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Essays in Behavioral Economics and Neuroeconomics

Rana Sulaiman Alogaily
Claremont Graduate University

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By

Rana Sulaiman Alogaily

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Approval of the Dissertation Committee

This dissertation has been duly read, reviewed, and critiqued by the Committee listed below, which hereby approves the manuscript of Rana Sulaiman Alogaily as fulfilling the scope and quality requirements for meriting the degree of Doctor of Philosophy in Economics.

Paul J. Zak, Chair
Claremont Graduate University
Professor of Economic Sciences

Thomas J. Kniesner
Claremont Graduate University
Professor of Economic Sciences

Pierangelo De Pace
Pomona College
Associate Professor of Economics

Abstract

Behavioral Economics and Neuroeconomics

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This dissertation is composed of three unrelated chapters on Behavioral Economics and Neuroeconomics, all of which are on different topics. Chapter 1: Willingness to Get Vaccinated Against COVID-19 and Reasons for Hesitancy Among U.S Residents. Chapter 2: Testosterone Administration Induces A Red Shift in Democrats. Chapter 3: Neurophysiologic Predictors of Mood in the Elderly.

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Willingness to Get Vaccinated Against COVID-19 and Reasons for Hesitancy Among U.S. Residents

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Abstract

Individual risk and time preferences are related with economic behaviours under uncertainty, as well as health related risky behaviours. A cross-sectional, survey-based study was conducted in the USA in February 2021, this study quantitatively examines the factors that are associated with the willingness to get COVID-19 vaccine, focusing on individual risk and time preferences and individual future self-continuity. Our results demonstrate that risk-averse individuals are less likely to accept the vaccine, while those who are more impatient, those with a strong connection with their future, and those who identify as Democrats are more likely to get the vaccine. Individuals who were willing to get the COVID-19 vaccine had higher scores on constructs representing higher levels of positive effect. Most Americans were willing to get a COVID-19 vaccine, but several vulnerable populations reported low willingness. Public health efforts should address these gaps as national implementation efforts continue.

I. Introduction

Since its outbreak in Wuhan, China in late December 2019, the coronavirus pandemic continues to wreak havoc in many nations. The pandemic has adversely affected almost every aspect of social life and has caused devastating effects on the economy. Reports from the Statistics Research Development Center (2020) indicated that even though it was hard to tell the extent of global economic damage as a result of the pandemic, it was expected that the effects would be severe. The COVID-19 pandemic has caused governments to trigger restrictions worldwide such as travel restrictions, social distancing measures, and closures to control the spread of the virus and protect the population against COVID-19 infection (Han et al., 2020). Although such restrictions might have saved lives, they have resulted in many businesses and market closures and people have lost their jobs and income, with no way of knowing when life will return to normal.

An effective COVID-19 vaccine is widely regarded as one of the best ways of ending the crisis today. Many vaccines administered to control the effect of COVID-19 have been approved by the World Health Organization (Ball, 2020). The availability of a vaccine alone is not sufficient to stop the spread of coronavirus. Instead, widespread adoption of the vaccine is necessary to achieve "herd immunity" where enough people are immune to the virus. However, surveys conducted in the second half of 2020 showed that many Americans do not want to get the COVID-19 vaccines, although the WHO has proven that the vaccines are safe to be used on humans. One of the reasons is the fear of the side effects and complications associated with administering vaccines (Menni et al., 2021). Furthermore, the amount and variety of news about the COVID-19 vaccine efficacy have led to a huge amount of conflicting information. The excess of contradictory information at the time of the study was extremely high. Many media outlets and websites have continuously supplied real-time data about new

cases and deaths without waiting for confirmation. They have also offered unauthorized medical advice (Mackey et al., 2020; Shaban Rafi, 2020). In addition, debates between individuals and organizations with a strong web and media presence frequently lead to conflicting and negative views (Shaban Rafi, 2020). Therefore, with the huge amount of misconceptions about COVID-19 and vaccines, what makes people decide to get the COVID-19 vaccine? What will convince them that the COVID-19 vaccine is safe for them and their families?

1.1. Purpose of the Research

World Health Organization has made an enormous effort to develop vaccines against the coronavirus and achieve herd immunity to stop the spread of COVID-19 as soon as possible. However, anti-vaccine advocates are working hard to spread misleading information regarding the COVID-19 vaccines (Mackey et al., 2020; Shaban Rafi, 2020). This will theoretically increase the number of vaccine refusers or delay people's decisions to take up COVID-19 vaccinations when it is available. Therefore, this study enhances our understanding of the decision-making process regarding COVID-19 vaccination and leverages these insights to identify messaging that efficiently motivates people to be vaccinated. Important questions arise: what is the relationship between risk-taking and COVID-19 vaccination decisions? What is the relationship between time preferences and COVID-19 vaccination decisions? What is the connection between people's present and future selves regarding their health , and how does that affect vaccination decisions? How soon people will take the vaccine after it is available in order to help society to reach herd immunity?

This study elicited individual differences in time and risk preferences as factors influencing people's decision to get the COVID-19 vaccine. Also, to the extent that people feel more continuity between their present and future selves, they are more likely to make decisions

with their future self in mind. Therefore, the study also examined future self-continuity in health as a factor influencing people's decision to get the COVID-19 vaccine. In further investigation, the study identified the preferred time for individuals to be vaccinated in the United States. Time and risk preferences as well as future self-continuity are associated with people's decision to get the COVID-19 vaccine, but there are other factors that could be related to that, such as age, ethnicity, occupation, education level, income level, political affiliation, health-related behaviors, health general index, emotions or feelings, and personality traits.

1.1.1. Hypotheses

This paper considers the effect of risk preference, time preference, and future self-continuity on Americans' willingness to get the COVID-19 vaccine.

H_1: Risk-averse individuals are more likely to get the COVID-19 vaccine.

H_2: Impatient people are more likely to get the COVID-19 vaccine.

H_3: People who feel more continuity between their present and future selves are more likely to get the COVID-19 vaccine.

H_4: Democrats are more likely to get the COVID-19 vaccine than Republicans.

Risk-averse individuals choose options that reduce uncertainty and are more likely to consider the safer alternative in risky situations; thus, they are more likely to get the vaccine (Binder et al., 2017). In addition, time preference plays a significant role in decision-making. Less patient individuals prefer immediate action over delayed promises (Herberholz et al., 2020); they are more willing to take the vaccine because of their strong desire for immediate rather than delayed utility (Hassen & Kibret, 2016; Rieger, 2015). Moreover, connection to the future self leads a person to engage in healthier behavior. In other words, people will take

actions that improve health outcomes in the future if they feel connected to their future self (Rutchick et al., 2018). Furthermore, there is a strong connection between people's political affiliation and intentions to receive the vaccine (Fridman, Gershon, & Gneezy, 2021). Democrats are more likely to believe a coronavirus infection poses a hospitalization risk than Republicans and they are more concerned about the emergence of new variants of the coronavirus (Gershon & Gneezy, 2021; Funk & Tyson, 2021). Also, Democrats believe that vaccination will improve the economy and reduce the disruption experienced during the pandemic (Gershon & Gneezy, 2021); thus, they are more willing to take the vaccine.

II. Literature review

This literature review revolves around empirical studies that look into the COVID-19 vaccine, health-related risky behaviors, as well as whether time and risk preferences might assist in explaining behaviors under uncertainty. The section starts with a look at the population's concerns about the COVID-19 vaccine. Subsequently, it expounds on the effect of individuals' risk and time preferences on their decision. Lastly, it focuses on how people make choices with the distant future in mind and how individuals' personalities, emotions and genes impact decision making.

2.1. COVID-19 Vaccines' Health Risks & Concerns

As scientists continue to develop vaccines to lower the severity of the COVID-19 virus, their safety and effectiveness remain critical aspects that influence people's decision to get the vaccinated. The already-established vaccines undergo intense procedures to eliminate misconceptions and assure their safety to the public. Also, various scholars have explored the

health risks of vaccines that may affect widespread vaccination programs. The vaccines cause systematic side-effects, including headache, fatigue, chills, fever, arthralgia, myalgia, and nausea (Menni et al., 2021). They also triggered local side-effects, including pain, swelling, tenderness, itching, swollen armpit glands, redness, and bruising. These side-effects are more prevalent among women than men and participants of 55 years and below (Menni et al., 2021; Tanaka et al., 2021). Furthermore, recent work has shown the risk ratio of developing ischemic stroke, appendicitis, and acute myocardial infarction are 0.97, 0.82, and 1.02, respectively. However, the effects of conditions associated with the vaccines were not important (Klein et al., 2021).

Apart from the risks associated with the vaccines, another concern is people's awareness issues. Extensive research suggests widespread public support, facilitated by people's awareness of the vaccine's trade-offs (Broockman et al., 2021). However, vulnerable populations, including but not limited to racial/ethnic minorities, children, the elderly, those who are socioeconomically disadvantaged, and with certain medical conditions, exhibited a lower understanding of the vaccine's benefits and risks (Kuy et al., 2020). Such a challenge undermines the vaccination efforts as people hesitate to get vaccinated because of misconceptions and negative attitudes towards the newly developed vaccines (Hornsey, Harris, & Fielding, 2018; Salerno et al., 2021). Nevertheless, despite the multiple side effects, there is a high acceptance of the vaccine as necessary for ending the pandemic (Kadali et al., 2021). Furthermore, various studies suggest that socioeconomic factors affect people's health-related behaviors and awareness of the vaccine (Ayyagari, Grossman & Sloan, 2011; Cerda & García, 2021).

While some of this research on COVID-19 vaccines illustrates the concerns and risks associated with the vaccines and the nature of COVID-19 vaccination hesitancy, there have been few studies on what factors influence hesitancy to get the vaccine among U.S. residents.

2.2. The Impact of Risk & Time Preferences

Risk preference is a significant predictor of health-related behavior (Graeber, Schmidt-Petri, & Schröder, 2021; Picone, Sloan, & Taylor, 2004; Falk et al., 2016). Recent studies have revealed the relationship between risk preference and vaccination; risk-taking participants believed that the COVID-19 vaccine was less risky compared to participants subjected to other conditions. In addition, they took less time to decide on getting the vaccination than those who were risk-averse (Trueblood, Sussman, & O'Leary, 2021; Mori et al., 2021). Van Der Pol, Hennessy, and Manns (2017) find the relationship between risk preference and willingness to adopt preventative health behaviors. In particular, there are significant differences between risk-seeking and risk-aversion in adhering to physicians' advice on appropriate health-related behaviors. Risk-averse people also exhibit a higher subjective perception; thus, they invest more in their health than risk-seeking individuals (Van Der Pol et al., 2017). However, an comprehensive study suggests that although risk-averse individuals are more concerned about their health, they are also worried about the side-effect of health investments, such as the side-effects of vaccinations (Herberholz, 2020).

Time preference also influences people's decisions in adjusting their health-related behaviors. Impatient people more often fail to invest in practices that improve their health (Sutter et al., 2013). It is also a significant predictor of individuals' other [health-related] behaviors; impatient people are more likely to forego physical check-ups (Herberholz, 2020), spend more money on alcohol and cigarettes, and exhibit a higher body mass index (Sutter et al., 2013). Several studies have shown that time preference also predicts people's desire to get

flu shots, finding that people with a lower time discount rates are more likely to get the vaccine (Guo et al., 2020; Shahrabani, Gafni, & Ben-Zion, 2008; Sloan, Padrón & Platt, 2009; Hassen & Kibret, 2016; Rieger, 2015). People with smaller time discount rates have higher time preferences, and are willing to vaccinate because of their strong desire for immediate rather than delayed utility (Frederick, Loewenstein & O'Donoghue, 2002; Moore & Vining, 2018; Cheung, 2020). It is worth noting that a strong relationship exists between risk and time preferences. de Oliveira et al. (2016) studied economic choices among the African-American community and found that more patient people are more likely to be risk-averse.

The combination of these factors influences people's decisions about vaccination. However, few studies have been found that illustrate the relationship between time and risk preferences, in the domain of finance, and the decision of whether or not to get the COVID-19 vaccine.

2.3. Future Self-Continuity

Future self-continuity is the extent to which people feel connected with their future self, and it contains three components: the vividness with which people can imagine their future self, the likability of the future self, and the similarity of one's perception of their present and future self (Hershfield et al., 2011). Several studies indicate a positive association between future self-continuity and improved health. People with higher future self-continuity engage in appropriate health behaviors relevant to mortality and morbidity, such as limiting smoking and alcohol consumption while promoting diet, physical activity, and sleep (Rutchick et al., 2018; Binder & Nuscheler, 2017; Hirshfield, 2011). Individuals that are more future-oriented are more likely to get the vaccination (Binder & Nuscheler, 2017). Such people expect to benefit from their current practices; thus, they will be more likely to consider vaccination to achieve

higher health outcomes in the future. Present-oriented individuals imply overconfidence, and are less likely to invest more in their health (Rutchick et al., 2018; Binder & Nuscheler, 2017).

While some research has been carried out on future self-continuity, no work has directly investigated the link between future self-continuity and the decisions related to getting the COVID-19 vaccine.

2.4. The Effect of Personality, Emotions & Genetics

Another aspect closely related to future-self continuity is the personality of the individual. There is an effect of personality differences and the decisions they influence on getting the vaccine. Agreeableness, conscientiousness, and neuroticism increase the odds of taking vaccination (Lin & Wang, 2020). Furthermore, the dependable, extraverted, conventional, calm, and sympathetic participants exhibited more willingness than the rest of the participants. Sympathetic and calm people have been found to typically adhere to rules and regulations stipulated by society or the government, implying a higher willingness to take the vaccine (Lin & Wang, 2020). Personality's effects also impact confidence and sense of collective responsibility towards curbing the coronavirus pandemic (Wisman et al., 2021). Additionally, emotionally stable people are more likely to get the vaccine because they make informed decisions, and are more consider its physical and psychological benefits (Wisman et al., 2021). Personality traits also affect people's willingness to participate in activities with uncertain outcomes. Sahinidis, Tsaknis, Gkika, and Stavroulakis (2020) found a positive relationship between risk aversion and traits such as openness, conscientiousness, and extraversion. These traits determine a person's self-control, innovation, and attitude, which affect their decision-making logic.

