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# Predictive Model Affecting the Fatigue Condition of Drivers in the Philippines

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## Abstract

Public transportation has been evolving through the past years. The latest mode of transportation is the application based rides also known as the transport network vehicle services. It has always been the safety of the passenger that is being prioritized. Drivers' health condition should also be taken into consideration especially now that there are an increasing number of deaths among the drivers due to accidents mainly caused by fatigue. In this regard, the study aims to determine factors affecting the fatigue condition of drivers in order to ensure the safety of drivers and their passengers. The study also aims to design a smart watch that will monitor the fatigue level of drivers in order to prevent untoward incidents that will affect the safety of both drivers and passengers. Factors such as blood pressure, heart rate and oxygen level were considered in the study. The researchers made use of statistical analysis such as analysis of variance, correlation and regression in order to determine which factors are significant predictors of the fatigue level of drivers and thus, the factors identified will be considered in the design of the smart watch that will monitor the fatigue level of drivers.

## Keywords
Fatigue, health condition, transportation, smart watch

## 1. Introduction

Transportation in the country has a major role in the daily activities of people. Public transportation has evolved these past few years. In the urban public transit, there are buses, trains and cabs (Teodorović & Janić, 2017). Public transportation brought a lot of opportunities for the rapid growth of demand for smartphones (Dickinson et.al, 2015). Nowadays, there are other modes of public transportation that have been modified. One of these is the application-based ride services. The involvement of public in transportation through social media is attaining much favor in the government that focuses on the translucency and involvement of the public in any ways. (Majumdar, 2016). Transportation have made it workable for government agencies to utilize social media sites like Facebook, Twitter and the like through the current developments in technology particularly in the communications (Criado, 2013). Application based ride companies like Uber, Lyft and Sidecar were able to manage drivers of private vehicles to provide safe, well founded service, reasonable fares for the riders with just an application through smartphone (Flores & Rayle, 2017). Based on a survey conducted, the stability of the taxi application based services are dependent on the consistent use of the riders. The survey showed that the technology has an intensive effect in the stability of the taxi application based service companies (Weng et.al, 2017). Because of increasing demand for this type of transport service, health risks for the drivers are also increasing.

A study by Chung & Wu (2013) stated that the major health risk of public transport drivers are stress and fatigue. The primary strain for the factors of stress is the reward and over commitment levels of drivers in rendering services based on the booking quota of the company (Chung & Wu, 2013). This could negatively affect the safety and health of both drivers and passengers, and may cause road accidents (He et.al, 2016).

Drivers for all types of vehicles have been experiencing fatigue due to long hours of driving for their daily work (Meng et.al, 2015). There is one major contributor to road accidents around the world due to fatigued driving. It was examined that despite of being fatigued, the driver still has the motivation to drive which led to a conclusion that behavior of the driver is a huge factor in fatigued driving (Jiang et.al, 2017).

There were studies that involved reduction of fatigue sleepiness while driving. Professional drivers are said to be at higher risk of drowsiness due to several factors like work, sleep apnea and driver behavior (Nazari et.al, 2017). Anxiety and mood states of the driver are considered as factors affecting their fatigue level. Also, personality and temperament are said to influence the fatigue level of the driver (Lal & Craig, 2001). In another study, chronic workload is being link to fatigue (Hancock & Verwey, 1997). Professional driving experience, hours of driving per day, time, days per week and the demographics of the driver are also considered as factors that affect their fatigue level (Useche et.al, 2017). Another factor that leads to fatigue is the particular period of the day wherein the driver receives bookings. It is said that the body and brain have circadian rhythm that affects the alertness and sleepiness level of a person; if the driver works at the drowsy times of the day he could experience fatigue (Kerkar, 2016). Ambient temperature, roadway, weather, light conditions and traffic are also one of the factors that lead to fatigue driving (Chowhury, 2015). Heart diseases, diabetes and poor cognitive performance are also associated with fatigue. Lastly, sedative drugs are also one of the factors that can lead to fatigue (Hocking, 2013).

Past researches focused mainly on the safety and health of passengers, however, there is limited amount of study that focused on the safety and health of drivers. Drivers tend to spend too much time in driving just to meet the quota allocation for a certain period of time. This practice could lead to serious health risks for the drivers that could lead to accidents and fatalities.

