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Mobile Application Development: The Mobile Intoxication Assessment Tool

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ABSTRACT

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This research and development undertaking during the senior year is a culmination of undergraduate study at Union College and is an opportunity to put knowledge gained to use. The purpose of this specific capstone project is to bring together not just the research and implementation techniques learned as a Computer Engineer but to also meld this discipline with another; Neuroscience. The objective of the project was to develop a full function software prototype in the form of a mobile phone application.

The mobile application (Mobile Intoxication Assessment Tool) constitutes a grouping of simple subtasks that can be completed on the touch screen of an Android powered smart phone. These subtasks are designed in such a way that they evaluate five primary abilities that are disrupted by acute alcohol intoxication. The five affected faculties include memory and problem solving abilities, fine muscle control, vision, and reaction time. The result of a user's cumulative scores on these simple tests paired with their personal information such as body weight, age, and height is compared to a "baseline sobriety reading". This baseline reading is calculated, at the time of the application's download, when the sober user completes a variation of the tests that will be administered during intoxication.

This project aims to identify a quantitative correlation between blood alcohol content (BAC) and the degradation of a users test scores from their "baseline sobriety reading" scores. Through a month long study, of 25 participants of legal drinking age, this correlation between variations in test scores and users intoxication was searched for. As was the ideal outcome, a strong correlation was discovered and the software prototype resulting from this research is able to provide a BAC reading. The software has yet to achieve the level of BAC prediction accuracy of a commercially available breathalyzer but further research is planned to remedy this.

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1. INTRODUCTION

You find yourself out with a few friends for drinks after work but as the night is coming to a close you begin to question your level of impairment. Unfortunately you left your pricey breathalyzer at home but luckily you have your android smart phone! Anyone who has ever been intoxicated could probably tell you that they would never be able to accurately evaluate their precise blood alcohol content or the extent of their impairment without assistance. So how is it possible to know if it's safe to get behind the wheel of a car or which drink is one too many? The root of this problem stems from the fact that alcohol's numerous effects on the body depend on far too many variables, and the way that a couple of drinks affects an individual one day may be completely different than the next. In addition to the difficulties faced in assessing one's own level of intoxication based on self-perceptions skewed by the alcohol consumed, conventional methods of accurate judgment are wrought with problems of their own. Breathalyzers, for instance, are too cumbersome or unwieldy to carry around regularly. While, on the other hand, BAC calculators that make these judgments based on complex calculations are more convenient but tend to be highly inaccurate due to human error. This unbiased or uninhibited, external, judgment of an individual's level of impairment is important in the process of making a wise decision when one's own faculties cannot be trusted. Wouldn't it be nice if you could carry this assurance with near breathalyzer levels of accuracy around in your pocket everywhere you went without hauling around a separate device?

In this research, it is proposed that a mobile application based on the assessment of certain skills and abilities that are impaired by acute alcohol intoxication can be used to judge an individual's level of intoxication with the accuracy of a commercially available breathalyzer. When a user first downloads and runs the application they will personalize the tool by primarily entering personal information that pertains to BAC calculation and secondly by providing a reading of their baseline sober abilities related to the subtests incorporated in the application. The individual will first be asked to enter their gender, height, weight and age. Additionally the user will set their "baseline sober state" for comparison during intoxication by taking tests similar to those that will be administered to measure intoxication. After the application has been calibrated for the individual, the information pertaining to how they act while sober will be saved and the application can now be used to gage their blood alcohol concentration at a later time. Once the user has been drinking they can now reopen the application on their phone and follow straight foreword prompts to complete a set of simple tasks as they are presented on the screen. These tasks or subtests will evaluate the user on their level of memory impairment, degradation of cognitive or problem solving abilities, level of acute ataxia, vision disruption (specifically diplopia), and delay in reaction time. Their scores on these subtests will then be compared to the baseline that was set when the application was downloaded. So the question is posed: *What tests, if any, can be programed into a mobile application which will allow judgment of an individual's blood alcohol content as accurately as a breathalyzer?*

The remainder of this report consists of a discussion on the background of this problem in the context of human condition monitoring applications and the important issues faced by developing such a system. This is followed by explicit description of the requirements and justification of the project relating to lesser alternatives. The report culminates with the subsequent project design based on the work outlined in the previous sections.

2. BACKGROUND

2.1 Issues and Implications

2.1.1 Economic

The obvious alternative to having this application's functionality readily available on the phone tucked away in your pocket would be the use of a far more costly breathalyzer. This pricey substitute would also require the user to carry a separate, possibly bulky, device with them in addition to shelling out upwards of $200 for an ordinary commercial model. The proposed alternative to the fiscally draining breathalyzer taking the form a smart phone application requires virtually no overhead and zero material costs. These cost benefits make it significantly less expensive to produce and this translates to a sale price that will be an insignificant fraction of the breathalyzer's cost.

2.1.2 Sustainability

It is highly likely that when the application is first produced the quantifiable correlation between BAC and the degradation of the application's test scores will not be as accurate as is ultimately desirable. This can be remedied in the long term by constantly evolving and updating this calculation based on user data collected by the currently released version of the application.

This primary release of the software will also have the sustainability draw back of being solely targeted at the android platform and subsequently just this market share. Future markets and work will consist of cross platform development and the migration of the software from the Android platform to others such as Apple and Windows.

2.1.3 Ethical

There are clearly a few ethical considerations that need to be addressed when dealing with this project. The foremost ethical stumbling block here stems from the application's possible misuse whether intentional or unintentional. For example, although it is ideal that this research yields an application that precisely determines BAC it may not work flawlessly and will therefore have the possibility of making errors. If any individual using this system were to be provided with an incorrect BAC reading they could make a detrimental or possibly life threatening decision based on this misinformation. This could happen in a situation where the application predicted a BAC lower than the users actual BAC and they made the choice to drive based on this reading. This person who was given a lower than actual BAC reading could then be arrested for DUI or worse put other motorists at severe risk. Thus until a significant level of accuracy can be verified in the BAC calculations a disclaimer will need to be provided with application use stating that this inaccuracy exists and advising against making any decisions based solely on its results.

2.1.4 Social

It is commonly known that intoxicated individuals tend to act as their sober self would never allow and that this compromised rationality or impulsiveness could potentially cause them to make costly social mistakes. The application proposed here, as a product of this research will allow users to quantifiably assess their impairment and give them a sense of self-awareness. Having this idea how drunk they are the user will be able to consciously choose to either stop drinking, or to continue with their reckless and possibly damaging behavior.

2.1.5 Health and Safety

The Uniform Crime Reports by the FBI cite that there were a total of 1,412,223 arrests made in 2010 for driving under the influence of alcohol (DUI) and another 560,718 arrests were made for drunkenness. [9] These staggering statistics are nothing compared to those who considered it a good idea to drive and were not stopped in time. In 2009 the National Highway Traffic Safety Administration reported a total of 33,808 alcohol induced traffic fatalities. [10]

Once this application achieves the desired level of accuracy and precision in reading a users BAC there will no longer be an excuse for any individual to not know where their sobriety stands before they get behind the wheel of a car. With any luck people will view their BAC reading as a wake up call and be able to make an informed decision to not drive. Given sufficient accuracy this research and subsequent software package will have the ability to reduce these heinous statistics and help users avoid arrest and even save lives.

2.2 Previous work

A large number of studies involving mobile device applications attempting to accurately evaluate some condition of the human user have been proposed to answer questions similar to the one being posed here. Emiliano et al. [2] proposed an application which used an ordinary smart phone to autonomously determine where a person is and what actions they are performing. These readings ranged from working out at the gym to listening to music in the car. In addition to putting together this status of a user, the application (CenceMe) would also share this information via social networking applications such as Facebook or MySpace. The challenge or question here was whether or not it was possible to use the multitude of sensors on a mobile phone to correctly judge a person's location and activities.

This problem was confronted using a three-step process, which began by analyzing the feasibility of such an evaluation of environmental analysis with any significant accuracy. Emiliano outlines the assessment of the physical faculties of the phone and first determines if this type of device would have the necessary computational power, battery life, etc. to support the application. In addition to looking at the basics of the phone, this first stage of development also reviewed each of the sensors and methods of data gathering that were proposed and determined how each would be used. This evaluation was done by both looking at the basic specifications as given by the manufacturer as well as measuring each sensors output over a varied set of inputs. After determining that a mobile device of this type would contain the necessary specifications to implement this application the actual software was developed in the second stage of the process. Finally to definitively answer the initial question, a user study of 22 individuals given the application for a three-week period was conducted. During these three weeks the users were asked to keep track of the applications assessment of their activities and location as compared to their actions in reality. Additionally the users comparisons of their actual events against what the application predicted events were used to evaluate the effectiveness of the application.

Other mobile systems have also been proposed to answer the question of accurately analyzing a user's various physical conditions as they apply to fields such as personalized healthcare. Preuveneers and Berbers [1] focused on diabetes and more specifically on making diabetics' lives simpler. This mobile healthcare system was designed to assist individuals diagnosed with diabetes by making well-informed decisions on daily drug dosage to achieve and maintain stable blood glucose levels. These complex dosage recommendations are compiled by monitoring user location and activity on a mobile phone, recognizing past behavior and augmenting the recording of blood glucose levels with contextual data.

Mulvenna et al. [4] devised a cognitive prosthetic for people with mild dementia that contains a combination of needs driven tools aimed at assisting users with mild dementia in their daily life. This application for mild dementia patients attempted to answer the posed question of what tools would help an individual suffering from this disease live a more comfortable life. The study began by first answering the question of feasibility just as Emiliano did. This feasibility assessment was done through a set of three iterative studies of a year each. Each study was preformed with 15 individuals with mild dementia who were observed and their expressed needs were taken note of. These needs were recorded so that they could be mapped to functional requirements and design specifications. After each yearlong iteration the prototype application was developed and modified to fit the expressed and observed needs of the patients. Eventually concluding field tests were performed where the latest version of the prototype application was installed on the participant's phones and evaluation of success was measured through interviews, observations, and diaries of individuals. This pair of personalized healthcare applications both used a three-step testing and implementation process similar to the "CenceMe" study.

