Jason Chari, Anna Xu, Kira Roybal
BTRY 4110 • 4/19/17

Analysis of Weight Loss Success in Middle-Aged People Using Categorical Data Analysis

Abstract

This analysis seeks to identify which factors affect middle-aged people's successful long term weight loss; impulsivity, amount of daily meditation, whether or not the subject kept a food diary, marital status, weight loss goal, and age are considered. Implementing a logistic regression on the dataset, the final model of significant predictors included age, impulsivity, weight loss goal, amount of meditation, and the interactions among age and amount of meditation, impulsivity and amount of meditation, and weight loss goal and impulsivity. Of these factors, higher weight loss goals, low impulsivity, and meditating a medium amount per day all contributed positively to weight loss. For all ages in this "middle-aged" category, meditating a low or medium amount per day also contributed positively to weight loss; however, for subjects with low impulsivity, meditating a low or medium amount per day contributed negatively to weight loss.

Introduction

Obesity is a rapidly increasing problem in the United States and around the world. With overall obesity rates in the US increasing from 11.1% in 1990 to a staggering 37.9% in 2015, the need for long-term weight loss solutions among obese individuals is more pressing than ever.[1] However, there are limitations for maintaining weight loss that extend beyond willpower and effort. In fact, our bodies respond to the reduced energy stores that accompany weight loss by inducing hormone release in the body, alerting the brain that fat stores have run low. In turn, this promotes the body to regain weight by decreasing the calories that muscles burn and by triggering increased appetite.[2]

The success of long-term weight-loss can be affected by a variety of individual and social factors. Some of these include level of impulsive behavior, amount of daily meditation, whether or not the individual kept a food diary, marital status, age, and an individual's level of goal-setting behavior. In this study, we will be asking the following research question: How do the previously mentioned factors, or combination of factors, affect weight loss success in middle-aged people?

The rest of this report is organized in the following way:

I. Description of Data & Subjects: Investigation of data and subjects, how the data were checked and cleaned, as well as description of characteristics of subjects.
II. Univariate analysis: Understanding the singular effect of each predictor on weight loss using contingency analysis and the best scale for each predictor.

III. **Fitting the Model: Description of the model fitting process, stating a final model, and interpreting the final model**
IV. **Assessment of Model Adequacy: Assessing the overall goodness of fit**
V. **Results & Discussion: Conclusions and discussion of results**

I. Description of Data & Subjects

The data in this study were collected from 315 middle-aged obese individuals. We have access to the following data for each patient:

Variable Name	*Description*	*Coding/Unit*	*Description of Characteristics*
impulse	"high" indicates strong tendencies for impulsive behavior "low" if weak tendencies for impulsive behavior	1 = High 0 = Low	50.0% High 50.0% Low
meditate	Amount of daily meditation.	Meditate low = reference level Meditate medium = 1 if meditation was medium and 0 otherwise Meditate high = 1 if meditation was high and 0 if otherwise	33.0% High 33.3% Medium 33.6% Low
diary	Whether or not kept a food diary	1 = Yes 0 = No	60.9% No 29.1% Yes
married	Marital status	1 = Yes 0 = No	58.0% No 42.0% Yes
age	age of participant	Numeric age	Min: 35, Median: 50, Max: 65 Standard Deviation: 8.462
goal	This is a measure of the frequency that participants set personal goals on a regular basis; a low score indicates fewer instances of goal-setting.	scale of "goal-striving" behavior (ranging from 0 to 21)	Min: 1, Median: 10, Max: 21 Standard Deviation: 3.294

