Introduction

People usually prefer rewards sooner rather than later, even when the later reward is larger. This phenomenon is known as temporal discounting. The degree to which people discount future rewards varies across age (Green et al. 1999) as seen in class, but other factors such as the framing of the question and magnitude of the reward (Allais's Paradox), depressive disorders (Pulcu 2014), impulsivity (Steward 2017) and more can affect the rate and steepness of the discounting curve.

Anxiety disorder is a general name for several mental disorders, such as social anxiety disorder (SAD) and generalized anxiety disorder (GAD). Symptoms can be excessive anxiety and worry about current and future events, irritability, restlessness and more. Anxiety disorders have been found to be related and inversely related to impulsive behavior in past studies (Barratt 1965, Jakuszkowiak-Wojten et al., 2015).

Intuitively and from the above studies, it is plausible to connect between anxiety disorders and an abnormal discounting curve. Two inverse results regarding the trend of the discounting curve can be guessed: On one hand, impulsive behavior, that might be one of the features of the disorder, can lead to a steeper curve, which reflects the preference of current reward. Another reason of preference of current rewards is a mental state of anticipation of a future threat, a state of mind that people suffering from anxiety disorders commonly have (DSM-5). On the other hand, excessive anxiety and worry about future events might lead to a shallower curve, reflecting the preference of future rewards and safety. Any way, we expect to see an abnormal discounting curve in subjects with anxiety disorder.

In this study, we set to assess the discounting curve of subjects with anxiety disorder using similar methods as the Green et al study we saw in class. As Green et al. showed in their article, the function which had the best fit was a hyperbola-like function defined by the following:

$$V = \frac{A}{(1 + kD)^s} \qquad \text{Eq (1)}$$

Where V is the subject value amount (the amount received today), A is the amount in the delayed amount, D is the delay factor and k, s are parameters of the hyperbola. We will try to fit this function to the data of the subjects and compare to results achieved in the paper.

Method:

A delay discounting task was administered to 3 participants: 2 subjects with mild generalized anxiety disorder and 1 subject with social anxiety disorder. One delayed reward amount of 1000$ was used, as in Green et al. 1999. Participants were asked to make a series of choices between a hypothetical 1000$ reward available after a delay and a smaller amount available immediately. There were ten delays for the 1000$ dollar reward ranging from 1 week to 25 years and twenty immediate amounts ranging from 1$ to 1000$. For each of the ten delays used for the 1000$ reward, the immediate amounts were presented in both ascending and descending orders. In the ascending series, the amount of the

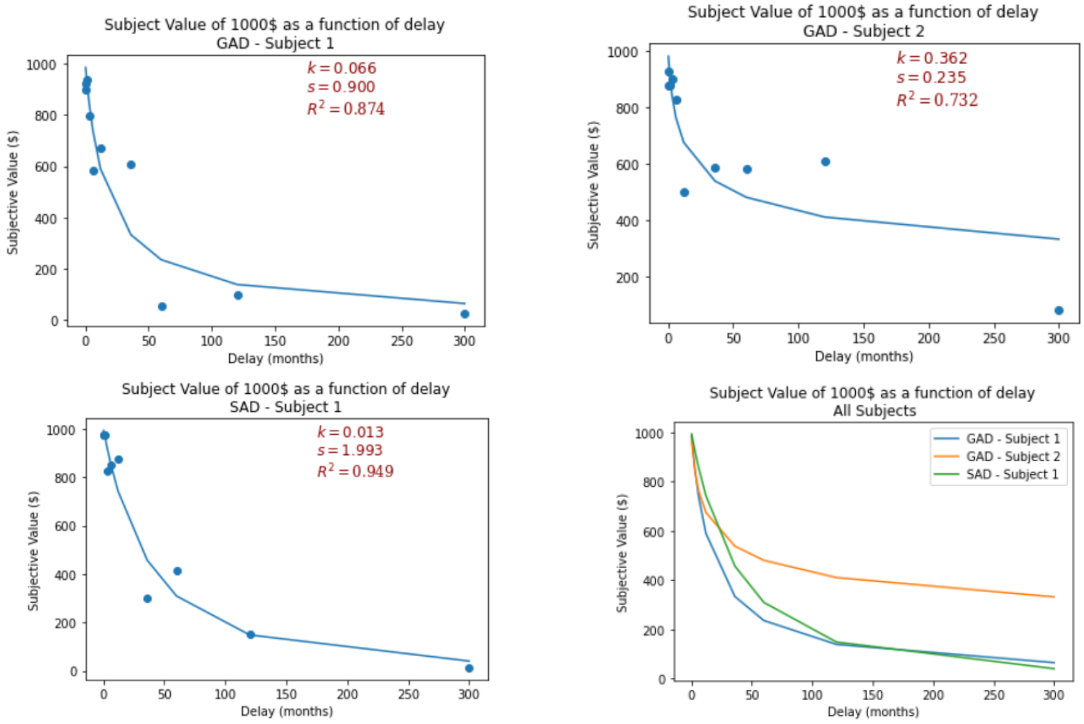
immediate reward was increased until the participant switched preference from the delayed to the immediate reward. In the descending series, the amount of the immediate reward was decreased until the participant switched preference from the immediate to the delayed reward. The subjective value of the delayed reward was defined as the average of the immediate amounts preceding and following preference reversal.

Participants executed the experiment on their personal computer in a shell program. The code of the experiment is added to the study. Participants were not paid for participating.

The social anxiety disorder subject was diagnosed by a psychiatrist as suffering from the disorder. The 2 subjects with mild generalized anxiety disorder have taken a GAD-7 assessment and have gotten a score of 9/21.