One factor that these studies, and the question proposed here, have in common is the desire to accurately observe a biological user's physical conditions through empirically collected data rather than requiring the user to explicitly enter the required information. These studies offer guidance as to how a similar question of empirical biological measurement could be answered. After observing a similar model of progression in each study, clearly the question being asked of this research could be answered with a comparable three-step process. Like the previous work done in this area, as represented by these given studies, testing will begin by answering the question of possibility. In the context of this project the first stage will consist of resolving exactly which tests will be effective in BAC determination and the subsequent development of the application. Much like the work that was done in each of the cited studies, ability tests will not be programmed in their final form prior to the study completion. This delay of final programming is because, among other reasons, if some skill tests were not used then their programming would have been purely a waste of time. Again following the blueprint formed by the preceding studies this research will progress toward its ultimate goal by then programming the actual application. Lastly the third step of validating the use of the virtually applied tests will be done via a second user study where the same set of tests will be administered to the same study group. The only deviation between the first and second studies will be the form that the ability tests take. In this last stage participants will be evaluated using the application version of all skill assessing subtasks. Preferably these tests will be as accurate as or more accurate than the first round of testing and both will have exhibited the BAC determining accuracy of a breathalyzer thus answering the proposed question.

3. DESIGN REQUIREMENTS

The following criteria represent the expectations placed on the resultant system after it has been implemented as well as those relating to the studies that will produce results for use in the concluding software package. These constraints will provide a clearer and more definitive tactic for defining a successful project and serve as tangible goals for completion.

3.1 Application/Software Requirements

3.1.1 Accurate BAC Prediction

The application representing the culmination of this study must be able to accurately predict a users BAC based on the deviation of their test results in order to be considered successful. But "accurate" can be a fairly inconclusive word unless it is defined. The software produced by this project will be, ideally, as accurate or more accurate than a commercially available breathalyzer. This would require the application to predict a users BAC with a certainty of +/- 0.01 at a low concentration of 0.05%. This desired level of accuracy would put the proposed testing procedure in the same league as other DOT and FDA approved methods of BAC evaluation.

No matter what the accuracy achieved through this study, the same level of accuracy needs to transfer over to the user population as it leaves the realm of the study. In other words the application must be able to maintain a high level of accuracy for individuals and demographics that were never a part of the original studies. The BAC predicting capabilities must remain effective for all users. This means that although each new user calibrates the tool for their own use upon download the data collection must continue to advance the calculations for increased effectiveness.

3.1.2 Usability

This project has the ultimate goal of developing a new method for the prediction of BAC but, although the approach being taken here is new, the idea of BAC assessment is not new. This means that to be successful this new method must out perform its alternatives in all aspects as completely as possible. All conventional methods for judgment of BAC have their flaws, as discussed in the following section, but one thing that one of the alternatives, a breathalyzer, does well is keeping the calculation process simple for the user. Since the breathalyzer could not be more straight foreword to use it is of the utmost importance that the testing progression that ultimately composes the BAC calculation tool and its various subtests are easy to understand and simple to follow.

3.1.3 Time Limit

Provoked by the same reasons for the constraints assigned to usability of the final application there must also be a limit on the time it takes to begin testing and receive a BAC approximation. The testing system should be able to be completed as quickly as possible with out jeopardizing accuracy or any other requirements in order to keep it competitive with its alternative methods. Clearly there is no conceivable way to allow this method of finding an individuals BAC to be more rapid than a breathalyzer but it can easily be formulated to out perform the more complex systems of calculation that are discussed in the following section. To be a viable option this new system should be able to be completed within a three to five minute time frame.

In addition to maximizing its competitiveness with alternative techniques for BAC evaluation the time limit design requirement is important to the systems real world convenience. The majority of people who will utilize this system of measurement will likely find themselves in a social drinking situation when they would like to know their level of intoxication. In the context of a social scene it would be inappropriate to expect individuals using this application to quarantine themselves off in a corner for an extended period of time each time they want a reading. Furthermore in the context of a social scene a user might find it far more difficult to complete a lengthy and time consuming test sequence due to a multitude of distractions. Finally, being able to receive a BAC reading in a relatively short period of time will also increase the likelihood that the tool sitting in a users pocket actually sees use and the benefits of personal BAC knowledge are reaped.

3.1.4 Cost

In keeping with the desire to create a system that is competitive with the other alternatives for BAC measurement that are commonly used it is appropriate for this system to be less costly. The breathalyzer exemplifies the most commonly used method for BAC evaluation but unfortunately for users, amongst its many other faults, it is extremely costly. Commercially available units of this popular BAC reading method are available for approximately $200 and quickly climb into ridiculous prices in the thousands boasting greater accuracy. This project and the subsequent creation of the idealized BAC predicting application requires very minimal overhead and is thus inexpensive to produce. This economy in implementation allows the low cost to be extended to the clients and potential users of the system at a price that brutally undercuts that of a breathalyzer. Offering an alternate way of receiving a BAC calculation at such an extreme price difference will allow a larger population access to these accurate readings of their impairment and hopefully allow the benefits to be amplified.

3.2 Study/Research Requirements

In order for the data gathered from the human studies that are requisite of this project to be considered relevant for use in the final product there are a number of criteria that must be satisfied by the research. The following three sections outline these necessary specifications relating to the data collection portion of the project.

3.2.1 Participants

Participants in the study will consist of 25 individuals, randomly selected out of the pool of Union College and Union Graduate College students who are determined to be regular social drinkers. These participants will be both men and women, between the ages of twenty-one and twenty-four. Although it may not be completely ideal for the candidate pool to be as limited as Union College undergraduates it makes the most sense for the sake of convenience. It is important that a separate group of students is used in the second round of study when all tests are implemented in application form. This inconsistency in participants is necessary to limit the possibility that the test results and data from the first round correlate to the individuals of the first study rather than the correlation between BAC and any potential user's test scores.

3.2.2 Environment

All testing involved in either the first or second study will be completed during regular social events where drinking is known to occur and participants in the study will be asked to step aside at a time previously unknown to them. The tests will be conducted in a location that is removed from where the drinking and socializing is occurring and will be kept constant in regards to the configuration. Prior to resuming the study on any given evening the testing arrangement will be reconstructed in an isolated room in the same fashion as all other nights. The setup will consist of placement of the video cameras in unobtrusive positions commanding a view of the table where participant and test administrator will sit facing one another. The camera will not capture the participants face in order to maintain their anonymity. It is important to keep the procedure and setting the same night after night, with the exception of slight randomizations in the subtests, as we are attempting to eliminate any outside variables. If the environment were allowed to differ between testing sessions or even with a session this could cause an unfavorable distraction of the subject.

3.2.3 Breathalyzer

The breathalyzer is unequivocally the most important material required by this study as it serves as the control and a base of comparison for every iteration of test score data. The entire study hinges on this one piece of equipment that will be counted on to always give an accurate reading so it was important to select the appropriate model for comparison. While trying to decide which breathalyzer model would become the basis for the entirety of the research the search process came down to three necessary characteristics. These three necessities were the display length (how many decimal places were shown), accuracy, and DOT/FDA approval. The model chosen for the project met these criteria with a screen displaying up to three decimal places, an accuracy of +/- 0.01 at 0.05% BAC, and boasting both DOT and FDA approvals. With instrumentation possessing these impressive statistics as the basis for comparison it is easy to hold the eventual application to these same high standards.

4. DESIGN ALTERNATIVES

4.1 Alternate Subtests and Abilities

4.1.1 Subtests

In the early stages of development of this project there were a number of tests that were removed from the pool of proposed tests to be looked at in this study. The reasons behind each subtests expulsion from the candidate group varied greatly but most eliminations were made due to over complexity issues, lack of scholarly information, or a surplus of subtests already focused on testing the same ability.

Impulsiveness Test

One of these alternate subtasks that were discarded was designed to test the impulsiveness of the user that is thought to increase with alcohol consumption. This test would have been modeled after ADD tests that establish a long and tedious pattern that the subject must follow and then suddenly breaks the pattern. A more impulsive person will miss this change and attempt to continue the previous pattern and will thus have more misses counted against them.

This test was not included as a separate test because some aspects of impulsive behavior are already incorporated in other subtests such as the "Simon Says" test that will be discussed in the following section. Additionally the research justifying this correlation was significantly lacking and there was no clear indication that there is more than speculation that the two are related.

Heart Rate

Another subtask that was eliminated early on was the idea of reading a participants heart rate in looking for a connection between this data and BAC. There is some insignificant speculation that perhaps as an individual consumes alcohol their heart rate increases up until a certain BAC and then drops off again to dangerous lows.

The reason that the determination of heart rate was excluded was primarily due to the fact that there is no compelling proof that BAC is linked to heart rate. Furthermore including readings of vital signs such as heart rate adds an unnecessary layer of complexity in both the study and the eventual application.

Maze Test

A third example of one of the many subtests that were rejected was this concept of a maze test that would have tested fine muscle control and problem solving abilities. It would have tested these two key abilities by asking users to complete a maze with out touching the walls of said maze in as little time as was required. The number of times the user collided with the walls of the maze would have then been linked to a reading of fine muscle control abilities. The time component would have provided some indication of problem solving ability degradation's relationship with alcohol consumption by comparison of completion rates for similarly difficult, randomizing, maze tests administered at different levels of drunkenness.

