Gaze Behaviour in Automation: Graphical Predictions

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Introduction

Here we provide a brief overview of the hypotheses for an experiment into Gaze Behaviour in Automation, found at osf.io/f2n4c. This document accompanies the pre-registration report, and assumes that the reader is reading this alongside the pre-registration report so is aware of the study rationale and design.

Here we clarify key predictions through plots.

Plotted Predictions

In the report we outline three key characteristics of gaze behaviour that generate our predictions: looking where one is going (*Hypothesis 1*), sequencing gaze into waypoints (*Hypothesis 2*), and look-ahead fixations (*Hypothesis 3*).

Time Headway

Here, we first outline the expected distribution of gaze Time Headway (how far ahead the driver is looking). The way the distribution varies across conditions relates to all hypotheses.

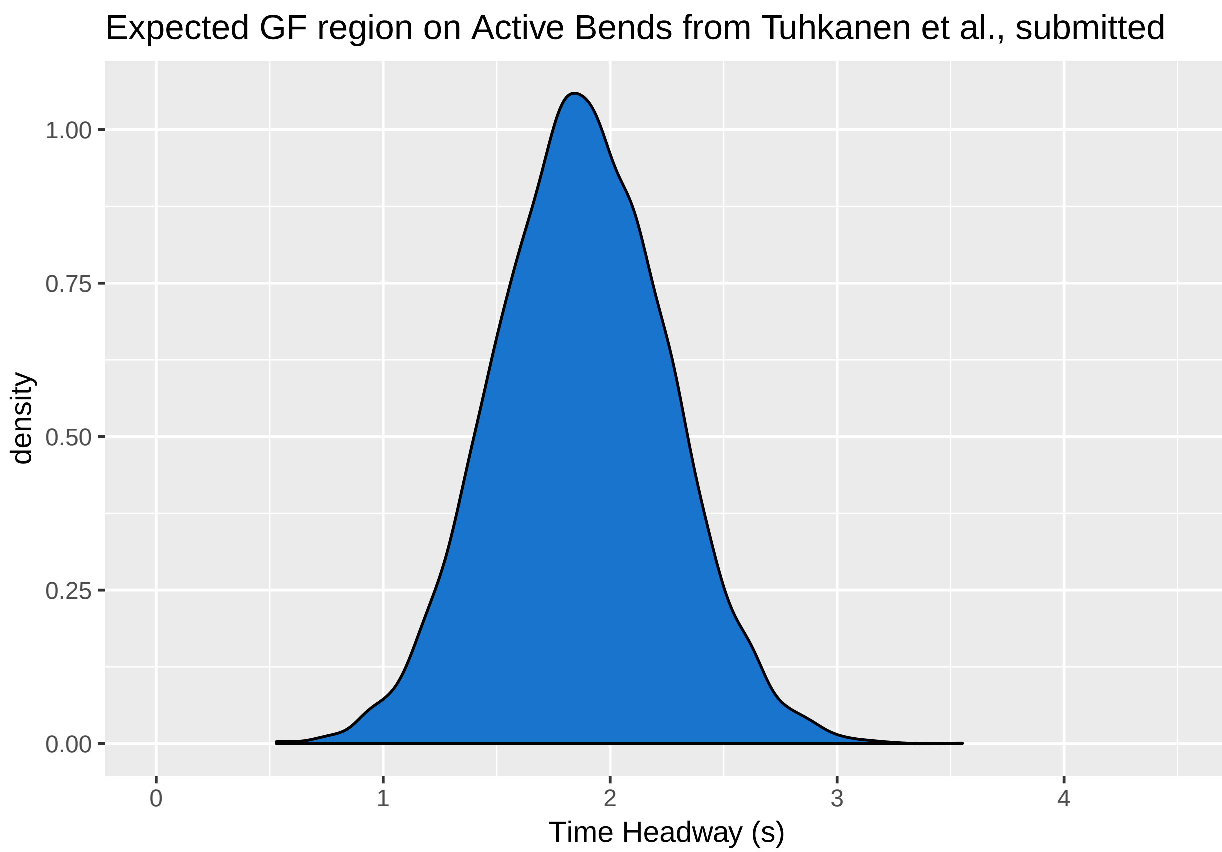
We have concrete predictions about the expected distribution of guiding fixations during Active driving on Bends. Our driving speed is a constant 8ms, and the bend radius is 25m. This gives us an angular velocity conditions in Experiment 1 of Tukhanen et al. (submitted). If are cautious with our predictions and therefore adopt generious bounds, we can estimate that gaze will predominantly fall within a region of .75 - 3s.

```
library("tidyverse")
```

```
## -- Attaching packages --------------------------------------------------------------- tidyverse 1

## v ggplot2 3.0.0     v purrr   0.2.5
## v tibble  1.4.2     v dplyr   0.7.6
## v tidyr   0.8.1     v stringr 1.3.1
## v readr   1.1.1     v forcats 0.3.0

## -- Conflicts ------------------------------------------------------------------ tidyverse_conflic
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
#create normal distribution function that takes max and min as we will recreate a
#few of these
myDistribution <- function(GFmin, GFmax){
  GFmean <- (GFmin+GFmax)/2
  GFsd <- ((GFmax-GFmin)/2)/3
  #print(GFmean)
  #print(GFsd)
  GFnorm <- rnorm(10000, mean=GFmean, sd=GFsd)
  return (GFnorm)

}

GF_active_bends <- myDistribution(.75,3.0)

#plot
ggplot() + geom_density(aes(x=GF_active_bends), fill="dodgerblue3") +
```

