Enabling Personal Alcohol Tracking using Transdermal Sensing Wristbands: Benefits and Challenges

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Abstract
Our current project involves the development of a wristband-mounted sensor that is meant to function as an alcohol use monitoring system. This paper focuses on the degree to which physical activity influences ethanol concentrations in the vapor secreted from the skin through collecting data from seven recruited participants when they conducting one designated activity, which could presumably affect the accuracy of detection results. We proposes a preliminary design of building a personal alcohol tracking system that can improve the reliability and affordability of current transdermal ethanol tracking devices to accommodate potential interferences presented in daily life and be intuitive to be used to raise the awareness of alcohol use.

Author Keywords
Personal alcohol tracking; transdermal skin vapor; false alcohol detections.

ACM Classification Keywords
H.5.m. [Information Interfaces and Presentation (e.g. HCI)]: Miscellaneous

Introduction
Numerous studies have shown that alcohol increases the risks associated with potentially dangerous activities [10, 9]; however, many people underestimate the risk of drinking

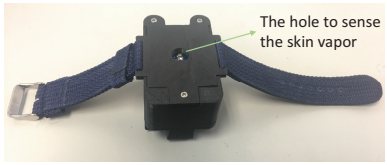

Figure 1: Prototype wristband showing the side in contact with the skin of the user. The hole permits the diffusion of vapor from the skin into the ethanol sensor.

before driving a car [10], riding a motorcycle [9], or operating heavy equipments. To address this issue, researchers have developed a number of wearable devices to enable 24/7 continuous monitoring of blood alcohol levels in order to facilitate accident prevention and/or monitor alcohol use behavior among individuals at risk of driving under the influence (DUI).

At present, there are two approaches to the transdermal quantification of blood ethanol levels. One approach involves the analysis of sweat [7], whereas the other focuses on vapor secreted by the skin [1, 5]. Wearable devices designed for the electronic monitoring of transdermal alcohol concentrations (TACs) in skin vapor tend to be less obtrusive for the user and allow for testing with greater frequency. Unfortunately, a number of environmental factors, such as materials that contain alcohol-like substances [4], have been shown to interfere with measurement results [5]. Furthermore, existing solutions were mainly designed for used as supervision tools to track offenders who were under probation [10]. It was not used to raise users' awareness of alcohol but to collect the concentration of ethanol in skin vapor for probation officers to assess the risk level of re-commiting DUIs.

Our objective in this study was to identify potential challenges associated with the use of wearable devices for tracking alcohol levels in vapor secreted by the skin, with a particular focus on the effects of aerobic activities. We conducted an experiment in which two groups of participants were tasked with jogging or drinking alcohol while wearing a wristband equipped with a sophisticated ethanol sensor. Patterns observed in the raw ethanol concentrations obtained in this pilot study were then used to identify factors that could potentially confuse alcohol screening algorithms. This insight guided us in devising alternative methods by which to resolve existing difficulties associated with the development of personal alcohol screening systems.

Pilot Data Collection

We first sought to identify the potential challenges in monitoring alcohol consumption when using wristband to track the concentration of alcohol in vapor passing through the skin. Our initial small-scale pilot study included 7 participants (5 males) ranging in age from 18-39 years (mean age 25). We created an experimental setting that would replicate many daily life situations that could potentially interfere with the proposed monitoring device, including aerobic activities. This study was approved by the Institutional Review Board of National Taiwan University (IRB No.: *201807HS035*).

Device

The prototype was a wristband equipped with Sensirion SGP30 multi-pixel gas sensor [3] and microcontroller. A 3D printer was used to fabricate a rugged case with a hole beneath the wristband to allow the diffusion of skin vapor into the gas sensor. The device was equipped with a 900mAh lithium-ion battery to ensure operability for at least 3 hours and a 128 MB NOR flash module for data storage. We had all of the study participants use the same wristband/gas sensor device to eliminate potential variations due to manufacturing differences between gas sensors. Thus, the data collection experiment was conducted using one participant at a time.

Procedure

Data collection began after a pre-study orientation session, during which the goals of the study were explained and eligible participants were asked to provide written informed consent. It is exceedingly difficult to establish minimum bounds to ensure the complete metabolization of alcohol.