While researchers consider the impact of people's personalities and emotions in decision-making, other factors like genetics also explain the variations. Because of genetic predispositions, people experience different reactions to events that require risk-taking, and their degrees of comfort towards them also vary (Meier et al., 2019; Barth, Papageorge & Thom, 2017). Although children may learn to make choices from their parents' experiences, they may also adopt similar attributes that they genetically inherit from them, such as making a risky decision (Nicolaou & Shane, 2019). This can be demonstrated by the fact that risk averse parents are more likely to have risk averse children (Brown & van der Pol, 2015). Thus, differences in genetic coding also influence people's decision-making

Even though an intercorrelation may exist among these traits, there have been few empirical investigations into the relationship between them and making the decision to get the COVID-19 vaccine.

III. Method and Data

A cross-sectional, survey-based study was conducted in the USA in February 2021. This was in the early stages of vaccination, so only 10.8 % of the population had received at least one dose, and 3.4% of the population had been fully vaccinated since the U.S. Food and Drug Administration (FDA) approved the first COVID-19 vaccine Pfizer–BioNTech on December 11, 2020. Data was collected using a Qualtrics panel, approved by The Institutional Review Board of Claremont Graduate University (#3930). The comprehensive survey covered demographic factors and the individual socio-economic and health statuses associated with individual decision-making involved with getting the COVID-19 vaccine.

After the exclusion of incomplete responses and participants who were already vaccinated, the final data included 735 participants from the general population. Requirements included participants being aged 18 years or over, having the ability to understand English, and being willing to take part in the study. Those who met these criteria were instructed to complete the survey after they confirmed their willingness to participate. The survey consisted of seven section, each containing different questions.

The first section focused mainly on participants' demographics such as age, gender, education, occupation, income, and political affiliation.

The second section examine the participant's mood using the Positive Affect Negative Affect Scale (PANAS) (Watson, Clark & Tellegen, 1988). This scale is comprised of several words that refer to the emotions or feelings that participants might experience and display, especially in light of the current pandemic situation, in terms of how these emotions influence them to act and make decisions. The final score is derived out of the sum of the ten items on both the positive and negative sides.

The third section contained lottery questions to measure risk preferences in vaccination decisions and in immediate or delayed rewards questions to measure time preferences (Folk 2016). Assumptions about individuals' risk preferences (risk averse or risk-seeking) provide the basis for decision-making in areas such as personal health. Most of the time, the decision to vaccinate depends on the benefits, effectiveness, and risk of the vaccine (Kalam el at., 2021). But in the case of the COVID-19 vaccine, the benefits may still remain unclear and will probably need some time to be validated. Therefore, assessing individuals' time and risk preferences, which are related to behaviors while uncertain, is crucial in a domain as diverse as health choices (Ferecatu & Önçüler, 2016).

The fourth section was the scale for measuring health-related behavior and health outcomes. Participants were asked to report their health using four questions adopted from the Patient-Reported Outcomes Measurement Information System (PROMIS) and Global Health Scale (general health, physical health, mental health, and contentment with social discretionary activities) (Rutchick et al., 2018). These behavioral determinants are associated with getting the COVID-19 vaccine as people's health and behavior influence the decision to get the vaccine.

The fifth section was about Americans' willingness or unwillingness to get the COVID-19 vaccine. If they were ready, then a second question would be presented: “When is the preferred time to get vaccinated (sooner or later)?”; this question was asked under the condition that the vaccine is available and free. In contrast, those who were unwilling to get the COVID-19 vaccine were asked why they refused to do so.

The sixth section was the five-year scale to measure future self-continuity. Participants were asked to select one pair of circles that best describes how similar and how connected they feel to a future self, regarding their health, five years from now (Hershfield, 2011). Future self-continuity has strong associations with health-promoting behaviors relevant to mortality and morbidity, such as limiting smoking, maintaining a healthy diet, participating in physical activity, limiting alcohol consumption, and getting a sufficient amount of sleep. Therefore, if people feel connected to their future self, they will probably take up the COVID-19 vaccine.

The last section examines personality inventory by using the Ten-Item Personality Inventory (TIPI), a measure of five personality traits (Extraversion, Agreeableness, Conscientiousness, Neuroticism , and Openness) (Nunes el at, 2018). Personality plays a large

role in decision-making and the process by which one makes said decision (Riaz, Riaz & Batool, 2012).

3.1. Models

$$log(willing\ rates_i) = \alpha + \mu\ Z_i + \beta\ X_i + \epsilon_i$$

The dependent variable has two potential outcomes: 1) yes, the participant is willing to get the COVID-19 vaccine, and 2) no, the participant is unwilling to get the COVID-19 vaccine. The approach would be to estimate a logistic regression model. Z_i , includes variables of interest, risk and time preferences, how they project themselves in the future regarding their health, and political affiliation. On the other hand, X_i represents a control for different demographic variables, which includes questions about age, gender, and race identification, as well as general health questions (see Appendix A). ϵ_i represents the error term.

IV. Results

4.1. Demographics, Personality, and Emotions affect

A simple statistical analysis was used to provide an overview of the participants integrated into the survey (see Appendix B). The number of participants who were willing to get the COVID-19 vaccine was 474, which is up to 63% of the total sample, and 271 participants were unwilling to take the vaccine (M=.63, SD=.483, $t(734)=35.451$, $p<.001$). Furthermore, 91% of the participants who were willing to get the vaccine said that they wanted

to get it as soon as they got the opportunity, while 6.1% reported wanting to get the vaccine after six months, and 3% after a year or more (M=1.13, SD=.437, $t(463)=55.350$, $p<.001$).

There were significant gender, age, and social status differences in the decision to get the COVID-19 vaccine. The percentages for male and female respondents who were reported as "willing to take the vaccine" were 54.5% and 45%, respectively; another 0.2% who responded identified themselves in another gender, making up the smallest proportion. The rate of males who were willing to get the COVID-19 vaccine was 1.3 times higher than the rate of females (Male: M=.72, SD=.449; Female: M=.55, SD=.498; $t(473)=4.902$, $p<.001$). In addition, there were significant age differences in the decision to get the COVID-19 vaccine. Being older significantly increased the willingness to get COVID-19 vaccine (Willing: M=4.45, SD=1.489; Unwilling: M=3.62, SD=1.556; $t(733)=7.124$, $r=.254$, $p<.001$). In particular, being older than 54 years significantly increased the willingness to get COVID-19 vaccine when compared to the younger groups (Age 55 and older: M=.79, SD=.412; Under age 55: M=.43, SD=.501; $t(733)=4.840$, $p<.001$). Also, being married increased the willingness to get the vaccine (Willing: M=.96, SD= .190; Unwilling: M=.89, SD= .317; $t(127)=2.177$, $p=.031$).

Further, respondents varied in ethnicity. White constituted the largest proportion, roughly 80%, 9.7% African-Americans, 5.2% Hispanic or Latino, 2.3% Asian, and less than 1% Native American (Willing: M=2.19, SD= .980; Unwilling: M=2.22, SD= 1.158; $t(733)=.296$, $r=-.011$, $p=.767$). The rate of White adults who were willing to get the COVID-19 vaccine was 1.5 times higher than the rate of Black or African-Americans adults (White: M=.66, SD= .473; Black or African-Americans: M=.44, SD= .499; $t(423)=3.813$, $p<.001$).

Additionally, differences were found in relation to participants' lifestyles, specifically education, employment status, and their financial status. In the total sample, more highly educated respondents were willingness to get the vaccine (Willing: M=3.87, SD= 1.870;

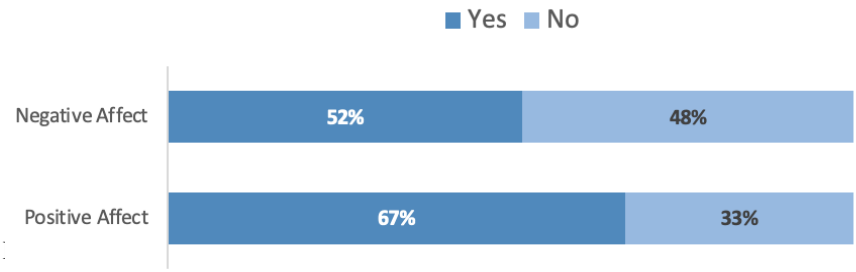
Unwilling: M=2.94, SD= 1.559; *t*(733)=6.842, *r=.245, p<.001*). In addition, willingness to get the COVID-19 vaccine was significantly differ in participants' occupations; those who were employed for wages or retired were more willing to get the COVID-19 vaccine (Willing: M=6.42, SD= 1.758; Unwilling: M=6.05, SD=2.154 ; *t*(479)=2.376, *r=.092, p=.018*). Also, willingness to get the COVID-19 vaccine significantly differed by earnings; higher-income respondents were more willing to get the vaccine (Willing: M=7.66, SD= 3.550; Unwilling: M=5.18, SD=3.567; *t*(733)=9.146, *r=.320, p<.001*).

Respondents varied in risk and time preferences. Willingness to get the COVID-19 vaccine was not significantly differ in participants' risk preferences (Willing: M=24.14, SD= 7.923; Unwilling: M=24.85, SD=7.456; *t*(733)=1.205, *r=-.044, p=.229*). There were no gender differences in participants' risk preferences (Male: M=23.83, SD= 7.833; Female: M=24.92, SD=7.659; *t*(724)=1.895, *p=.059*). However, significant differences were found in participants' time preferences; less-patient individuals were more likely to get the COVID-19 vaccine (Willing: M=13.22, SD= 11.163; Unwilling: M=9.68, SD=10.165; *t*(733)=4.281, *r=.156, p<.001*). Also, significant gender differences were found in participants' time preferences; male were more less-patient individuals (Male: M=14.09, SD= 11.279; Female: M=9.92, SD=10.224; *t*(733)=-5.246, *p<.001*).

Furthermore, participants who reported a stronger connection between their current and future selves were more willing to get the COVID-19 vaccine (Willing: M=4.75, SD= 2.075; Unwilling: M=4.18, SD=2.250; *t*(733)=3.455, *r=.127, p<.001*). In addition, willingness to get the COVID-19 vaccine was significantly different when considering participants' overall health; healthier people were more willing to get the vaccine (Willing: M=3.34, SD= 1.335; Unwilling: M=3.04, SD=1.384; *t*(733)=2.821, *r=.104, p=.005*).

Participants' willingness to get the vaccine was related to their different emotional reactions to COVID-19. Participants who were willing to get the COVID-19 vaccine (67% of

total participants) had higher scores on constructs representing higher levels of positive affect (Willing: M=29.6, SD= 8.882; Unwilling: M=28.05, SD= 9.219; *t*(733)=2.244, *p=.025*) and had lower scores on constructs representing lower levels of negative affect (Willing: M=18, SD= 9.003; Unwilling: M=19.4, SD= 9.072; *t*(733)=2.028, *p=.043*).



In the total sample, willingness to get the COVID-19 vaccine did not significantly differ in participants' personality traits (Agreeableness: (Willing: M=4.534, SD=.931; Unwilling: M=4.522, SD= .943; *t*(733)=.173, *p=.863*); Openness: (Willing: M=4.311, SD=.848; Unwilling: M=4.349, SD= .852; *t*(733)=.574, *p=.566*); Conscientiousness: (Willing: M=4.092, SD= .702; Unwilling: M=4.1, SD= .834; *t*(733)=.139, *p=.889*); Neuroticism: (Willing: M= 3.792, SD= .686; Unwilling: M=3.736, SD= 9.0.743; *t*(733)=1.033, *p=.302*); Extroversion: (Willing: M=3.689, SD= .848; Unwilling: M=3.651, SD= .852; *t*(733)=.574, *p=.566*)).

4.2. Vaccination as an Individual or Collective Responsibility

One question participants were asked to answer was whether they think getting vaccinated is more a matter of individual freedom or one of collective responsibility. In the total sample, 54.3% (N=399) said that getting COVID-19 vaccine is "a personal choice," and 45.7% (N= 366) said it is "part of everyone's responsibility to protect the health of others." Nevertheless, 63% (N= 295) of participants who were willing to get the vaccine indicated that

getting the vaccine is a collective responsibility (Willing: M=1.64, SD= .482; Unwilling: M=1.15, SD= .359; $t(691)=15.51$, $p<.001$). Participants also diverge on this question based on their political affiliation; 60% of Democrats indicated that getting vaccinated is part of everyone's responsibility to protect public health (Collective Responsibility: M=.40, SD= .492; Personal Choice: M=.33, SD= .469; $p=.027$), and a similar share of Republicans (68%) indicated that it is a personal choice (Collective Responsibility: M=.26, SD= .439; Personal Choice: M=.33, SD= .471; $p=.033$) with no significant differences found among Independents ($p=.530$).

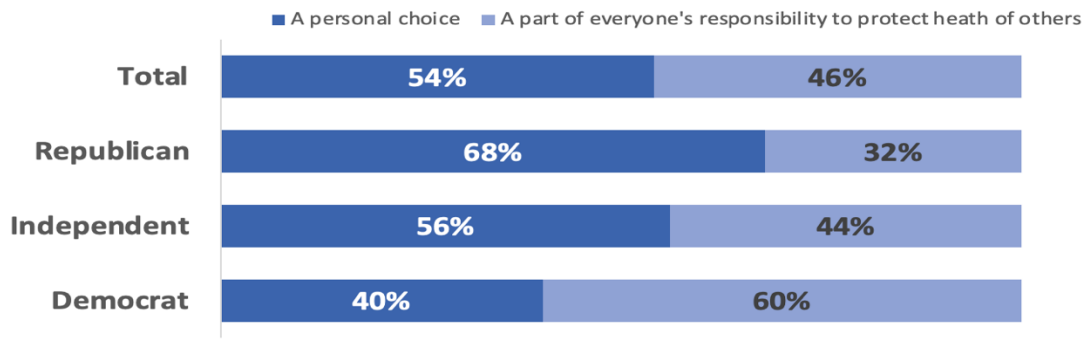


Figure 2: Participants Split by Party on Whether Getting COVID-19 Vaccine is a Personal Choice or Everyone's Responsibility

4.3. Different Groups Had Different Reasons for Not Getting COVID-19 Vaccine

One question that had been posted to participants who were unwilling to get the COVID-19 vaccine (N = 271) was "Why don't you want to get vaccinated?" The Linguistic

Inquiry and Word Count (LIWC) was applied. Among the responses, the main reason given was that they worried about possible side effects, cited by 52% of those asked (M=71, SD=40.847). Roughly 44% cited a lack of information on how the vaccine is effective (M=60.5, SD=34.785); 40% were concerned that the vaccine is too new (M=54.50, SD=31.32); 25% said that they were not sure if the vaccine is safe (M=34.5, SD=19.77), and 15% said that they were not sure if the vaccine is effective (M=20.50, SD=11.69). Additionally, one-fifth of the respondents said they do not trust the health care system (M=25.49, SD=15.027), 13% said they can prevent COVID-19 infection using current precautions (M=17.5, SD=9.958) and a similar percentage did not think they are at risk of getting sick from the virus (M=16.5, SD=9.381).