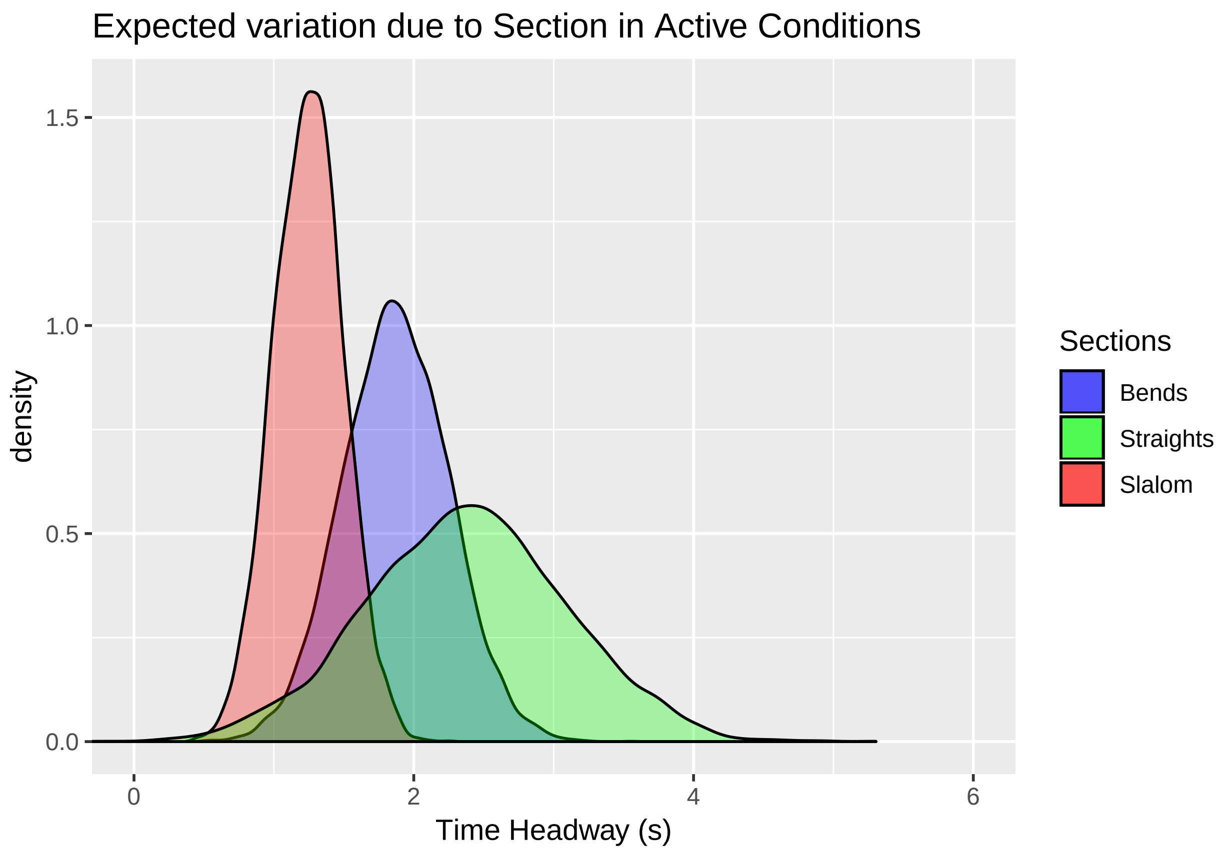
```
  coord_cartesian(xlim = c(0,4.5)) +
  labs(x= "Time Headway (s)",
       title="Expected GF region on Active Bends from Tuhkanen et al., submitted")
```



