values are spread over a large range of values. The range of changes in scores was from a minimum of 1.00 to a high of 37.00. The higher the change, the greater was the impairment from the alcohol on the DRUID® testing. Though the post alcohol overall DRUID® scores demonstrated impairment in pre and post drinking, there was a robust amount of variation in the pre and post DRUID® scores. This may have been due to numerous factors, e.g., variation in alcohol levels, tolerance to alcohol, and how the subject was influence in their cognitive and psychomotor skills by the alcohol.[41,42]

Another factor to be considered in the current study is that DRUID® impairment measurements were for increasing BACs only. There may be different responses on the DRUID® if measurements were taken on the decreasing or downside phase,of the blood alcohol level, i.e., after they have stopped drinking,[24,25,43] An important aspect of evaluating a potential smartphone/tablet based screening test, such as DRUID,® is the relationship of scores with an established battery of tests that measure similar cognitive testing and impaired driving ability.

While the appearance of alcohol impairment is best captured by more extensive cognitive and psychomotor testing batteries, the DRIUD® has significant potential value as a valid and reliable quick screening tool that captures many aspects of divided attention, balance, reaction time, and coordination.

As mobile technologies become an everyday part of our lives, it is important that the public feels confident that the content of the apps represents the best information available in safeguarding public safety.[44]

With further research and development of the DRUID® app, the future use of this type of smartphone/tablet type applications for alcohol and potentially drug testing will be undoubtedly more valid and reliable. It may prove to be more sensitive to lower BAC levels below the thresholds on the SFST tests. It may as well be sensitive to types of drug impairment and serve as a valuable impairment screening tool for alcohol and drug abuse for the workplace and clinical settings.

The DRUID® test is a compelling and useful smartphone/tablet based candidate as a rapid screening test for identifying cognitive and psychomotor impairment associated with the intoxication level of alcohol and effects on driving.

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Disclosure

Dr. Jack Richman and Lt. Stephen May report no personal or financial interest and no present or past employment or activity which would be incompatible with participation in any activity related to this study. This research

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Dr. Richman is Professor Emeritus from the New England College of Optometry and has lectured widely, both in this country and internationally.

For more than 50 years, he has practiced clinically and academically as a full professor and chief of the Pediatric Optometry and Binocular Vision service at the Pennsylvania College of Optometry, The Michigan College of Optometry at Ferris State University, and the New England Eye Institute in Boston.

His primary areas of lecture and clinical research have included binocular vision dysfunctions, pharmacology, eye movements, visual attention dysfunction, and the effects of drugs on the visual system. He has approximately sixty published articles and book chapters

Presently, he is retired from full time practice and teaching. He is a part time adjunct professor at the Massachusetts College of Pharmacy and Health Sciences – School of Optometry where he lectures and conducts research on vision and driving. Clinically, Dr. Richman continues to serve on the consulting staff at Spaulding Rehabilitation Boston and Spaulding Rehabilitation Hospital Cape Cod.

Dr. Richman has been active in law enforcement for over 26 years. He is a certified Standardized Field Sobriety instructor, a Drug Recognition Expert, and a Drug Recognition Expert instructor. He was the medical consultant to the National Highway Safety Committee's Technical Advisory Panel of the International Association of Chiefs of Police for more than sixteen years. He continues as a consultant to the committee. Presently, he is the police physician and a Drug Recognition Expert instructor for the Hingham Police Department in Massachusetts. He is active in training police officers in Massachusetts and throughout New England states on a regular basis.