

# Ambient Intelligence and Crowdsourced Genetics for Understanding Loss Aversion in Decision Making

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## Abstract

The big challenge for Artificial Intelligence is a better understanding of human nature. Our fundamental motivation is to understand the minds of modern people by uncovering mechanisms of the brain, genes, and body, and enhancing our health and cognitive talents with Artificial Intelligence technologies. This paper presents how we can quantify cognitive biases in the decision-making process and understand the evolutionary mechanisms using Ambient Intelligence and crowdsourced genetics technologies. We focus on prospect theory (proposed by Daniel Kahneman), which models how people choose between options involving gains or losses. People perceive losses to hurt more than gains feel good. This “loss aversion” is an important cognitive bias in decision-making. However, little is known about individual differences in loss aversion. We launched a citizen science project to test the hypothesis that mutations in genes related to neural processes are related to individual variation in loss aversion. Our preliminary experiment showed that DRD2 gene mutations may be related to individual variation in loss aversion. This crowdsourced genetics research is probably the first trial to report the possibilities of individual genetic differences in loss aversion behaviors. We discuss the future paradigms in Ambient Intelligence for health and cognitive enhancement.

## Introduction

In many ways, the brain is the final frontier. Thinking, cognition, emotion, and consciousness remain some of the most complicated unsolved mysteries capturing the attention of both the layperson and researchers in fields ranging from science to philosophy. Numerous disciplines are developing more ways to understand and manipulate the operation of the brain. At the basic science level, a variety of imaging techniques (PET, fMRI, EEG, MEG, NIRS, and

SPECT) have enabled great progress in the functional mapping of brain activity. These representations are helping to extend research efforts in many areas, such as neuroscience, cognition, psychology, and social behavior.

A series of projects that are currently emerging concern the definition of the connectome. The connectome is envisioned as a network map of the anatomical and functional connectivity in the human brain, elucidating the essential circuits for different activities. Notable projects include the U.S. government-sponsored Human Connectome Project (<http://www.humanconnectomeproject.org/>) and the Allen Mouse and Human Brain Atlases (<http://www.brain-map.org/>), which use the technique of combining genomics and neuroanatomy into gene expression maps. Simultaneously, Artificial Intelligence projects have been trying to reverse engineer the mammalian brain and develop computer simulation models of its activity. One well-known effort is Henry Markram’s Blue Brain Project (<http://bluebrain.epfl.ch/>), in which the key proposition is that the unit of macro level brain structure consists of large fields of neocortical columns. Such research is extending both neuroscience and supercomputing (Schürmann et al. 2014).

These kinds of scientific tool allow investigation into some of the more qualitative influences on brain operation in such areas as politics, economics, religion, and artistic expression, and in the nascent fields developing around this, such as neuromarketing and neuroeconomics (Lynch 2010). Interesting progress has recently been made in the neuroimaging of emotion, establishing some of the biophysical parameters of how feelings affect the human body (Nummenmaa et al. 2014; Wager et al. 2008). While we may have some degree of conscious awareness of our current emotional state, such as anger or happiness, the mech-

anisms that give rise to these subjective sensations have not been articulated in detail. In fact, one great hope outlined for personal connectome brain maps is that individuals may be able to share experience and the actual sensation of what something is like (Kaku 2014). At the moment, we are only able to share information, but the ability to share experiences could open up a whole new level of human communication, experience, and interaction. Finally, we might be able to make advances with seemingly intractable problems, such as the nature of subjective experience and qualia, and questions like “Is your experience of the color red the same as mine?” and “What it is like to be a bat?” (Nagle 1974).’