There were a vast number of reasons why this specific subtest was not executed in the finalized set. Primarily this subtask was not included because of the immense programming complexity that would be involved in creating a constantly randomizing maze that was able to sense wall contact. Moreover there are a number of more feasible tests for evaluating fine muscle control and problem solving skills that were implemented in the final set of tests.

4.1.2 Abilities

In addition to the subtest alternatives that did not make the final cut there were a number of abilities thought to be related to BAC that were purged before subtasks for them were even considered.

Balance

The idea that balance is negatively affected by the consumption of alcohol is not a new one by any stretch of the imagination but it presents many inconveniences for use in this project. This alcohol affected skill was thrown out from the application perspective because although a test such as holding the phone in on hand while balancing on one foot can be imagined it is not with out its detrimental flaws. The problem with judging balance begins with not being able to tell if the user is actually completing the task as assigned, on one foot. Additionally there are far too many other factors of movement in just holding a cellphone. Any lack of balance the phone perceives could simply be related to hand, arm, or other bodily movement allowed while maintaining a single leg stance and not actually due to a loss of balance.

Impaired Speech

Although there is significant research to support the idea that speech is affected by acute alcohol intoxication this testable ability was almost immediately dismissed. The foremost reason for this rapid expulsion from the list of abilities was due to the current state of speech recognition technology. Since speech itself is highly complex and varies heavily from person to person speech recognition technology is still in its infancy. It could take years to develop a method by which a mobile phone would be able to detect if a users speech could be considered "slurred" (sign of intoxication) or varied in any other way related to BAC.

Analgesia (Dulled Pain Perception/Senses)

Like impaired speech, it is well documented, but difficult to test, the fact that the senses, specifically pain perceptions, are dulled by alcohol. Again like impaired speech the concept of assessing a users level of acute analgesia was immediately removed from the list of testable abilities. Not only was this attribute removed rapidly due to the complexity associated with pain judgment due to variances in individual's level of pain tolerance but it's testing also runs into ethical implications. In short, it simply is not ethically sound to inflict pain on a subject for the sake of study.

4.2 Alternate Approach

4.2.1 Explicit Input

There are equations out there that allow a user to input the exact number of beers, shots, and glasses of wine that they have consumed and over what length of time to receive a BAC reading. These complex calculations also require the input of personal information such as weight and gender to increase their accuracy. In an attempt to simplify this process these equations have been embedded in simple to use calculators (see figure 1 below) that are strewn across the internet and wireless device software markets but they are not without a large number of flaws.

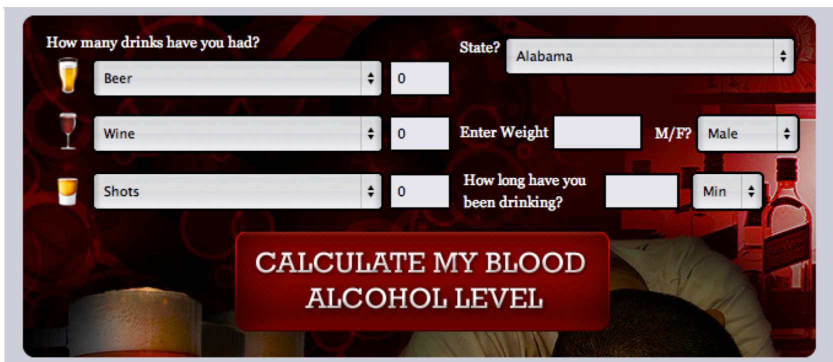

Figure 1: BAC Calculator Example

(Courtesy of: “bloodalcoholcalculator.org”)

The prime motivation for not following this approach is because of just how inaccurate and sensitive to error it can be. This is not to say that the equations themselves are flawed but the broader system as a whole is faulty. The primary reason for this methods failure is due to its extreme vulnerability to human error that is only magnified by alcohol consumption. An intoxicated individual will more than likely have difficulty with remembering precisely how many drinks they consumed in a given evening or exactly when they had their first drink. It is in this state of forgetfulness when mistakes begin to occur and it is all the more imperative to get a proper read on a users BAC but when it matters this method falls short.

The other reason why this method was not an ideal candidate for pursuit is most simply because it has been done before. This option for obtaining a BAC approximation has been implemented in every form imaginable and its flaws are glaring, leaving no logical reason for its further study.

4.2.2 BAC Chart

One exceedingly basic approach to the problem of BAC approximation comes in the form of an alcohol impairment chart. (see figure 2 below) Despite being the most fundamental form of BAC calculation it is still plagued by its fair share of flaws. In practical use its weaknesses are similar to those faced by the BAC calculator approach. The major drawback of having a drunk person use a table such as this is it still requires them to have kept track of their drink intake as well as time spent drinking. Inaccurate use of these tables is only further confounded by confusion regarding exactly how to read the table and the method of adjustment for the number of hours of drinking.

BLOOD ALCOHOL LEVEL FOR MEN

DRINKS	BODY WEIGHT IN POUNDS							
	100	120	140	160	180	200	220	240
1	.04	.03	.03	.02	.02	.02	.02	.02
2	.08	.06	.05	.05	.04	.04	.03	.03
3	.11	.09	.08	.07	.06	.06	.05	.05
4	.15	.12	.11	.09	.08	.08	.07	.06
5	.19	.16	.13	.12	.11	.09	.09	.08
6	.23	.19	.16	.14	.13	.11	.10	.09
7	.26	.22	.19	.16	.15	.13	.12	.11
8	.30	.25	.21	.19	.17	.15	.14	.13

= SLIGHTLY IMPAIRED — "BUZZED"
= IMPAIRED TO SEVERELY IMPAIRED

SUBTRACT ROUGHLY 0.015% FOR EACH HOUR OF DRINKING.

Figure 2: BAC Chart Example

(Courtesy of: "alcohol.stanford.edu")

5. STUDY DESIGN

This research undertaking was easily broken down into three essential stages. First there was a study that administers physical (on paper) and low fidelity program prototype versions of the proposed tests, derived from alcohol's affects on the body. After this first round of testing the subtests found to most efficiently correlate to BAC calculation were actually implemented in the final application. Following this first round study there will be a second user study to receive participant feedback as well as to validate the accuracy of the application and advance its accuracy. In comparing the applications derivation of the users BAC and the commercial breathalyzer's result we were able to definitively declare the there was a significant correlation between the two.

The start of this entire process began over the summer recess with the programming of the tests that were too complex to do in a physical manner; the low fidelity computer based prototypes. For the majority of the tests that were being considered there were foreseeable methods to accurately mimic their function and accuracy in a physical prototype such as on paper but there are a select few that were not this simple. The first round human trials proceeded with the mixture of these physical and virtual prototypes beginning in the second week of the winter term. By the eighth week of the winter term all of the tests that seemed hopeful from this study had been evaluated and programmed into the final application. This study was completed with 21 Union College students of legal drinking age who submitted one sober trial score as well as 1 to 4 intoxicated trials. As an assessment of the subtests usefulness in predicting BAC users test scores and subsequent predicted

BAC were compared to the breathalyzer data. As a final evaluation of the virtual subtests accuracy and function we plan to execute the second user study throughout the coming year (2012-13).

In the following year this final evaluation of the work that has been completed in an effort to answer the proposed question will commence with a larger group than that of the previous study. The second study will also make use of the same style of performing the test and comparing its result to that of a breathalyzer. The only deviation from the preliminary study will be that the entire set of subtests will, by this point, be fully integrated into an android powered device. In addition to boosting the accuracy and subsequent success of the application users will be asked for feedback on the usefulness, usability, and appeal of the final product for later revisions.

5.1 Memory Impairment

Through a large volume of studies that have been done on the effects of alcohol it is clear that there is a strong correlation between blood alcohol content (BAC) and memory degradation. [5][7][8] Although it is widely accepted that memory is impaired when a person drinks too heavily there is no agreement on why. Some studies have suggested that different doses of alcohol affect different brain regions and that high doses affect the hippocampus that processes memory. Other studies have cited a slowed metabolism of glucose in the brain, specifically in the occipital lobe and cerebellum. [5]

Previous work:

Schweizer and his collogues studied a number of cognitive processes related to memory and thought to be impaired by alcohol. These abilities included but were not limited to short-term and long-term verbal and visual memory, visual-spatial working memory, and immediate working memory. They speculated that alcohol-induced impairment of these memory processes would be demonstrated in a decline in performance from baseline for the twenty male test subjects. After running the study that consisted of nine tests designed to detect a concussion it was found that four of the nine cognitive processes they studied were notably affected for rising BAC. While only seven of the nine were significantly deteriorated for rising or declining BAC all nine cognitive abilities were at least marginally impaired. Schweizer states that the effect of alcohol on these processes that were not shown to be significantly degraded was most likely because the effects are more subtle than the concussion symptoms that the tests were designed for.[7] This demonstrates that although Schweizer et al were interested in testing processes that have been proven to be effected by alcohol they were not using the correct methods to observe this correlation. Finer grain and more directed methods of studying these mental processes are clearly required to quantize this relationship between memory degradation and BAC.

The task of judging an individuals level of memory impairment was handled by two separate sub-tests. The first of these sub-tests is the **"Simon Says"** test that requires the participant to play a color pattern memory game similar to the electronic "Simon Says" game that was popular throughout the 80s and early 90s. The second memory subtest took on the form of a number of **questions** pertaining to other portions of the over all test interspersed between various sub-tests. Questions were posed in an explicit as well as implicit fashion. In other words for some questioning the study participant was aware of what they were going to be asked (explicitly asked to remember) and at other times they were caught off guard (implicit recall of a fact). [7]

5.1.1 Simon Says

The "Simon Says" test was used to evaluate short-term visual memory in a quantitative manner by looking at the number of rounds that a test subject completed. The game consisted of four colored quadrants as shown in figure 3 below. One round of the game entailed one or more of the quadrants lighting up in a random sequence, to which the participant was required to respond to by clicking the same order of quadrants thus reproducing the pattern. At the start of each new round the sequence became one longer and the cycle was repeated until the user incorrectly attempted to reproduce the pattern.

