Show me your moves: Analyzing body signals to predict creativity of knowledge workers

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Abstract We propose a novel approach to measuring the collaboration of knowledge workers, using body sensing smart watches to capture psychometric data about individuals in a team. In a proof of concept study, we collected 2653 samples of body signals by equipping 15 people with our body sensing smartwatch over the course of three days during a design workshop. Additionally, we polled the users about their self-perceived team creativity at the end of each day. By employing multiple linear regression models, we found that body signals tracked by the smart watch correlate significantly with the perceived team creativity reported by the individuals. Comparing those correlations with known predictors of creativity such as mood states and personality traits we found that movement-related body signals predict creativity on the same accuracy level as mood states and personality traits do.

1 Introduction

The ability to innovate is one of the most important competitive advantages for companies (Somech, 2006). In order to survive, companies constantly compete to deliver the most creative and innovative new products, to adopt to changing governmental regulations or to adjust to rapidly shifting market conditions – all of which require creativity (Amabile, 1988). In order to succeed in this never-ending battle of adaption, companies rely on creative individuals working together in productive work groups.

Social science and psychology provide the foundation for studying human collaboration. Nonetheless, the output of collaborating knowledge workers is still hard to measure. For decades scientists and practitioners relied mostly on sparse, qualitative or subjective observations like survey responses or observed behavior in order to measure workgroup performance and creativity (Aral et al., 2012; Daggett et al., 2017). However, physiological data about users can likely provide "a richer account of user cognition than that obtained from any other source, including the user himself" (Minnery and Fine, 2009, p. 73). This assumption is reflected in the vast amount of literature that examines cognition and especially creativity by means of neuroscientist methods (e.g.: Gaskin et al., 2017; Jausovec and Bakracevic, 1995; Léger et al., 2014; Wagner et al., 2005).

Most studies utilizing methods of neuroscience to study creativity and cognition use medical grade equipment to collect body signals from participants (e.g.: Léger et al., 2014; Wagner et al., 2005). While this equipment is capable of collecting body signals with high precision, the costs of such equipment are also quite high. Gaskin et al. (2017) for example claim that the cost for professional heart rate monitors, EEG devices and blood oxygen sensors are multiple thousands of dollars. Another issue with high cost equipment is that it constraints the sample size as can be seen by various studies with low sample size in this area (e.g.: Jausovec and Bakracevic, 1995; Léger et al., 2014). Besides high cost and low sample sizes, medical grade equipment usually requires the user to be heavily tethered in order to measure body signals. The tethering of participants, however, might confound the actual measures of cognition and creativity.

Recent advances in digital technology, namely the rise of body sensing smartwatches, enable us to overcome all three of the limitations outlined in the paragraph above. Modern smartwatches can collect different physiological measures about its wearer (e.g.: heart rate, blood oxygen levels, acceleration, lighting) at a fraction of the cost for medical grade equipment. Additionally, a smartwatch is as unobtrusive as a bracelet (Gaskin et al., 2017), which minimizes the effect of the measurement device on the users' behavior.

In this proof of concept study, we aim to evaluate the use of body sensing smartwatches to predict creativity of knowledge workers in organizational settings. The research question that we are answering is: Can the data collected by smart watch based body sensors be utilized to identify factors that foster or mitigate creativity.

2 Related Work

2.1 Honest signals

The theoretical idea of this work is that human action and the reasoning for such action is mirrored in physiological and social signals. When we interact with individuals, those signals can display an objective measure of how fruitful the interaction is. Pentland & Heibeck (2010) called those signals *honest signals* in their 2010 book where they elaborated on implications, examples and opportunities that arise from the availability of such signals.

How those honest signals can be used to quantify human interaction is best demonstrated by an example: During one study Pentland & Heibeck (2010) invited a group of business executives to present one business plan each. Afterwards, each presentation was peer evaluated and the business plans were ranked according to how well the group thought the idea would sell. Additionally, each presenter was equipped with a sociometric badge to measure different social signals. The badges captured the variability in speech energy, the movement of the presenters and how many back and forth gestures such as smileys and head nodes occurred between the presenter and the audience. When using these measures to predict which business plan the executives would rank highest, Pentland & Heibeck (2010) achieved an almost perfect accuracy. In another study Pentland & Heibeck (2010) were able to use honest signals to predict job satisfaction and even creativity.