These types of neuroscience technologies and economic theory are already productively coming together in the area of bias awareness and management. We currently know that we are biased in our perception and interaction with the world on many levels due to evolution and culture (Swan 2015). There is the level of basic biology where nature’s evolutionary requirements filter, order, and hierarchize the overwhelming amount of data streaming into our senses before it is routed to our cognitive circuits. Similarly, culture and society put a lens on our perception from an individual and group dynamics perspective in the form of attunement to such aspects as power relations, social conditioning, status-garnering, and mate selection (Hrdy 1999). There are also several known human cognitive biases, including loss aversion, overconfidence, confirmation bias, rationalization, probability neglect, and hindsight bias (Kahneman 11) LessWrong (<http://lesswrong.com/>). This paper examines prospect theory, which concerns the perception of gain and loss, asymmetric aversion to loss, and some of the resulting decision-making practices. Loss aversion is a potentially complicated situation that may involve various cognitive operations, such as reward processing, reward anticipation, action-taking, risk-taking, risk-avoidance, and propensity for addiction (Swan 2013).

### **Prospect Theory: Understanding the Characteristics of Human Cognition**

The objective of this paper is to expand the MyFinder concept framework (Kido 11b, 13a) into the field of cognitive psychology. The purpose of the MyFinder concept is to apply individual differences in genes not only to medicine but also to the identification and enhancement of cognitive functions. In the following section, prospect theory, a fundamental theory for identifying cognitive psychological characteristics, is introduced along with the idea of community-oriented discovery science that connects prospect theory to personal genome research.

### **Prospect Theory (Kahneman 2011)**

Prospect theory models how people choose between, and evaluate options that involve gains or losses. People perceive value differently depending on whether they are gaining or losing something. Losses hurt more than gains feel good. This phenomenon is called loss aversion. For example, consider the following question.

Question: You are invited to bet money on a coin toss. If the coin lands on tails, you will have to pay ¥10,000. If the coin lands on heads, you will receive ¥15,000. Is this an attractive bet? Would you accept?

For most people, the fear of losing ¥10,000 is stronger than the hope of winning ¥15,000. Through a number of studies, Kahneman et al. concluded that “losses hurt more than gains feel good” (Kahneman 11) and discovered that most people will not bet money if they cannot win about twice more than they would lose. However, it is known that professional financial traders have a high tolerance to loss. When the participants were asked to “think like a trader,” their tolerance to loss increased while their emotional response to loss decreased considerably.

Figure 1 illustrates the psychological value of gains and losses. The graph is shaped like an “S” to show that as the amount gained or lost increases, perception (psychological valuation) of that gain or loss becomes blunted. Although ¥20,000 is considerably more valuable than ¥10,000, ¥1,000,000 is not much more valuable than ¥900,000. Furthermore, the S-shaped curve does not have bilateral symmetry; rather, the slope of the loss section is much greater than that of the gain section. This illustrates loss aversion.

Kahneman et al. used prospect theory to determine at what times people become risk-seeking. The fourfold pattern shown in Table 1 is derived from a combination of whether a person focuses on gain or loss, and how decision-making weights differ depending on whether the likelihood of an outcome is low or high. For example, the bottom left cell shows that people become risk-seeking in a “lottery” scenario where there is a very low probability of winning and the bottom right cell shows that people become risk averse in an “insurance” scenario where there is a very low probability of a large loss.

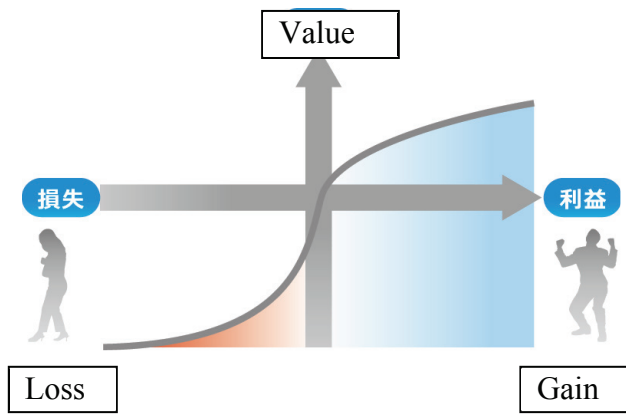


Figure 1. The Value Function in Prospect Theory (Kahneman 2011).