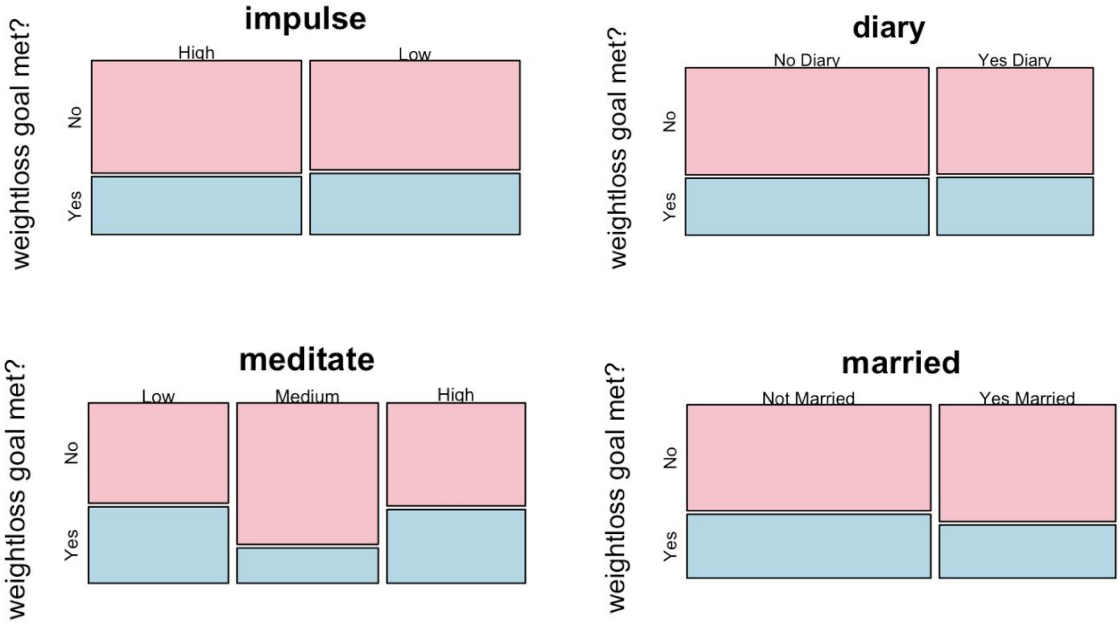
To clean the data, we ran histograms and boxplots for the continuous variables and mosaic plots for the categorical variables to visualize any outliers or unusual observations. When we found an observation that was clearly a data entry error, we deleted the observation. We deleted a total of 3 observations; one individual had an unknown meditation status and two individuals clearly had data

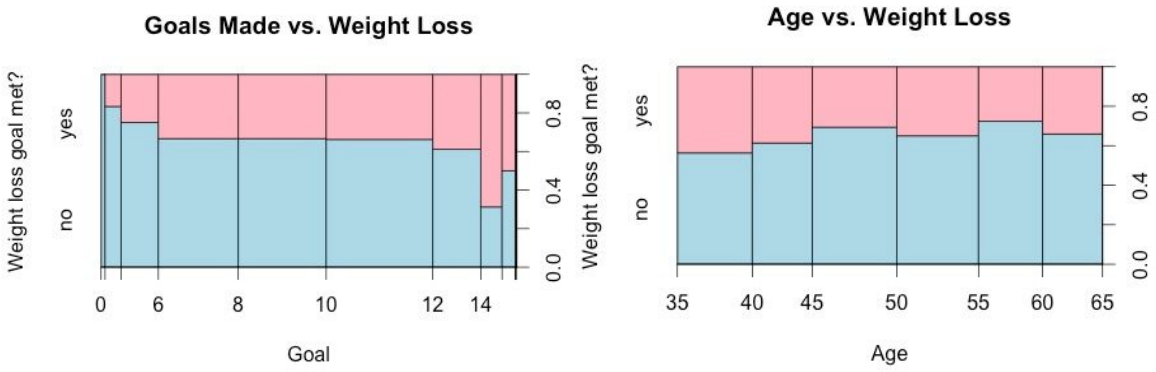
entry errors in the variable *age*, as the ages 3 and 111 are not middle-aged. Though our boxplots showed outliers in the variable *goal*, we are told that the measure is from 0 to 21 and all observations are on this scale, so we left this variable alone. After cleaning the data, we were left with a total of 312 observations.

Overall, 34.9% of individuals lost weight. The average subject did not keep a food diary, was not married, was ~50 years old, and set 10 personal goals on a regular basis. In our analysis, we treated *impulse, meditate, diary, and married* as categorical variables and *age and goal* as continuous variables.

II. Univariate Analysis

Shown below are mosaic plots illustrating the singular association that each variable has with weight loss success.





III. Fitting The Model (Multivariate Analysis)

To fit the best possible model to the data, we followed the following procedure:

1. **One-way model fitting with long term weight loss success as a predictor**
2. **Two-way model fitting with long term weight loss success as a predictor**
3. **Implementation of dredge() using the predictors identified as significant in (1) and (2), identifying the model with the lowest AIC value.**

CODING: 'meditate,' 'diary,' 'impulse,' and 'married' were treated as categorical variables and 'goal' and 'age' were treated as continuous (numeric) variables.

Note: The variable 'meditate' appears to follow a non-linear trend as shown in the univariate analysis above. Because the low and high categories appear to be similar, it seemed logical that the model could be fitted with those two levels combined, as a so-called "extreme" category. However, when this was attempted, the AIC value of the best model increased dramatically (from 373.1 to 390.2), so the original categorizations of low, medium and high were used.