Pentland & Heibeck (2010) explicitly elaborate on four different honest signals that the sociometric badge captured in the example above:

Influence: Is the amount of influence one person has over another during a social interaction. It can be measured by how much each interaction participant was talking. If one person was talking more than her/his counterpart, s/he had a higher influence during the interaction.

Mimicry: Pentland & Heibeck (2010) argue that when two people are deeply engaged in a conversation and on the same wavelength, then they tend to copy each other's actions. We can measure the amount of mimicry in a social interaction by either analyzing the speech patterns of both participants or by taking a look at the physical activity. The more alike the speech patterns and the physical activity are, the higher the degree of mimicry.

Activity: The intensity of physical movement or speech energy during a social interaction. If we are excited about a conversation topic or simply interested in our conversation partner, we tend to talk more energetically and move more.

Consistency: Consistency is an indicator of how consistent our speech patterns or movements are during a social interaction. If our speech pattern or our movement intensity change during an interaction then consistency is low. Low consistency can occur when a person is nervous and high consistency might be an indicator of high self-confidence.

Within our research we measure activity and consistency of participants wearing the body sensing smart watch application.

2.2 Creativity

In this paper we understand creativity as *the production of novel and useful ideas by an individual or small group of individuals working together* (Amabile, 1988). During an interview study Amabile (1988) identified factors that promote individual creativity based on the qualities of the problem solvers in the group. She found that amongst others especially *mutual understanding*, the *quality of the group* (whether people can work together efficiently), and the *social skills of the group members* are paramount properties that influence the creative work of the group.

For the creative process, Glover et al. (2013), following Yamamoto's (1963) work, outlined different properties of the creative thinking process. They argue that creativity is expressed in the dimensions *flexibility* (many different ideas), *fluency* (lots of ideas) i*nventiveness* (inventing and developing ideas), *originality* (unique ideas) and *elaboration* (detailed ideas).

3 Research Methodology

3.1 Hypothesis

In order to answer the question whether physiological measures collected by a smartwatch reflect self-perceived creativity we developed the following hypothesis:

> *Body signals captured by a smartwatch correlate significantly with an individual's perceived creative performance measured by self-evaluation.*

We will run a statistical analysis with data collected from a study as explained in the remainder of this section. Since personality traits and mood state are well known to influence the creativity of an individual (Baas et al., 2008; Isen and Baron, 1991; Mumford, 2003; Sung and Choi, 2009), we use those as a baseline to compare the strength of the correlation between body signals and self-perceived creativity against. We assume the correlation between body signals and self-perceived creativity to be equally strong as the correlation between mood states and self-perceived creativity or personality traits and self-perceived creativity. The overall goal of this research is to explore the possibility of utilizing smart watch based body sensors in creativity research as a substitute for medical grade equipment.

3.2 Measuring Creativity, Mood States & Personality

We are developing a smart watch application called Happimeter[1] in order to measure a person's honest signals and happiness over time and compare this with self-reported creativity. The Happimeter is an application that was developed at the MIT Center for Collective Intelligence. In order to measure the mood state, the Happimeter uses an experience-based sampling method. The user is polled four to eight times a day at random times to rate her personal happiness (Budner et al., 2017).

Following Amabile's and Glover's characterization, we designed the following five question survey for participants to self-evaluate their creativity. For each of the items we gave a Likert-type scale as answer option with which the participants could indicate if they either **(a)** *totally disagree*, **(b)** *somewhat disagree*, **(c)** *neither disagree nor agree*, **(d)** *somewhat agree* or **(d)** *totally agree* with the given item.

