Personality and Mental Health Assessment: A Sensor-Based Behavior Analysis

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***Abstract*—The purpose of this study was to estimate personality and mental health through behavior data measured by acceleration and voice intensity sensors. Results showed significant correlations between behavior and all personality and mental health traits studied except for openness. This methodology ascertained an effortless assessment of personality and mental health, which respects employee's privacy, and keeps up-to-date companies' workforce information.**

Keywords- human behavior; sensory technology; mental health; personality

I. INTRODUCTION

The wide study of personality theory and mental health has opened research directions to better understand personnel psychology. Companies are increasingly aiming to develop their human workforce by studying their employees' individual characteristics. Robbins [1] identified four individual-level variables, i.e. biographical characteristics, ability, personality, and learning, which have effects on employee performance and satisfaction.

However, since the use of questionnaire-based objective tests for both personality and mental health has been widely established [2], the time required for employers and employees to carry out such questionnaires is increasingly becoming wasteful and troublesome. On the other hand, recent technology enables to visualize office workers' interactions [3], identify human behavior within organizational situations and obtain associated tacit knowledge [4][5] without privacy intrusion or major burden.

The purpose of this study was to propose a sensor-based methodology to estimate behavior and to further demonstrate existing correlations between employee's behavior and, mental health and personality traits. Building on the aforementioned findings, this study provides conclusions involving personality traits and mental health in the working setting with a minimum required burden from both employers and employees.

This paper is organized as follows. Section II contains an overview of related personality and mental health studies in the workplace. In Section III, it is proposed a methodology to estimate behavior based on sensory data, which was used in Section IV to analyze the relationship with personality and mental health. Section V includes a summary of the paper and presents future work.

II. RESEARCH ON PERSONALITY AND MENTAL HEALTH

Personality has been defined as the characteristic manner in which one thinks, feels, behaves, and relates to others [6]. Robbins [1] claimed that all our behavior is at some extent explained by our personalities and experiences. Traits in personality psychology have been used to describe consistent inter-correlated behavior patterns [7]. The study of personality traits has increased the understanding of the differences between people's behavior in order to explain how certain personality traits better adapt for certain job types [1][8], how personality relates to the effective performance of teams [8][9][10], and how personality is a component of motivation [11].

With similar attention, mental health in the workplace has also been studied. A study has concluded that adverse psychosocial work conditions are predictors of depression worsening [12]. This result was independent from personality traits analyses, and demonstrated the importance of the study of mental health alone.

A. Personality traits in this study

The Five Factor Model (FFM) is a taxonomy, or descriptive model, of personality traits organized at the broadest level of abstraction in five factors or dimensions named: extraversion or surgency, agreeableness, conscientiousness, emotional stability versus neuroticism, and intellect or openness [7]. These traits became eventually known as the Big Five [13]. Extraversion describes traits relating energy, dominance, sociability, and positive emotions. Agreeableness includes traits such as altruism, tender-mindness, trust and modesty, defining a prosocial orientation towards others. Conscientiousness summarizes traits which facilitate goal-directed behavior. Neuroticism describes anxiety, sadness or irritability, contrasting emotional stability. Finally, openness describes the depth of an individual's mental and experiential life [14].

Locus of Causality traits are related to the motivation factor of an individual and it examines the source of the motivation when engaging on an activity. Locus of Causality's intrinsic motivation refers to doing something because it is inherently interesting, fun, or enjoyable. On the other hand, extrinsic motivation refers to doing something because it leads to a separable outcome, or because it responds to external demands. Each motivation trait has two secondary scales. Secondary scales for intrinsic motivation

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are enjoyment and challenge. Challenge orientation is related to problem-solving, while enjoyment orientation is related to writing and art involvement. Secondary scales for extrinsic motivation are outward and compensation scales. Outward motivation entails personal endorsement and a feeling of choice. Compensation, on the other hand, involves mere compliance with an external control [15][16].