Results of the above method:

1. **In a one-way model, only the parameters 'meditate' and 'goal' were significant.**
2. **Upon running all 15 two-way models, it was determined that the main effects 'impulse,' 'goal,' and 'meditate' were all significant. The parameter 'age' and its interaction with 'meditate' were both marginally significant, so they were included in the dredge() function and both ended up being significant in the full model ($p<.05$). The remaining two parameters of 'diary' and 'age' were excluded, as the main effects and interaction terms containing these variables had corresponding p-values that were all greater than 0.36.**
3. **After running dredge() on a global model containing the main effects 'impulse,' 'goal,' 'meditate,' and 'age' and their corresponding two-way interaction terms, the lowest AIC value of 373.1 corresponded to a model containing the predictors shown in the table below.**

Accordingly, these terms were chosen as the predictors in the full model shown below.

Intercept	Parameter Estimate			P-value	
Intercept	-4.14471			0.01957	
Variable	Parameter Estimate	Odds Ratio	Odds Ratio CI	P-value	Strength and Direction of Effect
Age	0.03932	1.04009898	(0.977, 1.110)	0.22140	Increased age, Increased success
Impulse - High	-2.38184	0.09238033	(0.009, 0.830)	0.03687	Higher Impulse, decreased success
Meditate - High	6.41860	613.14550150	(10.514, 46208.008)	0.00259	High Meditation, increased success Strong effect
Meditate - Medium	4.60397	99.87960226	(1.698 , 7263.614)	0.03007	Medium Meditation, increased succes Strong effect
Goal	0.06992	1.07242724	(0.961, 1.200)	0.21447	High goal-setting behavior, increased success
Interactions	Parameter Estimate	Sample Interpretation			P-value
age*Meditate_high	-0.09485	Because these are interaction terms, we cannot just exponentiate the parameter estimate to get the odds ratio. Our interpretation for the odds ratio would loo something like this: At age = 40, the odds ratio is -25.37.			0.02005
age*Meditate_medium	-0.07523				0.06752
impulse_high*meditate_high	-0.79489				0.23840
impulse_high*meditate_medium	1.07916				0.11897
impulse_high*goal	0.20600				0.01975

Jason Chari, Anna Xu, Kira Roybal
BTRY 4110 • 4/19/17

IV. Assessment of Model Adequacy

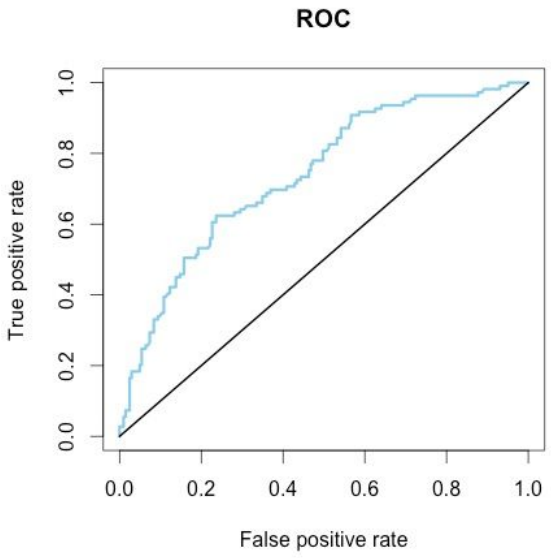
Classification Table

	Model Predicted That Weight Loss Goal Was Met	Model Predicted That Weight Loss Goal Was Not Met
Weight Loss Goal Was Met	178	25
Weight Loss Goal Was Not Met	65	44

From the classification table, we can see that our model correctly predicted the outcome 70.9% of the time. [(True positives + True negatives)/Total]