The five questions of the inventory are the following:

- (Q1) Would you characterize today's teamwork as successful?
- (Q2) Would you characterize today's group work as creative in the sense that you had many different ideas?
- (Q3) Would you characterize today's group work as productive in the sense that the ideas of your group where of high quality?
- (Q4) Would you agree that your team members motivated you?
- (Q5) Was there fair and equal participation of every team member in your group?

(Q1) aims to assess the mutual understanding within the specific group. If a participant highly agrees with **(Q1)** it indicates that the mutual understanding within the group is good. **(Q2)** and **(Q3)** assess the perceived creativity of the individuals within the group based on Glover et al. (2013) and Yamamoto's (1963) characterization. **(Q2)** is tailored to measure the *flexibility* and the *fluency* of the creative thinking process. **(Q3)** assesses *inventiveness, originality* and *elaboration* of the creative thinking process. **(Q4)** measures the *quality of the group* in which the creative process takes places and **(Q5)** assesses the *social skills* of the group

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[1] The Happimeter smartphone and watch code is open source and free for academic use. More information can be found at https://happimeter.org.

members. The participants of the study were instructed about the meaning of the different questions to guarantee a shared understanding regarding the survey.

To get a quantified measure of creativity each of the questions was given a score depending on the answer given by the participants. If a participant answered with “highly disagree”, then the score was 1, if the participant answered with “highly agree”, then the score was 5.. The scores of each question were added up to get a single measure of creativity per participant. This single measure of creativity has a value between 5 (least creative) and 25 (highly creative).

To sample the mood state of a user, a two-dimensional model, similar to the circumflex model of affect, is utilized with one dimension being pleasance and the other dimension being arousal (Posner et al., 2005; Russell and Pratt, 1980). For each of the two dimensions the user can indicate on a three-point scale how strongly aroused or how strongly pleasant she feels.

To measure an individual’s personality we used the NEO Five-Factor Inventory (NEO-FFI) (Costa and McCrae, 1989). The NEO-FFI comes in different versions, which differ in the number of questions they contain. The version utilized during our experiment had 50 questions. For each of the five personality types (neuroticism, openness, extroversion, consciousness and agreeability) there are 10 questions that assess the extent to which one person inherits that specific personality type. To each question a four-point Likert scale is given as answer option. As a result of the test each of the five personality traits has a score between zero and 30 points. A score of zero, means that the individual does not inherit that given personality trait at all, a score of 30 indicates that the individual inherits the personality trait to a high degree. The consistency of the NEO-FFI ranges from .68 to .86 which proves its validity (McCrae and Costa, 2004).

3.3 Experimental setting

To collect data, we conducted a study at a German bank. The study was conducted over the course of three days in which knowledge workers from several subsidies of the company were invited to participate in a workshop. The goal of the workshop was to spread a creative mindset within the company by educating key employees. The workshop consisted of several short, lecture-like sessions followed by interactive sessions in which the participants were advised to solve problems by employing creative methods. The agenda of the workshop was loosely oriented by the different phases of the design sprint method – a method developed by Google to nurture creativity when solving problems (Banfield et al., 2015).

In total twenty-eight employees participated in the workshop. Because of hardware availability issues, only fifteen participants could be equipped with our body sensing smart watch that had the Happimeter app installed to track body signals and mood states. The participants were selected randomly and had the opportunity to skip participation. These fifteen participants were split up into three groups with each group working on different problems. In order to track the body signals, the Happimeter application measured the different body signals in fifteen-minute intervals and reported them back to our database. To track the mood states, the Happimeter app asked the participant to indicate her mood state four to eight times a day. At the end of each day, all participants were asked to fill out the creativity survey to indicate their perceived creativity. Additionally, each participant was asked to fill out a NEO-FFI personality test.

During the introduction phase of the workshop the participants were briefed about the different surveys in order to ensure a common understanding of the different items within the surveys. Additionally, the participants were introduced to the research goals and the method of data collection. After the introduction phase, the participants were asked whether they wanted to participate in the study.