In the Philippines, there is no policy and programs implemented yet to address the fatigue of drivers especially in the public transport. That being so, the researchers aimed to determine the factors that affect the fatigue level of drivers in order to propose a smart watch that will monitor the health level of the drivers in order to promote safety of both drivers and passengers.

## 2. Methodology

The study was composed of three phases. First phase was about the assessment of the current profile of the transport network vehicle services drivers. Basically, age, gender and other related information were determined. Second phase was focused for the identification of significant factors that affect the fatigue level of the drivers. These significant factors were used for the formulation of the best model. The last phase was about the formulation of the best method, policies and practices. The researcher has finished both a qualitative and quantitative research to be able to satisfy fully the objectives of this study.

### 2.1. Data Collection

An online survey was conducted as the initial step for data gathering. The online survey was conducted with 100 users mainly composed of transport network vehicle services drivers that belong to a social media group mainly composed of Grab and Uber drivers and operators. This number of respondents was computed using the Slovin's formula. To facilitate response, highly structured questions were used in the design of the questionnaire. Factors to be considered in the study were obtained from review of related studies and literatures, direct observation, interviews and actual measurement of heart rate, oxygen level and blood pressure of the respondents.

### 2.2. Statistical Analysis

Descriptive Statistics was used in order to summarize and interpret data obtained from the study. Inferential Statistics were also used in order to determine which factors significantly affect the fatigue level of drivers. The factors considered in the study are clustered according to: (1) demographic factor, (2) road factor and (3) environmental factor. Sub-factors for each major factor are also considered in the study to further assess and analyze the data. Similarly, the researcher also used regression analysis to test which among the three variables such as blood pressure, oxygen level and heart rate are good predictors for fatigue level of drivers.

Finally, in order to come up with a design of proposed smart watch that will monitor the fatigue level of drivers, the researchers used Quality Function Deployment (QFD) tool. This tool will help the researchers to prioritize important criteria and technical attributes that will be considered in the design based on the requirements of the users. Failure

Mode and Effect Analysis was also used in order to determine the possible problems or failures that may occur in the design along with its causes and effects.

## 3. Results and Discussion

### 3.1. Identification of Factors

The table 1 below shows the summary of major factors and sub-factors that will be considered in the study obtained from review of related literatures, interview, surveys and actual observation.

Table 1. Independent variables

| FACTORS | SUB FACTORS |
|---|---|
| Human | Gender<br>Age<br>Driving experience<br>Smoking<br>Not smoking<br>Time for start of shift<br>Sleep time<br>Duration of shift<br>Eating time |
| Vehicle | Type of transport and Type of car |
| Road | Express highways<br>Ordinary highways<br>Slippery road |
| Environmental | Street light condition (clear, unclear, dark)<br>Holiday<br>Regular Days<br>Weekends<br>12:00MN-6:59AM<br>7:00AM-8:59AM<br>Working Time Patterns<br>12:00PM-1:59PM<br>5:00PM-7:59PM |

A. Human Factors

Human factors are composed of the demographic profile of the drivers namely: gender, age, driving experience and smoking habit. When age is increasing, cognitive related activities tend to deteriorate. It was proven that an aging brain, the prefrontal cortex part of the brain is affected which could lead to the decline in behavior of a person such as the perception of irrelevant information or proper coordination of multiple activities (Arnau et.al, 2017). In a previous study, the driver tends to disregard the feeling of being sleepy because they are used to it. This is due to the drivers' experience in the work, drivers still drive even if they are already sleepy or drowsy (Jiang et. al, 2017). According to a study, smoking was also known as one of the job stressors of public utility vehicle drivers (Useche et.al, 2017). Times for sleeping, start of shift and eating were also determined by the researcher to be able to know if it has effect on the fatigue level of the driver. Also, the duration of their shift was also determined. Based on the survey conducted both manually and online, common times for sleeping start of shift and eating and the duration of shift were shown in the table 2 below:

