NONLINEAR MODELING IN R WITH GAMS

Logistic GAMs for Classification

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Types of outcomes

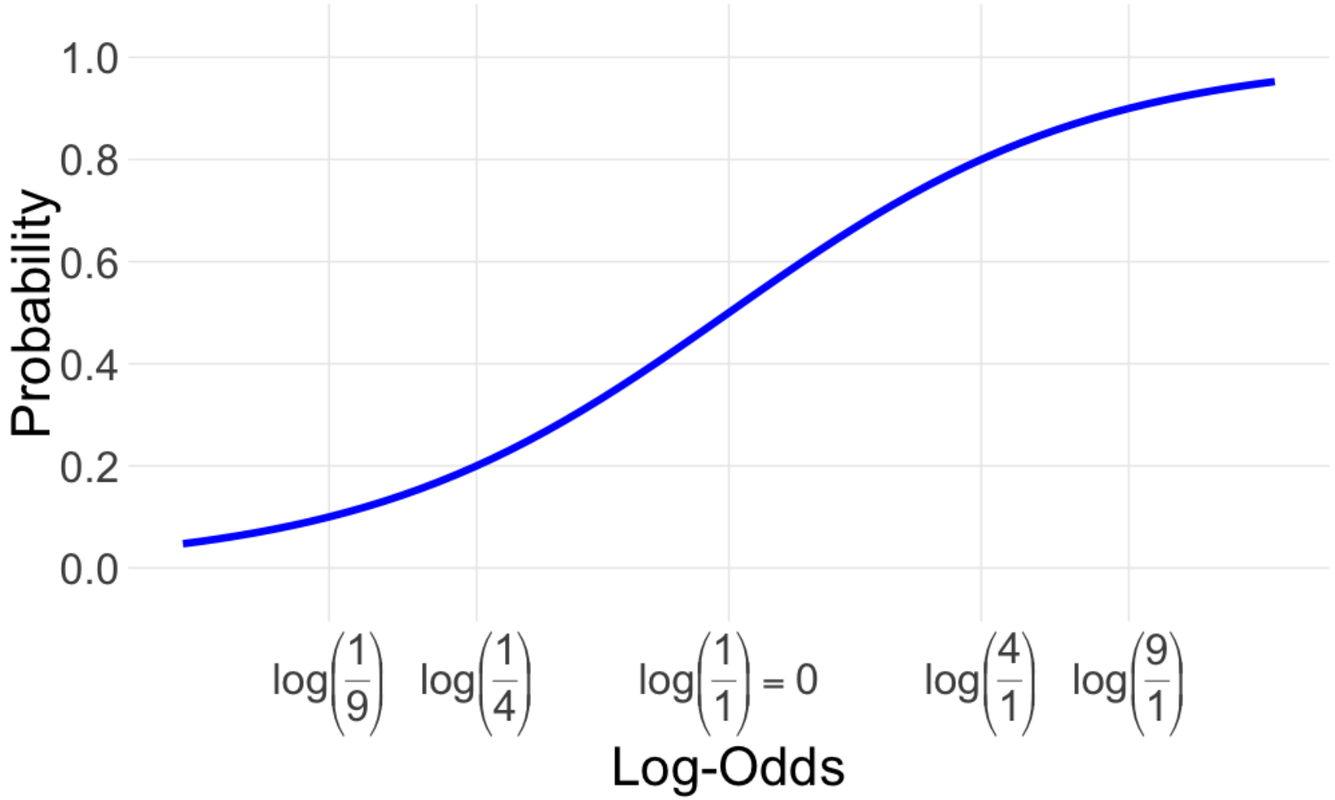
Continuous outcomes

- Speed of a motorcycle (mph)
- Fuel efficiency of a car (mpg)
- Level of pollution in soil (g/kg)