3.4 Hardware & Software

In our experiments we used a Pebble 2[2] smart watch to gather the different body signals. The Pebble 2 integrates the following sensors that are accessible via the SDK: heart rate monitor, 3-axis accelerometer and an ambient light sensor. Utilizing these sensors, we tracked six distinct body signals of the participants during our study:

Prevailing activity within the last fifteen minutes (activity): The activity can either be resting/sleeping, unspecific, walking or running. Pebble uses the measures of the sensor to identify the current activity of its wearer. A detailed explanation of the algorithms used to discern different activities was published by (Stockham, 2016).

Average heart beats per minute within the last fifteen minutes (avg. bpm): Studies have shown that stress and health conditions are mirrored in a person's heart rate (Thayer et al., 2012), which we assume to be influencers of creative performance. Additionally, prior research has shown that the heart rate reflects an individual's perceived creative performance (Jausovec and Bakracevic, 1995; Sternberg, 1999).

Average surrounding light level within the last fifteen minutes (avg. light level): The avg. light level variable is an indicator for the intensity of the surrounding light. It is taken from the ambient light sensor of the Pebble smart watch and can have a value between one and five. Different lighting conditions are known to influence happiness and creativity (Knez, 1995).

Average of accelerometer intensity within the last fifteen minutes (avg. accelerometer): This body signal is an indicator for the magnitude of movement

[2] Unfortunately, the pebble 2 smartwatch has been discontinued and is not produced anymore. The happimeter was migrated to a generic Android platform. More information can be found at https://happimeter.org.

in the physical space. It is calculated by summing up the average values of the three axes of the accelerometer. Studies have shown that more rigorous movement and especially sports can have an impact on an individual's creative performance (Bowers et al., 2014). The acceleration is measured in milli-G (gravitational force).

Variance of the accelerometer intensity within the last fifteen minutes (var. accelerometer): This body signal is an indicator for the consistency of movement in the physical space.

Vector magnitude count during the day (VMC): VMC is a measure of the total movement over the course of the day. More rigorous movement yields higher VMC values (Stockham, 2016).

We argue that those body signals reflect the same honest signals that Pentland & Heibeck (2010) used to predict the performance of presenters as introduced in the previous section. The honest signal *Activity* is reflected in the heart rate and the movement (VMC, acc. avg. and activity) of individuals. The accelerometer variance is a measure of consistency.

In comparison to the aforementioned sociometric badges, the pebble smartwatch provides the possibility to measure heart rate, light level and the activity through accelerometer. Additionally, the sociometric badges are able to make audio recordings and measure physical proximity between people. These features are currently being added to the new Android watch version of the Happimeter.

4 Results

In order to test our hypotheses, we employed different statistical methods such as correlation analysis between the creativity score and the independent variables and different multilevel regression models.

4.1 Data

We collected 2653 valid observations of body signals through the smartwatch application. Additionally, all 15 participants filled out the creativity survey at least once with a total of 34 surveys that were filled out. Moreover, 298 pairs of pleasance-arousal samples could be collected through the smartwatch application. In order to benefit from the large number of collected body signals, the pleasance-arousal samples and the filled-out surveys were related to each of the 2653 collected body signals in such a way, that one pair of body signals has exactly one pair of pleasance-arousal samples and one creativity score assigned to them.

The first two variables, pleasance and arousal, represent the mood state of a person. For the pleasance variable, no participant reported an unpleasant mood state during the time of our experiment.

Values for the average (hearth)-beats-per-minute (avg. bpm) variable vary between 0 and 239 bpm. Values below 20 bpm and above 220 bpm are considered measurement errors and were replaced by the overall mean. The average light level (avg. light level) variable ranges from one to five, with increasing values representing increasing levels of surrounding light. Values for VMC, acc. avg. and acc. var. were scaled by the root-mean-square of the series. The values for VMC range from 0 to 1.6545, the values for acc. avg. range from 0 to 1.3640 and the values for acc. var. range from 0 to 5.9208.

The last four variables represent the different personality types. We coded the different personality types as binary variable, a value of 1 indicates that a participant inherits a personality trait to a high degree (more than 25 points in the NEO-FFI inventory). Within our study we found no participant that inherits a personality trait that is related to anxiety.