General Causality Orientation is referred as the individual differences that can be characterized in terms of people's understanding of the nature of causation of behavior [17]. In other words, these traits characterize the degree to which human behaviors are volitional or self-determined. There are three causality orientations, namely, autonomy, control, and impersonal orientation. Autonomy orientation trait involves a high degree of experienced choice related to the initiation and regulation of one's own behavior. Control orientation trait involves people's behavior following controls either in the environment or inside themselves. Impersonal orientation trait involves people's experiencing their behavior as being beyond their intentional control [17].

Self-monitoring people are described as showing considerable adaptability and behavior flexibility to external factors, being capable of behave differently in different situations [1].

Type A personality is the trait describing people which is aggressively involved to achieve more in less time. Highly rated Type A people are highly competitive, cannot cope with leisure time, and are continuously measuring their success [1].

B. Mental health in this study

The mental health statuses considered for this study were depression and happiness. The viewpoint from which these traits were analyzed was to relate depression, and stress, against job satisfaction characterized by happiness in the workplace.

III. STUDY 1: ESTIMATION OF BEHAVIOR BASED ON SENSORY DATA

This first study proposed a methodology to estimate human behavior at the workplace based on objective data measured by sensors. An experiment was done in order to investigate the possibility of identifying human behavior.

A. Participants

Two male participants volunteered for this experiment. They were aged 25 and 44, and were all in sound health condition.

B. Apparatus

Business Microscope (BM) [5] developed by Hitachi Corporation was used in this experiment. Users wore BM like a neck-hanging name-tag, and BM records data from its acceleration, face-to-face (IR), temperature, and voice intensity sensors.

C. Procedure

Each participant wore a BM device and acted out behavior categories for 2 hours as if they were engaging in daily office working activities. The characterized behavior categories were walking, talking, desk working, and not-working related behaviors like sleeping, eating/drinking, or simply being unoccupied. These last were grouped, and hereafter referred as idle category.

D. Measurements

For the purposes of this study, this experiment only used acceleration and voice intensity sensory raw data with a sampling frequency of 50 Hz. Due to privacy concerns and to a limitation of energy consumption, each datum was observed for 2s long and was acquired once every 10s. The data captured by the device was wirelessly transferred to a server where it was stored.

While wearing a BM device, participants acted out behaviors, switching them from one to another. Every time they switched behaviors, participants marked the time, the location, the posture, and the behavior being acted.

E. Results

Sensor data chosen from each behavior category was plotted for analysis to reveal distinctive characteristics representing each acted behavior. Such information was used to build a method to estimate behavior. Such behavior was compared with the actual behavior characterized by participants to find out *hit* and *false alarm* rates. A hit was defined by corresponding predicted and actual behaviors. False alarm on the contrary was defined by a mismatch between them.

A graphic method, the Receiver Operating Characteristic (ROC), was used to evaluate and compare the performances of signal-noise discrimination [18]. ROC was used to portray the optimal criteria to detect behaviors and to select the most effective prediction thresholds.

1) Behavior detection criteria

In the walking category plot the amplitude and the frequency of the oscillations of acceleration data were calculated. The amplitude of the curve was calculated with the subtraction of the curve's minimum data value from the maximum data value. As for the number of oscillations of the curve, it was used the zero crossing method. The zero cross line was determined as the data's average line. The number of times the curve crossed the zero-crossing line were added up to obtain the curve's frequency.

Sound intensity curve was represented by temporal changes of sound volume. The data's mean and the standard deviation was calculated and used to obtain thresholds for data characterized by sound representing a talking behavior.

For desk working behavior plot, back and forth acceleration data was investigated. It was found that the mean of acceleration data at time *t*, and the mean of acceleration data at time *t-10s*, tended to be comparable. As differences in mean values of these succeeding two time

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points were limited in range, it was assumed that such behavior corresponded to small posture changes as those displayed by desk working behavior. Upper and lower limits of this range were calculated. Data found within this range was regarded as desk working behavior data.