Table 2. Table for Human Factors

| Start of Shift | Sleeping time | Eating time | Duration of shift (hours) |
|---|---|---|---|
| 4:00AM | 12:00 MN | Before shift | 12 |
| 5:00 AM | 1:00 AM | During vacant hours | 15 |
| 6:00 AM | 3:00 AM | Before going home | 16 |
| 7:00 AM | 8:00 PM | | 18 |
| 8:00 AM | 11:00 PM | | |
| 9:00 AM | | | |

B. Vehicle Factors

For the vehicle factor, type of car is classified into two namely sedan and SUV. Also, type of transport was identified. Since, in Grab and Uber there are other types of transport a rider can choose to. These types were generally classified as: sharing/pooling, Six-seater, premium and the usual and the most common type of transport which can only accommodate up to 4 people. Sharing/ pooling are a mode of transport wherein different riders can be accommodated as long as its destinations are clustered into same area. Maximum of 2 seats are given per rider (Dong et.al, 2018). Pooling is cheaper compared to other mode of transport. Six seater mode of transport is for riders that are five to six people in the group. Premium is a mode of transport wherein options of luxury cars are being offered such as Fortuner, Montero, Hummer, Tucson and Camry. These are just some of the car models accepted as premium. Lastly, is the usual type which for Grab is called GrabCar and for Uber it its UberX. This type of transport is mainly of sedans that can accommodate up to four passengers.

C. Road Factors

Nowadays, traffic has been one of the causes of stress for drivers. Road factors were also considered in the study since it can contribute to the stress level of the drivers and therefore can trigger the fatigue level. Road factors are classified into as express, ordinary and slippery. Road conditions affect the behavior of the drivers in such a way that drivers need to perform many driving tasks such as overtaking, regulation of speed of the vehicle and the speed of the approaching vehicles and the changing of gears (Ram & Chand, 2016).

D. Environmental Factors

Lastly, environmental factors are composed of the type of day, working pattern and street light condition. Shown below is the table for its sub- factors. During holidays, people tend to engage in recreational activities such as travel and other outdoor activities. With this, demand for public utility vehicles also tend to increase which will let the drivers drive for longer hours for longer trip distances. Also, majority of the accidents reported happened on a weekend or during a public holiday. Traffic patterns during weekends are more severe compared with the traffic patterns during a regular day (Anowar et.al, 2012).

Table 3. Table for Environmental factors

| Type of day | Working pattern | Street light condition |
|---|---|---|
| Holiday<br>Regular day<br>Weekends | 12:00MN-6:59 AM<br>7:00AM-8:59 AM<br>12:00NN-1:59 PM<br>5:00PM-7:59 PM | Clear<br>Unclear<br>Dark |

## 3.2. Result of Analysis of Variance

One-way ANOVA was used to identify the effect of each response variable with other response variables. The researchers used this tool to compare the heart rates, blood pressure and oxygen level of the drivers over time. Tukey's HSD was also used to further determine which variable affects other variables the most. The result was obtained through the use of Minitab to solve the relationship of each factor the response variables.

A. Heart Rates Over Time

(Ho): There are no significant differences on the heart rates of the drivers over time.
(Ha): There are significant differences on the heart rates of the drivers over time.

Table 4. ANOVA results for Heart rates over time

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Means among the heart rates | 14 | 35217 | 2515.50 | 119.26 | 0.000 |
| Error | 1317 | 27779 | 21.09 | | |
| Total | 1331 | 62996 | | | |

The results for the Analysis of Variance of heart rates over time indicated that as time passes, heart rates increases which contributes to increasing the stress level of the driver and therefore will lead to fatigue. Therefore, accept the alternate hypothesis which is that there are significant differences on the heart rates of drivers over time. This means that heart rates of drivers tend to decrease significantly over time.

B. Blood Pressure (Systolic) Over Time

(Ho): There are no significant differences on the systolic pressure of the drivers over time.
(Ha): There are significant differences on the systolic pressure of the drivers over time.

Table 5. ANOVA results for Systolic pressure over time

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Means among the systolic pressures | 14 | 81173 | 5798.06 | 112.58 | 0.000 |
| Error | 1317 | 67830 | 51.50 | | |
| Total | 1331 | 149003 | | | |

The results for the Analysis of Variance of blood pressure (systolic) over time indicated that as time passes, blood pressure (systolic) increases which contribute to increasing the stress level of the driver and therefore will lead to fatigue. Therefore, accept the alternate hypothesis which is that there are significant differences on the systolic pressures of drivers over time. This means that systolic pressures of drivers tend to increase significantly over time.

