

Exploring the Mind with the Aid of Personal Genome — *Citizen Science Genetics to Promote Positive Well-Being*

Takashi Kido^{a,b} & Melanie Swan^c

^aRiken Genesis Co., Ltd., Taito-ku, Taito, 1-5-1, Tokyo, Japan.

^bJST PRESTO, 4-1-8 Honcho, Kawaguchi, Saitama, 332-0012, Japan.

^cMS Futures Group, P.O. Box 61258, Palo Alto, CA, 94306, USA

Correspondence Email: kido.takashi@gmail.com

Abstract

Understanding the human mind and increasing individual happiness are important goals in Artificial Intelligence (AI) and well-being science. The recent revolution in portable self-tracking devices in the data-driven wellness movement and participatory-driven wellness communities, such as the Quantified Self community, provides us with new opportunities to collect psychological or physiological data for understanding the human mind. While new technologies make it possible to track our daily behavior and various biological signals such as physiological or genetic data more easily, one of the important remaining challenges is to discover our own truly meaningful personal values. Citizen science, scientific research by crowdsourcing or human-based computation, is a new and challenging framework that promotes interdisciplinary research in the fields of computer science, life/brain science, and social psychological/behavioral science, which may introduce new paradigms to the AI community. We have been working on citizen science projects related to the area of personal genomics and have developed a personal genomics information environment named MyFinder. The developed platform supports the search for our inherited talents and maximizes our potential for a meaningful life. In particular, we are interested in the human mind and the personal genome. In this paper, we introduce our MyFinder Project and present the results of a recent study on “social intelligence genomics and empathy building”, and discuss issues involved in exploring our mind within the context of personal genomics.

Introduction

Recent wellness self-tracking devices and social media platforms have provided us with new methods for quantifying our personal daily behavior [5,16,19,24]. This presents us with new opportunities for understanding the human mind and for increasing individual happiness, both

of which have been the ultimate goals of artificial intelligence (AI) and personal health science, respectively [9,17]. In order to explore different approaches for improving personal wellness using AI, we organized a workshop titled “Self-Tracking and Collective Intelligence for Personal Wellness” at the AAAI 2012 Spring Symposium. The aim of the workshop was to integrate individual and collective approaches to improving wellness [9]. The individual approach focuses on recently developed self-tracking technologies for monitoring personal health, such as sleep, diet, exercise, and vital signs data, as well as technologies for analyzing personal medical data and personal genome data. The collective approach employs collective intelligence, i.e. the knowledge of other individuals and groups, as a potential source of knowledge on personal wellness. To achieve these aims, we examined how AI and other technologies can be used to help us to create value in our future potential wellness. Examples of such applications include (1) self-tracking for personal wellness (sleep monitoring, diet monitoring, vital data monitoring, personal medicine, personal genomics, new self-tracking devices and portable mobile tools), and (2) collective intelligence for personal wellness (data mining for scientific discoveries on collective data, biomedical informatics and systems biology and data visualization). Through discussions at the symposium, we realized that feedback interactions from both approaches are very important for designing successful personal well-being research frameworks. We therefore attempted to design frameworks specifically tailored to analyze the personal genome, which is a particularly ambitious undertaking in the biomedical community [1,2,10,11,24]. The price of sequencing a human genome has decreased markedly in recent years; from 2 billion US dollars in 2000 to 10,000

US dollars within the next few years [1,10]. We consider that this rapid reduction in costs will help us to answer very challenging questions, such as “Is our mind explained by brain activity and genetic interactions?” We also believe that personal genomics, and biomedical and cognitive interpretations thereof, will play an important role in realizing personalized medicine as well as increasing our understanding of the human mind [1,2,7,10,11,12,18].

The aim of this paper is therefore to introduce MyFinder, present the results of our “social intelligence genomics and empathy building study”, and discuss issues related to exploring our mind using personal genomics.

The Concept of MyFinder

The MyFinder project is a novel research framework for representing one’s personal genomic environment. It combines the notion of an intelligent agent in the AI community and personal genomics research in the biomedical community [10,11]. The MyFinder project has two goals. The first is to provide a personal genomic environment that enables us to find our inborn nature, strengths and talents, and to maximize our potential (individual approach). The second is to provide a research platform for scientific discovery through community computing (collective approach). A visual illustration of these two approaches is given in Figure 1.