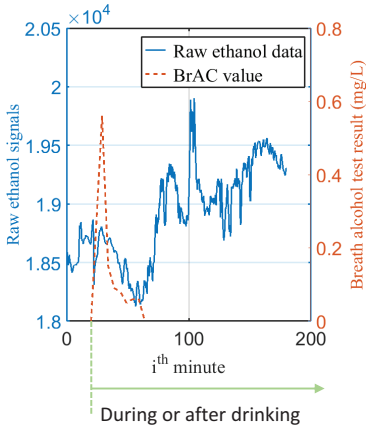

Figure 2: Raw ethanol levels (solid blue line) and breath alcohol concentration (dotted red line) obtained using proposed wristband monitoring device from P1. Note that raw ethanol readings are inversely proportional to TAC values; i.e., raw ethanol readings decrease with an increase in TAC values.

Thus, the participants who were assigned to consume alcohol during the experiment were also required to sign a liability waiver acknowledging that they might remain under the influence of alcohol following completion of the experiment. In signing the waiver, the participants gave up any legal rights to sue our research team in the event if they were caught by police due to operating a vehicle while under the influence of alcohol or injuring themselves due to impaired cognitive ability.

In real-world scenarios, people tend to perform everyday activities while they are continuously tracked by this alcohol tracking device. To demonstrate the potential impact on the skin vapor during or after performing everyday activities, we choose two exemplar everyday activities, i.e., drinking alcohol and jogging for a period of time. Therefore, following the orientation session, the participants were randomly assigned to two groups: an alcohol consumption group (3 males and 1 female) and an exercise group (jogging for 30 min) (2 males and 1 female). We asked participants to perform either one of the two exemplar everyday activities while tracking by the device in this pilot data collection. Data collection was conducted in three phases: (1) preparation, (2) activity, and (3) post-activity

Preparation phase: All participants wore the wristband on their non-dominant hand. During the 20-minute preparation phase, they remained seated; i.e., they did not participate in any activity that could conceivably alter the concentration of ethanol in the skin vapor. Our aim in implementing the preparation phase was to verify the diffusion of skin vapor into the gas sensor and achieve an equilibrium state in terms of ethanol concentration.

Activity-performing phase: The participants were instructed to perform a group-designated activity. Participants in the drinking group were given 10 minutes to consume 45 mL of vodka (40%), which is approximately to the moderate drinking amount of alcohol containing in one can of a 355 mL (12 oz) beer (5%) [2] . After participants finished drinking, we will ask them to perform a breath alcohol test every five minutes. Participants in the exercise group walked to a track to participate in low-intensity jogging for 30 minutes before returning to the lab.

Post-activity phase: All participants then again remained seated in the lab (as in the preparation phase). All participants wore the wristband for a total of 3 hours.

Following the data collection experiment, the flash was removed from the device and attached to another board via USB for data extraction. Each participant was reimbursed $500 NTD (approximately $16.5 USD) for the 3 hours spent participating in the experiment.

Preliminary results

In the following, we summarize some of the challenges involved in using a transdermal ethanol sensor to monitor alcohol use, based on the dataset collected in the pilot study. All of the participants used the same wristband; therefore, we used raw ethanol readings of the SGP30 gas sensor as an indicator of TAC (transdermal alcohol concentration) levels. Note that raw ethanol readings are inversely proportional to TAC values; i.e., raw ethanol readings decrease with an increase in TAC values.

Delayed changes in ethanol readings

Fig. 2 plots raw ethanol readings and BrAC (Breath alcohol concentration) curves. Ingested alcohol passes through the intestine into the blood, which transports it throughout the body before eventually being eliminated through the liver. A portion of the ethanol is transported to the surface of the skin via a process of passive diffusion from blood flowing through skin capillaries (insensible perspiration) and

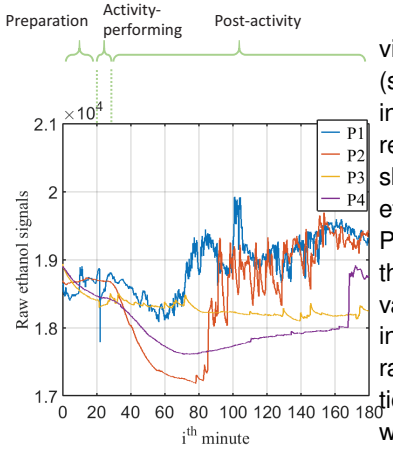

Figure 3: Data collected from participants in the drinking group (P1 $\sim$ P4) over a period of 3 hours.