The different racial groups examined at in the study had somewhat different reasons for being unwilling to get vaccinated. For example, about half of Black or African-Americans participants were more likely than White adults to cite concerns about the side effects of the COVID-19 vaccine (M=78.19, SD=50.319). Importantly, 45% of Black or African-Americans adults cited that the vaccine is unsafe (M=25.17, SD=20.156). Furthermore, most of the White participants said they do not trust vaccines because of a lack of information on the vaccine's long-term effects (M=63.33, SD=35.316).

Reasons why individuals were unwilling to get the COVID-19 vaccine also differ somewhat by partisan identification. Among Republicans and Independents, some major reasons given were that they are worried about possible side effects (M=71.96, SD=41.419), that they lack information on how the vaccine is effective (M=63.06, SD=35.357), and that the vaccine is too new (M=56.71, SD=31.754).

Table 1: Reasons of Unwilling to Get COVID-19 Vaccine

Reasons why participants unwilling to get COVID-19 vaccine	**Total**	**Political Affiliation**		**Ethnicity**	
		Independent	**Republican**	**White**	**African Americans**
Worried about possible side effects	52%	57%	50%	40%	53%
Lack information on how the vaccine is effective	44%	49%	42%	44%	22%
Vaccine is too new and want to wait and see how it works for other people	40%	44%	40%	42%	18%
The vaccine is unsafe	25%	22%	26%	23%	45%
Do not trust the health care system	19%	22%	19%	18%	18%
The vaccine is ineffective	15%	12%	14%	14%	18%
Can prevent COVID-19 infection using current precautions	13%	8%	18%	12%	10%
Healthy and can withstand a COVID-19 infection	12%	10%	14%	11%	10%
Other	7%	7%	8%	7%	8%

4.4. Predicting Willingness to Get the COVID-19 Vaccine

This study investigate the aspects that influence people's willingness to take the vaccination; thus, this was the response variable. A logistic regression model was used in order to find the predictors of the COVID-19 vaccine's acceptability. The analysis adopted participants' risk and time preferences how they project themselves in the future regarding their health, and their political affiliation as the independent variables. The analysis also integrated

some control variables, which were age, gender, race identification, and health outcomes (see Appendix A).

The results suggest that Democrats are more likely to get the vaccine (see Table 2). Being a Democrat increases the odds ratio of willingness to accept immunization by 3.47 ($p< .001$). In addition, there is a significant effect of self-continuity on willingness. The results reveal that developing the feeling of continuity between the present and future increases the odds ratio of being willing to be vaccinated by 1.108 ($p=.007$). Also, time preferences were positively significant in predicting the desire for vaccination, and increased the willingness for vaccination by an odds ratio of 1.03 ($p=.038$); less-patient individuals were more willing to get the COVID-19 vaccine. Also noted was that risk-averse individuals are less likely to get vaccinated. In particular, being risk-averse does not change the odds of willingness to be vaccinated ($p=.308$). The results remained significant when controlling for age, gender, race identification, and health outcomes. Adults age 55 and older were more willing to get the vaccine by an odds ratio of 1.39 ($p<.001$). In addition, the odds ratio of willingness of males to get the vaccine increased by 1.86 ($p<.001$). Being White also increased the odds ratio of receiving the vaccine by 1.61 ($p=.032$), and being healthy increased the odds ratio of receiving the vaccine by 1.13 ($p=.044$) with predictive accuracy of 70.9%.

Table 2: LPM and Logistic Regression Analysis

	Dependent variable: Willing to Get COVID-19 Vaccine			
	LPM	VIF	Logit	Odd Ratio
Democrat	0.240***	1.044	1.246***	3.475
	(0.035)		(0.193)	
Future self	0.023**	1.068	0.102**	1.108
	(0.008)		(0.038)	
Time Preferences	0.006 **	1.121	0.029*	1.029
	(0.002)		(0.008)	
Risk Preferences	−0.003	1.112	−0.012	.988
	(0.002)		(0.011)	
Male	0.124***	1.059	0.619***	1.857
	(0.034)		(0.171)	
White	0.086	1.196	0.478*	1.613
	(0.045)		(0.224)	
Age	0.070***	1.364	0.328***	1.389
	(0.012)		(0.063)	
Overall health	0.024*	1.063	0.134*	1.134
	(0.012)		(0.059)	
Constant	0.061		−2.507***	
	(0.083)		(0.588)	
F-value	17.669			
p-value	(.000)			
R-squared (adj.)	.154			
Note:	*p<0.05; **p<0.01; ***p<0.001			

V. Discussion

As the world adopts measures to curb the coronavirus pandemic and the establishment of vaccines, some countries struggle to convince their people to get the vaccine. One primary question concerns why people may be unwilling to take preventive measures, even when the vaccine might not be available. Various publications exist that seek to investigate health behavior; for instance, questioning why people disregard an appropriate diet and not cease smoking in order to reduce the chances of developing cardiovascular conditions and other lifestyle-related diseases. Similar issues arise with the spread of coronavirus and the development of the awaited vaccine. Considering the virus' possible fatal effects, one would expect people to receive the vaccination to protect themselves from the adverse health problems linked to COVID-19. However, some people are unwilling to get the vaccine, asking why they are supposed to embrace it, despite it reducing the risk of severe illness from the virus. Adopting preventive health behavior is a personal responsibility, but this study reveals that various factors influence people's decision to get the vaccine.

This research examines people's willingness to get the vaccine using the dataset recording social-economics characteristics, personality traits, and lifestyle behavior. Since the future is uncertain, risk preference plays a critical role in vaccination. Previous research shows a positive correlation between risk aversion and the demand for immunization. Risk-averse individuals choose options that reduce uncertainty; thus, they are more likely to get the vaccine (Binder et al, 2017). Such individuals are more likely to consider the safer alternative, which is receiving the vaccine. However, this analysis shows that the risk-averse are less likely to take the vaccine, contradicting the expected results. This may be a result of risk-averse people tending to emphasize reducing the costs and being unwilling to consider options that may

trigger health effects (Herberholz, 2020). Risk-averse individuals may avoid vaccination if it is costly during the initial stages (Binder et al, 2017). Risk-averse individuals may also be unwilling to take the vaccine because of the side effects, such as fatigue, muscle pain, diarrhea, headache, and pain in the injection section (Trueblood et al., 2021), as well as discomfort associated with the vaccine. Therefore, risk-averse individuals may ultimately prefer forgoing these side effects that may otherwise disrupt their daily activities.

Time preference also affects people's preventive health-related behaviors, implying that people may prefer an option immediately rather than waiting for a better one later (Falk et al., 2016). Most of the preventive health-related behaviors involve instantaneous costs and delayed advantages. Thus, people's valuation for future outcomes compared to immediate ones is fundamental in making decisions about getting the vaccine. As expected, the results reveal that impatient individuals are more likely to get the vaccine. People with high time preferences are impatient and prefer beneficial options in the moment more than waiting to avoid consequences that may occur later (Herberholz et al., 2020). The same concept may relate to the vaccine, meaning that less patient individuals are more willing to take the vaccine and benefit from it immediately. Some people are unwilling to take the vaccine over issues as safety and effectiveness; such people may wait until health agencies address this issue and assure them about its safety. On the other hand, the impatient individuals are ready to take the vaccine despite the vaccination campaigns' myriad of challenges.

The connection between people's current and future ambitions also influences their decisions to undertake the vaccination. Future-oriented individuals are more likely to consider preventive health-related behavior because they view them as beneficial for their health, and will allow them to achieve their goals by reducing disruptions (Adelman et al., 2017). The idea of one's future self is also a reliable predictor in decision-making and influences people to adopt the most appropriate pro-health behavior, meaning that people will take actions that

improve health outcomes in the future. In other words, they will be willing to get the vaccine because it will help them maintain their health. People with this characteristic exhibit more self-control and engage in activities that align with their future goals (Adelman et al., 2017). Because they feel connected and compatible with the future, they are willing to take the vaccine to secure a safe future. These people typically adopt other practices that reduce long-term consequences, thus influencing their decisions regarding health-related matters.

Politics is an inevitable aspect influencing Americans' decisions in getting the vaccine. A poll conducted in 2020 by Suffolk University reveals that Democrats were twice as likely to get vaccinated than Republicans (Brewster, 2020). Political differences in opinions about the management of the virus have been prominent, influencing the presidential election outcomes; Pew Research Center shows that Democrats are 27% more willing to take vaccination compared to Republicans (Funk & Tyson, 2021; Fridman et al., 2021). Our results reveal that Democrats are more willing to be vaccinated, as expected. Democrats typically support the vaccine initiative because they believe that vaccination will improve the economy and reduce the disruption experienced during the pandemic. Therefore, Democrats will be more likely to take the vaccine and follow the government's directives, including getting the vaccine.

The desire for the COVID-19 vaccine also differs with gender. The discrepancy between gender arises from socio-economic factors and cultural beliefs. As various vaccines become available across the globe, people develop different attitudes towards them. The results show that men are more likely to get a vaccination indicating the change in their attitude towards health affairs. Men are statistically more vulnerable to the virus because of their higher levels of smoking and drinking compared to women. It has also been found that they tend to be more irresponsible in adopting preventive health behavior, including wearing masks, hand washing, and staying at home (Bwire, 2020). Therefore, the increase in men's willingness to take the

vaccine could improve their efforts to protect themselves from severe illness, given that they disregard some practices that may prevent infection.

In addition, COVID-19 effects vary with age, and they are more adverse for older people as immunity also reduces with age. Countries encourage the old cohort to get the vaccine, and they give them priority over other people (Malik el al., 2020). The results show that older people are more willing to get the vaccine; however, some beliefs discourage older people from getting the vaccine, such as lack of trust. Several countries face this challenge arising from insufficient public awareness, and it may spark misconception concerning the vaccine. While older people are willing to get the vaccination to protect themselves, others claim that the virus is dangerous (Rayman & Calder, 2021) and has adverse health effects, as well as that vaccination reduces their lifespan. Nevertheless, older people are willing to get vaccinated to increase their chances of survival.

Marriage is also a critical factor influencing people's attitude towards the vaccine. Married people, particularly those with children, fear for their health and that of their children. They tend to adhere to the protocols laid out by the government and other institutions to lower their risk of infection. This study shows that such individuals are more likely to accept the vaccine compared to those of other categories. Married people are also willing to get the vaccination because they want to set a good example for their children, who may be unwilling to participate in the practice (Konopińska et al., 2021).

Further, participant ethnicity has an effect on whether or not they would be vaccinated. Historical oppression and current disparities in care are linked to a mistrust of the healthcare system among some Black Americans and may result in these differences in health outcomes (Malik et al., 2020). Thus, this study found that Black Americans were less likely to get the COVID-19 vaccine than White Americans.

In addition to racial disparities, COVID-19 vaccine acceptance differs based on education, employment, and income. According to the U.S. Bureau of Labor Statistics, as years of education increases, unemployment rates decrease, and income increases (2019). The current study found that as years of education increase, willingness to get the COVID-19 also increases. Considering that one primary challenge with immunization is the distortion of information and the spread of rumors that inflict fear, higher educated participants may be less vulnerable to misconceptions about the virus, and may believe in its effectiveness and safety. Additionally, employed and retired participants reported a higher acceptance rate of a COVID-19 vaccine. Finally, income levels also affect people's perception of the vaccine. A survey on the global vaccination rate shows that high-income countries have higher proportions of their citizens vaccinated compared to the low-income earning countries (Solís Arce et al., 2021). The findings show that high-income countries have the capacity and resources to manufacture the vaccine and avail it to their citizens; these countries also provide reliable information to their people concerning the vaccine, unlike low-income earners. This difference also manifests itself at individual levels. Therefore, these findings demonstrate that higher income individuals were more willing to get the COVID-19 vaccine when it becomes available.

While the desire for vaccination varies with socio-economic status, personality traits and emotions also influence people's willingness to receive the vaccine. These traits represent a thinking pattern, which affects their response to external stimuli and association with other people. These traits affect people's attitudes towards vaccination as well as their behavior, which consequently determines their health outcomes. Lin and Wang (2021) reveal that those who tend to be critical, anxious, open to new ideas, reserved, and disorganized are less willing to get the vaccine. Sympathetic, calm, and self-disciplined people, on the other hand, believe vaccines benefit their health. Such people also tend to adhere to social norms (Lin & Wang,

2021); thus, they are willing to receive the vaccination to protect themselves and others from the virus.

VI. Conclusion and Implications

Vaccination is amongst the reliable approaches to lowering the severity of a virus, thus helping people maintain stable health. However, anti-vaccination campaigns undermine COVID-19 immunization, which may trigger a health crisis. The United States encourages its citizens to get the vaccine, but activists and related agencies front campaigns criticizing the vaccine. While these practices may change people's minds and opinions towards the vaccine, other factors also influence the acceptance or refusal of the vaccine. This research shows that risk and time preference are particularly critical aspects that influence people's decisions about health, and therefore their willingness to get the vaccine. The government should accept that people's behavior affects their choices, and it cannot compel them to receive the vaccination. It is a challenge because, despite the government's directives and campaigns to popularize the vaccine, people still reserve their rights to get the vaccine or not. In particular, risk-averse people are less likely to accept the vaccine, while those who are more impatient, those with a strong connection with their future, and those who identify as Democrats are more likely to get the vaccine. Sympathetic people are also more willing to accept the vaccine because they believe it is helpful for their health. In addition, males, educated persons, high-income earners, and those who are married are more likely to get the vaccination. Risk and time preferences measurement could be included in national longitudinal surveys as these affect a variety of economic decisions, including decisions about investments in health. This would allow a better understanding of the complex decisions that underlie risky health behaviors to design effective interventions that help modify cultural perceptions and make future health benefits of healthy

behavior more attractive today. In addition, feeling more connected to one's future self could cause people to place more importance on health and health behaviors. Therefore, more research could further investigate and examine possible mechanisms that link future self-continuity to adaptive health behaviors, and future research should further explore the relationships between general risk-preferences, health-specific risks, and trust in the healthcare system, as well as consequences for decision-making.