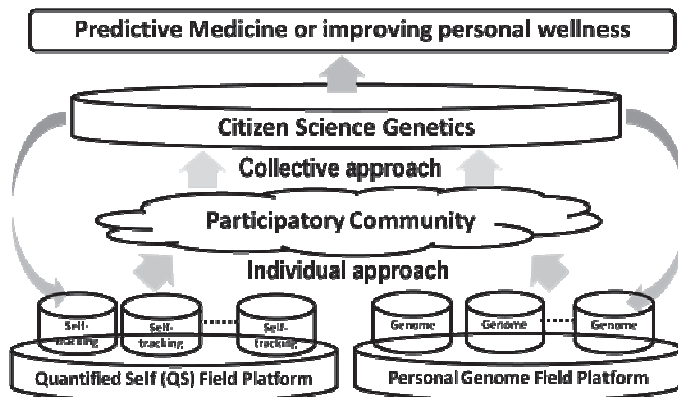


Figure 1: The Concept of MyFinder

Current System Design of MyFinder

We have been developing a self-tracking environment for collecting personal activity and mental status data on a daily basis. Several examples of such self-tracking, daily event data and how they can be displayed are shown in Figures 2A-C.

Figure 2A shows an event summary and event graph. The user can visually record his/her daily score logs for seven event categories and analyze their personal logs. Colors in the table indicate the frequency of the events.

Figure 2B shows a weekly view of the user’s life logs. A higher score represents high performance in each event category. Figure 2C shows the correlation between each score log for two different categories. We expect that MyFinder will provide a useful online tool for self-tracking such values and behaviors for personal wellness applications [10,11,19,20]. These self-tracked data types will be integrated with data on their personal genome to clarify the correlation between an individual’s genes and their behavior patterns.

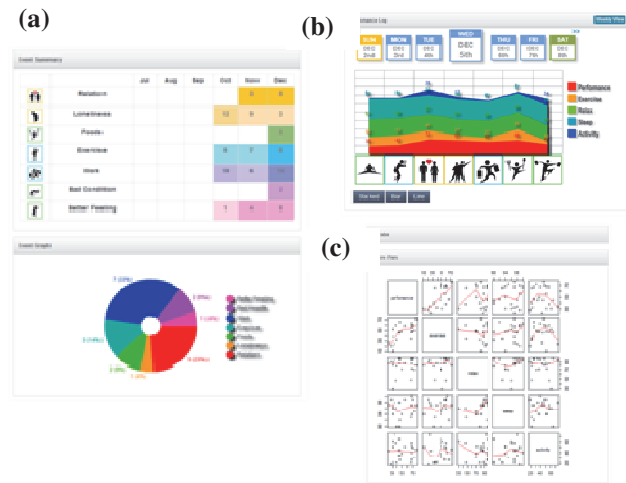


Figure 2: The snapshots of MyFinder

(a) Event summary and event graph

(b) Weekly view

(c) Pair-wise correlations

Self-Tracking Values and Behavior with Personal Genome

One of the challenges associated with the system is to extract an individual’s values and behavior from their daily personal life logs. Recording daily events would incentivize users to discover their behavior patterns and to modify their behaviors using positive willpower. We therefore established the Quantified Self (QS) community in Tokyo to share personal findings among the QS community [19,20]. Here we show examples of the tracking records, interpret the data and describe our findings.

(1) Personal Findings from Self-Tracking Activities

The following are examples of daily personal observations:

- My type of enneagram may be “Type3”.
- I often use the words, “Freedom To Fail”, and I like challenges.
- I like to be calm rather than busy.
- I usually come up with ideas in the morning.

- I wake up early in the morning (4:30 AM); the following habits may lead me to “flow” states.
 - Record my dreams and draw images
 - Reading bibles and books
 - Take a bath and meditate
 - Writing a diary
 - Running

(2) Findings from Personal Genome Interpretation

Personal genomics is a revolutionary movement in the biomedical and personal medicine community. Can our mental status be explained by brain activity and genetic interactions?