C. Blood Pressure (Diastolic) Over Time

(Ho): There are no significant differences on the diastolic pressure of the drivers over time.
(Ha): There are significant differences on the diastolic pressure of the drivers over time.

Table 6. ANOVA results for Diastolic pressure over time

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Means among the diastolic pressures | 14 | 7116 | 508.31 | 18.88 | 0.000 |
| Error | 1317 | 35456 | 26.92 | | |
| Total | 1331 | 42573 | | | |

The results for the Analysis of Variance of blood pressure (diastolic) over time indicated that as time passes, blood pressure (diastolic) increases which contribute to increasing the stress level of the driver and therefore will lead to fatigue. Therefore, accept the alternate hypothesis which is that there are significant differences on the diastolic pressures of drivers over time. This means that diastolic pressures of drivers tend to decrease significantly over time.

D. Oxygen Level Over Time

(Ho): There are no significant differences on the oxygen level of the drivers over time.
(Ha): There are significant differences on the oxygen level of the drivers over time.

Table 7. ANOVA results for Oxygen level over time

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Means among the oxygen levels | 14 | 411859 | 29418.5 | 449.21 | 0.000 |
| Error | 1317 | 86249 | 65.5 | | |
| Total | 1331 | 498109 | | | |

The results for the Analysis of Variance of oxygen level over time indicated that as time passes, oxygen level decreases which contribute to increasing the stress level of the driver and therefore will lead to fatigue. Therefore, accept the alternate hypothesis which is that there are significant differences on the oxygen levels of drivers over time. This means that oxygen levels of drivers tend to decrease significantly over time was done to know the relationship and the significance of the factors with each other, and to determine its effects to the fatigue level of the drivers.

## 3.3. Result of Correlation Analysis

The table below shows the result of correlation analysis. Correlation analysis was done by the researchers to determine which factors affect the blood pressure, heart rate and oxygen level of drivers. In this way, the researchers were able to identify which factors should be considered in the formulation of policies to further address the fatigue issues of drivers in the workplace. P- value of less than 0.05 has a correlation.

Table 8. Result of Correlation Analysis

| FACTORS | BP (S) | BP (D) | HR | OL |
|---|---|---|---|---|
| Age | + | + | + | + |
| Smoking | + | - | + | - |
| Eating time | + | - | - | + |
| Wake up time | + | + | - | - |
| Sleep time | - | - | - | - |
| Driving hours | - | + | - | + |
| Period of the day | + | - | + | - |
| Type of car | + | - | + | - |
| Type of transmission | + | - | + | - |
| Type of Transport | + | - | - | - |
| Type of road | + | - | + | + |
| Streetlight condition | + | - | - | + |
| Type of day | - | - | - | + |
| Working pattern | - | + | + | + |
| | Age | Smoking | Eating time | Wake up time |
| Smoking | + | | | |
| Eating time | + | - | | |
| Wake up time | - | + | - | |
| Sleep time | - | - | - | + |
| Driving hours | - | - | - | - |
| Period of the day | - | + | - | - |
| Type of car | + | - | - | - |
| Type of transmission | + | - | - | - |
| Type of transport | + | + | + | + |
| Type of road | + | + | + | - |
| Streetlight condition | + | - | + | - |
| Type of day | + | + | + | + |
| Working pattern | - | - | - | + |
| | Sleep time | Driving hours | Period of the day | Type of car |
| Driving hours | + | | | |
| Period of the day | + | + | | |
| Type of car | - | - | + | |
| Transmission | - | + | - | + |
| Transport | - | - | - | + |
| Type of road | - | - | - | + |
| Streetlight condition | - | - | - | + |
| Type of day | + | - | - | + |
| Working pattern | + | + | + | - |