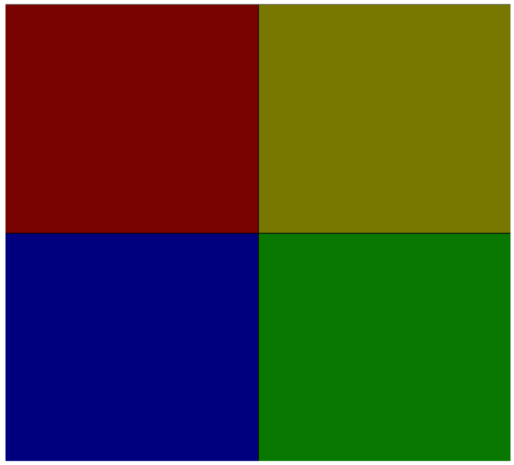

Figure 3: "Simon Says" quadrants

Measures:

- Number of rounds completed
- BAC at time of test

5.1.2 Questions

The questions subtest was designed to assess an individual's ability to explicitly as well as implicitly remember certain facts. These subtasks were designed to evaluate short-term and long-term verbal, visual, and declarative (explicit) memory as well as immediate working memory. In the implicit case the participant was asked to recall a number of predetermined facts about other subtests or small details of the over all test such as the first color presented in the "Simon Says" subtest. In the explicit case of this subtest the subject was given a randomized string of words or numbers of a set length and their recall of this series was measured. Both the implicit and explicit versions of the questioning subtests were evaluated in a similar fashion. They were first evaluated for accuracy (percentage correct) in the sense that the number of letters or numbers correctly recalled out of total string were noted.

Measures:

- Percentage of correct answers
- BAC reading at time of test

5.2 Problem Solving Ability Impairment

Based on the significant number of studies linking memory deficiencies as well as problem solving ability degradation to acute alcohol intoxication the two are affected in a similar fashion. Like the reasons for alcohols on memory the reasoning behind its affects on problem solving are not fully understood. It is highly debated whether it is only alcohols affects on the early stages of information processing that cause these deficiencies via a domino effect on later stages or it is total information processing that is affected. [8][5][7]

Previous work:

In Schweizer's study he not only studied the affects of alcohol on cognitive abilities such as memory but his study also crossed into those cognitive processes related to problem solving. Similar to memory degradation, Schweizer et al concluded that the problem solving cognitive abilities of the test subjects were equally affected. [7]

5.2.1 Math progression

The math progression subtest assessed a participant's problem solving cognitive functionality by asking them to complete a set of simple mathematical equations. Different skill levels in mental arithmetic were compensated for through the base-lining process that each user completed in a sober state before any readings are taken. Each equation consisted of five numbers smaller than ten and each of the four simple operators (+, -, ÷, ×). Each equation was different than the others in the set in the sense that the numbers used were varied and the operators were not in the same order with the same set of numbers. It was desirable for each equation to only make use of numbers less than ten and the same set of four simple operations to maintain a constant level of difficulty between variations. The test began by revealing the first number and after a short delay the operator to be applied to the first revealed number followed by the second number after an additional brief delay. The result of this first calculation and the subsequent calculations was referred to as the "running total" and the next operator reveled was applied to this value in conjunction with the following number. This pattern of reveling a number, an operator, and another number was repeated until the fifth and final number had been revealed and the participant was asked for their final answer.

A short "pilot study" was done in this fashion in order to determine an appropriate delay between subsequent revealed operators and numbers. The study consisted of a sober trial of four different equations of equal difficulty as defined above. One equation was calculated using a quarter second delay, the second used a half second delay, the third used a full second, and the fourth used two seconds. From this brief study a delay of half a second was decided upon.

Example: (each new line represents a time .5 seconds after the one above it)

2
2 +
2 + 8 (=10)*
2 + 8 ÷
2 + 8 ÷ 5 (=2)*
2 + 8 ÷ 5 ×
2 + 8 ÷ 5 × 6 (=12)*
2 + 8 ÷ 5 × 6 –
2 + 8 ÷ 5 × 6 – 2 = **10****

*The values in red correspond to calculations that would be done in the test subjects head. (not revealed to the subject)

**The value in green corresponds to the answer that the participant would have been expected to give. (not revealed to the subject)

Measures:

- Percentage of correct responses
- BAC at time of test

5.2.3 Mental rotation

The mental rotation subtest like the previous subtests was designed to evaluate the cognitive abilities of a test subject. In this case the task was formulated to test an individuals visuospatial abilities. The test consisted of the subject being given one image of an object with a single perspective ("base image" on the left) and three other images with the same or similar objects seen from various perspectives. The participant was then asked to compare the "base image" to the three alternate images and decide which one was the same object but shown from a different perspective and which two were entirely different (see figure 4 for clarification). One comparison image always matched the "base image" while the remaining two did not match the "base image" or possibly one another. This subtest consisted of one image matching trial per trial set.

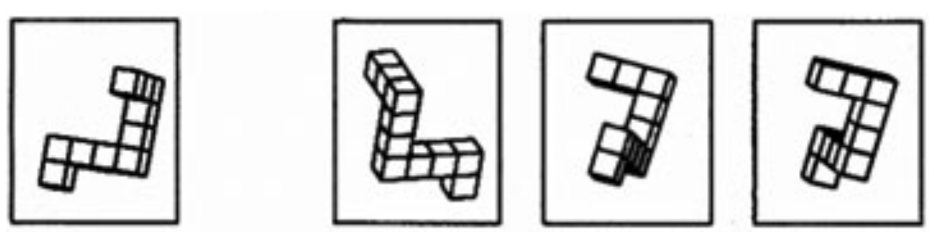

Figure 4: Mental Rotation Images

Measures:

- Percentage of correct responses
- BAC at time of test

5.3 Acute Ataxia (degradation of fine motor control)

Although problem solving and memory cognitive functions begin to be affected at relatively low levels of BAC (about .10%) marked degradation of fine motor control does not show up until higher levels of intoxication. Along with more severe cognitive impairment notable acute ataxia begins to show up at BACs of .15% and greater. [11]

5.3.1 Dot following

The dot following subtest measured a test subject's ability to complete a basic task that required a great amount of fine muscle control/dexterity. The participant was asked to place a finger on a dot slightly smaller than the average fingertip so that they may keep it covered to the best of their abilities. The dot started on the left side of the screen after a countdown from three. As the dot moved from left to right across the screen, following a randomized black line (figure 5 below), the user followed it with their finger maintaining coverage. The duration of time the dot was not covered was counted against them and success was evaluated as a percentage of time covering the dot as a fraction of total time. During the study this subtest was video recorded for later analysis of effective covering of the dot.

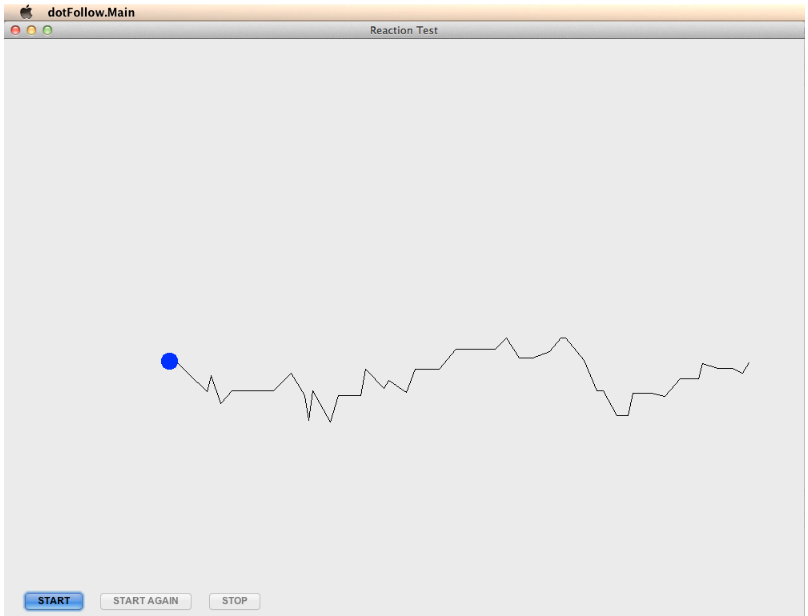

Figure 5: Dot Following Line

Measures:

- Percentage of time finger was not covering the dot
- BAC at time of test

5.3.2 Shape draw

The shape draw subtest was also designed to assess the fine motor control abilities of a participant in the study but allowed for time as well as accuracy to become factors. The test consisted of just three geometric shapes (square, right triangle, and circle). The object was for the individual taking the test to trace within the outline of the shape starting at a point of their choosing and ending at the same location (example shown in figure 6 below). Furthermore the test taker was required to do so as quickly and with as little error (traced line outside of the shape) as possible.

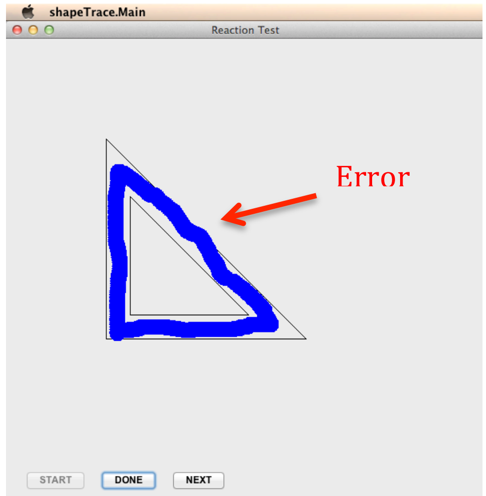

Figure 6: Shape Trace Example From Computer Application

For the purpose of the first round of testing this task was run using these shapes printed out on paper and a large flat tipped marker (used to mimic a finger on a touch screen) for tracing. Placing a transparent piece of graph paper over the drawn image and simply counting the number of squares outside the lines determined the error rate. Video data was also collected in this experiment.