	Gain	Loss
<b>High probability Certainty effect</b>	1. 95% chance of winning \$10,000 2. Fear of disappointment 3. Risk averse 4. Accept unfavorable settlement	1. 95% chance of losing \$10,000 2. Hope to avoid loss 3. Risk seeking 4. Reject favorable settlement
<b>Low probability Possibility effect</b>	1. 5% chance of winning \$10,000 2. Hope of large gain 3. Risk seeking 4. Reject favorable settlement	1. 5% chance of losing \$10,000 2. Fear of large loss 3. Risk averse 4. Accept unfavorable settlement

Table 1. The Fourfold Pattern of Prospect Theory (Excerpt from the Japanese Translation of Kahneman 2011).

Kahneman et al. used insights into human psychology in the context of gambling to understand the phenomenon of loss aversion. However, loss aversion also applies to non-monetary losses and gains. For example, a person's degree of loss aversion can be gauged based on how strongly they agree with the statement "If I lose a sweater at home, I keep on searching until I find it." Strong agreement with this statement indicates a high degree of risk aversion (aversion to the loss of a sweater). In other words, it is also possible to interpret loss aversion as a "psychological phenomenon of not wanting to let things go."

### Are There Individual Differences in the "Psychological Phenomenon of Not Wanting to Let Things Go"?: Measuring Loss Aversion (De Baets and Buelens 2012)

It is only relatively recently that research into individual differences in loss aversion has come into the spotlight due to advances in neuroscience (Tom et al. 2007).

De Baets and Buelens (2012) developed a 20-question Loss Aversion Questionnaire (LAQ) to measure individuals' degree of loss aversion. Whereas Kahneman et al. studied probabilistic decision-making in the context of gambling, items in the LAQ resemble those of a personality test.

De Baets and Buelens (2012) assessed the validity of the LAQ using two groups of people (N1 = 187, N2 = 455) and found that individual differences in loss aversion can be measured using a psychometric questionnaire (the LAQ). They also found that loss aversion is positively related to risk aversion and anxiety. However, their prediction that loss aversion is negatively related to impulsivity was not supported because they observed a significant positive relationship contrary to their prediction. They are uncertain of the reason for this outcome.

De Baets and Buelens (2012) showed that the LAQ scores differed significantly between groups of participants. The well-educated group and the older age group had a lower degree of loss aversion. For example, whereas the mean LAQ score in the younger age group (younger than 36 years, n = 228) was 3.38, the mean score in the older age group (n = 233) was 2.85 ( $p < 0.0001$ ). Similar significant decreases in mean score were seen for risk aversion, anxiety, and impulsivity. Moreover, LAQ scores (as well as anxiety and impulsivity) differed significantly between occupations ( $p < 0.001$ ). The student group had the highest scores for loss aversion and anxiety, the entrepreneur group had the highest score for impulsivity, and the manager group had the lowest scores for impulsivity and anxiety. The group with the lowest LAQ score was the civil servant group. Although LAQ scores did not differ between men and women, women had a significantly higher degree of anxiety than men.

### The Evolutionary Meaning of Prospect Theory

It is very interesting that De Baets and Buelens' (2012) research into the LAQ showed that loss aversion significantly differs depending on occupation, age, and education level. What does the finding that older people and well-educated people show a lower degree of loss aversion signify? How can we interpret the finding that the civil servant group showed the lowest degree of loss aversion?

In their research, Kahneman (Kahneman 2011) suggest that the very strong degree of loss aversion observed in every kind of human indicates that humans are genetically endowed with this characteristic at birth. This tendency for

losses to hurt more than gains feel good can also be interpreted from an evolutionary perspective: individuals that react to threats more quickly have a survival advantage. However, De Baets and Buelens (2012) found that there is individual variation in loss aversion, and that environmental factors (i.e., age, education level, and occupation) are highly influential in this variation. Based on these findings, it can be surmised that humans are born with a high degree of loss aversion and that a tremendous amount of effort (education and years of life) is required to break its spell. This idea is illustrated by the words of the Buddha: “let go of obsessions.” Although “humans are born with obsessions, desire is born from obsession, and anger is born from desire,” enlightenment can be reached by cutting off desires and obsessions that arise from ignorance.