Based on the result, age has a relationship with the blood pressure of the driver. Driving hours have negative relationship with blood pressure. Driving hours is also correlated with the oxygen level. Age has negative relationship with the sleep time. This just means that age affects the sleep time of the driver. Sleep time is also correlated with the wake up time. This just means that wake up time is being affected by the amount of hours of sleep taken by the driver which definitely affects the fatigue level of the driver. The factor period of the day when the driver feels exhausted have a negative relationship with the eating time. This just means that as the driver gets tired, the energy intake has already been used up. Streetlight conditions have relationship with the age. This just means that older people is affected by the amount of light. Type of day is correlated with the eating time. An example of type of day is a holiday. During holidays, rider demand is high so the driver tends to eat on time since he is accepting bookings continuously. Driving hours is correlated with the sleep time. This means that driving for longer hours could affect the sleep time of the driver. Type of car is negatively related with the sleep time. Types of car are sedan and SUV, which have different

transmissions and could possibly make the driver gets tired faster. In this way, the sleep time of the driver could be not sufficient enough to regain the energy being used up. Transmission is negatively correlated with the period of the day the driver feels exhausted. Manual transmission has different configuration with the automatic transmission. According to the drivers, automatic transmission is a lot easier. This is the reason why the driver can feel exhausted within the day because majority of the drivers use manual transmission because it is more economic. Transmission is also correlated with the type of car. Transmissions are manual and automatic; types of car are either sedan and SUV. These factors affect the fatigue level of the driver in such a way that driver could get tired faster in manual transmission vehicle which using sedan type of car. Working pattern is negatively correlated with the type of car. This means that sedan or SUV types of car could affect the working pattern in which the driver stresses the most. Streetlight condition is related with the types of transport namely usual, premium, sharing and 6- seater vehicles.

### 3.4. Result of Regression Analysis

To further analyze the relationship of factors considered in the study to the fatigue condition of the drivers, regression analysis was used. Response variables for the analysis is the fatigue condition of drivers measured in blood pressure, heart rate and oxygen level based on corresponding times of the day, while the independent variables are factors and sub-factors clustered as (1) demographic, (2) road and (3) environmental. The regression equation for every response variable are shown in the equation below.

(1) Regression Equation for Heart Rate

HR 1PM = 56.73 + 0.174 Age - 0.086 Years of driving - 1.32 Smoking + 0.04 Eating time
- 0.110 Driving hours + 0.511 Period of the day - 0.40 Street light condition + 0.874 Type of day
- 0.223 Working pattern

(2) Regression Equation for Blood Pressure (Systolic)

BP (S) 8PM = 140.94 + 0.131 Age - 0.753 Years of driving + 0.01 Smoking
+ 1.09 Eating time- 0.373 Driving hours + 1.976 Period of the day the driver fe- 1.79 Street light condition
+ 0.225 Type of day - 0.738 Working pattern

(3) Regression Equation for Blood Pressure (Diastolic)

BP (D) 8PM = 106.9 - 0.586 Age + 4.25 Years of driving - 11.59 Smoking
- 12.55 Eating time+ 1.55 Driving hours - 5.19 Period of the day the driver fe- 1.43 Street light condition
+ 4.20 Type of day + 2.12 Working pattern

(4) Regression Equation for Oxygen Level

OL 4PM = 10.2 - 0.050 Age - 0.19 Years of driving - 0.14 Smoking - 2.60 Eating time
+ 2.278 Driving hours - 0.61 Period of the day - 0.52 Street light condition + 2.07 Type of day
+ 0.368 Working pattern

The results of the regression analysis explain that the maximum heart rate of a person tends to decline linearly with increasing age. Smoking has been linked to the heart rate, a smoker is at higher risk of having heart related medical condition (Sandesara, P.B. et al., 2018). Years of driving and driving hours' variables are considered as physiological factors that contribute to fatigue. For the variable eating time, heart rate is said to be converted to energy expenditure every minute (Ceesay, A., Prentice, A., Day, K., and Scott, W., 2017). Major factor for the variability of heart rate is the circadian rhythms, which in the independent variables are the period of the day where the driver feels tired, working pattern and street light condition. There is a difference between night and day heart rates (Kleiger, R., Stein, P., and Bigger, J., 2005). Wavelength of light can affect the response level of people depending on the exposure to duration of light and intensity. It was found that the alertness level of people to light affect the heart rate (Cajochen, C., et al., 2005).