Measures:

- Amount drawn outside of shape outline
- BAC at time of test

5.4 Diplopia (blurred vision)

High doses of alcohol have been found to slow the thalamus that helps to deal with sensory and motor information and thus affecting vision. Additional studies linking alcohol intoxication to visual deterioration have cited a decrease in glucose metabolism by 29% in the occipital lobe in late stage drunkenness. The visual cortex resides in the occipital lobe, which may explain the blurred vision at high levels of BAC. [5] Unlike the many other affects of alcohol that begin to manifest themselves in earlier stages of intoxication, diplopia does not begin until BAC passes .20%. [8]

5.4.1 Line counting

The line counting subtest examined the vision of a test subject to determine their level of vision impairment. This task consisted of a grouping of horizontal lines with equal lengths but a fluctuating number of lines of a constant thickness per group (see example in figure 7 below). Additionally the distance between individual lines in any one grouping was held constant to eliminate the impact of extraneous variables.

Figure 7: Line Test Example

Once presented the line grouping the participant was asked to count the number of lines in the grouping as quickly and accurately as possible.

Measures:

- Accuracy of response
- Percentage of correct responses
- BAC at time of test

5.5 Delayed reaction time

Another inhibiting affect of alcohol on the body, degradation in reaction time, is closely related to the same causes of memory and problem solving cognitive degradation. Surprisingly alcohols affect on reaction time begins with blood alcohol concentrations as low as .05%. [8]

Previous work:

Tzambazis saw this correlation between memory, cognitive ability, and reaction time. She hypothesized that it was deterioration in the speed of detection under conditions impaired by alcohol that contributed further to delays in memory access and problem solving. Her study looked at affects of alcohol on total information processing that involves high-order cognitive abilities as examined by the Wechsler Adult Intelligence Scale - Revised (WAIS-R). She also assessed early stage information processing that is dominated by reaction time and inspection time abilities. She was able to conclude from her study of eight males and eight females that, among other observations, both simple and complex reaction time was significantly longer with alcohol consumption. [8]

5.5.1 Random Dot

The Random Dot test simply and quickly obtained a participants reaction time. This test consisted of a computer application that displayed a window with one large dark green circle in the center representing a light that was off as demonstrated in figure 8 below.

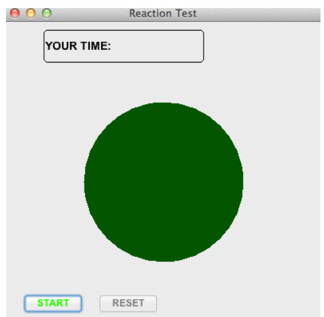

Figure 8: Dot Reaction Timer

The participant in the study was asked to click the "start" button in the lower left hand corner of the window when they were ready. The green "light" represented by the darkened circle illuminated after a randomized delay and the user was instructed to click the "stop" button or tap the space bar as quickly as they could after it illuminated. The "stop" button replaced the "start" button in the lower left corner after the "start" button was clicked so that the participant did not need to move the cursor. If the user pressed "stop" or tapped the space bar too soon a "fault" was counted, a red light illuminated where the green used to be, and the subtest was restarted. If the "stop" button was pressed after the green light had illuminated then the individuals "reaction time" was displayed at the top of the screen after the heading "YOUR TIME:"(see figure 9 below for examples of these two cases). This happened a total of 4 times and an average of the 4 times was taken.

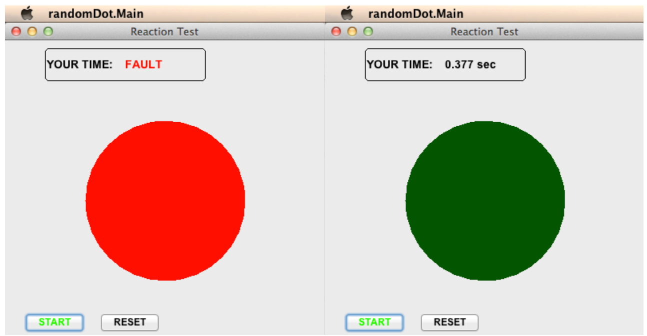

Figure 9: Random Dot Test Fault and Success Examples

Measures:

- Reaction time as measured by application
- Number of faults (if any)
- BAC at time of test

5.5.2 "Whack-a-Mole" or 9 circle

The "Whack-a-Mole" or nine circle subtest was also designed to test a participant's reaction time in conjunction with a fine muscle control component to the test. The test was comprised of nine circles in three rows of three. When the test began one of the nine circles turned red. In a random pattern the previously red circle returned to neutral and a new (or same circle) was illuminated in red as shown in figure 11 below.

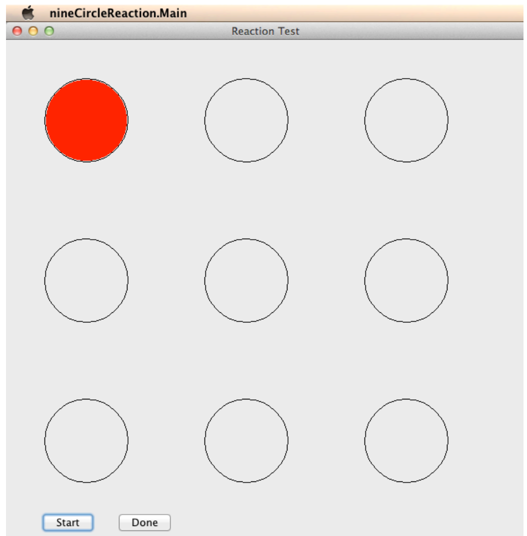

Figure 10: Nine Circle Reaction Test

In total there were ten red circles illuminated throughout the duration of the task and each remained illuminated for two seconds. The goal on the part of the participant in the study was to place their finger over the red circle before it returned to the neutral background color. This test like the others was video recorded in order to determine the subject's accuracy and ability to reach the illuminated circle in time.

Measures:

- Number of misses (if any)
- BAC at time of test

6. RESULTS

At the conclusion of the first round of human studies conducted throughout the winter term of 2012 the raw data needed to be analyzed to determine if the initial, motivating question was answered. After careful analysis of this data utilizing a number of statistical analysis tools it was concluded that the research had, indeed, uncovered a strong indicator of BAC or level of intoxication. The data analysis also yielded an equation for the prediction of intoxication level as a function of test score deviation.

6.1 Data Assessment

The first evaluation method that we applied to our data was the T-test. A T-test is used to gauge weather or not the means of two different groups of data are statistically different from one another. Here, the T-tests indicated that there was a significant effect of blood alcohol content on test scores, t (20) = 3.66, p = .002, such that cognitive task scores differed as a function of BAC. There was a relationship between participant's cognitive task scores and BAC, β = -.64, p = .002, such that test scores predicted blood alcohol content. BAC also explained a significant proportion of variance in test scores, R^2 = .41, F (1,20) = 13.42, p = .002, such that a significant percentage of decrease in test scores can be attributed to a rise in blood alcohol content (figure 11). The scores were found to be reliable, α = .75. These results clearly indicated that the scores resulting from the cognitive tests used were accurate measures of blood alcohol content.

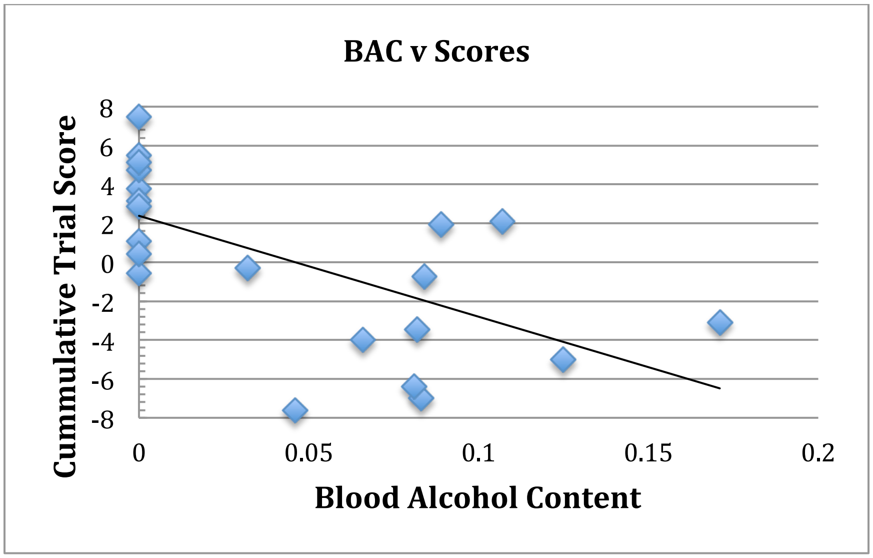

Figure 11: BAC v Scores Plot

6.2 Task Elimination

Three tasks were eliminated from the series of cognitive tasks used in the application due to the nature of their results after the user study. Both Dot Follow and Whack-a-mole were eliminated because of a likely Type-2 error, or "miss". In the case of these two tasks, the data yielded was not found to be statistically significant. There probably was a real world effect, such that as participant blood alcohol content increased, scores on the two tasks decreased. However, this effect was not shown in our results. This could be due to a fault in the degree of precision that the tasks were measuring. If this degree was too precise or specific, it is likely that the effect was missed. This is acceptable, because reaction time (assessed through Whack-a-mole) and hand-eye coordination (assessed through both Whack-a-mole and Line Trace) are tested in other cognitive tasks throughout the application. One of the three explicit questioning schemes, word series memorization, was eliminated as well for the same reasons. This exclusion leaves two types of explicit questioning tasks, number and letter series memorization, in the final application set.