### **Community-Oriented Discovery Science**

The goal of citizen science initiatives is to form communities through voluntary participation (mostly through crowdsourcing) that collect scientific data, analyze data, and develop tools related to health and wellness (Catlin-Groves 2012; DIY Genomics 2013; Kido and Swan 2013; Swan 2012a; Swan 2012b). By promoting the creation of insights through collective intelligence, we aim to create and validate scientific hypotheses that previously would have been too difficult to handle, and to create new fields of science. For example, in Kido (2013a) and Kido and Swan (2013b, 2014), we describe projects on such topics as the effects of vitamin supplements, optimistic/pessimistic tendencies, and sleep.

The research project described in this paper, which aims to determine the evolutionary meaning of prospect theory, focuses on topics that have not yet been well researched, and will open up a new field that connects personal genome research to cognitive psychology research. In addition, it is likely that many potential participants in citizen science projects would be attracted to a topic that provides insights to enrich people’s lives by helping them to “let go of obsessions.” The intellectual curiosity of wanting to know oneself, and altruistic thoughts of contributing to society by making important scientific discoveries and solving social problems (insights about leading a happy life), would be major incentives for participation. Thus, this is an ideal topic for a citizen science project.

Furthermore, analysis of the process of creating insights through collective intelligence in citizen science initiatives is related to such research fields as field informatics, which was proposed by Ishida (Ishida 2012), and Larry Leifer’s (Leifer 2013) “innovation design.” Therefore, the authors believe that this type of analysis will lead to the creation of new methods of creating knowledge and new research fields in information science.

Our ongoing project, MyFinder, (Kido 2011b) has two objectives. The first is to find innate potential characteristics and personality traits and to bring out the maximum potential in one’s abilities (individual approach). The second is to create a research platform that facilitates scientific discoveries through community computing (collective intelligence approach).

In terms of the first objective, while recent personal genome research has focused on the realization of custom-made medical care by finding disease risks and drug effects, MyFinder is unique as emphasis is placed on aspects relating to wellness, mental sciences, and behavioral sciences. MyFinder is based on recent findings relating to gene expression control and the epigenome (Kido 11a) and supports the hypothesis that our physical, chemical, and psychological stress greatly influences the activity of our genes. For instance, recent research has reported that the act of laughing affects diabetes (Kido 11a), and positive mental stress caused by laughing is associated with turning on and off the genetic switch that controls gene expression at the cellular level. It will be possible for an intelligent agent to monitor our daily physical, chemical, and mental stress by way of everyday observation and analysis of our daily habits including eating, sleeping, work style, time management, social interaction, skills, and preferences. The intelligent agent technology can be effective in learning individual behavioral characteristics and stress status.

Regarding MyFinder’s goal to build a research platform for scientific discoveries using community computing, MyFinder learns each user’s personality by monitoring daily behavior and aims to interactively inform the user of its findings using psychology-based and behavioral science-based findings (e.g., including the Enneagram theory in psychology; [www.enneagraminstitute.com](http://www.enneagraminstitute.com)). This function will aid an individual in rediscovering his/her innate potentials and personality.

### **Making Scientific Discoveries with Community Computing: Thinking Fast and Slow Study**

The objective of this paper is to present new developments in personal genome research (developments focused on exploration of the human mind) by analyzing past research on genetic analysis in combination with psychological and behavioral science data. This section will describe a citizen science project, the Thinking Fast and Slow Study, which took the concept that human thinking is composed of complex interactions between fast thinking and slow thinking and attempted to combine it with cognitive psychology and personal genome science. This was the first attempt to verify individual differences in the “psychological phenomenon of not wanting to let things go” (i.e., loss aversion) using genetic and psychometric testing.



## Objective of the Project

To test ideas in *Thinking Fast and Slow* by Daniel Kahneman (Kahneman 2011) as a citizen science project and to validate the following hypothesis.

## Hypothesis

Mutations in genes related to neural processes are related to individual variation in loss aversion.

## Study Design

### A: Selection of Candidate Genes

A literature review was conducted to investigate whether individual genetic differences are related to loss aversion, and the 13 single nucleotide polymorphisms (SNPs) shown in Table 2 were selected for analysis. These were gene mutations identified using such methods as comparing diseased individuals to healthy individuals, psychometric testing, and functional MRI (fMRI). They have been reported to be associated with heroin and cocaine addiction, neural processes involved in reward and emotion processing, gambling addiction, optimism, and tendency to avoid failure (Clarke et al. 2012; He et al. 2012; Peciña et al. 2012; Sapphire-Bernstein et al. 2011; Smillie, Cooper, and Pickering, 2011; Wilson et al. 2012).