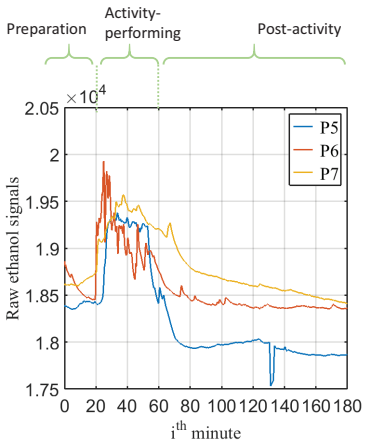

Figure 4: Data collected from participants in the exercise group (P5 $\sim$ P7) over a period of 3 hours.

via perspiration; i.e., the secretory activity of sweat glands (sensible perspiration). A considerable delay between the ingestion of alcohol and detection at the skin precludes the real-time estimation of blood alcohol concentrations using skin measurements. Fig. 2 illustrates the delay using raw ethanol readings and BrAC values obtained from participant P1. In this case, the delay was 28 minutes (delaying from the 29th to 57th minute); however, detection delays tend to vary with ethanol dose, body weight, and metabolic rate. As indicted from data collected in this study, the values of delay ranged from 28 $\sim$ 124 minutes. Furthermore, the detection delay increases with the amount of alcohol consumed within a period 2–3 hours after acute intoxication [6]. In the next section, we will discuss potential design to reduce the impact of this TAC changing delay.

Interpersonal difference in raw ethanol curves

Fig. 3 plots all of the data collected from participants in the drinking group. At the beginning of the post-activity phase, most of the ethanol curves (P1, P2, and P4) presented a similar trend; i.e., raw ethanol readings were at their lowest (18,081, 17,175, and 17,604, respectively). The ethanol curve of P3 presented a less pronounced decrease to a low value of 18,084. These minimum values (i.e., troughs) appeared at different time instances: P1 (57th minute), P2 (78th minute), P3 (150th minute), P4 (83th minute). Furthermore, the degree to which ethanol readings decreased varied according to the individual, and this could greatly complicate the interpretation of data.

Fig. 4 presents all of the data collected from participants in the jogging group. At the beginning of the activity phase, there was a general increase in the raw ethanol reading when the participants started jogging. Swinging of the arms while running caused increased the circulation of air from the surrounding environment. That air contained less skin vapor and therefore less ethanol; therefore, the raw ethanol reading increased as the concentration of ethanol decreased. Once finishing jogging, the ethanol readings decreased as ethanol evaporated from the skin (in response to the intense exercise). Nonetheless, the degree to which the ethanol levels decreased varied according to the individual (17,851, 18,354, and 18,413, respectively). After jogging, the readings from P5 decreased significantly to a minimal value of 17,851. This could confuse the detection algorithm.

Influence by human activities

Fig. 5 superimposes data collected from P1 (drinking group) with data collected from P5 (exercise group). The lowest value from P1 was 18,081 at the 57th minute. The lowest value from P5 was 17,851 at the 166th minute. In such situations, the use of a naive threshold approach would create confusion in the detection of drinking events. Methods to resolve this confusion are outlined in the following section.