Table 1: Independent Variables

Variable	# Valid Measures	Variable	# Valid Measures
High Pleasance	2428	Activity: walk	114
Neutral Pleasance	225	Activity: run	3[3]
Low Pleasance	0	VMC	2653
High Arousal	143	Acc. Avg.	2653
Neutral Arousal	1904	Acc. Var.	2653
Low Arousal	607	Is Open	2
Avg. bpm	2653	Is Agree	2
Avg. light level	2653	Is Conscience	2
Activity: rest	1097	Is Extro	2
Activity: none	1479		

4.2 Body signals and creativity

One major finding was that movement related body signals do correlate with the self-perceived team creativity. We found that especially the movement intensity, measured by the accelerometer averages, does correlate significantly with self-perceived creativity. Additionally, the activities of the participants, measured by the Pebble activity metric, demonstrate an even better predictor for creative performance. Lastly, also the heartrate average does correlate significantly with creative performance.

A regression analysis with body signals as independent variables further strengthens our argument that self-perceived creativity is mirrored by the body

[3] The three measures of “Activity: run” all resulted from one person that went for a 45-minute run in the morning of one workshop day.

signals. We find that the movement intensity measured by the accelerometer average has a positive impact on creativity, whereas a high variability in movement measured by the accelerometer variance has the contrary effect. When looking at the different activities that are tracked by the smart watch, we find that if a person went for a run before the workshop started, s/he perceived her/his work more creative.

These results demonstrate that body signals captured by a smart watch can indeed reveal the self-perceived creativity of a person. Especially the movement patterns of individuals and whether a person is doing sports before a working session seem to predict the creativity of individuals.

Table 2. Correlation of creativity with mood states (n=2653)

	1	2	3
1 Creativity score	1.00		
2 Pleasance	.02	1.00	
3 Arousal	.08***	-.07***	1.00

Table 3. Correlation of creativity with body signals (n=2653)

	1	2	3	4	5	6	7
1 Creativity score	1.00						
2 Avg. bpm	.05**	1.00					
3 Avg. light level	.02	.20***	1.00				
4 Activity	.20***	.37***	.20***	1.00			
5 VMC	.01	.19***	.09***	.22***	1.00		
6 Acc. Avg.	.09***	.20***	.01	.03	.04**	1.00	
7 Acc. Var.	-.02	.52***	.12***	.31***	.13***	.12***	1.00

Table 4. Correlation of creativity with personality (n=2653)

	1	2	3	4	5
Creativity score	1.00				
1 Is Open	.05**	1.00			
2 Is Agree	.02	.20***	1.00		
3 Is Conscience	.20***	.37***	.20***	1.00	
4 Is Extro	.01	.19***	.09***	.22***	1.00

Table 5. Multilevel Regression Models (grouping by participant ID)

Variables	I	II	III	IV
High pleasance	-	.501***	-	.463***
Neutral arousal	-	.527***	-	.591***
High arousal	-	.824***	-	.899***
Avg. bpm	.000	-	-	-.000
Avg. light level	-.001	-	-	-.075
Activity: none	.009	-	-	0.028
Activity: walk	-.106	-	-	-.016

Activity: run	2.434**	-	-	2.549***
VMC	-.527***	-	-	-.420***
Acc. Avg.	.393**	-	-	.379**
Acc. Var.	-.155***	-	-	-.253***
Is Open	-	-	1.336	0.975***
Is Extro	-	-	.479	-.229*
Is Conscience	-	-	-.567	-.722***
Is Agreeable	-	-	-2.895*	-3.135***
Constant	20.462***	19.412 ***	21.997***	21.400***
Random effects std. dev.	2.348	2.376	1.804	1.818
R^2 (marginal / conditional)	.007 / .680	.008 / .688	.297 / .684	.311 / .701
N / Groups	2653 / 15	2653 / 15	2653 / 15	2653 / 15
AIC	10189.59	10154.89	10219.76	10118.7
BIC	10254.31	10190.19	10260.94	10224.61

4.3 Mood States, Body Signals and Creativity

To validate the results shown above, we compared the correlations between body signals and creativity with the correlation between mood states and creativity (tables 2, 3, 4). We found that self-perceived creativity correlates with arousal as well as with movement and the heart rate, and also with the activity of a person. Regarding pleasance we did not find a significant correlation.