Further, we expect that whenever steering requirements (number of adjustments to the direction of travel per second) increase, we expect that the distribution of gaze landing points will fall within narrower bounds that are, on average, closer to the driver. The expectation that the gaze distribution will become narrower in the order as follows: straight (widest) > bends > attractors/repellors. This will be due to more tightly coordinated steering and gaze behaviours during Active conditions when steering requirements are high. *Tightly* coordinated gaze and steering behaviour refers to a driver that is looking where they are going (*Hypothesis 1*), in the guiding fixation zone (*Hypothesis 2*), with few look-ahead fixaitons (*Hypothesis 3*), picking up visual information 'just in time' to make the appropriate steering commands. Consequently, the distribution of Time Headway is expected to vary with road section. We expect something looking like the following:

```
GF_active_slalom <- myDistribution(.5,2)
GF_active_straights <- myDistribution(.25,4.5)

p <- ggplot() + geom_density(aes(x=GF_active_bends, fill="blue"), alpha=.3) +
  geom_density(aes(x=GF_active_slalom, fill="red"), alpha=.3) +
  geom_density(aes(x=GF_active_straights, fill="green"), alpha=.3) +
  coord_cartesian(xlim = c(0,6)) + labs(x= "Time Headway (s)",
  title="Expected variation due to Section in Active Conditions") +
  scale_fill_identity(name = 'Sections',labels = c('Bends','Straights','Slalom'),
                      guide = 'legend')
```