We currently have narrowed down the finalized set of application tests to include seven cognitive tasks that still evaluate problem solving, memory, blurred vision, fine muscle control, and reaction time. The user study allowed us to get a clear sense of which tasks yielded the strongest correlational data and related best to intoxication level prediction.

7. FINAL DESIGN AND IMPLEMENTATION

Throughout the 2012 winter term, while the human studies were being conducted, the application was being built in parallel with the studies. The first tasks to be programmed into the final application were those that seemed to be well correlated to blood alcohol content based, loosely, on unofficial observations made during a handful of the initial human trials. This method of parallel development was implemented in an effort to maximize the short amount of time allotted for the project. This method avoided unnecessary programming work by observing the studies being conducted in an attempt to predict what the results may indicate about each of the proposed tasks being tested in the study. Based on these preliminary speculations on the direction of the study as well as the final results a total of 8 different types of cognitive ability testing tasks were programmed into the Mobile Intoxication Assessment Tool.

7.1 Memory Impairment

Memory impairment is tested by three types of tasks that fall into two categories in the application. These three types of sub-task in the application test the user in much the same way that participants were tested during the study. The memory impairment effect of alcohol consumption is currently tested by the “Simon Says” task and the two questioning methods (implicit and explicit).

7.1.1 "Simon Says"

The application version of "Simon Says" functions in much the same way as the java prototype version that was used during the study and tests the same memory abilities. As shown in figure 12 below the "Simon Says" screen of the application consists of the same 4 color quadrants in the same locations as the low fidelity java prototype version. Also like the on computer prototype test, the task presents a color pattern that the user must reconstruct to the best of their abilities.

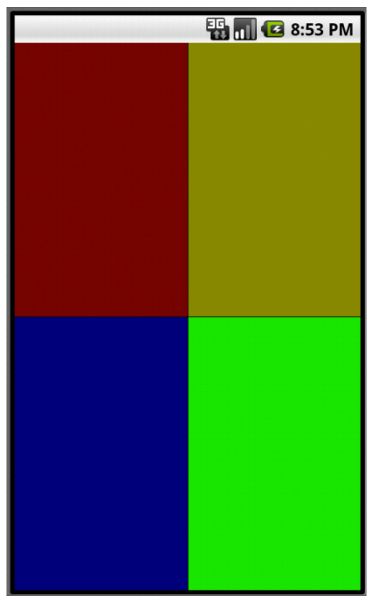

Figure 12: "Simon Says" (application version)

A score for this sub-task is computed by simply counting the number of correct rounds that the user completes (corresponding to length of longest pattern) before failing. This pattern length score is then normalized, based on all study participants data, for use in the scoring of the total set of tasks.

7.1.2 Interspersed Questions

7.1.2.1 Implicit

The implicit questioning portion of the application is the same as the style of questioning that was used in the study. The only change from the prototype version of this sub-task to the application version is the change in presentation and response methods. In the study the question was read by the participant from a piece of paper and written on the same paper. In the application, as can be seen in figure 13 below, the question is posed on screen and the users answer is provided in the orange highlighted box provided below the question.

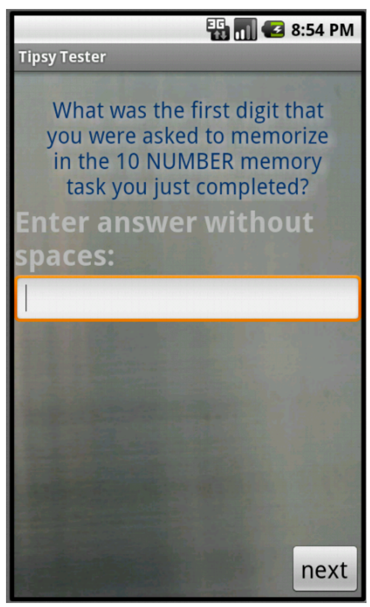

Figure 13: Implicit Questioning

In the current format of the application testing sequences there are a total of two implicit questions interspersed between the other tasks. The score for this sub-task is simply either one point added to the users previously accumulated implicit questioning score or zero points added to the composite implicit questioning score. In other words if the user answers correctly then they gain one point on their pre-normalized implicit questioning score but if they answer incorrectly no points are added. After both implicit questions are answered the subject's score (either 0, 1, or 2 points) is normalized for use in the scoring of the total set of tasks.

7.1.2.2 Explicit

Like the implicit questioning, the explicit questioning portion of the testing process is of the same style that was used in the human studies except for the method of question display and answer acceptance. As can be seen in figure 14 below the explicit questioning task took on two separate forms. This task either consisted of a set of 10 letters or 10 numbers that were displayed to the operator for exactly 15 seconds. After the 15-second time limit in the study the letters or numbers were covered by another piece of paper and the user was asked to rewrite the string to the best of their abilities. In the application version, after the 15 seconds has elapsed the 10 character string disappears and is replaced by an answer box in which the user must recreate the string.

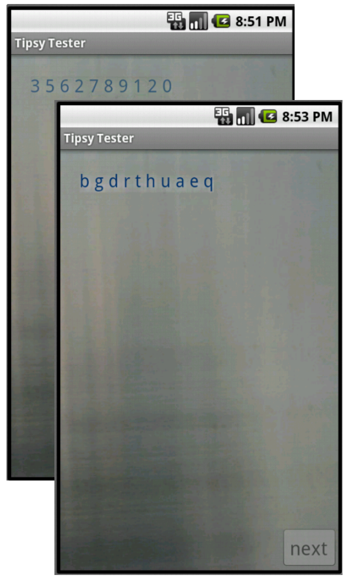

Figure 14: Explicit Questioning

Each test sequence currently contains one type of each explicit questioning type (1 letter and 1 number) interspersed between the other tasks of the progression. Unlike the implicit questioning method of scoring the explicit questions are not a cumulative score for the two different instances presented to the subject. Each type (letter/number memorization) is scored separately out of 10 and normalized separately for later use in the scoring of the total series of tasks.

7.2 Problem Solving Ability Impairment

7.2.1 Math Progression

The application version of the math progression sub-task utilized the same style of equations as the studies. This means that all calculations resulted in integers, each operator (+, -, x, /) was used once, and only single digit numbers were presented in the equation. During the human studies, slowly sliding a blank sheet of paper over another page that had the equations printed on it revealed the equations. In the study sliding the blank page to the right after a short delay revealed one digit or one operator at a time until the equal's operator was shown and the user was asked to provide an answer. In the application version this single digit or operator reveal process was done by sliding the entire equation string in from right to left and fading it out after the entire equation has been shown (figure 15). After the completed equation disappears an answer box appears to receive the user's answer.

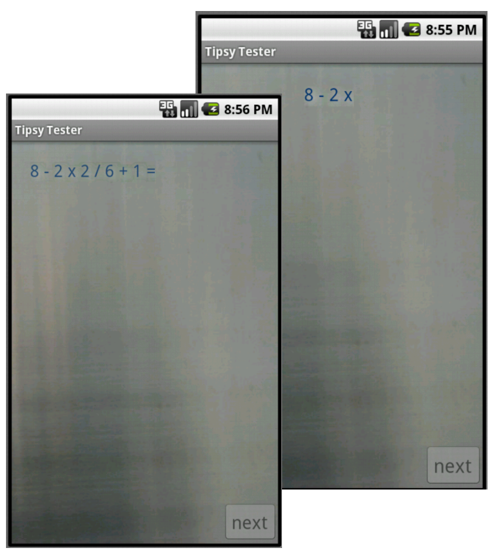

Figure 15: Mathematical Progression (application version)

Each participant in the study completed a total of 10 math progressions per testing session but the application version currently only contains 5 progressions per testing set. Each of the progressions is scored to be either correct or in correct, earning 1 point or 0 points respectively and their cumulative score on the 5 sequences (0 – 5 points) is normalized for use in the scoring of the total set of tasks.

7.2.2 Mental Rotation

The programmed version of the mental rotation sub-task most clearly resembles the physical prototype version of the same task used during the human studies. During human trials each subject was presented a set of 4 images, as is shown in figure 15 below, and asked to pick the one on the right that represents a rotated version of the image on the left. The application version of this task makes use of the same images that were used in the study and only differs from the physical prototype version in the answering style. The method of circling the correct answer that was used in the studies is simply replaced by three buttons in the Mobile Intoxication Assessment Tool as can be seen in figure 16 below.

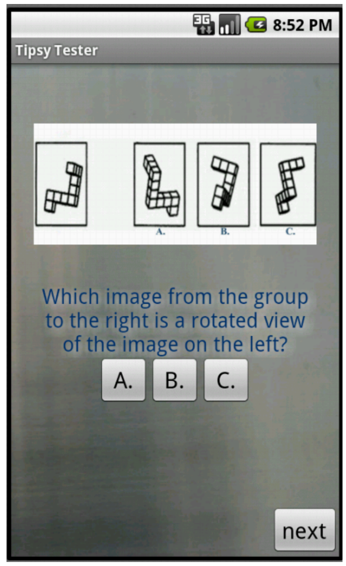

Figure 16: Mental Rotation (application version)

As was true in the study, the user completes one mental rotation task per testing sequence for which they receive 1 point for a correct response or 0 points for an incorrect answer. The users score on the mental rotation sub-task is also normalized for the final scoring of the testing sequence.