Preliminary System Design

The challenges identified in the pilot study were used to guide our development of a reliable personal alcohol screening system. The proposed system would comprise an *adaptive alcohol detection module* and an *easy-to-understand user interface*. The alcohol detection module would employ a model pre-trained for general users in conjunction with contextual information inferred by other components or sensors to enhance accuracy. In the previous section, we observed the changing trend of raw ethanol curves exhibiting a similar pattern, e.g., increasing ethanol readings when running or delays between the ingestion of alcohol and detection at the skin, among data collected in either one group. We can collect data from more participants when they perform a set of the most-commonly performed activities. Then, based on the collected data, we train a set

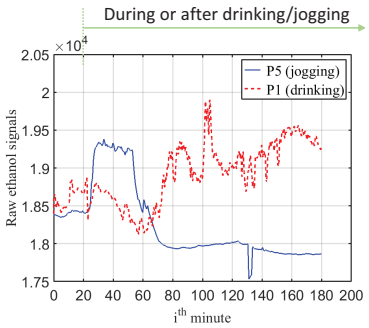

Figure 5: Comparison of data collected from P1 in the drinking group (red dotted line) and P5 in the exercise group (blue solid line).

of models to characterize people under different activity-performing cases. Given that the changing pattern exhibit similar changing patterns when users perform one type of activities as demonstration in data collected in the previous section, it is possible to identify some statistical features which can reflect the characteristics of the specific changing pattern, which can tolerate for individual differences of levels of concentrations in skin vapor. Moreover, with the help of other auxiliary sensors, such as accelerometers for detecting motion, the system could infer the behavior, e.g., doing exercises, of the user based on readings from the auxiliary sensor so that the system can select suitable models with feature distribution similar to the runtime collected data for avoiding false alcohol detections introduced when performing that behavior and predicting the amount of delays between the alcohol use and detection at the skin. Furthermore, the lack of precision due to interferences from other alcohol-like substances, e.g., isopropyl alcohol found in rubbing alcohol, could easily be corrected by installing additional gas sensors capable of distinguishing compounds that might otherwise skew the results.

The user interface should provide "categorized indicators" directly informing users if they completely metabolize alcohol and supportive feedback to trigger further alcohol screening to make sure current sobriety levels, which is different from the design goal of previous supervision tool, e.g., SCRAM ankle monitor [4], to record offenders' TAC for identifying their alcohol use by parole officers [10]. Fig. 6 demonstrates daily alcohol tracking scenarios without and with the proposed personal alcohol tracking design. In Fig. 6(a), since people tend to underestimate the risk of drinking alcohol, especially after drinking a moderate amount of alcohol (e.g., 1 can of 355 mL beer), before conducting tasks requiring high cognitive abilities. People would have optimism bias and think they are legal or safe to complete

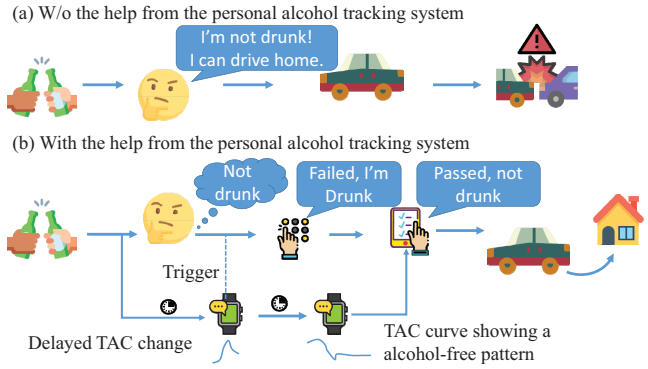

Figure 6: The potential application scenario of the proposed personal alcohol tracking system.

the tasks, and therefore, skip performing additional alcohol screening if they do not get any reminders from the system. On the contrary, if there is a personal alcohol tracking system providing reminders to trigger further alcohol screening, e.g., asking people to draw a pattern to unlock the screen and detecting alcohol through the drawing pattern while unlocking the screen [8] or performing a breath alcohol test with a breathalyzer. Once people fail in alcohol screening tests, they would be aware that alcohol still influences their cognitive abilities and would be re-evaluate if they are ready to perform the task until the raw ethanol curve shows a alcohol-free pattern. This transdermal ethanol sensing technology cannot provide the accuracy of breathalyzer devices; however, it could still be used to enhance awareness of current alcohol levels as well as micro-reminders or suggestions to guide the actions of high-risk individuals.

Conclusion & Future Work

We will seek to identify other factors that can influence ethanol measurements in skin vapor. We will also recruit a larger number of participants in assessing the effects on

TAC values. The challenges observed in data collection experiments will help us to refine the design of the personal ethanol tracking system in terms of accuracy and usability.

Acknowledgements

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