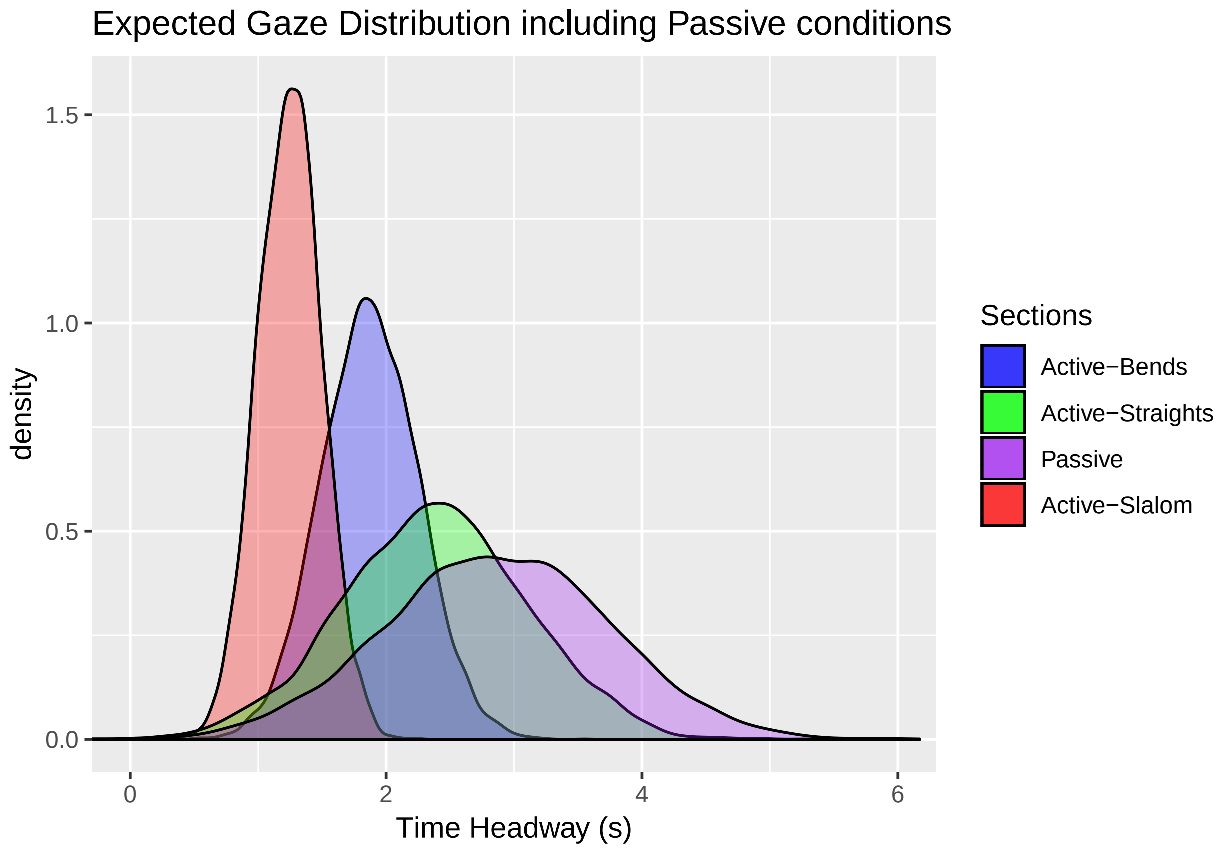
```r
show(p)
```



For Passive driving, where there is no steering needed, we expect the distribution of gaze to be more variable, with more look-ahead fixations (Navarro et al., 2016) and generally more dispersed gaze (Louw & Merat, 2016). We do not have strong expectations about how gaze might vary with section in the Passive conditions.

```r
GF_passive <- myDistribution(.25,5.5)

p + geom_density(aes(x=GF_passive, fill="purple"), alpha = .3) +
  scale_fill_identity(name = 'Sections',
  labels = c('Active-Bends','Active-Straights','Passive','Active-Slalom'),
  guide = 'legend') +
  labs(title = "Expected Gaze Distribution including Passive conditions")
```

```
## Scale for 'fill' is already present. Adding another scale for 'fill',
## which will replace the existing scale.
```