7.3 Acute Ataxia (degradation of fine muscle control)

7.3.1 Shape Draw

The version of Shape Draw that was implemented in the final version of the application was also very similar to its physical prototype counterpart. The same three geometric shapes, approximate path widths, and traced line widths were used in both versions. As was true with the prototype version the user is asked to trace within the lines of the shape to the best of their ability. In the study a marker with a flattened tip of the same diameter as the line width used in the application was used to trace within the shape outline. In the application version the marker (that was meant to mimic a finger) is replaced by the user's finger. The test begins when the user first touches the screen and ends when they lift their finger off the screen so as in the human study the user is asked to make one continuous line. As can be seen in figure 17 below, the application allows the user to easily see when they have gone outside of the shapes bounding lines as the traced path changes color from dark blue to bright orange.

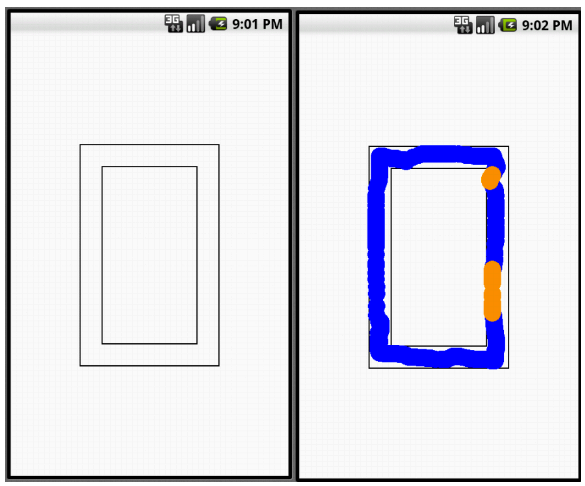

Figure 17: Shape Draw (application version)

Scoring of this sub-task was slightly more complex than the other tasks as there was no straightforward right or wrong answer. Unlike the other tasks a users score here has negative connotation because it is the number of instances and duration of the instances in which the users finger exits the shape outline. To quantify this relationship and calculate a score the number of individual circles (the traced line is made up of a multitude of closely spaced circles) that fall outside the shape (orange) is noted. This score fits with the other scores of the total sequence after it is normalized based on the total set of user data giving it a positive correlation like the others.

7.4 Diplopia (blurred/ double vision)

7.4.1 Line Counting

The application version of the line counting sub-task is another example of a close physical prototype to application version relationship. During the study each participant was asked to view a grouping of lines and write down the number of lines that they saw. The application version is no different in the presentation of the line groupings but does vary in the method of answer reporting. The programmatic form of the line counting task utilizes the same images, displayed on screen, that were presented to the subjects of the study on paper but in the application a scrollable menu of possible counts is used to answer (figure 18).

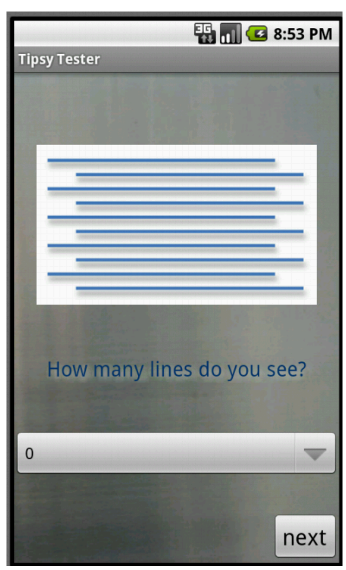

Figure 18: Line Counting (application version)

In the study each test sequence consisted of 4 line counting examples but the application version only uses half of this amount per test sequence. The 2 line counting tasks in each application test progression are randomly placed amongst the other tasks. For this task the user is awarded either 1-point for a correct answer or 0 points for an incorrect answer and it is the accumulation of the score on both versions that is normalized for later total scoring.

7.5 Delayed Reaction Time

7.5.1 Random Dot

The application form of the 4-trial random dot reaction timer (random dot) is nearly identical to its low fidelity java prototype version. As in the java prototype, the task is started and the large, dark circle in the center of the screen lights up 4 distinct times (figure 19). The user reacts to the changing of the circles color (lighting up) in the prototype version by tapping the space bar but in the application version the screen is tapped to stop the timer. The time between the circle lighting up and the user stopping the timer is registered as their reaction time. A total of 4 reaction times are gauged and an average is calculated.

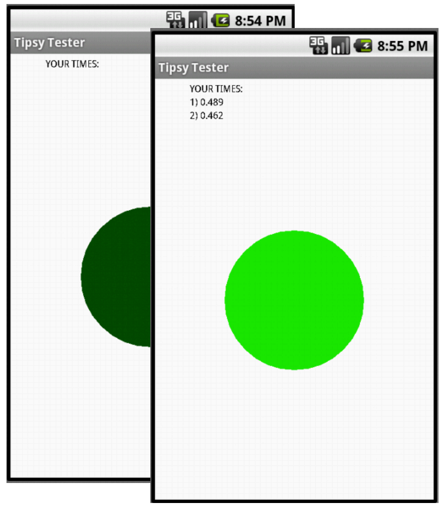

Figure 19: Random Dot Reaction Timer (application version)

Scoring of the reaction timer sub-task is done in the application, as it is done in the prototype version, by taking the average of the 4 reaction time readings provided by the user's tapping on the screen. This average reaction time is normalized, just as all the sub-task scores are, for use in the total sequence scoring.

8. PRODUCTION SCHEDULE

Time management and proper scheduling in a project of this magnitude is absolutely crucial and can very easily make the difference between success and failure. As is to be expected with an undertaking of this caliber and size there was an ideal schedule laid out but this is not the schedule that ended up governing the flow of the project. This endeavor began, in an unofficial capacity, in the summer of 2011 and officially drew to a close at the conclusion of winter term 2012. Although the end of the winter term was the official end date for the projects in terms of its scholastic motivation, we have plans to continue our research and development of the Mobile Intoxication Assessment Tool. This continuation of the venture into the future as is addressed later in the “future work” section (section 11).

8.1 Spring/Summer (2011)

In hindsight, the aspirations that we had for the summer before the project officially began were slightly too extensive, given other time commitments. Major work on the project began in the summer however some initial research and development of potential cognitive ability tasks was done in the spring term of 2011 and as early as the winter term of the same year. When principal work began on the prototype tasks it was planned that all of the prototypes that were preliminarily designed in the spring term would be implemented as low fidelity java prototypes by the conclusion of the summer.

As work progressed, starting with the most complex tasks, it became clear that it was unnecessary for some of the more simple tasks to be programmed as java prototypes. The schedule was quickly revised to reflect this revelation and producing low fidelity java prototypes for those tasks that were deemed too complex to do on paper became the main focus at this stage. Keeping in line with the revised timeline, the 5 tasks, which were deemed, too complicated to do in a physical manner were finalized and exported as individual executable jar files. Unfortunately with the main focus directed at finishing the set of java prototype tasks the remaining 4 prototype tasks, which took on a physical form, were not completed before the start of the 2011 fall term.

8.2 Fall (2011)

With the official start of the project for the 2011-2012 school year we were already behind based on our original schedule that had our first round of study beginning in the fall. During the fall term we set out to complete the remainder of our preparation for the study, complete one round of human trials, and have the application programming started.

The physical prototypes and variations of each were designed, implemented, and printed very early in the term and the final preparations for the first round of study were also made in a timely fashion. Regrettably, due to other unforeseen delays we were not able to conduct the study we had planned on during the fall term but we did have a fully planned and designed study ready to be executed at the onset of the following term.

As for the application development portion of the project we were still on schedule but it was quickly noted just how extensive the task of creating an application from the ground up would be. As our goals for the term dictated, we were able to have a significant amount of the application programming process underway by the close of the fall term. Additionally the lengthy, 6 week, winter recess of Union College allowed for further progress to be made on the application.

8.3 Winter (2012)

At the start of the 2012 winter term the project was again behind based on the initial time estimates and further concessions were required to regain ground. Our primary planning of this project and its subsidiary human trials had indicated working to complete two separate studies, the second of which was intended to be completed during the winter term. We additionally set out in the winter term to have a working prototype version of the Mobile Intoxication Assessment Tool by the completion of the term.

With the realization that a pair of studies could not be squeezed into 10 weeks the approach going forward was modified to direct focus toward just one pivotal study. The second study, on the other hand, that had been designed to assess the application and the underlying equation or BAC prediction accuracy was moved to future work. Throughout the first couple of weeks of the winter term effort was concentrated on recruiting students to participate in the study. In the following 5-6 weeks the human studies were conducted utilizing the mixture of java and physical prototypes. During the final weeks of the term attention finally shifted to analyzing the results of the study to determine an answer to the primary question and the development of an equation relating score deviation to BAC. Delightfully, an exceptionally strong correlation between the BAC readings, received from the breathalyzer, and the participant's deviation in test scores was found. It was possible, from this study, to conclude that it was possible to predict BAC from the proposed cognitive ability tasks as well as develop a rough equation for the relationship.

The success of the project was extended into the application programming side in addition to the shocking results of the study. By approximately the 8th week of the winter term the application, in its current state, was assembled with the finalized set of cognitive ability testing tasks. After analysis of the study results were compiled, it was possible to determine an equation relatin performance to BAC by first normalizing each of the individual task scores and adding them together. This composite was then applied to a linear equation, the x-intercept of which was shifted based on the users performance on their sober round of testing. Ultimately this yielded what a rough approximation of BAC. The coarseness of the equations predictions was to be expected with the relatively small pool of data that was collected. This equation in its current form would probably benefit from limiting its precision going forward and instead offering an approximate BAC range for the time being. Another study with a larger test group in the future will provide for the greater accuracy we are looking for in the equation's ability to predict BAC and allow a shift back to providing a single BAC reading.