As for the idle behavior category, the acceleration data's frequency of vibration was analyzed. The most suitable data for analysis was found along the acceleration's vertical direction; therefore the zero crossing number was used to calculate this behavior's data frequency.

2) Sequential detection method

The ROC curves for each behavior category are shown in Figure 1. The variance of dots in each graph represents the performance of criteria using various threshold combinations. The results showed that the best detection performance (represented by a red dot) was found in the following order: walking behavior category, talking, desk working, and idle behavior. For this reason it was adopted a sequential detection order which set the sensitivity [18] of each detection method as the detection order priority. Thus, walking behavior was the first category to be detected from the entire sensor data set. From the remaining data, talking behavior was detected, then desk working, and finally idle behavior category.

IV. STUDY 2: STUDY OF PERSONALITY AND MENTAL HEALTH BASED ON BEHAVIOR DATA

The purpose of this study was to analyze the relationships among personality and mental health, and behavior estimated by the method proposed in Section III. An experiment was conducted, and a correlation analysis was done in order to validate that sensory data can be used to assess personality and mental health.

A. Participants

Ninety two Japanese participants, 77 males and 15 females, ranging between 21 and 61 years old (M = 35.93, SD = 8.50), who worked as software developers at a certain company volunteered for the experiment. They were all capable of moving freely and perform routine office activities.

B. Apparatus

The apparatus for this study were the same as those used in study one. Refer to Section III.B.

C. Procedure

Participants wore individual BM devices every working day for 71 days, time in which they engaged in normal daily working activities. Participants' behavior was detected according to the procedure explained in Section III. Also participants conducted 8 sets of questionnaires, 5 relating personality, and 3 more relating mental health.

D. Measurements

To assess the big five personality, the Big Five Inventory [14], which consisted of 44 items, was used. The Work Preference Inventory (WPI) which consists of 30 items was used to assess Locus of Causality [16]. The 12-item General Causality Orientation Scale Questionnaire (GCOS) was used to assess General Causality Orientation [17]. It was also used the Self Monitoring trait questionnaire developed by Lennox and Wolfe [19], and the Type A questionnaire developed by Bortner [20].

As for mental health, two scales for depression and one for happiness were used. Although these states could be related to a general happiness scale, in this study the term mental health was used to describe them. The Center for Epidemiology Studies Depression Scale (CES-D) was developed by Radloff [21], and consisted of 20 items. Also the Beck Depression Inventory Second Edition (BDI-II) was used and consisted of 21 items. It is a self-administered questionnaire assessing the severity of depression in adults and adolescents [22]. The last mental health trait studied was satisfaction. The Oxford Happiness Questionnaire (OHQ) was used to assess this trait [23].

E. Results

This study considered unitary behavior samples and behavior events as measurement units. A behavior sample was defined as each datum in a set of data corresponding to an estimated behavior category (one sample per 10s). A behavior event was defined as the sequential group of 2 or more samples under the same behavior category. A chronological summary showing the time series of estimated behavior samples and events was prepared for each participant. This summary indicated what type of behavior category a participant engaged in and for how long.

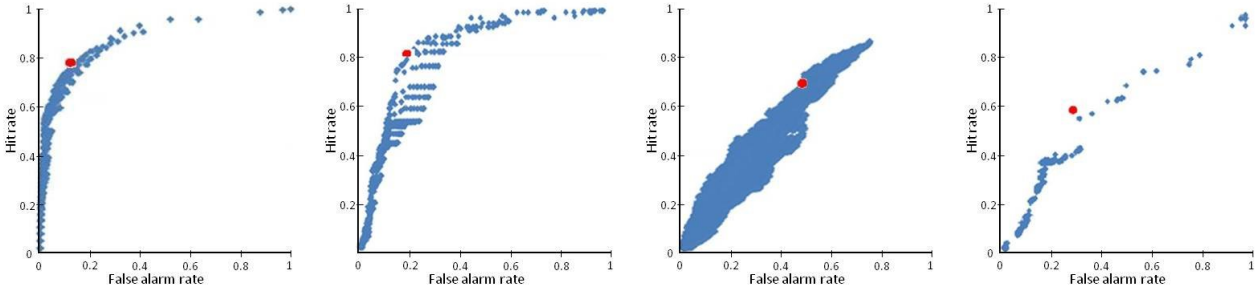

Figure 1. ROC curve for (a) walking detection, (b) talking detection, (c) desk working detection, (d) idle detection.