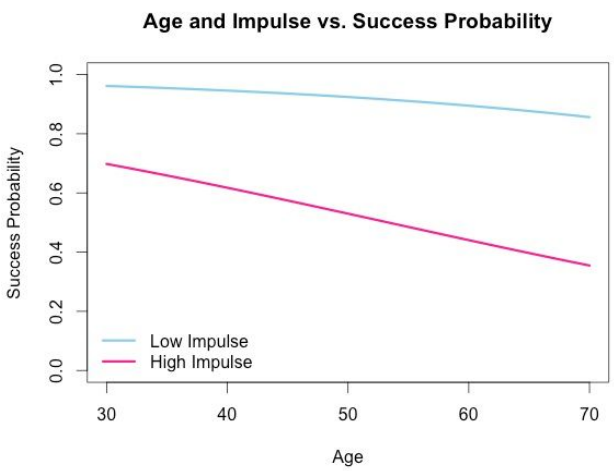
ROC Curve

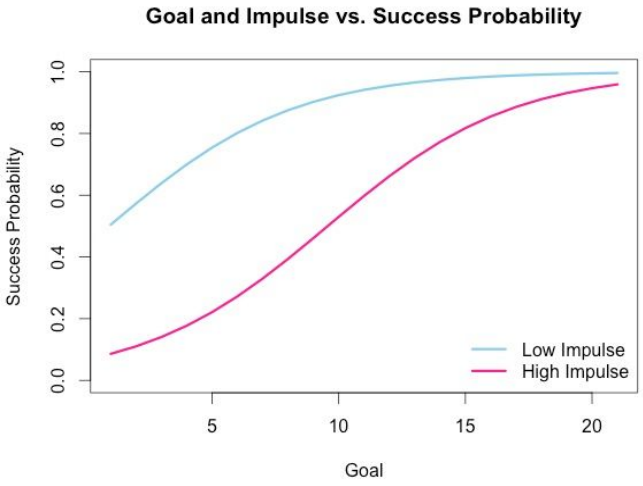
We plotted an ROC curve of true positive rate against the false positive rate. With an AUC value of 0.738, it appears that the model has fairly good accuracy; from the plot below it certainly appears to perform better than random assignment.



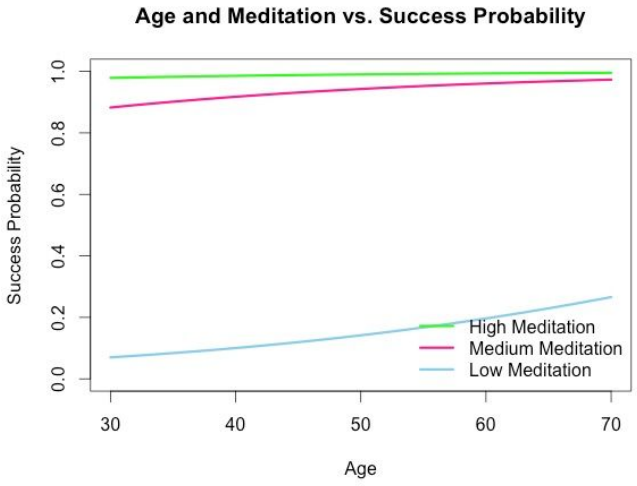
Jason Chari, Anna Xu, Kira Roybal
BTRY 4110 • 4/19/17

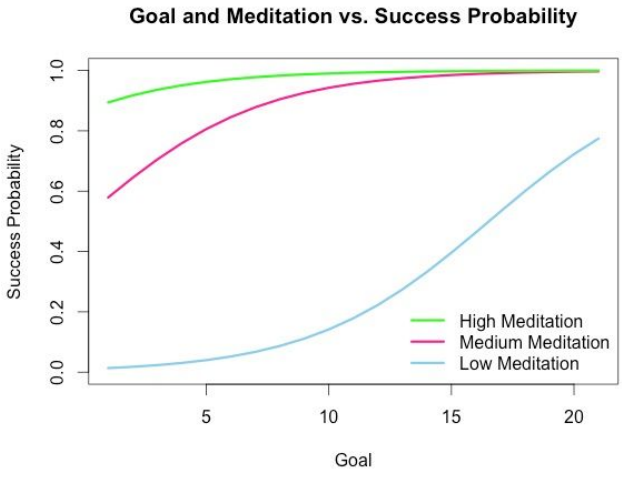
Success Probabilities of Sub-populations





- **In the graph on the left, we compared *high impulse* to *low impulse* for different ages. (We set the meditation variable to medium and *goals* to 10 because it was the median number of goals.) As a result, we can see that individuals with low impulse were much more likely to have success in weight loss compared to those with high impulse and that this success slowly declined as age increased. The lines are not perfectly parallel because we had interaction terms in our model.**
- **Similarly, for the graph on the left, we compared *high impulse* to *low impulse* across the range of possible goals set (1 to 21). (We set the meditation variable to medium and *age* to 30 because it was the median age.) We can see once again that low impulse individuals were more likely to succeed. As expected, as goal habits increase, individuals were more likely to succeed.**





- **In these two plots we compared the three levels of meditation. (We set impulse to high and used median age and median goal.) Individuals with high levels of meditation were more likely to succeed in losing weight. If the individual had low meditation, the number of goals they set heavily influenced their probability of success.**

Jason Chari, Anna Xu, Kira Roybal
BTRY 4110 • 4/19/17

Lack of Fit Test

Null Hypothesis: 'extra' parameters (those in the saturated model, but not in our model are equal to zero.
Alternative Hypothesis: at least one of these 'extra' parameters is not zero ("Lack-of-fit")

Test statistic: LR Statistic
Because our p-value (0.024) is less than alpha = 0.05, we have sufficient evidence to reject the null hypothesis and conclude that there is a lack of fit.