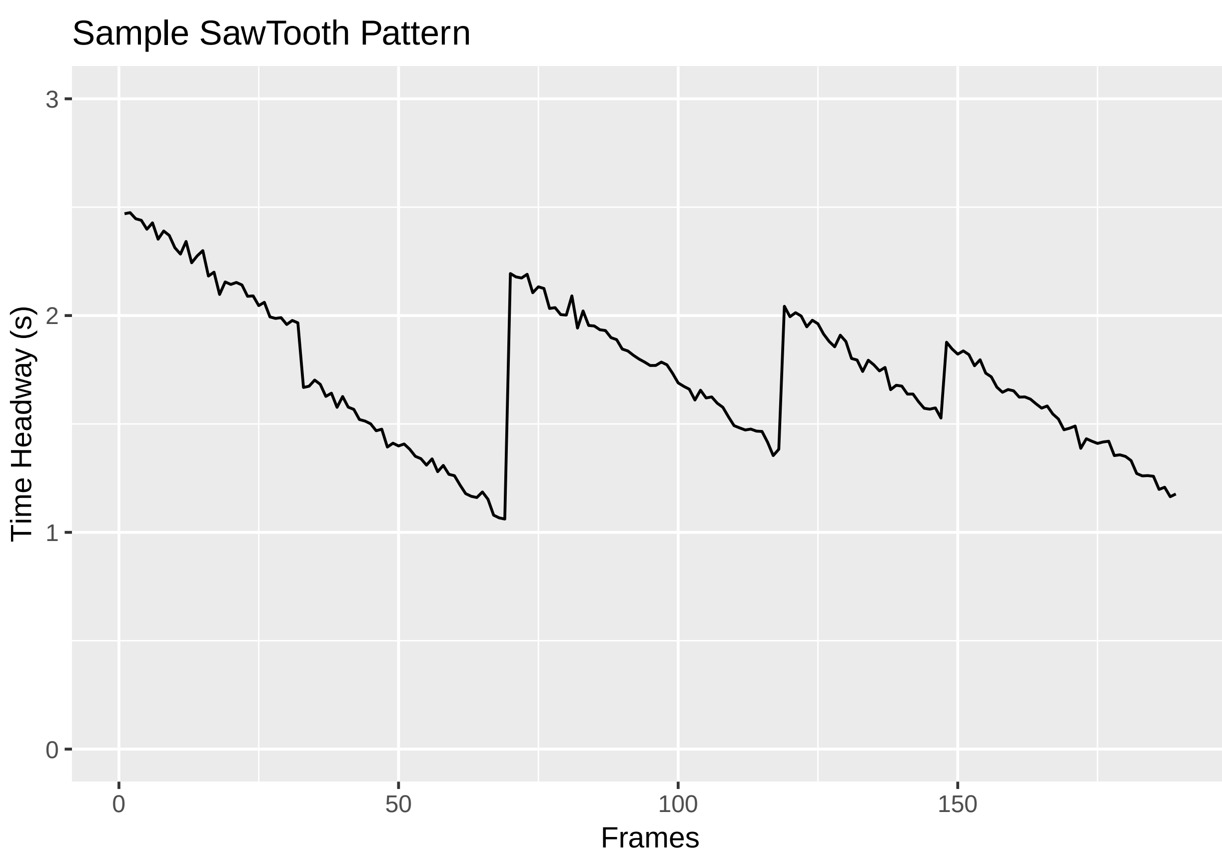
Saw-tooth pattern

The previous section made relatively high-level predictions about how gaze is expected to vary across conditions. The literature also allows fairly precise predictions about the qualitative nature of individual gaze signals during active steering. This 'Saw-tooth' pattern relates to *Hypotheses 2 & 3*. - H2) *In Active Steering conditions we expect to see saw-tooth gaze patterns. Gaze will first land approximately 2s ahead (Tuhkanen et al., submitted), a 'tracking fixation' will follow the point on the ground for ~.5s, before a saccade is generated to a new point onto the path approximately 2s in the future. The estimates for the Time Headway at which gaze lands varies slightly due to the task performed, from 1s-3s. Similarly, the estimated length of time for which a waypoint is fixated before a new forward saccade is executed varies from ~.3s (Tuhkanen et al., submitted) to ~1s (Wilkie et al., 2008).*

Below we show an example trace that exhibits the saccade-fixate-saccade characteristics that we expect.

```
#Gaze Landing Points. Take 5 saccades from .75s-3s range
GLPs <- rnorm(5, mean  = 1.875, sd= .375)

#Tracking Times. Take 5 times from .3 - 1s range
TrackTs <- rnorm(5, mean  = .65, sd= .116)

#Create a sawtooth pattern from from GLPs and TrackingTimes

rate = 60 #sample rate.

#assumes a constant velocity of tracking.

sawtooth <- vector() #initialise empty vector
```

```r
for (i in 1:length(GLPs)){
    GLP <- GLPs[i]
    TrackT <- TrackTs[i]
    GLP_min <- GLP - TrackT
    Len <- TrackT * rate
    Fixation <- seq(from=GLP, to=GLP_min, length.out = round(Len))
    sawtooth <- c(sawtooth, Fixation)
}

#add some noise
noise <- rnorm(length(sawtooth), mean = 0, sd = .025)
sawtooth <- sawtooth + noise


ggplot() + geom_line(aes(x=seq_along(sawtooth), y=sawtooth)) +
  labs(x = "Frames", y="Time Headway (s)", title="Sample SawTooth Pattern") +
  coord_cartesian(ylim = c(0,3))
```