Results:

We can see the fitted function for every subject in the following graphs:



Curves were fit using non-linear least squares regarding Eq (1), as implemented in the Scipy package in python. In red we have the values found for the 2 parameters in Eq (1) and the R^2 value of the fit. For each delay, the average over all trials was determined as the subjective value. We can compare the value of the parameters fitted to those of the original paper:

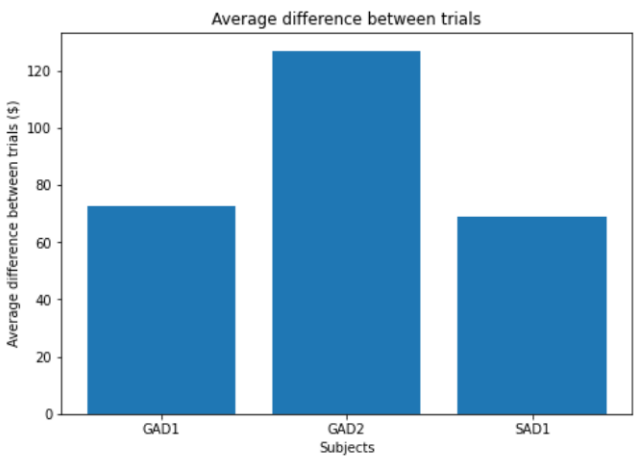
Age differences in fits of Eq. (1) to group and individual data

Group	Parameters for fits to group medians			Parameters for individual fits				
	k	s	R^2	Median k	Median s	Median R^2	$s<1.0$ (%)[a]	$s<1.0$ (%)[b]
Children	0.618	0.368	0.995	1.026	0.252	0.919	91.7	75.0
Young adults	0.075	0.724	0.996	0.169	0.704	0.977	75.0	50.0
Older adults	0.010	0.957	0.998	0.016	0.800	0.965	53.1	40.6

We can see that for subject SAD1, the s parameter is very high compared to the median s value for all age groups and across group and individual fits. The s parameter is the rate of change of subjective value over time: When the s parameter is very small, the change of subjective value over time is very small (For example, there will not be much difference in the subjective value of 1000$ between 5 and 10 years). When the s parameter is very big, the subjective value will continue to change over time. As stated in the article and seen in the table above, we see an increase in the s parameter with age. This might be attributed to developmental changes in the way time is scaled: “To children, delays greater than a few years may be relatively equivalent”. Regarding that notion, we can see in subject SAD1 an abnormal scaling of time regarding all age classes in the experiment. The k parameter for this subject is also low compared to the subjects age class and is closer to the “Older adults” age class.

Looking at subject GAD2, the s parameter is very low compared to median s value of relevant age class (Young adults). It seems that the s parameter is more suited to be that of a younger age class. Therefore, we can also state that there is some abnormal scaling of time regarding the age class of the subject. The k value is also on the low side of the median, but not significantly. We get a low R^2 value for this subject fitted curve, but this is because of the significant loss in subjective value in the 300-month delay. That delay is not the interesting part of the trend compared to the shorter delays and therefore we can ignore this low score.

The average difference between the ascending trials and descending trails was also computed and can be seen in the following graph:



We can see that for subjects GAD1 and SAD1, the answers were quite consistent and for GAD2 there was more fluctuation in the subjective value between ascending and descending trials.

Discussion:

The results show that out of the 3 subjects tested, the fitted parameters for 2 of the subjects are not close to the parameter medians found in Green et al. regarding age classes, even when the fitted function is the same as the original experiment and explains most of the variance. Abnormality was mostly in the *s* parameter of the fitted functions and this parameter has been attributed to the time scaling of the subject. This might hint that subjects with mental disorders of the anxiety family might have abnormal temporal discounting function, where the reason is different scaling of time by the subject.

The different scaling of time can vary with the type of disorder. At its core, anxiety consists of constant worrying. The events which are the subject of the worrying can be current or in the future and the focus to what events the subject worries about can change with the disorder. Social Anxiety Disorder (SAD) is mostly worrying about future interactions with people. This might cause a different time scaling of future events, giving a future time more value. Subjects with Generalized Anxiety Disorder (GAD) worry more about everyday life events, therefore given near future time more value.

As this is a small sample size, not much more can be said. More subjects of the same disorders are needed in order to find median and other statistics as in the original experiment. Also, mapping subjects to mostly worrying about current or future events can help derive correlations between the discounting functions and the predicted abnormal time-scaling. Even though, 2 subjects having abnormal discounting function does hint that correlations might be found.

References:

Pulcu, E., Trotter, P. D., Thomas, E. J., McFarquhar, M., Juhasz, G., Sahakian, B. J., … Elliott, R. (2014). Temporal discounting in major depressive disorder. *Psychological Medicine*, *44*(9). https://doi.org/10.1017/S0033291713002584

BARRATT, E. S. (1965). FACTOR ANALYSIS OF SOME PSYCHOMETRIC MEASURES OF IMPULSIVENESS AND ANXIETY. *Psychological Reports*, *16*. https://doi.org/10.2466/pr0.1965.16.2.547

Green, L., Myerson, J., & Ostaszewski, P. (1999). Discounting of delayed rewards across the life span: age differences in individual discounting functions. *Behavioural Processes*, *46*(1), 89–96. https://doi.org/10.1016/S0376-6357(99)00021-2

Steward, T., Mestre-Bach, G., Vintró-Alcaraz, C., Agüera, Z., Jiménez-Murcia, S., Granero, R., & Fernández-Aranda, F. (2017). Delay Discounting of Reward and Impulsivity in Eating Disorders: From Anorexia Nervosa to Binge Eating Disorder. *European Eating Disorders Review*, *25*(6). https://doi.org/10.1002/erv.2543