The lack-of-fit test was also run on the next four best models outputted by the dredge() function, resulting in similar or lower p-values. Based on these poor results, we decided to apply various transformations to the model to improve the fit, including implementation of log and exponential transformations to the two continuous variables 'goal' and 'age.' These transformations only served to accentuate the existing lack of fit. However, the fit was greatly improved upon removal of the medium level of the variable 'meditate,' increasing the p-value of the lack-of-fit test above the p=0.05 threshold to 0.15. A similar result was achieved upon removal of the high category of 'meditate,' resulting in a p-value of 0.13. Furthermore, the AIC value of the overall decreased dramatically to 237.65 in the former case. While these results may seem enticing, they are accompanied by a removal of large subsets of the sample; the number of total observations decreased from 312 to 209 in the former case and 208 in the latter case. Losing a third of the sample of individuals for the sake of better fit is not an acceptable maneuver, so we retained our original final model.

Whole Model Test

Null Hypothesis: Model with these 10 predictors is *not* better than an intercept-only model
Alternative Hypothesis: At least one predictor is significant.
Test statistic: X^2 statistic.

```
Null deviance: 403.76  on 311  degrees of freedom
Residual deviance: 351.42  on 301  degrees of freedom
```

403.76 - 351.42 = 52.34

Comparing 52.34 to X_{10}^2 we get $p = 9.87*10^{-8} < .0001$. We have sufficient evidence to reject the null hypothesis that our model with these 10 predictors is *not* better than an intercept-only model.

V. Results and Discussion

In conclusion, we identified age, goal, meditation level, and impulse as significant variables, while diary, and married were insignificant.

For clarity, we restate our final model:

$$F(x) = \frac{1}{1+e^{-(\beta_0 + x(\beta_{age} + \beta_{impulse} + \beta_{meditate} + \beta_{goal} + \beta_{meditate*age} + \beta_{impulse*meditate} + \beta_{impulse*goal}))}}$$

From the results of the logistic regression we find that for every one year increase in age, the log-odds of weight loss decreases by 0.05; for every lb. increase in weight loss goal, the log-odds of weight loss increases by 0.28; having low impulse, versus high impulse, increased the log-odds of weight loss by 3.18; meditating a low amount, versus a high amount, decreased the log-odds of weight loss by 5.62; meditating a medium amount, versus a high amount, increased the log-odds of weight loss by 0.06; for each age, meditating a low amount (versus a high amount) increased the log-odds by 0.09; for each age, meditating a medium amount (versus a high amount) increased the log-odds by 0.02; for each weight loss goal value, having low impulse (versus high impulse) decreased the log-odds by 0.21; for a low impulse individual, meditating a low amount decreases the log-odds by 0.79; for a low impulse individual, meditating a medium amount decreases the log-odds by 1.87.

An issue that we encountered during the analysis occurred in our lack-of-fit test and analysis. The low p-value corresponding to our final model indicated that there was indeed lack of fit in our model. Transformations applied to the data were either unfruitful or severely diminished the number of observations. As a result, we decided to retain our original full model.

This study could be further expanded by considering other possible weight loss factors, such as smoking status, whether or not a subject takes high cholesterol medication, how many meals a subject eats per day, and what region of the United States a subject is from (Pacific Northwest, Southwest, Midwest, Northeast, or South). The latter factor may provide a confounding concept of cultural upbringing, as it may be more difficult to achieve long term weight loss if it involves deviating from one's upbringing.

Citations

1. "US Obesity Levels, 1990-2015 - Obesity - ProCon.org." *Is Obesity a Disease?* N.p., n.d. Web. 16 Apr. 2017. <http://obesity.procon.org/view.resource.php?resourceID=006026>.
2. Rettner, Rachael. "Here's Why It's So Hard to Maintain Weight Loss." *LiveScience*. Purch, 04 Mar. 2016. Web. 16 Apr. 2017. <http://www.livescience.com/53942-weight-loss-biology.html>.