One of the QS Tokyo participants sequenced his entire genome and annotated disease risk, drug response information, and other genetic talent information, such as Alcohol flush reaction, hair curl, smoking behavior, food preference, longevity, pain sensitivity and avoidance of errors. The following are examples of personal information derived from personal genomic information:

- I have a low tolerance for alcohol. (ALDH2)
- My muscle performance is the same as many world-class sprinters (ACTN3)
- My ability to avoid errors is not very efficient (DRD2)
- My tendency to seek novelty is high (DRD4)
- I do not have any serious disease risks at present.
- My father knew the risks of colon cancer from his genotype data and had a polyp removed. He is fine now.
- Several of the predictions are preliminary and do not appear to reflect my current status. I am currently seeking answers to these issues.
- Behavior change: I have started to exercise and read.
- It is fun. I am interested in the evolution of the human mind and in my behavioral trends.

(3) Behavior Change through Self-Tracking

We attempted to analyze how self-tracking activities can change an individual’s behavior. Our next challenge was to design a scheme to investigate personal incentives and processes necessary for changing an individual’s behavior. Behavior design models such as B.J Fogg’s Behavior model [3] and flow theory [4] will be important in this analysis.

Citizen Science with Personal Genomics

Citizen science is a scientific research framework conducted by voluntary participants contributing to data collection, analysis of scientific data and development of tools. The citizen science movement can be considered as the “democratization of science” [5,24]. Traditionally science has mainly been conducted by professional researchers employed by universities and government research laboratories; so-called “citizen scientists” may be

amateur or nonprofessional scientists. Citizen scientists often partner with professional scientists to achieve common goals. Large voluntary participants often allow scientists to conduct research tasks that would be too expensive to accomplish by other means. The potential advantages of citizen science are as follows:

- Democratization science
- Cost benefits
- New incentives for individuals as citizen scientists

Challenging issues for successful citizen science are considered to be the following:

- How to increase an individual’s incentives to participate in the community.
- How to facilitate democracy in the citizen science community.
- How to improve the quality of science using self-reporting data.

Human computation [7], mechanism design in game theory, and gamification will provide important tools and theoretical frameworks for realizing successful citizen science.

We have been conducting citizen science genetics projects with DIY genomics using the Genomera platform [6]. In the following sections we introduce our ongoing projects and preliminary scientific discoveries.

Social Intelligence Genomics and Empathy-Building Study

We are currently conducting a citizen science program on social intelligence genetics research. The following study protocols are related to our social intelligence research [5,6].

Summary: Mental performance and social intelligence genomics are new and important areas of research. Recent studies have found links between personal genetic profiles and aspects of social intelligence [13,14,15,21,22,23]. This study seeks to investigate the overall social intelligence profiles of individuals by examining their genetic profiles and responses to phenotypic questionnaires. In addition, the potential for improving social intelligence skills through intervention will also be examined.

Hypothesis: Individuals with certain genetic profiles (e.g., a particular genotype) may exhibit a greater natural capacity for improving social intelligence.

Genotype data: At least three genetic polymorphisms will be examined: OXTR rs53576, DRD2/ANKK1 rs1800497, COMT Val158Met rs4680, and CRHR1, which have been associated with optimism and empathy, extraversion, and altruism, respectively [13,14,15,21,22,23].

Phenotype data: Recognized standard online survey instruments will be used for the phenotypic assessment of optimism, empathy, extraversion and altruism.

General personality indicator

- Big Five Personality Test (Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism) (44 questions) (REQUIRED)
- NEO Personality Inventory-Revised (NEO PI-R) (300 questions) (OPTIONAL)

Empathy

- Self-reported empathy
- IRI – Interpersonal Reactivity Index (28 questions) (REQUIRED)
- Empathy Quotient test (Baron-Cohen) (60 questions) (OPTIONAL)

Behavioral empathy

- Reading the Mind in the Eyes (Baron-Cohen) (OPTIONAL)
- Video and audio empathy tests
- Reading the Mind in Films (Baron-Cohen) (OPTIONAL)
- Reading the Mind in Voice (Baron-Cohen) (OPTIONAL)

Optimism

- Life Orientation Test – Revised (10 questions) (REQUIRED)

Extraversion

- (Same as above) Big Five Personality Test (Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism) (44 questions) (REQUIRED)

Altruism

- NEO Personality Inventory-Revised (NEO PI-R) – Section A3 (10 questions) (REQUIRED)

Study methodology: The study will be conducted using a crowdsourced cohort. Enrollment will be open and ongoing, with a minimum of 100 participants sought for the first phase of data analysis. Study recruitment and management will be via the internet-based health collaboration community, Genomera [6]. Basically, participants will join the study, provide informed consent, agree to share personal genotype data for the polymorphisms of interest, and complete the online surveys. Personalized feedback will be provided to participants and optional interventions will be offered for social intelligence skill-building.