Appendix

Appendix A

Variable		**Description**
Dependent variable		
Willing to get COVID-19 vaccine	Willing_vaccinated	1 if the individual willing to get the vaccine and 0 if not
Independent variables		
Risk Preference	Risk_level	Multiple price lists (31 hypothetical choices between a lottery and a safe option)
Time Preference	Time_level	Multiple price lists (31 hypothetical choices between an early payment ”today” and a delayed payment “in 12 months.”)
Future Self-Continuity	Future_self	A values 1 through 7 representing A through G
Political affiliation	Democrat	1 if the individual is Democrats and 0 otherwise
Control Variables		
Age	Age	1 if the individual is 55 years and older and 0 otherwise
Gender	Male	1 if the individual is Male and 0 otherwise
Ethnicity	White	1 if the individual is White and 0 otherwise
Health outcomes	Overall_health	A values 1 through 5 representing participants health outcomes "Fair", "Poor", "Good", "Excellent", "Very Good"

Appendix B

Descriptive Statistic Table

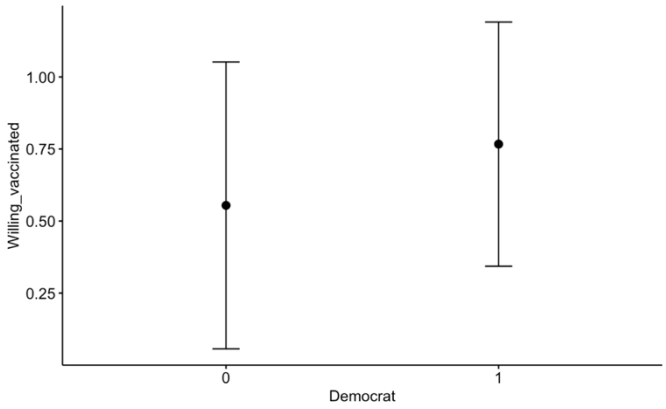
Variable name	N	Mean	St. Dev.	Min	Max
Willing to get COVID-19 vaccine	735	0.631	0.483	0	1
Time preferences	735	11.912	10.933	1	32
Risk preferences	735	8.597	7.752	1	31
Future Self-Continuity	735	4.541	2.157	1	7
Republican	735	0.298	0.458	0	1
Democrat	735	0.362	0.481	0	1
Male	735	0.478	0.500	0	1
White	735	0.803	0.398	0	1
Black	735	0.097	0.296	0	1
Married	735	0.612	0.488	0	1
Insurance	735	0.895	0.306	0	1
Education	735	3.527	1.816	1	8
Income level	735	6.747	3.751	1	12
Age	735	4.144	1.565	1	6
Overall health behaviours	735	3.088	0.613	1	5
Overall health	735	3.229	1.360	1	5
Physical health	735	3.147	1.410	1	5
Mental health	735	3.399	1.418	1	5
Social activities relationships	735	3.280	1.440	1	5
BMI	735	2.072	0.945	1	4
Extroversion	735	3.675	0.849	1	7
Agreeableness	735	4.530	0.935	2	7
Conscientiousness	735	4.095	0.753	1	7
Neuroticism	735	3.771	0.707	1	6
Openness	735	4.325	0.849	1	7

Appendix C

Pearson's Correlation of Willingness to Get the Vaccine

	corr	**P_ value**	**t**
Time preference	0.156	0.000	4.281
Risk preference	-0.044	0.229	1.202
Future self	0.127	0.001	3.455
Male	0.177	0.000	4.879
Age	0.254	0.000	7.124
Democrat	0.212	0.000	5.865
Republican	-0.106	0.004	-2.897
Education	0.245	0.000	6.842
Employment status	0.092	0.013	2.505
Income level	0.320	0.000	9.147
White	0.138	0.001	3.785
Black	-0.132	0.000	-3.604
Overall health	0.104	0.005	2.821
Extroversion	0.021	0.566	0.574
Agreeableness	0.006	0.863	0.173
Conscientiousness	-0.005	0.889	-0.139
Neuroticism	0.038	0.302	1.033
Openness	-0.021	0.566	-0.574

Appendix D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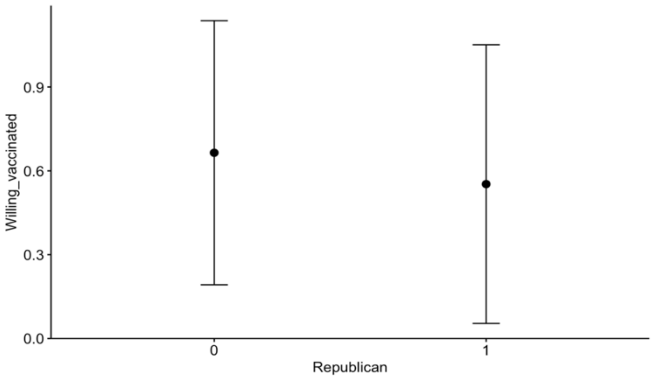
0.50
0.25
0
1
Democrat


Willing_vaccinated
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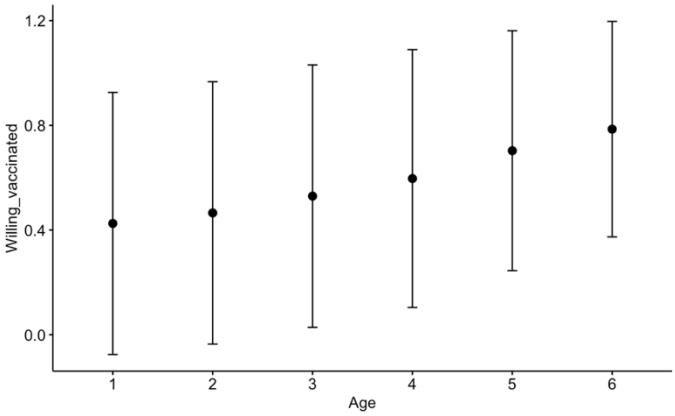
0.6
0.3
0.0
0
1
Republican


Willing_vaccinated
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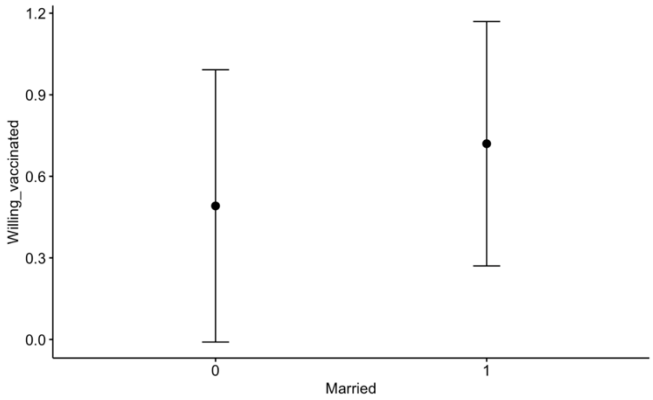
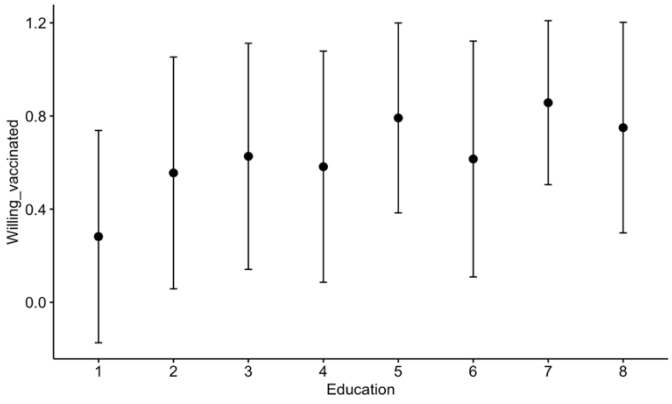
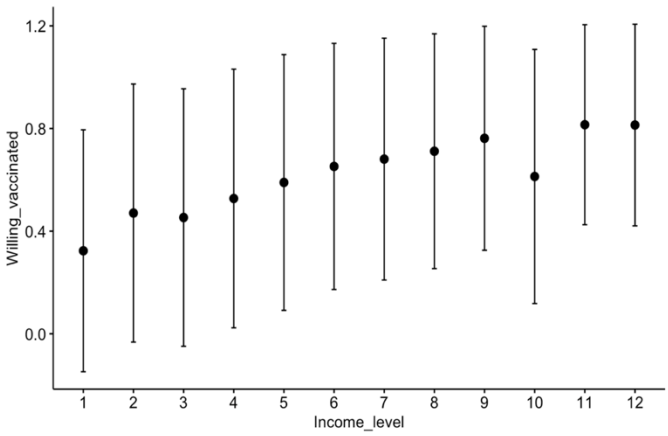
0.8
0.4
0.0
1
2
3
4
5
6
Age


Willing_vaccinated
1.2
0.9
0.6
0.3
0.0
0
1
Married


Willing_vaccinated
1.2
0.8
0.4
0.0
1
2
3
4
5
6
7
8
Education


Willing_vaccinated
1.2
0.8
0.4
0.0
1
2
3
4
5
6
7
8
9
10
11
12
Income_level

Appendix E

Survey Sections

Instructions:

This is a survey about decision making. The survey will take approximately 20 minutes to finish.
Funding for this study has been provided by different organizations. Earnings for your participation will be paid to you after this experiment completes. There is no deception in this study.
Your answers are very important for our study so please answer them carefully and thoroughly. All of the information that I obtain from you will be kept confidential and it will be used only for the study.

Section 1 (Socio Economic)

1. What is you gender?
2. What is your age?
3. Please specify your ethnicity
4. What is your educational background?
5. What is your employment status?
6. What is your yearly income level?
7. What is your marital status?
8. How many children do you have?
9. Generally speaking, do you usually think of yourself as (political affiliation)
10. Do you have health insurance?

Section 2 (basal mood (PANAS))

1. Taken all together, how would you say things are these days — would you say that you are extremely happy, somewhat happy, or unhappy?
2. This scale consists of a number of words that describe different feelings and emotions. Please read each item and indicate the extent you feel right now, that is, at the present moment:

Section 3
(Staircase to eliciting risk preferences)

Please imagine the following situation (note that these are hypothetical scenarios):

Suppose you were given the choice between a lottery or a sure payment.

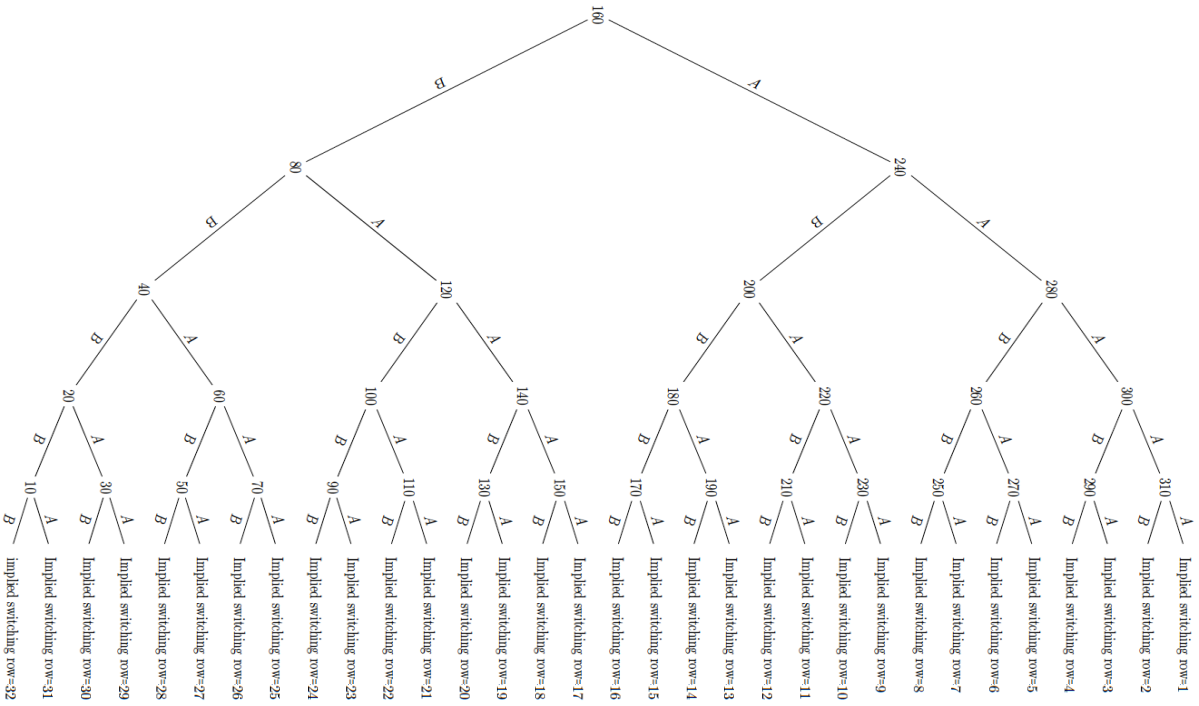
The lottery is the same in each situation (a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing).

The sure payment is different in each situation.

1. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $160 as a sure payment?
2. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $80 as a sure payment?
3. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $40 as a sure payment?
4. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $60 as a sure payment?
5. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $70 as a sure payment?
6. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $50 as a sure payment?
7. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $20 as a sure payment?
8. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $30 as a sure payment?
9. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $10 as a sure payment?
10. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $120 as a sure payment?
11. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $100 as a sure payment?
12. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $90 as a sure payment?
13. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $110 as a sure payment?
14. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $140 as a sure payment?
15. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $150 as a sure payment?

16. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $130 as a sure payment?
17. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $240 as a sure payment?
18. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $200 as a sure payment?
19. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $180 as a sure payment?
20. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $190 as a sure payment?
21. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $170 as a sure payment?
22. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $220 as a sure payment?
23. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $230 as a sure payment?
24. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $210 as a sure payment?
25. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $280 as a sure payment?
26. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $260 as a sure payment?
27. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $270 as a sure payment?
28. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $250 as a sure payment?
29. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $300 as a sure payment?
30. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $290 as a sure payment?

