INTRODUCTION:

METHODS:   
*Sample Information:*

Pupillary light reflex trajectories were collected in 101 healthy participants with enrolled in groups of daily, occasional and no cannabis consumption. Daily cannabis consumption was defined as smoking or vaping a cannabis flower product at least one time per day, every day of the week for 30 days prior to enrollment (N = 33); occasional consumption was defined as smoking or vaping cannabis flower product on at least one day but no more than two day per week in the 30 days prior to enrollment (N=36); and no cannabis consumption was defined as not having used cannabis in the month prior to enrollment (N=32). Videos of the pupillary light reflex test were recorded prior and post cannabis consumption on the study visit date and processed using task-specific video segmentation techniques (Steinhart Thesis), to create a frame-level trajectory of percent change from baseline values of pupil size for each eye on each participant at time point (prior and post consumption). After video segmentation and pre-processing, 88 post consumption trajectories of the right eye were collected, and after removing one outlier and matching to pre-consumption a total of 84 participants were used in this analysis.

In this sample of 84 participants, there were 29 non-users, 30 occasional and 25 daily users. Participants ranged in age from 25.1 to 45.3 years with an average of 32 years (sd = 5.02); an average BMI of 25.4 kg/m2 (sd. 4.41); and approximately 58% male (N = 49). Time between cannabis consumption and post testing varied from 53 – 84 minutes with a median of 62 minutes. Participants in the no use category were allowed to rest with their eyes closed for approximately equal time as allowed for cannabis consumers to use cannabis.

*Functional Data Analysis*

Functional data analysis (FDA) is a field of statistics that models curves or trajectories of information without extracting pre-defined specific features. It allows examination of differences in the patterns of the curves as it relates to an outcome, and how the patterns of the curves differ based on individual characteristics. Two methods of FDA were used in this analysis (1) scalar-on-function regression (SoFR) and (2) function-on-scalar regression (FoSR). In SoFR, an outcome, such as cannabis consumption status, is regressed on the trajectories to find differences in the trajectories that are associated with the outcome. However, in FoSR the trajectories are regressed on covariates such cannabis use frequency to determine how the trajectories differ by the covariate. In this analysis, a SoFR model was used to determine the subtle differences in the pupillary light reflex that discriminate between cannabis users versus non-users, while the FoSR models were used to distinguish trajectory patterns that are associated with cannabis use frequency. Additionally, due to the variability in the time from cannabis consumption to the post test, a FoSR model was used to explain differences in trajectories due to cannabis use frequency and time differences in wait time between cannabis use and testing.

*Prediction Analysis*

Two separate logistic regression model were used to predict cannabis user and not users. The first model used single value summaries of the trajectory data which included: (a) minimal constriction, the magnitude of peak decrease as a percentage of the pre-illumination diameter; (b) AUC, the magnitude of rebound dilation after the point of minimal constriction; and (c) slope (Steinhart thesis). The second model used the prediction from the SoFR model, which assessed information from the full trajectory of the pupillary light reflex during the post test. Receiver operating characteristic curves (ROCs) for each model were used to assess the accuracy of the models with area under the curve.

RESULTS:

The ROC curves for the prediction analysis compared the discrimination ability for two models; one uses summary features of the trajectory of the pupillary light response and the second used the full trajectory of the pupillary light response (Figure 1). The AUCs, used to quantify the discrimination ability of the model, for these prediction models ranged from 0.68 to 0.71, with the model using the full trajectory of pupillary light response having the higher AUC. This indicates that models using full trajectory information of pupillary light response may have the ability to discriminate between cannabis smokers and non-smokers.

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| Figure 1: |
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The full trajectory model used in the prediction analysis was a SoFR model that found differences in the average trajectory of smokers and non-smoker to predict the group for each trajectory. In Figure 2, a plot of the odds ratio between smoker and non-smoker trajectories is shown. From this plot, statistically significant differences are seen between 2 and 3.7 seconds with a peak difference at 2.97 seconds (OR: 2.66, 95% CI: [1.26, 5.59]) and between 5.7 and 7.2 seconds with a maximum difference at 6.53 seconds (OR: 0.367, 95% CI: [0.164, 0.822]) .

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| Figure 2: |
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| \* Dashed lines indicate 2\*se confidence interval around the estimate |

The FoSR model was used to show differences between the average trajectories of pupillary light reflex in daily, occasional and non-users. A separate model estimated the average trajectory of smokers and non-smokers. In Figure 3, the average trajectories are overlaid with solid lines for cannabis use frequency and a dashed line for the all smokers. The non-user and non-smokers compass the same individual and therefore overlap completely. From the figure, we can see a stronger initial constriction in non-users and a steady rebound after the light test; however in smokers of both groups there is less initial constriction and the slope of the rebound dilation is shallower.

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| Figure 3: |
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Using the FoSR model, we plotted the differences between the average trajectories for occasional and non-users, daily and non-user and daily and occasional users (Figure 4). These plot significant regions of difference between occasional and non-users as well as daily and non-user; however there are no significant differences in the average trajectories of daily and occasional users.

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| Figure 4 |
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The effects of the testing delay after the cannabis consumption may impact the results of the previous analyses, so we examined the distribution of this testing delay and modelled it’s effects the mean trajectories of smokers at delay times of 60, 65, and 70 minutes from cannabis consumption. The distribution of the testing delay is show in Figure 5. The testing delay ranged from 53 to 84 minutes with a mean of 62.22 minutes (sd = 5.57). Figure 6 depicts the average trajectory of non-smoker and smokers with a 60-, 65-, and 70-minute delay in testing. As shown in the figure, the initial pupil constriction after the start of the light test is reduced smokers with less delay in testing and reaches constriction similar to non-smoker with a longer delay in testing. However, the slope of the rebound dilation is still shallower in smokers with any of plotted test delays.

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| Figure 6: |
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DISCUSSION:

Main Points:

1. We were able to discriminate between smokers and non-smokers using only data after cannabis consumption.
2. Models using the information from the full trajectory of the pupillary light reflex have more power to discriminate vs models with summary features
3. Average trajectories of pupillary light reflex differ between occasional and non-user; and between daily and non-users
4. Point of minimal constriction vary by minutes testing delay but the average slope of the rebound dilation seems to differ between non-smoker and smoker even with the testing delay

Limitations:

1. Sample size small
2. Data noisy, no systematic length of light stimulus; recording googles did not fit well on all subjects
3. Did not adjust for baseline pupil size
4. Prediction analysis did not use an independent test set.

Strength:

1. Participant did not “over” consume cannabis during the test may not have gotten as “high” as they would on a regular basis – but we can still measure an effect difference (not really a limitation)

HOW DOES THIS FIT INTO A LARGE CONTEXT?