Gene	SNP	Reference	Comment
PDYN	rs1022563	Clarke12	Heroin and cocaine addiction
PDYN	rs1997794	Clarke12	
PDYN	rs910080	Clarke12	
DRD2	rs4581480	Pecina12	Reward and emotion processing & openness to experience
DRD2	rs12364283	Pecina12	
DRD2	rs4274224	Pecina12	
DRD2	rs1076560	Pecina12	
DRD2	rs2283265	Pecina12	
DRD2/ANKK1	rs1800497	Smillie11	Reward-prediction Decision-making
COMT	rs4680	He 12	
5-HTTLPR	rs25531	He 12	Gambling Disorder Optimism
T102C	rs6313	Wilson12	
OXTR	rs53576	Sapphire11	

Table 2. Analyzed Single Nucleotide Polymorphisms (SNP).

### B: Phenotype Data: Loss Aversion Questionnaire

Sample items on the LAQ, a psychometric test for gauging loss aversion, are shown in Table 3 (shown in the original English for accuracy). Responses to each item are given on a scale from 1 (*strongly disagree*) to 5 (*strongly agree*). For example, a high score (e.g., 5 points) on the first item (“If I lose a sweater at home, I keep on searching until I find it”) indicates a high degree of loss aversion. Items with an “R” after the sentence are graded in reverse (a high

score indicates a low degree of loss aversion). For example, a low score (e.g., 1 point) on the second item (“I really don’t care if someone talks bad about me behind my back”) indicates a high degree of loss aversion. Loss aversion is calculated on a 5-point scale for each item, and the total of all the items is the loss aversion score (LAQ score).

Sample questions gauging loss aversion
1. If I lose a sweater at home, I keep on searching until I find it.
2. I really don’t care if someone talks bad about me behind my back. (R)
3. I would feel very down if I got fired, even if I know I will find a similar job.
4. In marriage, a woman should keep her own last name.
5. Losing your house to a fire is bad, but I would manage. (R)
6. I wouldn’t care if I had to move to a smaller place. (R)
7. I’d rather quit than get fired.
8. I don’t care what people would think if I was suddenly unemployed. (R)

Table 3. Sample Questions from the Loss Aversion Questionnaire (LAQ).

### C: Implementation of a Citizen Science Project

The participatory crowdsourcing platform Genomera (2013) was used to conduct an online citizen science project called the “Thinking Fast and Slow Study” (<http://genomera.com/studies/thinking-fast-and-slow-study>). This project investigates genes related to not only loss aversion, but also other topics covered in Kahneman (2011), including optimism, overconfidence, and “fight or flight” tendencies. The phenotypic data analyzed were the LAQ scores, and the genotypic data analyzed were typing data of 13 candidate genes (SNP) from a 23andMe (23andMe 2013) report. The study started in June 2013. By August 2014, a total of 44 volunteers had participated and 29 volunteers had shared genotype data for the 13 SNPs from the 23andMe report. Correlations between genotype data and phenotype data were assessed using genetic statistics. For each SNP, the Kruskal-Wallis test was used to compare genotypes between the three groups, the p-value was calculated, and the strength of correlations was compared.

### Participant Attributes

Of the volunteers who made their gender known, 17 were men and 11 were women. Fewer than 10 volunteers made their age public, and most of them were in their late 20s to late 30s. The vast majority were living in the United States (distributed across various cities), but a few were not. Most

volunteers who disclosed their race were white and a few were Asian. Twenty-one people, from whom LAQ responses and genotype data had been collected, were included in analysis.