1) Detected behavior

After analyzing the number of behavior samples of the 92 participants, three outlier participants were excluded as they provided significantly less number of samples (< M – 2 x SD) due to their absence in the experimentation settings. The results hereafter report data from the remaining 89 participant, 74 males and 15 females (M = 36.07, SD = 8.56). From the total number of detected samples, 28% were detected as walking, 15% as talking, 30% as desk working, and 21% were detected as idle behavior. There were a 5% of samples which could not be detected as any of the proposed behaviors.

2) Behavior characteristic variables

Characteristic variables were obtained for the behavior samples and events of individual participants. The behavior characteristic variables (BCVs) were represented by letters triplets. The first letter of each triplet represented the behavior categories. This is W, T, D, and I represented walking, talking, desk working, and idle behaviors, respectively. The second letters in a triplet were A, T, E, and D, and represented time instances. A as a triplet's second letter represented the entire time span. T as a triplet's second letter represented the time ratio per day. This ratio was obtained by dividing a given behavior total time over the total time in a day. The letter E as a triplet's second letter represented the number of events per day. The letter D as the second letter in a triplet represented the behavior events duration. If the second letter of the triplet was A, the third letters of a triplet were T or E. In this case T represented the time ratio, and E represented an event. However if the second letter of the triplet was T, E, or D, then the third letter of a triplet were A, D, or M, which stood for average, standard deviation, and median.

Personalities like intrinsic or extrinsic motivation are estimated to be related to the variation of behavior. In order to assess this variation, the percentage of behavior-engaged time over all the experiment's time span and the number of events per day was calculated. It was also calculated the average, standard deviation and median of behavior-engaged time (time ratio T and number of events E) per day.

The concept of absorption is important for some personality traits and it is considered to be strongly related with uninterrupted behavior engagement. Therefore the average, standard deviation and median of the time continuance of each behavior were also calculated (triplets with "D" as the second letter).

3) Correlation among personality traits, mental health, and BCVs

Big Five personality scores and BCVs combinations whose correlations were significant are shown in Table I. Extraversion showed positive correlation with walking behavior variables. It was also found negatively correlated with talking events (TEA, TEM) and desk working related variables (DAE, DAT, DEA, DTA, DTM). These results suggested that people who often walk, and often spent their time away from their desks were likely to be extraverted.

TABLE I. PEARSON'S CORRELATION BETWEEN BIG FIVE PERSONALITY SCORES AND BCVS

	E	A	C	N	O
WAT	0.212 *	0.082	-0.142	0.006	0.076
WED	0.235 *	0.089	-0.109	0.118	0.147
WTA	0.216 *	0.091	-0.141	0.009	0.078
WTD	0.255 *	0.221*	0.015	-0.010	0.181
WTM	0.239 *	0.096	-0.130	0.010	0.081
WDA	0.238 *	0.120	-0.081	-0.102	0.059
WDM	0.226 *	0.128	-0.089	-0.039	0.104
TEA	-0.216 *	-0.164	0.032	0.129	0.018
TEM	-0.213 *	-0.140	0.043	0.110	0.027
TDD	-0.131	0.064	0.209 *	-0.041	-0.071
DAE	-0.298**	-0.029	-0.111	0.184	-0.002
DAT	-0.285**	0.000	-0.039	0.058	-0.142
DEA	-0.210 *	0.048	-0.132	0.216*	0.077
DEM	-0.204	0.099	-0.118	0.233*	0.078
DTA	-0.284**	-0.008	-0.036	0.059	-0.158
DTM	-0.273**	-0.007	-0.039	0.056	-0.154

n=89; **p<.01; *p<.05
E: extraversion, A: agreeableness, C: conscientiousness, N: neuroticism, O: openness