31. What would you prefer: The lottery a 50 percent chance of winning $300 when at the same time there is a 50 percent chance of winning nothing, or would you rather have the amount of $310 as a sure payment?



(Staircase to eliciting time preference)

Please imagine the following situation (note that these are hypothetical scenarios):

Suppose you were given the choice between receiving a payment today or payment in 12 months.

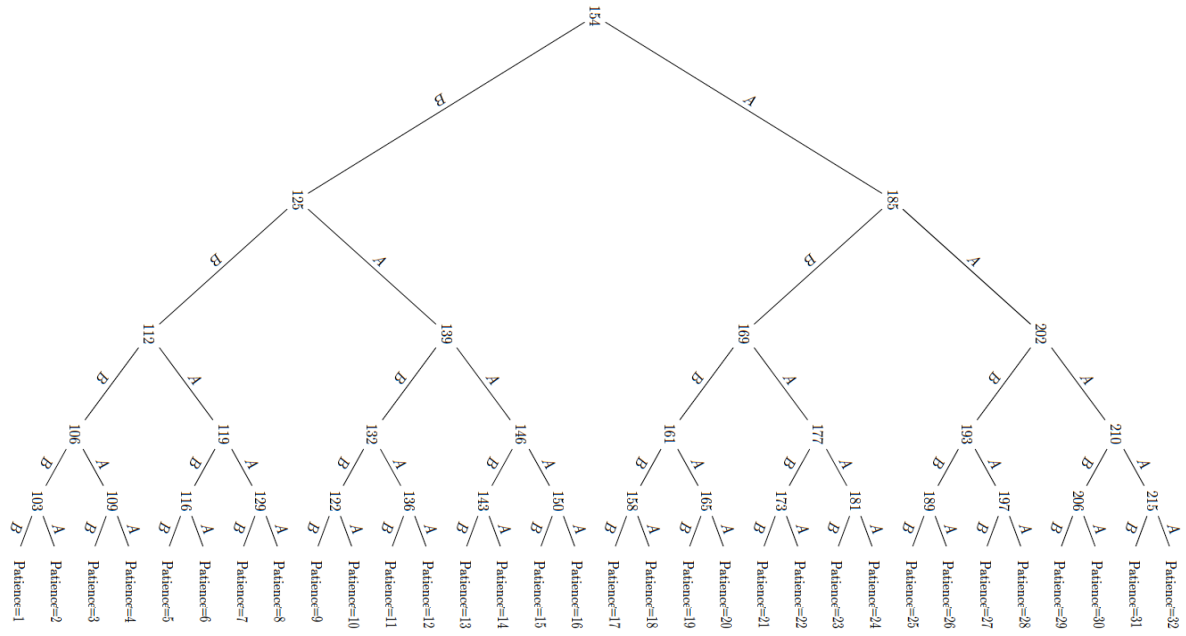
The payment today is the same in each situation.

The payment in 12 months is different in each situation.

For each situation, we would like to know which you would choose.

1. Would you rather receive $100 today or $153 in 12 months?
2. Would you rather receive $100 today or $125 in 12 months?
3. Would you rather receive $100 today or $112 in 12 months?
4. Would you rather receive $100 today or $106 in 12 months?
5. Would you rather receive $100 today or $103 in 12 months?
6. Would you rather receive $100 today or $109 in 12 months?

7. Would you rather receive $100 today or $118 in 12 months?
8. Would you rather receive $100 today or $122 in 12 months?
9. Would you rather receive $100 today or $115 in 12 months?
10. Would you rather receive $100 today or $139 in 12 months?
11. Would you rather receive $100 today or $132 in 12 months?
12. Would you rather receive $100 today or $128 in 12 months?
13. Would you rather receive $100 today or $135 in 12 months?
14. Would you rather receive $100 today or $146 in 12 months?
15. Would you rather receive $100 today or $142 in 12 months?
16. Would you rather receive $100 today or $150 in 12 months?
17. Would you rather receive $100 today or $185 in 12 months?
18. Would you rather receive $100 today or $201 in 12 months?
19. Would you rather receive $100 today or $193 in 12 months?
20. Would you rather receive $100 today or $197 in 12 months?
21. Would you rather receive $100 today or $189 in 12 months?
22. Would you rather receive $100 today or $210 in 12 months?
23. Would you rather receive $100 today or $214 in 12 months?
24. Would you rather receive $100 today or $205 in 12 months?
25. Would you rather receive $100 today or $169 in 12 months?
26. Would you rather receive $100 today or $161 in 12 months?
27. Would you rather receive $100 today or $157 in 12 months?
28. Would you rather receive $100 today or $165 in 12 months?
29. Would you rather receive $100 today or $176 in 12 months?
30. Would you rather receive $100 today or $172 in 12 months?
31. Would you rather receive $100 today or $180 in 12 months?



Section 4

(Health- related behaviors)

1. How often do you smoke **tobacco** products (such as cigarettes, cigars, pipes, or hookah)?
2. How often you have an **alcoholic drink**?
3. How often do you use **drugs** (prescription or illegal)?
4. How often do you **exercise**?
5. How would you rate your overall habits of eating **healthy foods**?
6. How would you describe your **sleep quality**?

(Health General)

I use likert scale

1. In general, how would you rate your physical health?
2. In general, how would you rate your mental health, including your mood and your ability to think?
3. In general, how would you rate your overall health?
4. In general, how would you rate your satisfaction with your social activities and relationships?

(BMI)

1. Your height in feet?
2. Your weight in pound?

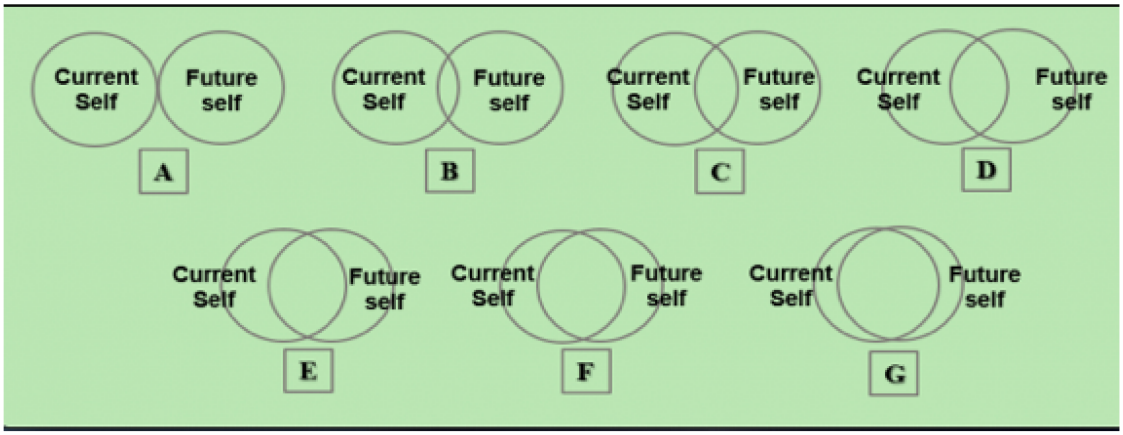
Section 5 (COVID19 Questions)

1. Do you think getting vaccinated against COVID-19 is a personal choice or a part of everyone's responsibility to protect heath of others?
2. Have you taken COVID-19 vaccine?
    1. If No: Are you willing to get COVID-19 vaccine?
        1. If No: Why you don't want to get vaccinated?
        2. If Yes: Will you prefer to take the vaccine sooner or later?
    2. If Yes: Will you prefer to take the vaccine sooner or later?

Section 6 (future self-continuity health)

In regard to your health.

1. Choose the set of circles that best represent how similar and connected you feel to your future self in 5 years' time.



2. Do you think it will be positive or negative change in your future self?

Section 7 (personality inventory "Big 5")

The following statements inquire a number of personality traits that may or may not apply to you. For each item, please rate how well each statement describes you by using the scale below. ***I see myself as***:

	1 Strongly disagree	2 Disagree	3 Slightly disagree	4 Neither agree nor disagree	5 Slightly agree	6 Agree	7 Strongly agree
Extraverted, enthusiastic.	○	○	○	○	○	○	○
Critical, quarrelsome.	○	○	○	○	○	○	○
Dependable, self-disciplined	○	○	○	○	○	○	○
Anxious, easily upset.	○	○	○	○	○	○	○
Open to new experiences, complex.	○	○	○	○	○	○	○
Reserved, quiet.	○	○	○	○	○	○	○
Sympathetic, warm.	○	○	○	○	○	○	○
Disorganized, careless.	○	○	○	○	○	○	○
Calm, emotionally stable.	○	○	○	○	○	○	○
Conventional, uncreative.	○	○	○	○	○	○	○

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Testosterone Administration Induces A Red Shift in Democrats

By

Rana Alogaily[a], Giti Zahedzadeh[a], Kenneth V. Pyle[a] , Cameron J. Johnson[b], Paul J. Zak[a*]

Abstract

We tested the fixity of political preferences of 136 healthy males during the 2011 U.S. presidential election season by administering synthetic testosterone or placebo to participants who had identified the strength of their political affiliation. Before the testosterone treatment, we found that weakly affiliated Democrats had 19% higher basal testosterone than those who identified strongly with the party (p=.015). When weakly affiliated Democrats received additional testosterone, the strength of their party fell by 12% (p=.01) and they reported 45% warmer feelings towards Republican candidates for president ($p < .001$). Our results demonstrate that testosterone induces a “red shift" among weakly-affiliated Democrats. This effect was associated with improved mood. No effects were found of testosterone administration for strongly affiliated Democrats or strong or weak Republicans. Our findings provide evidence that neuroactive hormones affect political preferences.

Keywords: Preferences, Warmth, Affiliation, Neuroscience

[a] Center for Neuroeconomics Studies, Claremont Graduate University, Claremont, CA 91711
[b]Department of Psychiatry, Loma Linda University Medical Center, Loma Linda, CA 92354
[*] Corresponding Author. paul.zak@cgu.edu

Introduction

Political preferences are thought to be largely determined by young adulthood (Alwin et al., 1991; Weiss, 2020). Political partisanship motivates individuals to vote for the party with which they identify and to interpret political information in ways that are sympathetic to their party's policy stances (Sanders et al., 2002; Bartle & Bellucci, 2014). Partisan identities are stable personality features and rarely change due to campaign ephemera (Muirhead & Rosenblum, 2020). Party identification has been conceived as an affective attachment to a social group (Green et al., 2004). One's genes appear to explain up to 50% of party affiliation, leaving an opportunity for life experiences to alter political preferences (Hatemi, et al. 2010). The brains of conservatives and liberals may even be different (Schreiber, 2017) though the evidence for this is mixed (Zmigrod & Tsakiris, 2021).

Even with all these indicators, why people vote for or support one political candidate over another rather than simply voting for their own party is poorly understood (Shor & Rogowski, 2018; Castle, Layman, Campbell & Green, 2017). Several lines of evidence suggest that Democrats are more open to new ideas and cognitively flexible compared to Republicans (Eichmeier et al., 2019; Haas, Baker & Gonzalez, 2017; Merolla et al., 2013; Capra et al., 1999). Suggestive research has shown that physical strength and income together reduce support for redistributive policies, stances that political conservatives are more likely to support (Petersen et al., 2013). At the same time, research and casual observation shows increasing political polarization by voters that may causes member of both parties to deflect information counter to their party affiliation (Huddy, Mason, & Aarøe 2015; Schreiber et al. 2020).

Even voting can be seen as irrational since the time and effort of casting one vote is unlikely to change the outcome of an election and benefit oneself (Rogers, Fox & Gerber, 2013; Blais & Young, 1999). Most studies show that political attitudes and voting behavior are

unaffected or only marginally effected by advertising or political debates (Le Pennec & Pons, 2019; Coppock, Hill & Vavreck, 2020; Guess et al., 2021) though social media presence may matter (Lin, 2017). This suggests that political preferences are stable aspects of one's personality (Bakker, Lelkes & Malka, 2021).

The present research hypothesized that manipulating voters' biological states using a neuroactive hormone, testosterone (T), would influence Democrats to support Republican U.S. presidential candidates. We chose to investigate T because its effects on behavior can be substantial. T increases aggression, risk-taking (Stanton et al., 2011), punishment of those who violate social norms, and other antisocial and selfish behaviors (Zak et al., 2009). Men with naturally high T levels are more likely to have physical altercations, divorce more often, spend less time with their children, are hypercompetitive, have more sexual partners, face learning disabilities, and lose their jobs more often than men with lower T (Dabbs & Dabbs, 2000). Studies in monkeys show that when beta males become alphas, T rises (Raleigh et al., 1984). Some evidence suggest that amygdala activity, a region of the brain associated with emotion, affects voting behavior (Rule et al., 2010) and that Republicans may have more activity in this region than Democrats (Schreiber et al., 2013). While T is synthesized in the body's periphery, some of it passes into the brain and the amygdala is one of the primary locations of central T receptors in humans (Batrinos, 2012; Volman et al., 2011). Based on our previous research showing that weakly affiliated Democrats political preferences could be influences by synthetic oxytocin administration (Merolla et al., 2013), we hypothesized that weak Democrats would have higher basal T and would be the only group affected by synthetic T.

Judgments about candidates' physical appearances, including markers of T such as musculature (Sinha-Hikim et al., 2012), jaw size (Verdonck et al., 1999), and hairiness (Mooradian et al., 1987), correlate with voting choices and election outcomes (Ballew and Todorov, 2007; Fernández-Villanueva & Bayarri-Toscano, 2021). Like most neuroactive

chemicals, T varies second by second, preparing people for challenges by changing neural activity and associated behaviors. Yet, the moderate variation in endogenous T often yields fragile associations between T and tasks in experiments (O'Carroll, 1998). Alternatively, manipulating T pharmacologically produces causal associations with behavior.

Materials and Methods

General Procedures. The study was run between March and November of 2011. This time period was chosen because the Democratic and Republican primary campaigns for the U.S. presidency made politics and political choices salient through extensive news coverage. In the months prior to the general election, President Obama's reelection was in doubt. Polls in August 2011 showed President Obama, running as a Democrat, being defeated by Republican candidate Mitt Romney by two percentage points. At the same time, Romney was tied with Republican Rick Perry, and was ahead in the polls of Republicans Ron Paul and Michele Bachmann by two and four points, respectively.