## Results of the Preliminary Analysis

Correlations between loss aversion and SNPs are shown in Figure 2. SNPs are shown on the x-axis and the negative log of the p-value ( $-\log(p\text{-value})$ ) is shown on the y-axis. Each plotted point corresponds to a single SNP, and the higher a point is on the vertical axis, the stronger the correlation. The SNP most strongly correlated with the LAQ score was rs4274224. The relationship between the rs4274224 genotype and the LAQ score is shown in Figure 3. The x-axis shows rs4274224 (a polymorphism of the DRD2 gene) and the y-axis shows the LAQ score. People with the AG genotype ( $n = 12$ ) had the lowest LAQ score of 59.3, whereas people with the AA genotype ( $n = 6$ ) had the highest LAQ score of 72.5. The difference in LAQ score between people with the AA genotype and people with the AG/GG genotypes was statistically significant ( $p = 0.029$ ).

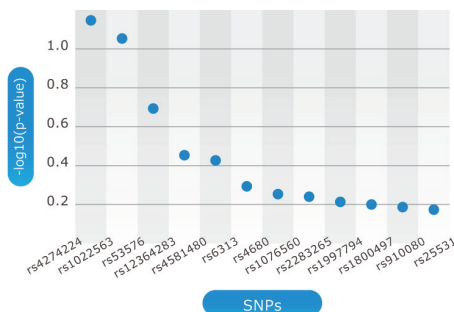


Figure 2. Correlation between Single Nucleotide Polymorphisms (SNPs) and Loss Aversion Score (p-value distribution).

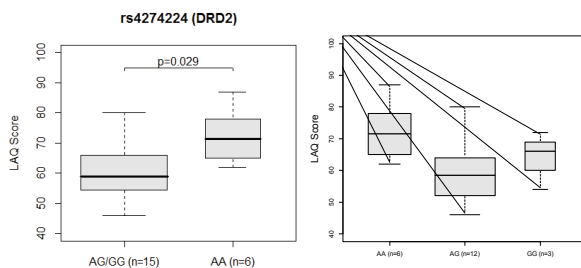


Figure 3. Significant Correlations between Loss Aversion Score (LAQ) and rs4274224 genotype.

## Discussion

In a brain activity experiment using fMRI, Peciña et al. (2012) showed that people with the DRD2 mutation

rs4274224, which had the strongest correlation with loss aversion (LAQ score), with AA genotype, were more responsive to the prospect of a monetary reward and to emotion words than people with the AG, or GG genotypes. Furthermore, they had significantly lower scores on a psychometric test gauging openness to experience.

Kahneman (Kahneman 2011) posits that human decision-making consists of interactions between instinctive, emotional “fast thinking” (system 1) and conscious, logical “slow thinking” (system 2), with most everyday decisions being made through the first system. Kahneman writes that although system 1 can process massive amounts of information in an efficient manner, it makes a lot of errors, and he provides several examples of research illustrating this.

The hypothesis derived from the results of this preliminary study is that people with the AA genotype are genetically endowed with a brain mechanism that makes them more prone to system 1 thinking. This hypothesis predicts that people with the AA genotype, who are more prone to system 1 thinking, will be more prone to instinctive decision-making and therefore will show a high degree of loss aversion.

Almost all of the 21 participants were European (American). The frequency of the DRD2 polymorphism rs4274224 among Europeans and Americans differs greatly from that among Asians. The percentage of people with this polymorphism who have the G allele is lower among Japanese people (28.8%) than among Europeans (50.9%). If our hypothesis is correct, it will mean that the AA genotype, which is associated with being more prone to system 1 thinking, is more common among Japanese people (AA = 52.1%) than Europeans and Americans (AA = 26.9%). This difference could raise questions about the experience-based assertion about Japanese society, that it is “unskilled at predicting probability and tends to make decisions based on 0% or 100% probability.” (Kido and Kamatani, 2014)

However, a conclusion cannot be drawn yet about this hypothesis, and it must be verified in larger groups. Analytical accuracy should improve if the sample size is increased.