Intrinsic Locus of Causality personality scores and BCVs combinations whose correlations were significant are shown in Table II. Talking related variables were negatively correlated with intrinsic locus of causality, and both of its subscales, enjoyment and challenge. It can be argued that intrinsically motivated people have a strong preference for working individually without talking or interacting with people around. However, as it is shown in Table II, idle behavior variables were found positively correlated with challenge subscale alone. It might be argued that the nature of intrinsic locus of causality and challenge orientation, motivate these people to find time to think and reflect about their own initiatives.

Other results showed that extrinsic motivated people did not tend to stay in their desks or focus on their work for long periods as desk working related variable (DAT, DTA, DTM, DDM) were all negatively correlated with extrinsic locus of causality and compensation subscale.

TABLE II. PEARSON'S CORRELATION BETWEEN INTRINSIC LOCUS OF CAUSALITY AND SUBSCALES PERSONALITY SCORES AND BCVS

	Intrinsic	Enjoyment	Challenge
WTD	0.203	0.126	0.209*
TEA	-0.254*	-0.216*	-0.230*
TEM	-0.220*	-0.174	-0.214*
TTA	-0.211*	-0.210*	-0.173
TTM	-0.212*	-0.222*	-0.166
TDM	-0.226*	-0.231*	-0.174
DEA	-0.217*	-0.048	-0.283**
DEM	-0.168	0.005	-0.246*
IAT	0.280**	0.157	0.298**
ITA	0.285**	0.169	0.298**
ITD	0.209*	0.136	0.225*
ITM	0.264*	0.151	0.272*
IDA	0.239*	0.119	0.277**

n=89; **p<.01; *p<.05

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General Causality Orientation personality scores and BCVs combinations whose correlations were significant are shown in Table III. Talking related variables correlated negatively with the autonomy trait. On the other hand, impersonal trait correlated positively with desk working and idle behavior related variables. It can be argued that people who do not actively engage or face external circumstances tend to spend their time at their desks.

These results implied that people with high impersonal score, whose behavior is marked by decisions beyond their control, tend to follow directions as they are told. In other words, these people might not leave their desks or stop working. These findings are comparable to idle behavior variables being positively correlated with impersonal trait. It can be argued that as these people did not leave their desks, they might have time to loosen up, even in front of their desks.

Self monitoring trait was positively correlated with walking related variables (WAT, WTA, WTM, WDA, WDM). This suggested that people with high sociability skills, or those rating high in self monitoring, engage for longer periods in walking behavior. High self-monitoring rated people are able to show striking contradictions between their public persona and their private self [1]. Thus, by the fact that self monitoring correlated negatively with talking related variables (TEA, TEM) it can be argued that even though these people regulate their behavior by walking or interacting with others, they might be reluctant to show their opinions by an apprehension of social disapproval.

Type A trait correlated positively with the number of walking events per day (WEM). This suggested that people who tended to walk more often are likely to be competitive or involved in achieving more in less time. It might be argued that these people are often walking around, looking for self-improving opportunities.

Mental health scores and BCVs combinations whose correlations were significant are shown in Table IV. Both depression scales utilized in this study presented similar results which highlighted positive correlation with talking, desk working, and idle behavior related variables (TEA, TEM, DAE, DEA, DEM, IEA). These results suggested that people who more often engaged in talking, desk working, and idle behaviors present higher depression or stress scores. By the fact that BDI-II depression scale positively correlated with walking idle events related variables (WEA, IEM) it can be argued that both, unoccupied behavior people or persistently walking people, might display high work depression or stress.