Participants. One hundred and sixty four eugonadal men volunteered for this study. Twenty five participants were excluded as foreign nationals who were ineligible to vote in the election and three participants were dropped for having basal T that fell outside the normal range leaving N=136. Participant average age was 22.3 years (SD=6.91) and the sample was moderately ethnically diverse, with participants self-identifying as Caucasian (74%), Asian (11%), Latino (8%), and African American (6%). Participants identified themselves as Democrats (44.03%), Republicans (8.21%), and Independents (29.10%). The remainder identified as having another affiliation or no party affiliation. Participants arrived at 8pm at the laboratory and provided written informed consent before inclusion in the study. After consent, participants were screened for possible contraindications for T administration by a licensed medical doctor (CJJ). Exclusion criteria included significant medical or psychiatric illness,

medications that interact with T, and drug or alcohol abuse. No participants were excluded and no adverse events occurred. Only men were included as the T preparation we used, Androgel 1% (AbbVie, North Chicago, Il), is FDA approved for men only.

Research with Human Subjects. The Institutional Review Board of Claremont Graduate University approved this study (#1387) and there was no deception of any kind.

Blood Draws, Processing, and Analysis. After consent and medical screening, participants had a 20 ml blood draw from an antecubital vein by a qualified phlebotomist to establish basal total T levels. There are several measures of T one can use but all are highly correlated so we measured total T. Participants returned to the lab 16 hours after T administration following published pharmacokinetics (Swerdloff et al., 2000) for a second blood draw to measure the change in total T. Assays were performed by Yerkes Biomarkers Core (Atlanta, GA) using kits from Diagnostic Systems Laboratories (Webster, TX). Assay CV were acceptably low (Inter-assay: 1.55% at 3.04 pg/ml, n = 2, Intra-assay: 1.60% at 23.87 pg/ml, n = 2).

Drug Administration. After the first blood draw, participants were then led to a semi-private room, asked to remove their shirts, and were given a colorless hydroalcoholic gel containing either 10 g of Androgel (55.8% of the sample) or an identical-appearing inert substance. The protocol was double-blind, i.e. neither participants nor the experimenters knew which substance was provided. Participants received application instructions and were observed spreading the gel on their shoulders and upper back following the Androgel package insert.

Political Preferences and Surveys. Participants completed questionnaires measuring demographics, trait emotional responses (Affective Intensity Measure, AIM; Larsen, Diener & Emmons, 1986) and an anger inventory (Singer, 2007). Political preferences were assessed by ascertaining the strength of party affiliation. Next, a "feeling thermometer" was used to

measure support for five Democratic (Barack Obama, Joe Biden, Bill Clinton, Nancy Pelosi, Harry Reid) and five Republicans (Mitt Romney, Newt Gingrich, Sarah Palin, Mike Huckabee, Rand Paul) who were running for president or were allied with the sitting president and might run in the future. Feeling thermometers run from 0 to 100 and have been widely used in political science to assess attitudes toward individuals and groups (Wilcox et al., 1989). Feeling values were averaged across the five candidates in each party with higher values indicating greater favorability. Figure 1 shows the timeline of the experiment.

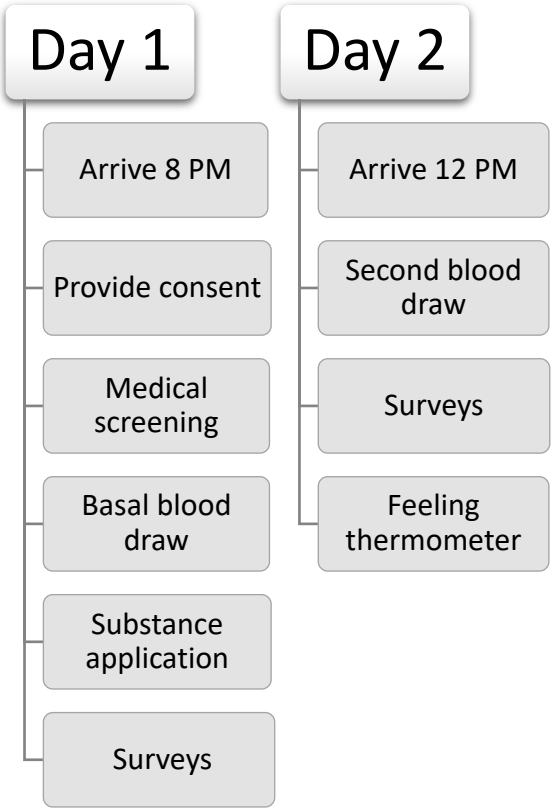

Figure 1: Experiment timeline for Days 1 and 2.

Results

Testosterone treatment. There were 61 participants in the placebo group and 75 in the treatment group. For the placebo group, testosterone levels did not significantly change from before to after substance administration (M1=478.53, SD1=183.17; M2=495.07, SD2=150.65; t=-0.999, p=.322). However, average T levels in the treatment group increased by 64.6% (M1=479.45, SD1=161.54; M2=789.35, SD2=230.07; t=-12.406, p<.001).

Testosterone and party identification. A one-way ANOVA was performed to determine if there were differences in basal T levels by major political party and independents, finding no difference (Democrats: M=498.86, SD=185.29; Republicans: M=460.01, SD=185.41; Independents: M=445.63, SD= 146.93; F(4,128) = .915, p=.457). Testosterone levels post-treatment were identical across party affiliation and for independents (Democrats: M=637.81, SD=234.57; Republicans: M=610.42, SD=186.12; Independents: M=634.29, SD= 238.18; F (4,128) = 1.316, p=.268).

Next, we investigated if basal T varied by strength of party affiliation. Weakly affiliated Democrats had 19% higher average basal T than did strongly affiliated Democrats (Weak: M=529.58, SD=189.92; Strong: M=445.90, SD=163.17; one-tailed t(61) = -2.00, *p=.043*). No difference in T was found for strongly versus weakly-affiliated Republicans (Weak: M=461.47, SD=253.64; Strong: M=458.78, SD=131.74; t(9)=-.023, p=.982). Independents do not have a party and so were not analyzed for strength of affiliation.

Treatment and party affiliation. T given to Democrats affected the strength of party affiliation as (F(1, 63) = 13.94, p < .001). Paired t-tests show the effect was only significant for weakly-affiliated Democrats in whom T administration reduced average party affiliation by 12.46% (M1=65.25, SD1=12.41; M2=57.12, SD2=12.15; t(23) = 2.798, p=.01; Fig. 2). There

was no effect on party affiliation for strong or weak Republicans (M1=66.00, SD1=16.25; M2=62.71, SD2=12.97; $t(3) = .943$, $p=.415$).

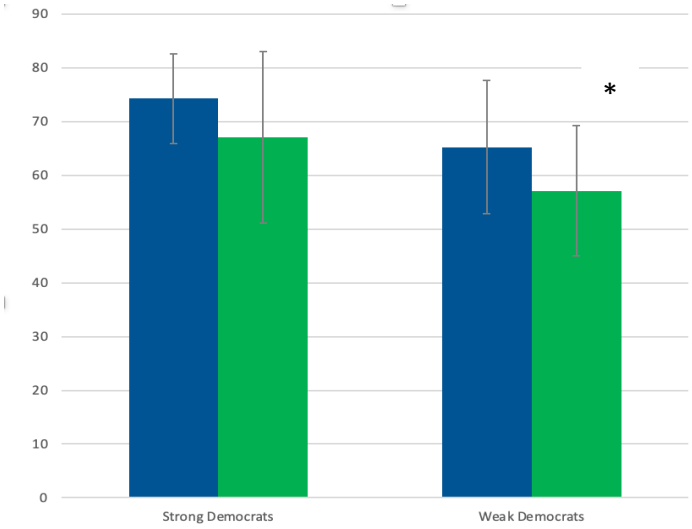

Figure 2. T administration reduced the average strength of party affiliation by a statistically significant 12.46% (p=.01) for weakly affiliated Democrats but had no effect for strongly affiliated Democrats.

T and affect. Average positive affect was unchanged from pre- to post-treatment for placebo Democrats (M1=3.64, SD1=0.81; M2=3.88, SD2=0.78; $t(24) = -1.659$, $p = .11$) and treatment Democrats (M1=3.75, SD1=0.842; M2=3.53, SD2=0.842; $t(31) =1.561$, $p= .129$). Nor did positive affect change for weak Democrats (M1=3.9, SD1=0.852; M2=3.7, SD2=0.733; $t(19) = 1.165$, $p=.129$). Similarly, positive affect was unchanged in Republicans who received a placebo or T (Placebo: M1=3.71, SD1=0.756; M2=3.71, SD2=0.488; $t(6)=0$, $p=1$; Treatment: M1=4.20, SD1=0.837; M2=4.20, SD2=0.447; $t(4) =0$, $p=1$). Positive affect also remained stable for Independents in both conditions (Placebo: M1=3.50, SD1=1.051; M2=3.60, SD2=0.883; $t(19)=-0.567$, $p=.577$; Treatment: M1=3.62, SD1=0.973; M2=3.67,

SD2=0.730; t(20) =-0.271, p=0.789). There were no differences in self-reported anger due to T treatment (D: p=.101, R: p=.810, Ind: p=.353).

Red shift. Warmth by Democrats for Republican candidates increased 18.2% from Day 1 to Day 2 using paired t-tests (M1=23.88, SD1=14.431; M2=28.22, SD2=15.072; t(58) = -2.018, p=.048). This effect was not due to a preference change by placebo Democrats (M1=25.96, SD1=14.706; M2=27.26, SD2=12.702; t(27) = -0.497, p=.623). Rather, it was Democrats who received T who drove the change (M1=22.00, SD1=14.152; M2=29.09, SD2=17.097; t(30) = -2.140, p=.041). Comparing Democrats by strength of affiliation, increased warmth towards Republican candidates was driven by weakly-affiliated Democrats in the treatment condition (M1=23.24, SD1=14.747; M2=33.79, SD2=15.892; t(23) = -2.651, p=.014) but did not affect strongly affiliated Democrats (M1=17.14, SD1=11.495; M2=13.01, SD2=10.148; t(6) = 1.069, p=.326; Fig. 3).

Republicans and Independents. Republicans had no change in warmth for Democrats from Day 1 to Day 2 (M1=31.64, SD1=22.429; M2=29.44, SD2=27.066; t(10) = .602, p=.560), including those receiving a placebo (M1=28.57, SD1=17.49; M2=30.71, SD2=17.16; t(6) =-.817, p=.445) and treatment Republicans (M1=37.00, SD1=31.696; M2=27.20, SD2=19.267; t(3) = 1.189, p=.320). Independents who received the T treatment showed no change in warmth for Republican candidates (M1=35.05, SD1=14.445; M2=34.45, SD2=15.104; t(20) =0.167, p=.869) or Democratic ones (M1=52.05, SD1=12.286; M2=48.18, SD2=14.594; t(20) = 1.372, p=.185).

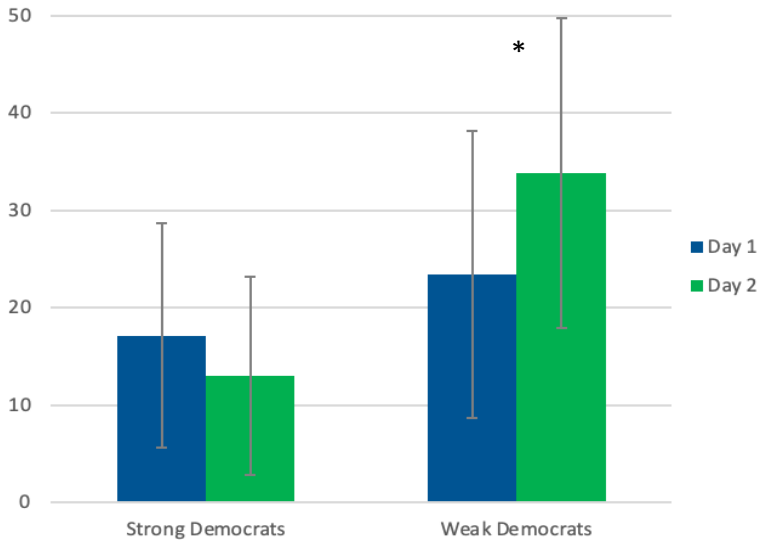

Figure 3. Weakly-affiliated Democrats who received testosterone reported 45% increased average warmth towards leading Republican candidates compared to their baseline average (p=.014). T did not affect warmth for Republicans by strongly affiliated Democrats.

Discussion

Campaigns spend hundreds of millions of dollars on political advertising, an amount that increases with every election (Franz & Ridout, 2007). Political ads can affect voter turnout (Goldstein & Freedman, 2002) and may have a short term impact on stated candidate preferences (Gerber et al., 2011). A well designed study exploiting media market spillovers found that political advertising affected stated preferences in the 2000 US presidential election using a feeling thermometer and other measures (Huber & Arceneaux, 2007). Yet, the consensus view is the effects of political advertising are small and this effect is conditional on a large set of variables (Motta & Fowler, 2016). Swing voters are key targets of political advertising since they are most likely to be persuaded (Mayer, 2007).

Our key finding, that T influenced political preferences for weakly affiliated Democrats, contributes to the analysis of political adverting and persuasion. Our previous research using synthetic oxytocin administration to influence political preferences showed that changes only occurred for weakly affiliated Democrats (Merolla et al., 2013). Extending our previous finding, the analysis here showed that weakly affiliated Democrats were persuadable physiologically while strong Democrats and all Republicans were not. Among weak Democrats, T also reduced the strength of party affiliation and cooled their feelings toward Democratic presidential candidates. This indicates, consistent with our previous study, that weakly affiliated Democrats are more likely to be swing voters than weakly affiliated Republicans. Our findings also suggest that advertising that induces increases in T, at least among men, can influence voting behavior. For example, advertising for luxury goods can increase T in men (Pozharliev et al., 2021) and advertising featuring competition is likely to have a similar effect as vicarious experiences of winning raise T (McCaul, Gladue & Joppa, 1992; Bernhardt et al., 1998). Our findings here suggest political advertising that increases T, when targeted at weak Democrats, could be an effective strategy employed by Republican candidates.