For the multilevel regression (table 5) with participants as the second-level grouping variable, we first used only the mood state related variables as predictor for the creativity score. In the second and third model we employed the same approach with personality traits and the body signals itself. Lastly, we created one regression model containing all dependent variables. We find that a neutral arousal state and high arousal both have a positive impact on self-perceived creativity. A high pleasance state also has a positive impact on creativity. Comparing those results with the body signals, we find that the accelerometer average and variability seem to have a slightly weaker coefficient. However, going for a run in the morning has a greater impact on creative performance than the different mood related variables.

4.4 Personality, Body Signals and Creativity

As a second baseline we chose the personality of the participants. Looking at the correlation between the different personality traits and the creative performance we find that most of the personality traits seem to influence creativity strongly. The openness of participants is a strong indicator for creative individuals and being agreeable seems to strongly mitigate the perceived creativity of an individual as does being conscientious. Extroversion has a weak impact on creativity.

For the regression analysis we find the different personality traits to mostly be insignificant in model III. However, if we look at the combined model IV, we find all personality traits to be significant, this indicates that personality traits alone are an insufficient predictor for perceived creative performance, and that combining those variables with physiological measures improves the quality of the regression model.

4.5 Summing up

We find the predictive power of body signals towards self-perceived creativity on a similar level as the predictive power of mood states and personality towards self-perceived creativity. The regression coefficients of the personality related variables seem to be somewhat more predictive than the coefficients of the body signals, yet they are insignificant in a model that does not contain body signals. Therefore, our hypothesis seems to be confirmed: *Body signals captured by a smartwatch correlate significantly with an individual's self-perceived creative performance*.

Moreover, our findings are in line with prior research analyzing the relationship between body signals and creativity or performance. As introduced in section 2, Pentland & Heibeck (2010) analyzed the performance of business pitches by using the honest signals as a predictor. They found a high level of activation (measured by increased movement) to be one of the predictors for a successful pitch. In addition, they found low consistency (measured by a high variability in movement) to mitigate success in that context. We were able to replicate these findings with self-perceived creativity as the dependent variable and different movement related variables as well as the heart rate as independent variables. We found the honest signal *Activity*, measured through movement intensity (acc. avg., VMC, Activity: walk, Activity: run), reflects self-perceived creativity. Low *Consistency* on the other side, measured through movement variability (acc. var.), reflects low self-perceived creativity.

5 Limitations and Future Work

The major limitation of this study is the small sample size which constrains the validity of our findings with just 15 participants over three days. For example, participants only indicated pleasant mood states during the time of the study. Another issue with the sample size can be found for the variable Activity: run, which only occurred three times in our dataset. Moreover, all instances of this variable resulted from the same person going for a 45-minute run in the morning. Further studies have to show whether there is general relationship between going for a run and self-perceived creativity.

Yet another limitation is the metric by which creativity was measured. Self-evaluated creativity might not reflect the actual creativity during the group work process. Future studies should re-evaluate the findings with more objective measures.

Additionally, we are working on improving the employed smart watch application to include more sensors to get a more holistic view of the participants' body signals. We aim to replicate this study with an extended version of our body sensing smartwatch which will able to capture the speech energy of the participants as well as the physical proximity between the participants. Collecting those measures will enable us to not only analyze the body signals on the individual level, but to also take the differences between the body signals of the different participants within a group into account.

Despite the aforementioned limitations, we showed that body sensing smart watches can be a viable tool to measure creativity and performance of knowledge workers in organizational settings. Thus, we encourage fellow researchers to employ similar methods of data collection to further deepen our understanding of how physiological measures can reflect creativity and other hard to measure personality traits.

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