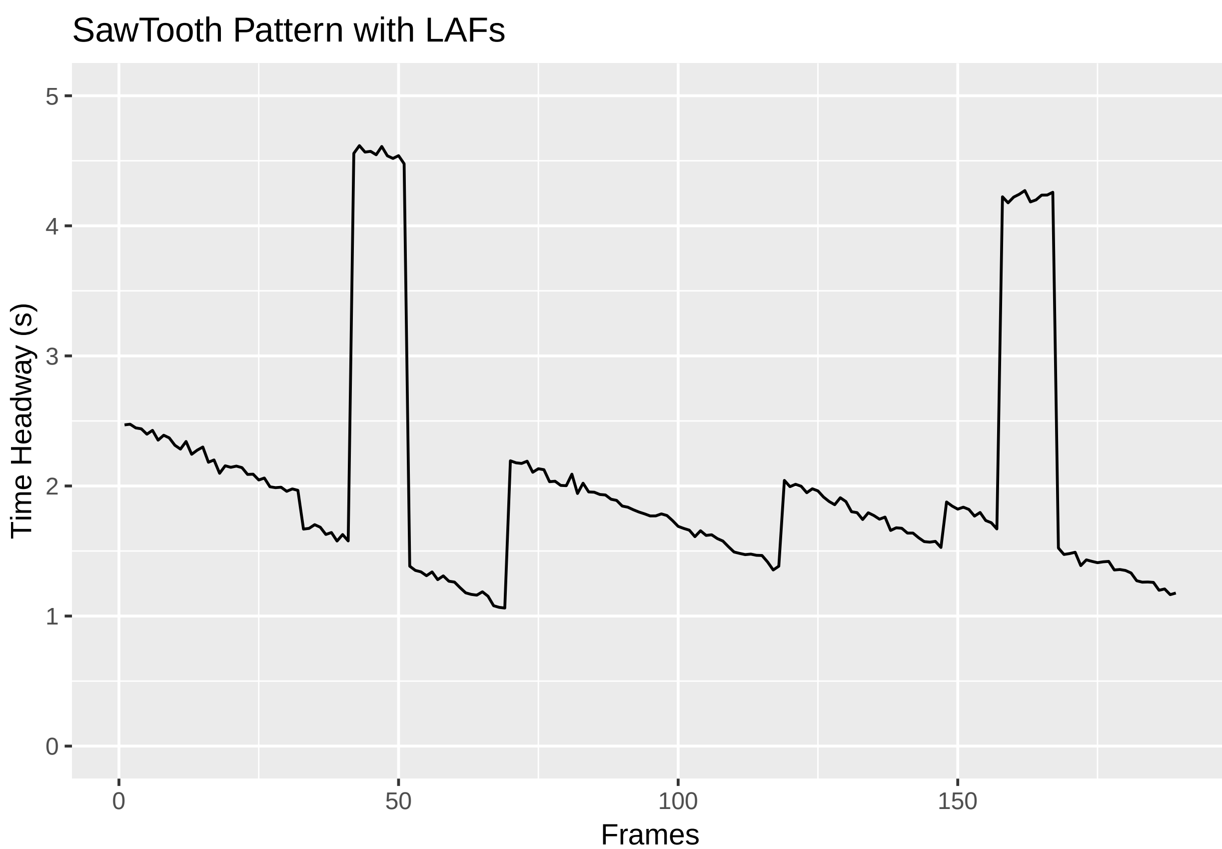


- H3A) *In Active Steering conditions the saw-tooth pattern (H2A) will be interspersed with occasional look-ahead fixations even further ahead, beyond the guiding fixation zone. As with H2A, we have limited precision in the precise Time Headway expected for LAFs, only that they are generally ~4s and above (Lehtonen et al., 2013, 2014).*

Below is an example simulated trace of a gaze signal with look-ahead fixations.

```r
#Simulate lookaheads within range of values.
LAF <- rnorm(2, mean  = 4.5, sd= .5)
```

```r
LAFs <- rep(LAF, each = 10) #replicate.
LAFs <- LAFs + rnorm(length(LAFs), mean=0, sd=.05) #add noise.
#add into sawtooth array.
i <- round(length(sawtooth)/4.5)
j <- round(length(sawtooth)/1.2)
h <- length(LAFs)/2
sawtooth[i:(i+h-1)] <- LAFs[1:h]
sawtooth[j:(j+h-1)] <- LAFs[(h+1):length(LAFs)]

#plot
ggplot() + geom_line(aes(x=seq_along(sawtooth), y=sawtooth)) +
  labs(x = "Frames", y="Time Headway (s)", title="SawTooth Pattern with LAFs") +
  coord_cartesian(ylim = c(0,5))
```



The above plots show the expected nature of gaze during Active steering conditions. We expect the signal to vary between Active and Passive modes,but it is difficult to plot exactly the nature of this variation, not least because we expect gaze behaviour during Passive control to be variable and therefore not have a 'typical' signal trace.