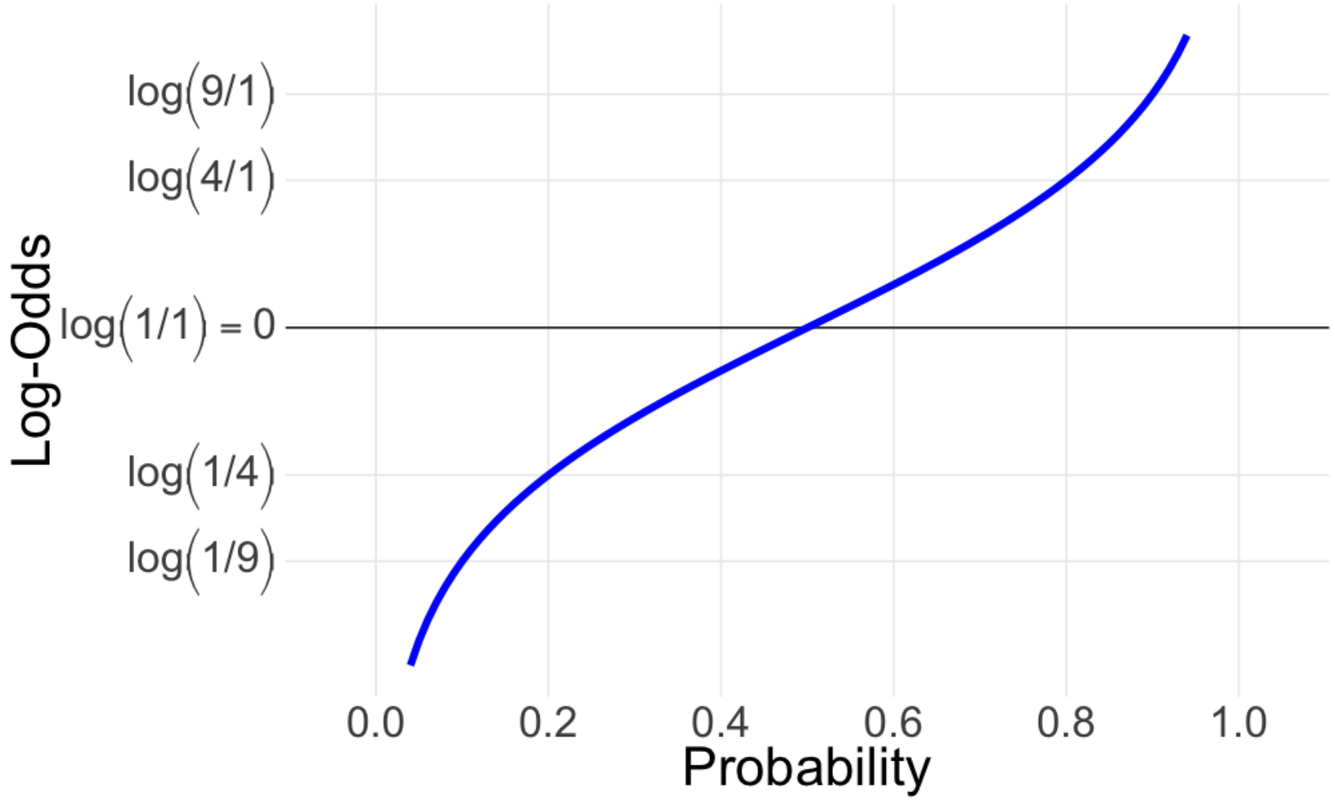
Binary outcomes

- Presence or absence of an organism in a location
- Whether a purchase was made
- Yes/No answer on a survey

Probabilities and Log-Odds: Logistic Function



Probabilities and Log-Odds: Logit Function



Logistic and Logit Functions in R

```
plogis() # Logistic
qlogis() # Logit

qlogis(plogis(0.5))
[1] 0.5

qlogis(0.25) == log(1/3)
[1] TRUE
```

Logistic GAMs with mgcv

```
gam(y ~ x1 + s(x2),
    data = dat,
    family = binomial,
    method = "REML")
```

Logistic GAM outputs

The csale data set

```
head(csale)
```

```
  purchase n_acts bal_crdt_ratio avg_prem_balance retail_crdt_ratio
1        0     11         0.00000          2494.414           0.00000
2        0      0        36.09506          2494.414          11.49123
3        0      6        17.60000          2494.414           0.00000
4        0      8        12.50000          2494.414           0.80000
5        0      8        59.10000          2494.414          20.80000
6        0      1        90.10000          2494.414          11.49123
  avg_fin_balance mortgage_age cred_limit
1        1767.197     182.0000      12500
2        1767.197     138.9601          0
3           0.000     138.9601          0
4        1021.000     138.9601          0
5         797.000      93.0000          0
6        4953.000     138.9601          0
```

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Let's practice!