Study phases: Phase I will investigate whether the findings of previous studies are replicated in the crowdsourced cohort. Phase II may explore the potential causes and influences of these personality traits with online questionnaires focusing on belief elicitation and other attributes, and whether suggested recommendations and interventions delivered via a mobile platform and/or other methods are effective for improving social intelligence, for

displaying the desired individual traits, and for assessing the user experience in the study.

Preliminary Results

We investigated the relationship between OXTR gene mutations in the two self-reporting empathy tests: EQ and IRI and present the results in Figure 3. The X-axis shows the SNP genotype (OXTR genes, rs53576). We currently have 15 EQ and IRI score samples with genotypes. GG has a higher value than AA and AG (Figure 4B). A previous study showed that individuals with A allele typically score low on tests of optimism [23], and we obtained similar findings in previous report [23]. Individuals with the GG genotype tend to have higher scores in both EQ and IRI tests than individuals who with the AA/AG genotype. Although the *P*-values for EQ and IRI currently do not show strong statistically significant associations ($p=0.195$ and $p=0.098$, respectively), increasing the sample size is expected to increase the statistical robustness of the analysis.

Interestingly, the current results differ from our initial expectations. Figure 4A shows that individuals with the AG genotype have lower EQ/IRI score values than

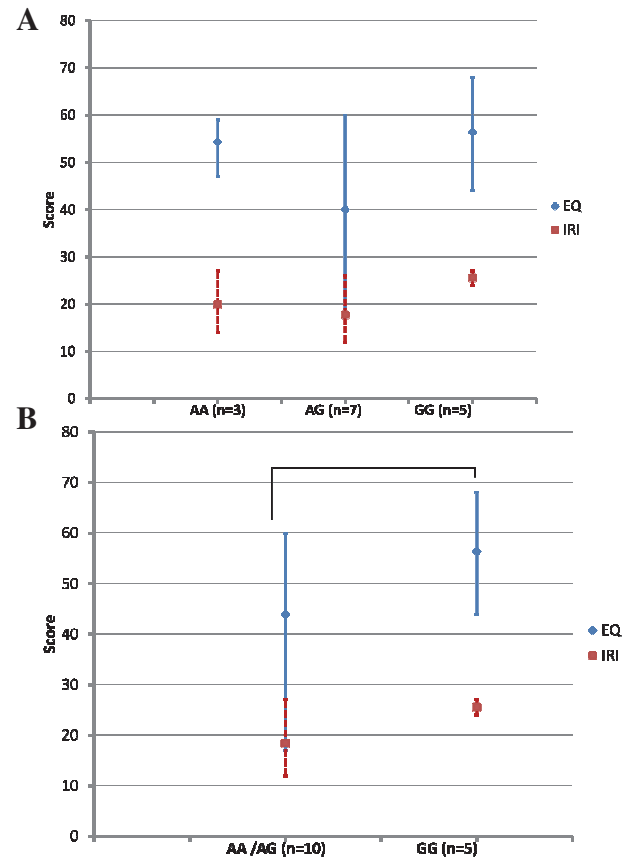


Figure 4: The relationships between OXTR genetic mutation and EQ/IRI score, (A) AA vs. AG vs. GG, (B) AA/AG vs. GG.

individuals with the AA genotype (Figure 4A). These findings suggest that the hypothesis of our initial expectation [5,6], that an increase in the frequency of the G allele corresponds with increased optimism, is not valid; rather, an increase in the frequency of the A allele corresponds to decreased optimism. Despite the small sample size (n=15), we expect that the relationships will become clearer as the number of samples increases.

Discussion

Interpretation of Preliminary Results and Implications

It has been suggested that a genetic predisposition exists for psychological qualities such as optimism, empathy, extraversion, altruism and openness to experience [13,14,15,21,22,23]. Our Social Intelligence Genomics and Empathy-Building Study supports previous findings that carriers of the A allele of the OXTR SNP rs53576 score lower on standardized test instruments (e.g., the EQ and IRI) than those with other genotypes. Our current results therefore support the hypothesis that psychological traits have a genetic basis and that OXTR may be involved. The 15 participants in the current study are mostly Europeans, and as such their genotype frequencies of rs53576 differ from those of Asians [23]. Asians, in turn, have higher frequencies of the A allele of the OXTR SNP rs53576 than Europeans [23]. This disparity in allele frequencies may explain why Asian people are considered less optimistic than Europeans [23]. However, this assumption is currently debatable and further investigation with a larger sample size is necessary. Although the precise molecular mechanisms of OXTR in the brain are unclear, previous research suggests that polymorphic variation may modify epigenetic expression of OXTR. [23] This will be an interesting biological area for future research.