That T had no effect on strongly affiliated Democrats also replicates our previous research. One clue for this finding is the 19% higher average basal T for weak vs. strong Democrats. Weakly affiliated Democrats' basal T was statistically identical to basal T of Republicans, perhaps indicating that the former are "sheep in wolves clothing" and may have consciously or unconsciously stated a Democratic party affiliation when a Republican one would be more appropriate. Yet, a study during the 2008 US presidential election found no basal differences in T between Democrats and Republicans, though no analysis by strength of party affiliation was performed (Stanton et al., 2009). Nevertheless, the administration of neuroactive hormones typically have a larger effect on behaviors when basal levels are lower

indicating a preference change would be expected to be greater for strongly affiliated Democrats, yet we did not find this indicating a state-trait interaction.

When T enters the brain, it increases the activity of the neurotransmitter dopamine in striatal regions that are associated with risk taking (de Souza Silva et al., 2009; de Macks et al, 2011). This may have led Democrats, especially weakly affiliated ones, to take the risk of stating their true preferences for presidential candidates. Weak Democrats would already have been more open to Republican candidates' platform compared to strong Democrats and the additional T appears to have pushed them toward taking the risk of a Red Shift. The self-report data needs to be taken with some skepticism since no actual votes were cast or donations made to Republican candidates. But, these open minded Democrats seemed to need a push to support Republicans, in this case a physiologic push.

A weakness of the study is the under representation of Republicans. This is a function of using a convenience sample of college students. Future research should examine the effects of T on older adults as well as on women, either by direct administration of T or by using primes such as videos, known to increase T endogenously. An experimental study of political mobilization found that political ads with emotional content persuaded participants to take an interest in, and vote in, an upcoming election (Brader, 2005). The findings reported here, along with additional research, will help close the gap between political consultants who design strategies so their clients win elections and the academic research studying which approaches are most effective in attracting swing voters. Our results suggest that political advertising depicting emotional themes that raise T could influence swing voters and perhaps elections.

Data Availability. The data are available at Open ICPSR-155441.

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Exploratory Study: Neurophysiologic Predictors of Mood in the Elderly

By
Paul J. Zak[a*], Rana S. Alogaily[a]

Abstract

The elderly are particularly vulnerable to low moods. Yet, the elderly have an elevated risk of clinical depression because of to an aversion to self-report moods and isolation from family and friends who could observe them. The present study explored whether data from a commercial neuroscience platform were able to predict low mood and low energy in members of a retirement community. Neurophysiologic data were collected at 1Hz and averaged into daily measures while mood and energy were based on daily retrospective self-reports. The analysis demonstrated that two neurophysiologic measures were statistically associated with mood and energy. These variables predicted low mood and low energy with 64% and 65% accuracy. Principal components analysis showed that neurologic variables were statistically associated with mood and energy two days in advance. This exploratory study calls for additional experiments to identify the causal factors that threaten emotional wellness in older populations.

[a] Center for Neuroeconomics Studies, Claremont Graduate University, Claremont, CA 91711
[*] Corresponding Author. paul.zak@cgu.edu

Introduction

Depression is one of the primary public health concerns globally. The elderly are particularly vulnerable to depression due to age-related neural atrophy, hypertension, and social isolation (Boima et al.,2020; Meeks et al., 2011; National Academies of Sciences, Engineering, and Medicine, 2020). There are a variety of ways to halt the onset of depression, including social support, psychological counseling and pharmacotherapy (Nakagomi et al., 2022; Santini et al., 2016; Cacioppo & Patrick, 2008; Miller et al., 2020). Such interventions are more effective if a decline in mood can be identified before a major depressive episode occurs (Garland & Solomons, 2002). The ability to passively assess mood states using technology would be an important public health advance self-reports of mood have poor predictive accuracy (Sau & Bhakta, 2017). Several alternative approaches to predict low moods are being investigated. For example, using smartwatches and machine learning to analyze sleep as depressive episodes are associated with disordered sleep patterns (Bader, Skurla & Vahia, 2020).

Chronic low mood increases morbidity and mortality especially in older adults (Van den et al,. 2021; Mroczek et al., 2015). When people experience low moods and the symptoms last for two weeks they are diagnosed as clinically depressed (National Institute of Mental Health, 2018). The lifetime incidence of depression is 14.6% for adults in developed countries (Lim et al., 2018) and women are approximately twice as likely as men to have an episode of depression (Kuehner, 2017). Those aged 65 and older in the U.S. have a one in four depression risk (Byers et al., 2010; Explore Depression in the United States, 2021). Life events can increase the likelihood of depression in seniors, including declining health, financial straits, loss of loved ones, reduced social interactions, inadequate healthcare, and the inability to participate in activities (Rodda et al., 2021; Matos et al., 2021; Cheruvu &

Chiyaka, 2019; Bekhet & Zauszniewski, 2012; Valiengo et al., 2016). Depression in old age is also a risk factor for dementia resulting in a cascade of mental health disorders (Maier et al., 2021).

Positive affect in the elderly has a host of favorable impacts on health, including a lower risk of cardiovascular disease (Dockrey & Steptoe, 2010), less reported pain (Zautra, Johnson & Davis, 2005; Song et al., 2015), increased exercise (Khazaee-pool et al., 2015), improved immune function (Okely et al., 2017; Dockrey & Steptoe, 2010), and higher-quality social relationships (Steptoe, Dockray & Wardle, 2009). It is likely that the causal flow connecting positive mood to improved health and social functioning is bidirectional (Uchino & Rook, 2020; Golden et al., 2009) and depends in part on one's genetics (Menezes et al., 2019). The importance of mood states on healthspan, and the risk seniors face for chronic low mood and/or depression, calls out for a more fundamental understanding of the causes of mood variations (Caracciolo et al., 2011). While this research develops, the data that quantify activities and physiology using wearable technologies suggests that it may be possible to predict mood states in the elderly in order to create interventions to reduce or eliminate the degradation of health from persistent negative affect.

Low mood has a neurophysiologic signature that can be used as data for early detection of depressive symptoms. Not only is there a great need to predict depressive symptoms, the use of neural data obviates the need to constantly query individuals about their mood states, reports that tend to be inaccurate especially in the elderly (Mauss & Robinson, 2009; Brown & Astell, 2012). Colloquially, we say that people are “worried to death” but there is evidence for this (Taggart et al., 2011) and indeed there is an extensive literature relating negative mood states and clinical depression to anxiety (Aherens et al. 2008). Anxious individuals have elevated activity of the “sympathetic” autonomic nervous system; sympathetic in this sense means "connection between parts" and denotes the branch of the

nervous system that is arousing and is associated with the 4Fs (fight, flight, flee, and fornication; Saviola et al., 2020). Typical measures of sympathetic tone include heart rate and electrodermal activity. Most pharmacotherapies for depression reduce sympathetic tone along with other effects (Shores et al., 2001). While basal sympathetic tone varies substantially across individuals (Giuliano et al., 2017), it is a reliable prodrome for depression (Kalin, 2020; Schreuder et al., 2020; Wichers & Groot, 2016).

When individuals are anxious, it inhibits their ability to enjoy life, including elderly adults (Bourland et al., 2000). Neurologic data on immersion in social experiences can provide an objective measure the quality of social interactions and the absence of anxiety (Brenes, 2007). It is well-established that social activities in the elderly reduces anxiety (Lewinsohn & Libet, 1972; Leonavičius & Adomaitienė, 2013, Márquez-González et al., 2014; Rider, Gallagher-Thompson, & Thompson, 2016) as do supportive relationships (Everard et al., 2000; Santini et al., 2016; Holtfreter et al., 2017). Seniors often create opportunities for social interactions by volunteering (Heejung & Fengyan, 2016), investing in friendships (Santini et al., 2016), and joining activities (Holtfreter et al., 2017). Socially-active seniors are less likely to suffer from loneliness.

Depressive symptoms seniors may arise when individuals no longer engage in activities that previously had been enjoyable (anhedonia). But, even with observation, it may take weeks of months to correctly classify an individual as depressed since variations in moods are common. When depressive symptoms are identified early, the prognosis for patients is substantially improved (Garland & Solomons, 2002). The interaction between immersion in social life and mood has the potential to be measured using neurophysiologic variables (Elizabeth et al., 2006; Mendlowicz & Stein, 2000).

The present exploratory study sought to relate self-reported mood to neurophysiology data. This is a difficult task as consciously-filtered self-report measures are typically

unrelated to neural activity (Brown & Astell, 2012). At the same time, endogeneity of measures is also a concern. As a result, mood was only assessed on self-report once a day while neural measures were obtained at 1Hz during 8-10 hours of daily data collection. The first step in creating a potential early detection measure for melancholia is to determine if neurophysiologic measures are associated with changes in mood. The present study used a sample of healthy seniors rather than a clinical population in order to test the hypothesis that a combination of neural measures derived from a wearable sensor can predict changes in mood states.

Materials and Methods

Participants. Twenty-four participants were recruited from a Texas residential living facility. Residents were provided with Apple Watch 6s with an app called Immersion Mobile to collect neurophysiologic data. Data were collected for 20 days between January 18 and February 24, 2021 for up to 10 hours each day. The analysis averaged neurophysiologic data for each day resulting in 480 observations.

Procedure. Participants were sent an email every day at 6am and asked to complete an online survey reporting their mood, health, and energy the day before. If no response was collected by noon, participants were reminded via email and text to complete the survey. Because self-report data were retrospective, these data must be lagged by one day to align with neurophysiologic data. The lagged self-reporting likely induces biases in the data due to poor recall and misattribution of arousal (Thomas & Diener, 1990; Zillmann, 2018), decreasing the likelihood of significant associations to physiologic signals.

Neurophysiology. A commercial platform (Immersion Neuroscience, Henderson, NV) was used to measure neurophysiologic responses collected at 1Hz. The independent variables

obtained from the Immersion platform were average immersion for each day and average psychological safety. Neurologic immersion combines signals associated with attention and emotional resonance and measures the value the brain places on social experiences (Barraza, Alexander, Beavin, Terris, & Zak, 2015; Zak & Barraza, 2018; Zak, 2020). The second neurologic measure, psychological safety (PS), measures sympathetic tone from the vagus nerve that captures anxiety (Zak & Nowack, 2021; Zak et al., 2021). In addition, we created an additional variable called peak immersion, defined as

$$\int_{t=0}^{T} (v_{it} > M_i) d_t / Im_i$$

where v_{it} is average neurophysiologic immersion for each participant in day *i* at time *t* to the end of the day at time *T*, M_i is the median of the average time series of immersion for day *i* plus the standard deviation of day *i* across all participants at the same day and this is divided by the sum of total immersion Im_i for each person for each day *i*. That is, peak immersion (PI) cumulates the highest immersion moments for an individual during the day cumulating high-value social experiences.

Self-Report Measures. Mood was assessed by averaging four questions on a 1-5 scale (cheerful, stressed, lonely, energy) with stressed and lonely reverse coded. Mood was defined as "Low" if it was the median of 4 or lower and was labeled “High" for values greater than 4. Mood has only moderate interpersonal and intrapersonal variation (Intrapersonal CV: 10.80%, Interpersonal CV: 16.26%). Energy was used as a second dependent variable because social activities are typically energizing and because this variable has more variation than Mood (Intrapersonal CV: 23.64%, Interpersonal CV: 31.45%). "Low" energy was defined as a value of the median of 3 or lower and "High" was for values greater than the median. Sickness was a binary variable and physical health was measured on a 1-5 scale. The only demographic data collected in this exploratory study was biological sex.

Statistical Analysis. While the data constitute a panel, both Mood and Energy show little time series variation. As a result of statistical tests (Results), each observation was analyzed as an independent. The Appendix reports panel data analyses for completeness. The analysis begins with t-tests and correlations relating Mood and Energy with neurologic variables. Then, we test mean-corrected differences of neurologic variables for low and high Mood and Energy. An ordinary least squares (OLS) regression was estimated to predict participants' Moods and Energy using immersion, psychological safety, and peak immersion as independent variables and including Sick as a control. Logit regressions were also estimated to establish predictive accuracy. In addition, since neural variables are expected to be moderately correlated, Principal Components Analysis (PCA) were used to seek to improve predictive accuracy.

Results

Time Series Aspects. We estimated an AR(1) regression for Mood and Energy for each participant to assess the time series properties of the self-report data. The estimated coefficients for the lagged term for the 24 regressions was averaged for both dependent variables and an augmented Dickey-Fuller test was applied to test for a random walk or time trend. Both Mood and Energy time series averaged coefficients show they are random walks (Mood: ADF(1), p=.28; Energy: ADF(1), p=.32). For individual time series, only six participants' Mood and Energy failed to be a random walk at conventional significance levels ($ps \leq .05$) with only one participant's time series failing for Energy (Table A1). This indicates that the lagged time component of the dependent variables do not affect, or have very little effect, on the current value. As a result, each observation can be analyzed independently, ignoring the time dimension.

Principal Components. The first principal component (Neuro measures (-2)) loaded on Immersion, PS and PI with a 2 day lag. The second principal component (Neuro measures) had positive loading for contemporaneous Immersion, PS and PI. The third principal component (Neuro measures (-1)) loaded on Immersion and PI with a one day lag (Table A2).

Mood. Mood varied from 1 to 5 (M= 3.92, SD= .663; Figure 1). Mood was statistically related to PS (r=-.141, $t(320)=59.08$, $p=.015$). However, it was unrelated to immersion and PI (Immersion: r=-.061, $t(443)=153.42$, $p=.217$; PI: r=-.009, $t(249)=23.59$, $p=.891$). Immersion was statistically identical for low and high Mood ($M_{high}= 3.63$, $M_{low}=3.63$; $t(405)=.026$, $p=.980$), as were PS and PI for high and low Mood (PS: $M_{high}= 1.77$, $M_{low}=1.76$; $t(288)=.145$, $p=.4885$; PI: $M_{high}= .479$, $M_{low}=.419$; $t(218)=1.385$, $p=.168$). There were no gender differences in participants' Moods ($M_{male}=4.0$, $M_{female}=3.65$; $t(21)=1.119$, $p=.276$).

Ordinary least squares regression was used to test if immersion, PS, and PI were related to participants' Moods. The regression was statistically significant ($R^2 = .122$, $F(4, 165) = 4.106$, $p = .003$). Immersion and PI were associated with Mood but PS was not (Immersion: $\beta = .667$, $p = .012$; PS: $\beta = -.062$, $p = .504$; PI: $\beta = -.647$, $p = .031$). A logistic regression found that only PI was significant (Immersion: OR = 2.676, $p= .287$; PS: OR = .769, $p= .428$; PI: OR = .106, $p= .035$) with predictive accuracy of 64.1% ($p = .064$) as shown in Table 1.