Furthermore, research by De Baets and Buelens (2012) has shown that a person’s degree of loss aversion is strongly influenced by environmental factors (i.e., age, occupation, and education level), with older people and well-educated people showing a lower degree of loss aversion. One hypothesis is that system 1 thinking, which is prone to genetic influences, can be controlled using system 2 thinking, in other words, that people can learn how to utilize the strength of their thinking. At The Center for Compassion and Altruism Research and Education (CCARE) at Stanford University, research is being conducted on topics such as the strength of human will, mindfulness, and the effects of meditation, from psychological and neuroscientific perspectives (CCARE 2013) (Kelly 2013). The major chal-

Challenges for the future are to use scientific methods to uncover the mechanisms by which education and self-discipline contribute to decision-making and to apply the findings to create a highly effective self-training program.

It has been shown that dopamine receptor (DRD2) mutations are also related to creativity and mental illness, and there is a common pattern between highly creative people and schizophrenics, with the same dopamine receptor mutation being seen in many cases (Kido 2011a). DRD2 mutations affect the process of dopamine transmission in the brain, and may influence a person's degree of loss aversion, their tendency to seek out new experiences or knowledge, and their responsiveness to emotion words. It will be an important challenge to determine how DRD2 mutations influence brain mechanisms.

## Future Directions

The objective of this paper was to demonstrate how personal genome information and Artificial Intelligence technology can be used to bring about new scientific discoveries, not only in the field of personalized medicine but also in fields related to the characteristics of human behavior and cognitive psychology. Therefore, we proposed the concept of MyFinder, which combines the notion of an intelligent agent with personal genome research, and attempted to implement it, hypothesizing that the methodology and findings of social psychological evaluation of disease risk predictions from personalized medicine and personal genome information could also be applied to the field of cognitive psychology.

We then decided to apply the MyFinder concept approach to assess individual differences in loss aversion, which is a central theme of prospect theory in cognitive psychology, and launched a citizen science project on the topic. The preliminary study showed that DRD2 gene mutations may be related to individual variation in loss aversion. The two hypotheses deduced from the results of this study, namely, (1) that DRD2 gene mutations are related to individual variation in loss aversion, and (2) that a person can become less loss averse through education, should be discussed and validated among scientific experts. Nevertheless, it appears that a new scientific field regarding the formation and evolution of the human mind will be created. In addition, unlike previous methods, the citizen science approach of promoting scientific discovery through community computing could in itself be a topic for Artificial Intelligence research as a method of creating new knowledge to promote innovation design.

Furthermore, as discussed in Kido (2013a), the MyFinder concept was conceived from our desire to know more about ourselves, an idea that deeper examination reveals is reflected in the philosophical question "Who am I?" (For

example, Perry (2008) has some deep philosophical insights about personal identity). We believe that we, ourselves, make the decisions that determine the course of our lives, but what if these decisions were mostly controlled by characteristics encoded in our genes or by unconscious signals from our social environment? It is also important to research the philosophical and societal impacts of the significance of understanding ourselves.

However, there are issues with the approaches used today. The goal of the MyFinder concept is to monitor our everyday physical, chemical, and mental stresses, and to study behavioral and cognitive characteristics by having an intelligent agent monitor and analyze signals from the human mind and body as well as human behavior. However, this goal has not yet been realized. The behavioral characteristic data described in this paper is mainly based on psychometric tests. We believe that, in the future, it will be important to use ambient intelligence technologies, such as MIT's Affective Computing (Picard 2000), that pick up mental health signals regarding stress level, mood, and sleep from wearable sensors and then use these data for such applications as behavioral support and feedback. Furthermore, there is room to apply many types of Artificial Intelligence techniques, such as deep learning, Bayesian estimation, and data mining to the extraction of knowledge from personal big data, to the purpose of scientific discovery.

As we discussed in Kido (2013a), the field of Artificial Intelligence was born from the desire to know oneself and gain a better understanding of human nature. We hypothesize that the rapid lifestyle changes that modern people experience may have a large influence on their minds and bodies from an evolutionary perspective. Our fundamental motivation for this research is our desire to enrich the minds of modern people by uncovering the mechanisms of the brain, genes, and body, and correcting them using Artificial Intelligence. We would like to combine biomedical science, cognitive science, and evolutionary psychology to help to create a future society where modern people and technology evolve together.

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## Contributions

The paper was primarily conceived and written by Takashi Kido. Melanie Swan contributed to the citizen science study section.

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