### 3.5. Proposed Design of the Smart Watch

The researchers were able to come up with a model that can address the gap for the safety of the drivers in terms of the drivers' health level. A prototype model was created after the concept development done through a survey and then Quality Function Deployment was used to evaluate drivers' requirements. Based on the results, accurate heart rate and the delivery of exact location are the most important functions the drivers prefer. Product's alarm system is the highest. Next to this is the friendly interface of the application. Since most of the drivers are not used to dwelling with application based alarm system and also drivers need to focus on the road and that if in case the driver's in danger, they would be able to deactivate the alarm easily. Then the quality of the materials is also important for the drivers. Since it would be for the benefit of their health, it is preferred that the product would be composed of non-hazardous chemicals. The drivers prefer the product to be not internet dependent since they have to be efficient in the internet data consumption for them to be able to minimize cost. Minimum power consumption and breakage have the same weight. Then, it is also preferred that the product is wireless. Most of the drivers prefer the product to be wireless for fashion and style. Least important is the affordability. According to the drivers, product should be of value. It does not have to be expensive nor cheap, but the most important thing is that it works and it helps in their health improvement.

The prototype was named Life Time. Life Time features an application that will monitor the heart rate, blood pressure and oxygen level of the drivers while driving. It also has a feature that notifies the closest person of the driver about the health and fatigue condition of the driver like critical levels of oxygen, blood pressure and heart rate. It also has a GPS that keeps track of the exact location of the driver that will enable the family member or closest person of the driver to reach them in case of emergencies. The figure 1 below shows the proposed design and technical specifications of the product. The prototype has two components, the smart watch and the application that will be installed in the smartphone in order to support the functions of the smart watch. This


Figure 1. Proposed Design of Smart Watch

A. Functions of the Smart Watch

- Monitors the heart rate of the person, oxygen level and blood pressure
- Once the heart rate strikes the critical level, it will send a notification through an application installed in a smartphone.
- Then, it will send signal to the application for the alarm system to let the person be awake for a certain time.

B. Functions of the Application for the Smart Watch

- Once the heart rate, blood pressure or oxygen level strikes the critical level, the application would send message to immediate contact persons such as the operator or family members about the health condition of the driver. The application could save up to 5 contact persons.
- Exact location of the person is also included in the message.
- It has a chart in which the person could compare his/her health conditions with a normal person for his/her age.
- The application is compatible with Android operating software which is used by the majority of the drivers.
- It would alarm once the heart rate, blood pressure or oxygen level strikes the critical level.
- The value for the critical level for the heart rate, blood pressure or oxygen level can be modified.

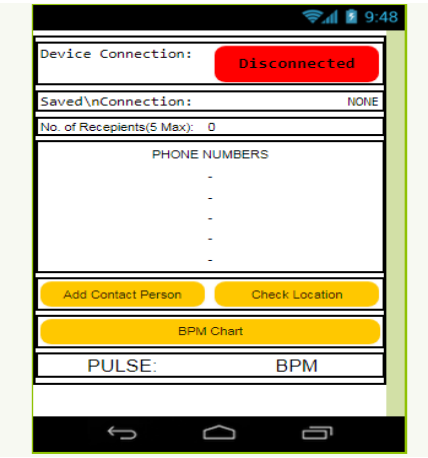


Figure 2. Appearance of the Application

## 4. Conclusion

Based on the result of the study, the following conclusions were drawn:

Correlation analysis was used to prove that factors in demographic, road and environmental that have significant relationship to the fatigue condition of the drivers in terms of the following: blood pressure, heart rate and oxygen level. Different factors and sub-factors were identified to have positive and negative correlation to the fatigue condition of the drivers.

Regression model was developed in order to predict the heart rate, blood pressure and oxygen level of the drivers with the corresponding time of the day using regression analysis. These factors served as the basis for the researchers in designing a smart watch that will monitor the health condition of the drivers in order to ensure safety of both drivers and the passengers.

Using the factors identified in the study, the researchers were able to come up with a proposed design of smart watch that will efficiently monitor the health condition of the drivers. The smart watch has a tracking device that records the blood pressure, heart rate and oxygen level of the user and has an supporting application that will send notification to the closest person of the user in case of emergencies. The smart watch sends alarm every time the user reach the critical level of heart rate, blood pressure or oxygen level and has a GPS that tracks the exact location of the user.

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