9. COST ANALYSIS

9.1 Project Costs

In comparison to the majority of other senior projects this project was relatively low cost at a total out of pocket expenditure of $220 (Table 1). Costs were allowed to stay low due, in part, to the computer science department's generosity in allowing us to borrow an Android phone that had been previously purchased. Additional, funds were saved because no monetary reward for the participants in the study was required to motivate involvement. The largest expense was the breathalyzer but this device can be reused in a similar capacity in the large-scale study that is planned within the next year that promises to be far more costly.

Supplies	**Cost**
Paper and ink for physical tasks	$10
Washable markers	$4
Binders (25)	$86
Breathalyzer	$120
Total:	**$220**

Table 1: Project Costs

9.2 Price Setting for Application Release

The plan going forward regarding the application is to market and sell a finalized version of the Mobile Intoxication Assessment Tool. The release will only occur once the appropriate level of BAC predicting accuracy is achieved through the large-scale study that is slatted to run over the coming year, a version for the iPhone platform is created, and both versions are virtually bug free. The eventual release of the application to a broad user base on two separate platforms begs the question of what price to charge for the tool. We hope to answer this question by completing a short market analysis study. The plan is to go to a public location, such as a mall, and briefly interview individuals in our target demographic. The interview process will demonstrate exactly what the application does and then gauge the individual's willingness to pay a series of different prices. In other words after explaining the device we could ask: "would you pay $0.99 for this? $1.99? $2.99?" and so on until we discover a price that nobody would pay. To be certain that we are asking the correct types of people these questions we will also record anonymous personal data such as age and gender. The final price that will be charged is inevitably the price that allows for the greatest profit calculated by multiplying the number of votes for each individual price point by that price.

10. USER'S MANUAL

The Mobile Intoxication Assessment Tool (or "Tipsy Tester") is a mobile application that has been designed to judge an individuals level of intoxication based on a set of cognitive ability tests (or tasks). This set of tasks is designed to measure 5 specific effects of alcohol consumption on the human body that have been shown by our research to correlate well to level of inebriation. Particularly the users fine muscle control, memory, and problem solving abilities as well as their visual capabilities and reaction times are tested. The testing is administered as a progression of on screen tasks that automatically score the operators performance. The user receives an aggregate score on the total set of tasks, which is then used to approximate a Blood Alcohol Content reading or level of intoxication. Currently BAC is the scale of measurement being used due to a lack of a superior, commonly understood, universal scale.

10.1 Why it does what it does

Since the Tipsy Tester is aimed at testing the effects that alcohol has on the body directly and the way that a specific individual reacts to the consumption of alcohol the tool bypasses the chemical processes that plague BAC readings. These flawed chemical readings do not allow for an accurate individualized picture of how a person will act while under the influence of alcohol or how they, as a person, are affected. This tool is able to offer a customized reading of how severely users cognitive abilities have been degraded by the alcohol consumed. This customization is necessary because every person reacts differently to the various levels of alcohol intoxication, which is why tools such as breathalyzers that use quantitative measures (ex. amount of alcohol in the blood stream) to gauge intoxication are flawed. It is a dangerous assumption to make that one individual will be able to function in the same capacity (ex. driving a car) given the same blood alcohol content reading. This is why it is important that the Mobile Intoxication Assessment Tool judges this functioning directly rather than via measurements that do not translate well to the real world actions or abilities of an impaired individual.

10.2 How to use it

The Mobile Intoxication Assessment Tool operates in two different modes to accommodate guest users and intoxicated first time users as well as the owner of the tool for whom it has been calibrated. Both modes work by correlating the difference between the users calibration sober score (averaged score for guest) and their current intoxicated test score to a rating of their level of their intoxication level (BAC for now). The system works by requiring the downloader of the application to take a set of sub-tests, similar to those that will be administered while they are intoxicated, while sober to calibrate the tool. Their aggregate score on this sober completion of tasks is then set as their baseline sobriety score and is used as a base for later comparison to inebriated test scores. After setting this initial baseline, a drunken user can put their level of drunkenness to the test with personalized accuracy in owner mode or in guest mode with less accuracy.

10.2.1 Guest Mode

If the application owner is intoxicated when the tool is initially downloaded or they are with someone who does not own the application the less accurate guest mode of the Mobile Intoxication Assessment Tool can be utilized. This mode of testing is less accurate due to the lack of personalization that is achieved by calibrating a baseline score as described previously. Instead of a personally set baseline score an average of all sober scores recorded during the 6 week long study, of 21 participants of age 21-23 that was conducted at Union College in early 2012, is used. Intoxicated test scores (aggregate of normalized scores on all sub-tasks) that are determined in guest mode are compared to this average baseline sober score and the difference between scores is converted to a BAC value.

10.2.2 Owner Mode

If the application owner has calibrated the tool for their own use by completing the sober set of tasks the more accurate owner mode of the application can be used to get an accurate picture of how the alcohol is affecting their body. In this mode of use the operator's score on each of the individual sub-tasks is normalized based on the results of the 2012 Union College study. Their aggregate score, consisting of all normalized sub-task scores, is compared to their baseline sober score and the difference between the two is converted to a BAC value based on an equation developed from the results of the same Union College study.

11. FUTURE WORK

As is to be expected with any open-ended project of this magnitude, given a definitive deadline for completion, there are inevitably unfinished or unrealized initial design criteria when the time limit expires.

11.1 Second Study

This project was initially planned in a format that entailed two separate human studies, each of which would answer a different question. The first study was completed as planned and answered the vital question of exactly which of the prototype tests should be included in the finalized set of application tests. The first study also served the purpose of yielding an equation that could be used to quantify the relationship between the scores on these tests and blood alcohol content. The second of the two studies would have used the equation integrated into the android application with the set of tests that were deemed relevant to BAC calculation. The testing would have been run in much the same way as the first round of study with the substitution of the smart phone application for the low fidelity prototypes used in the first study. This second round was designed with the goal of evaluating the accuracy of the equation derived from the first round data as well as the over all usefulness of the tool. The answers to these questions would have provided direction for the advancement of The Mobile Intoxication Assessment Tool in the future. Since these questions of accuracy need to be answered it is vital that the future work on this project will begin with the completion of a second round of human studies, of this format, utilizing the finalized mobile application.

11.2 Increased Accuracy

As was mentioned previously, this sort of project requires a certain level of calibration, most of which can be derived from a significantly large collection of user data and can only improve with greater statistics. This being said, there will always be room for further increases in the accuracy of the BAC/test score relationship equation and the tuning of the individual tasks via continued data collection. This further data gathering could be realized by a number of different methods.

11.2.1 Large Scale Study

The most straightforward way to enlarge the pool of data would be to complete another human study, similar to the one proposed above, but on a larger scale with respect to the number of participants and the duration of study. The study of a much larger group of social drinkers over a period of longer than a month would allow for a better read on how test scores relate to blood alcohol content. The larger, as well as broader, sample size would allow for the minimization of extraneous variables such as differing levels of intellect from subject to subject. The longer period of the proposed study would compensate for any potential learning curve associated with using "The Mobile Intoxication Assessment Tool" as everyone would reach a similar level of understanding over time.

11.2.2 Limited Release

Another approach that could yield accuracy increasing data would be to release the most current version of the application to android users and collect their feedback on its performance. This method could potentially be more problematic because it is much less controlled than the suggested large-scale study as it relies on android users ability to self-report and measure their own blood alcohol content. The inaccuracies introduced by simply releasing the application and requesting feedback could be limited if participants are officially recruited to a more formal study and are provided with the necessary tools for the measurement and recording of their BAC data. Although the individual participants would still be responsible for their own monitoring the methods used to collect BAC and test scores would at least be held constant.

12. CONCLUSION

The goal of the current study undertaking and subsequent programming work was to create a mobile device that could offer an accurate, convenient, and fun way to measure BAC. The application and study were designed to provide this accurate measure with as little dependence on the users negatively impacted faculties as possible. In other words we designed the application so that the user does not need to worry about how they are going to determine how inebriated they are but take comfort in knowing that they can get these answers from the application. Using the Mobile Intoxication Assessment Tool an individual can follow along with the prompts and cognitive ability tests on their mobile device and make an educated decision on how they should proceed based on the provided reading.

Previous research has shown that there are a variety of cognitive abilities that are negatively impacted by acute alcohol intoxication. Based on these findings, tasks that evaluate these affected abilities in a focused manner were developed to demonstrate a hindrance in performance due to the consumption of alcohol. The current research investigated whether it was possible to determine BAC based on the collective performance on these tasks while intoxicated when compared to performance while sober. We wanted to know first of all if there was a correlation between drunkenness (BAC) and an individual's performance on the designed tasks. Secondarily, we wanted to determine (if an over all correlation was detected) precisely what tasks related most efficiently to the users level of inebriation. This study was conducted using participants who were given cognitive trials while sober and while in various states of intoxication. Scores were then correlated with BAC.

Our research suggests that, with enough data, BAC can be accurately determined using a series of cognitive tasks in this way.

In the end we determined that performance on these cognitive tasks can be used to predict BAC however not all of the designed tasks demonstrated a statistically significant relationship. These tasks that did not relate as strongly as the others, namely “dot follow”, “whack-a-mole”, and 10 word explicit memorization, were eliminated from the final application prototype. Our research yielded a significant answer to our initial question in finding that we could indeed predict BAC using this cognitive ability testing. It did not, however, yield enough data to produce high accuracy in converting a raw score to a BAC reading with the small data set.

A raw prototype version of the application has been assembled with the finalized set of cognitive ability tasks incorporated in it. Going forward we will continue to study the test score-BAC reading relationship and increase our accuracy of prediction using this prototype application. With this future work we hope to be able to determine, with confidence, a user’s level of inebriation given a certain score on our cognitive tests and allow the user to rely on this tools accuracy.

13. REFFERENCES

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