The OHQ results showed that high talking, and desk working behavior people often showed frustration or discontent (TAE, TAT, TEA, TEM, TTA, TTM, TDM, DAE, DEA, DEM). It can be argued that people who talked for longer periods, would be able to cope with dissatisfaction.

TABLE III. PEARSON'S CORRELATION BETWEEN GENERAL CAUSALITY ORIENTATION PERSONALITY SCORES AND BCVS

	Autonomy	Control	Impersonal
WED	0.163	0.233*	0.085
WTD	0.231*	0.133	-0.041
WDA	0.175	-0.120	-0.240*
WDD	0.148	-0.244*	-0.182
TAE	-0.238*	0.000	0.101
TAT	-0.273**	-0.016	0.065
TTA	-0.278**	-0.029	0.060
TTD	-0.305**	-0.034	0.054
TTM	-0.254*	-0.032	0.051
TDA	-0.216*	-0.029	0.009
TDM	-0.292**	-0.096	0.034
DAE	-0.016	0.059	0.304**
DEA	0.041	0.054	0.331**
DEM	0.083	0.087	0.323**
IEA	0.077	0.117	0.296**
IED	0.148	0.222*	0.165
IEM	0.100	0.147	0.301**

n=89; **p<.01; *p<.05

V. CONCLUSION AND FUTURE WORK

The present study proposed a methodology to estimate personality from sensory data information. However studies pertaining personality with emphasis to the workplace are numerous, the established measuring method used by those studies were questionnaire tests. This study built up a clear methodology through which personality is estimated unobtrusively and without the need of questionnaires, through the use of acceleration and voice sensory information.

In Study One it was effectively detected walking, talking, desk working, and idle behaviors, with hit and false alarm rates of 0.78 and 0.12, 0.82 and 0.19, 0.69 and 0.48, and 0.59 and 0.28, respectively. In Study two, the correlation analysis showed significant correlations between behavior and all personality and mental health traits studied except for openness. Personality variables that showed significant correlations with greater extent of behavior variables were extraversion, intrinsic motivation, challenge, and happiness.

Also, the behavior category which showed significant correlation with the greater number of personality variables

TABLE IV. PEARSON'S CORRELATION BETWEEN MENTAL HEALTH SCORES AND BCVS

	CES-D	BDI-II	OHQ
WEA	0.103	0.221*	-0.083
WDA	-0.174	-0.139	0.237*
TAE	0.204	0.144	-0.215*
TAT	0.191	0.166	-0.235*
TEA	0.282**	0.267*	-0.287**
TEM	0.250*	0.271*	-0.267*
TTA	0.188	0.158	-0.228*
TTM	0.176	0.151	-0.211*
TDM	0.072	0.152	-0.270*
DAE	0.239*	0.254*	-0.255*
DEA	0.283**	0.371**	-0.283**
DEM	0.211*	0.355**	-0.255*
IEA	0.223*	0.264*	-0.156
IEM	0.173	0.246*	-0.119

n=89; **p<.01; *p<.05

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was desk working behavior category revealing 31 significant correlations; while the behavior category which showed significant correlation with the least number of personality variables was idle category with only 18 significant correlations.

The results in this study suggest that it is possible to effortlessly assess personality and mental health, respecting the privacy of employees, and without the need of questionnaires. What has been argued as a benefit of the use of questionnaires (greater choice) is a major weakness; the use of questionnaires allows for questionnaire items' omission or misrepresentation, thus affecting the overall effectiveness and goals of the assessment. This limitation affects the informant himself who is the ultimate beneficiary of the research efforts. Furthermore, personality is continuously shaped by experiences, and thus questionnaires are limited to cope with personality's changing nature. As the methodology presented in this study is set by continuously loading data, the personality and mental health information obtained will always provide up-to-date information. In addition, saving employers' and employees' time, is yet another benefit proposed by this study, which opens a new behavior estimation research direction, and thus its continuation is essential. Future studies should deepen this study's findings: it should consider additional working settings; the improvement of the behavior detection method including participants from both genders, and a larger set of behavior categories.

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