Table 1. OLS & Logit Regression Models Predicting Participants' Mood

Variable	*OLS*	*VIF*	Logit	Odd Ratio
Immersion	.667* (.264)	2.878	.984 (.925)	2.676
PS	-.062 (.093)	1.156	-.262 (.331)	.769
PI	-.647* (.297)	2.788	-2.241* (1.063)	.106
Sick	-.661*** (.194)	1.017	-1.133 (.811)	.322
Intercept	1.776* (.900)		-2.915 (3.139)	
F-value	4.106			
p-value	(.003)			
R-squared	.091			

Note. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We next explored the three PCA factors in the regression. Regressing Neuro measures (-2) was statistically significant (Neuro measures (-2): ß=.285, *p*=.005), but Neuro measures and Neuro measures (-1) were not (PC2: ß=.167, *p*=.100; PC3: ß=.178, *p*=.089). In addition, a logistic regression for high and low Mood did not produce any significant variables (Neuro measures (-2): OR = 1.384, *p*= .517; Neuro measures: OR = 1.323, *p*= .569; Neuro measures (-1): OR = .595, *p*= .312) and had predictive accuracy of 66.7% (Table A3).

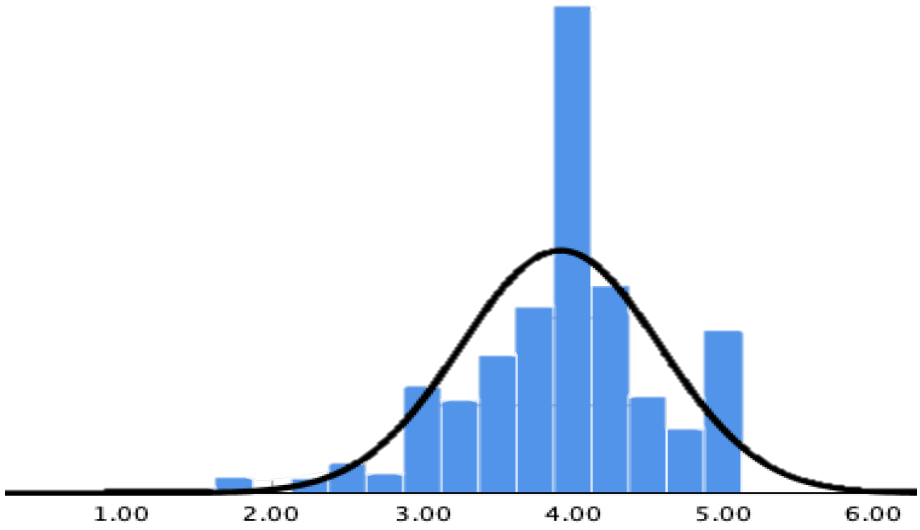

Figure 1. Distribution of participants' mood

Energy. Energy varied from 1 to 5 (M= 3.158, SD= 1.01; Figure 2). Immersion, PS and PI were all unrelated to Energy by themselves (r=-.041, $t(443)=153.42$, $p=.404$; PS: r=-.095, $t(320)=59.08$, $p= .104$; PI: r=.004, $t(249)=23.59$, $p= .956$). Low and high Energy did not have variations in immersion, PS or PI (Immersion: $M_{high}= 3.62$, $M_{low}=3.67$; $t(425)=.886$, $p=.376$; PS: $M_{high}= 1.84$, $M_{low}=1.81$; $t(306)=.545$, $p=.586$; PI: $M_{high}= .453$, $M_{low}=.461$; $t(239)=.166$, $p=.869$). There were no gender differences in participants' energy ($M_{male}=3.17$, $M_{female}=2.82$; $t(21)=.846$, $p=.407$).

Regression estimates revealed significant associations for Immersion and PI with Energy (Immersion: $\beta = 1.160$, $p =.003$; PS: $\beta = .078$, $p =.560$; PI: $\beta = -.966$, $p =.025$). A logistic regression for high and low Energy did not produce any significant findings (Immersion: OR = 3.213, $p= .199$; PS: OR = 1.483, $p= .213$; PI: OR = .445, $p= .421$; Table 2) and had predictive accuracy of 65.3% ($p= .186$).

Table 2. OLS & Logit Regression Models Predicting Participants' Energy

Variable	*OLS*	*VIF*	Logit	Odd Ratio
Immersion	1.160** (.378)	2.878	1.167 (.908)	3.213
PS	.078 (.133)	1.156	.394 (.316)	1.483
PI	-.966* (.426)	2.788	-.810 (1.006)	.445
Sick	-.966 (.426)	1.017	-.999 (.819)	.368
Intercept	-.967 (1.292)		-5.520 (3.142)	
F-value	2.983			
p-value	(.021)			
R-squared	.067			

Note. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Next, we used ordinary least squares to test if Neuro measures (-2), Neuro measures, and Neuro measures (-1) were related participants' Energy. One variable, Neuro measures (-2), was significantly associated with Energy (Neuro measures (-2): ß=.415, *p*=.016; PC2: ß=.238, *p*=.169; PC3: ß=.195, *p*=.270). A logistic regression for high and low Energy found a significant association for Neuro measures (Neuro measures (-2): OR = 1.117, *p*= .850; Neuro measures: OR = 9.956, *p*= .014; Neuro measures (-1): OR = 3.739, *p*= .134) and produced a predictive accuracy of 74.1% (Table A4).

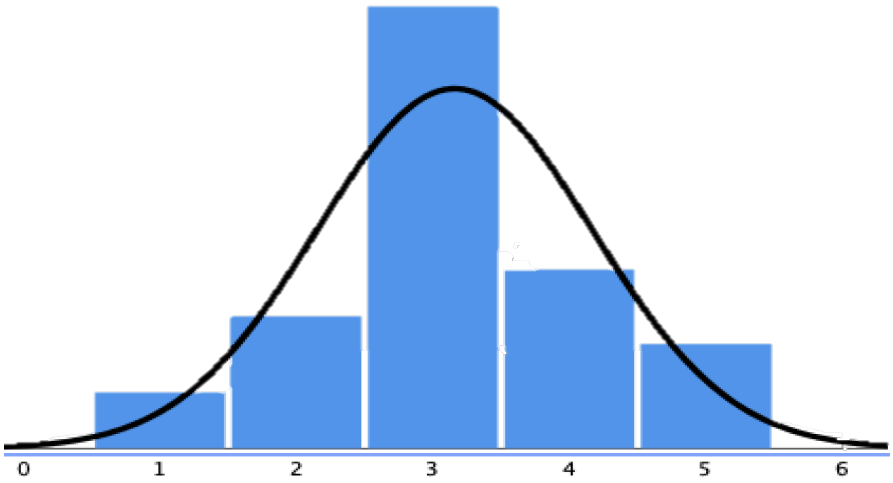

Figure 2. Distribution of participants' energy

Discussion

The study investigated whether neurophysiologic data could predict Mood and Energy in a vulnerable older population. The analysis demonstrated that immersion and peak immersion were associated with both Mood and Energy, though the latter with an unexpected sign. Immersion captures the value of social experiences, a key aspect of flourishing (Baños et al., 2012; Uysal, 2015). Increasing the quantity and quality of social experiences tends to increase positive affect (Martino, Pegg & Frates, 2017; Sun, Harris & Vazire, 2020) and can improve life satisfaction (Zak, P.J., 2022; Hsu, 2012; Ferring et al., 2004).

Our analysis was unable to show that psychological safety had a positive effect on Mood or Energy. Extensive research has related psychological safety and the absence of anxiety to improved mood (Shannon, 2016). Psychological safety regulates people's emotional well-being (Zhou et al., 2021) using social support to reduce anxiety (Remtulla et

al., 2021; Frazier et al., 2017). When anxiety is reduced, the quality of social relationships improves adding to the quality of life (Bowling et al., 2003; Hansson, 2002).

As expected, we showed that sickness reduces Mood and Energy. Illness reduces the desire and ability to socialize and obtain the advantages they confer (Meek et al., 2018; Simon, 2001; Godil et al., 2017). Sickness negatively affects quality of life in the elderly in part by inducing negative moods (Wróblewska et al., 2021). Chronic illness reduces the independence and mobility of the elderly (Yohannes, Baldwin, & Connolly, 2000) affecting their ability to socialize (Bucks et al., 2008; Meek et al., 2018).

A contribution of the exploratory study here is the demonstration that high-frequency neurophysiologic measures are able to predict retrospective self-reported emotional states. The approach used here has been called "brain is a predictor" in neural measures predict attitudes and behaviors (Berkman & Falk, 2013; Zak, 2020; Zak, 2022). Neural measures can be used to influence behavior change (Riddle et al., 2016) and thereby improve the quality of life (Zak, 2022). An additional benefit of neural predictors of emotional states is the possibility to identify the physiological processes inhibiting the quality of life so that interventions are focused and effective (Morawetz et al.,2020).

As people age, self-reported mood tends to decline (Lukaschek et al., 2017; Okamura et al., 2018). As a result, monitoring and creating interventions to sustain positive mood in seniors is an important public health issue. This exploratory study calls for additional experiments to identify the causal factors that threaten the emotional wellness in older populations. We have shown that this can be done with off the shelf wearables and a commercial software platform. Retirement homes could benefit from this new assessment to do early intervention for their residents, which will increase their utility. Hence, the high customer satisfaction would increase the demand for retirement homes. Demonstrating the ease in measurement is the foundation to improving the emotional health of the elderly so

they can live happier, healthier, and longer lives. In addition, this study could encourage the healthcare insurance companies to use the method provided to forecast their customers' mental health, resulting in a lower cost of the treatment for further stages. Also, the commercial neuroscience platform could be used for patients with depression who have been treated in order to avoid re-hospitalization to reduce costs and improve the quality of care.

Appendix

Appendix 1

Augmented Dickey-Fuller (ADF) Test for Mood and Energy

Participants	Mood	Energy
	P value	P value
1	0.64	**0.05**
2	**0.02**	0.22
3	0.08	**0.02**
4	0.23	0.58
5	**0.02**	**0.05**
6	0.89	0.89
7	0.63	0.63
8	0.12	0.13
9	**0.04**	**0.02**
10	0.07	0.57
11	**0.02**	0.31
12	0.40	0.47
13	0.06	0.34
14	0.11	0.76
15	**0.00**	0.63
16	0.57	0.52
17	0.10	**0.04**
18	0.06	0.13
19	0.10	0.10
20	**0.00**	
21	0.72	0.71
22	0.80	0.16
23	0.42	0.08
24	0.56	**0.04**
Average	0.28	0.32

Appendix 2

	Principal Components Analysis (PCA)		
Variable	Neuro measures (-2)	Neuro measures	Neuro measures (-1)
Immersion	.207	**.946**	-.006
Immersion(-1)	.033	.029	**.955**
Immersion(-2)	**.956**	-.023	.084
Peak	.067	**.929**	-.066
Peak(-1)	.075	-.101	**.923**
Peak(-2)	**.899**	.104	.219
Safety	-.258	**.636**	.067
Safety(-1)	-.401	.290	.417
Safety(-2)	**.702**	-.021	-.424
% Variance Explained	28.12%	25.52%	23.53%

Appendix 3

OLS & Logit Regression Models Predicting Participants' Mood

Variable	*OLS*	*VIF*	Logit	Odd Ratio
Neuro measures (-2)	.285** (.092)	1.000	.325 (.501)	1.384
Neuro measures	.167 (.097)	1.071	.280 (.492)	1.323
Neuro measures (-1)	.178 (.100)	1.129	-.519 (.514)	.595
Sick	.030 (.642)	1.129	-20.19 (40192)	.000
Intercept	3.904*** (.116)		-.919 (.502)	
F-value	3.927			
p-value	(.016)			
R-squared	.428			

Note. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix 4

OLS & Logit Regression Models Predicting Participants' Energy

Variable	*OLS*	*VIF*	Logit	Odd Ratio
Neuro measures (-2)	.415* (.158)	1.000	.111 (.586)	1.117
Neuro measures	.238 (.168)	1.071	2.298* (.937)	9.956
Neuro measures (-1)	.195 (.172)	1.129	1.319 (.880)	3.739
Sick	.498 (.172)	1.183	24.877 (40192)	.000
Intercept	3.035*** (.197)		-.614 (.643)	
F-value	2.420			
p-value	(.081)			
R-squared	.316			

Note. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix 5

Random & Fixed Effects Models

Variable	*Mood*		*Mood>4*	
	Fixed effects	Random effects	Fixed effects	Random effects
Safety	.0940 (.127)	.0494 (.107)	.0210 (.115)	-.0108 (.081)
Immersion	-.0375 (.223)	.0155 (.215)	-.3177 (.202)	-.1791 (.187)
Peak	.111 (.233)	.0795 (.230)	.2360 (.210)	.1149 (.204)
Sick	-.0686 (.179)	-.2148 (.172)	-.1546 (.162)	-.2406 (.147)
Intercept	3.828*** (.821)	3.702*** (.759)	1.3981 (.7427)	.9659 (.646)
F-value	8.778	0.5416	3.135	1.027
p-value	(.000)	(.705)	(.000)	(.395)
R-squared	.545	.011	.2999	.022
Hausman Test	.0404		.0423	

Appendix 6

Random & Fixed Effects Models

Variable	*Energetic*		*Energetic>3*	
	Fixed effects	Random effects	Fixed effects	Random effects
Safety	.0231 (.226)	.0983 (.193)	.0269 (.104)	.0599 (.092)
Immersion	-.3137 (.398)	-.2088 (.386)	-.0049 (.183)	.0295 (.179)
Peak	.4306 (.415)	.4152 (.411)	.1516 (.191)	.1493 (.190)
Sick	-.3680 (.320)	-.4087 (.309)	-.227 (.147)	-.2299 (.144)
Intercept	4.199** (1.467)	3.587** (1.361)	.2757 (.676)	.0504 (.637)
F-value	4.8766	0.9053	6.254	1.027
p-value	(.000)	(.462)	(.000)	(.283)
R-squared	.3998	.019	.461	.028
Hausman Test	.8614		.931	

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