This study also is considered to be an important step toward understanding the genetics underlying positive well-being and many questions related to positive well-being remain to be investigated in the future. The mechanisms of the human mind are very complex, and the relationships between genetic factors and environmental factors are interdependent. Understanding the interactions between genetic factors and environment factors will be a very important challenge. Brain science, psychology, genetics and AI will provide the tools and frameworks with which to elucidate these mechanisms.

Future Work for Understanding the Human Mind in Conjunction with the Personal Genome

How our mind has evolved over the course of evolution is a challenging research question. Minsky has raised several ideas on human mind models in his book [17]. Minsky argues persuasively that emotion, intuition and feeling are not distinct things, but different ways of thinking. We are interested in understanding how various ways of thinking

evolve and how the complex diversity of personalities emerges.

Kahneman discusses the issues of cognitive processes and psychological factors associated with human behavior in his book [9]. The author argues that cognitive biases exist in human thinking processes and introduces persuasive evidence that both loss aversion and optimism biases are involved in human decision processes in behavioral economics. We are currently investigating whether social intelligence skills can be improved through intervention using mobile phone platform as we believe that the way in which modern digital technologies affect the human cognitive mind is an interesting research topic. Personal genomics research may reveal the genetic biases underlying cognitive mechanisms and in so doing, facilitate our understanding of these biases within the context of human evolution.

Personal genomics research and its contribution to understanding the human mind is expected to be useful for realizing predictive medicine [1,2]. An important area of future biomedical research is developmental disorders, such as ADHD and autism. One of the goals in this research field is a systematic understanding of such disorders by elucidating the fundamental mechanisms involved in the human mental developmental processes of fetuses and adults. Personal genomics and biomedical analyses using AI technologies will make important contributions to this area.

Another interesting application of our research is in well-being science. Our citizen science genetics project could facilitate the development of tools for finding an individual's inherited talents and to understand the basic mechanisms involved in the human sense of happiness from an evolutionary viewpoint. Psychological theories for well-being, such as positive psychology, would be closely related to this area. The Stanford CCARE (The Center for Compassion and Altruism Research and Education) [25] project is attempting to understand the processes involved the human sense of compassion as well as developing useful educational programs. It may provide us with important insights for maximizing our potential in life.

Challenges for Combining AI and Data-Driven Wellness

We expect that the research framework for MyFinder and our citizen science genetics project for exploring the human mind will incorporate new developments in AI, primarily because understanding the human mind has been one of the primary goals of AI. New developments in self-tracking wellness devices and collective intelligence computation for large datasets of biological and personal data will promote scientific investigations on the human mind. In addition, developing well-being applications with AI technologies will contribute to an increase in healthy lifestyles. Several new wellness applications will be developed for increasing personal wellness. Finally, a

citizen science-based approach to such research promotes the development of new methods for scientific discovery. Mechanism design for human computation and gamification will be important topics in AI research. Our project will facilitate research in the following important areas of AI and data-driven wellness:

- Data collection and integration from personal self-tracking devices
- Behavior pattern analyses of personal life logs and psychological analyses
- Knowledge representation of human cognitive processes
- Mechanical design of human computation and gamification for citizen science applications
- Integration of large data sets and biomedical data mining within the context of systems biology and personal genomics interpretation
- Field study and exploration of new methodologies for “field informatics” [8]

These challenges will promote AI research and the development of data-driven wellness will contribute to an increase in quality of life. It will be possible to address aspects related to well-being science, ethics, and religion with greater clarity through these research investigations.

Summary

In this paper, we described the research framework of our ongoing project, MyFinder. We reported some of our findings related to personal self-tracking and citizen science projects related to personal genomics. We described a citizen science project for studying social intelligence and discussed the potential and limitations of this framework. Issues related to exploration of individual minds with personal genomics and the potential contributions of AI and well-being science were also examined.

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