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Visualizing Logistic GAMs

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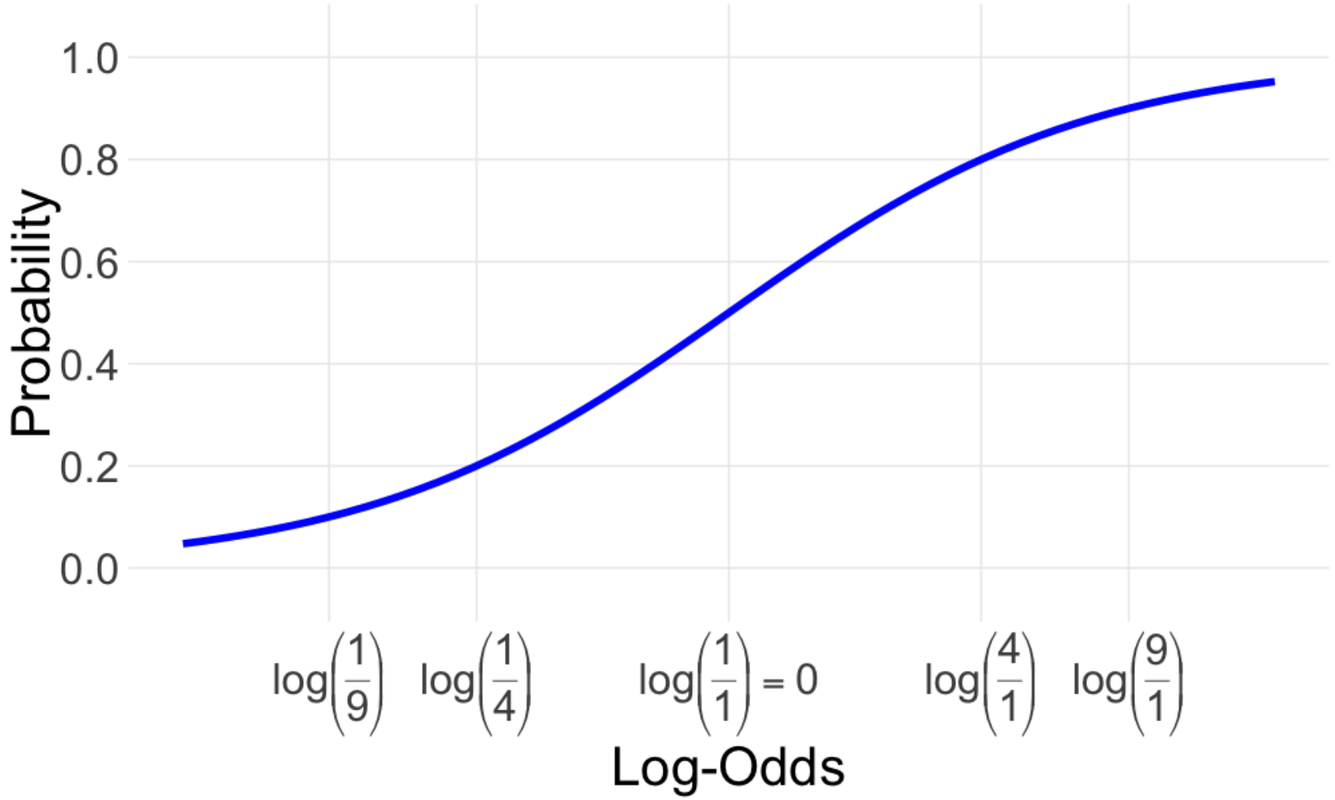
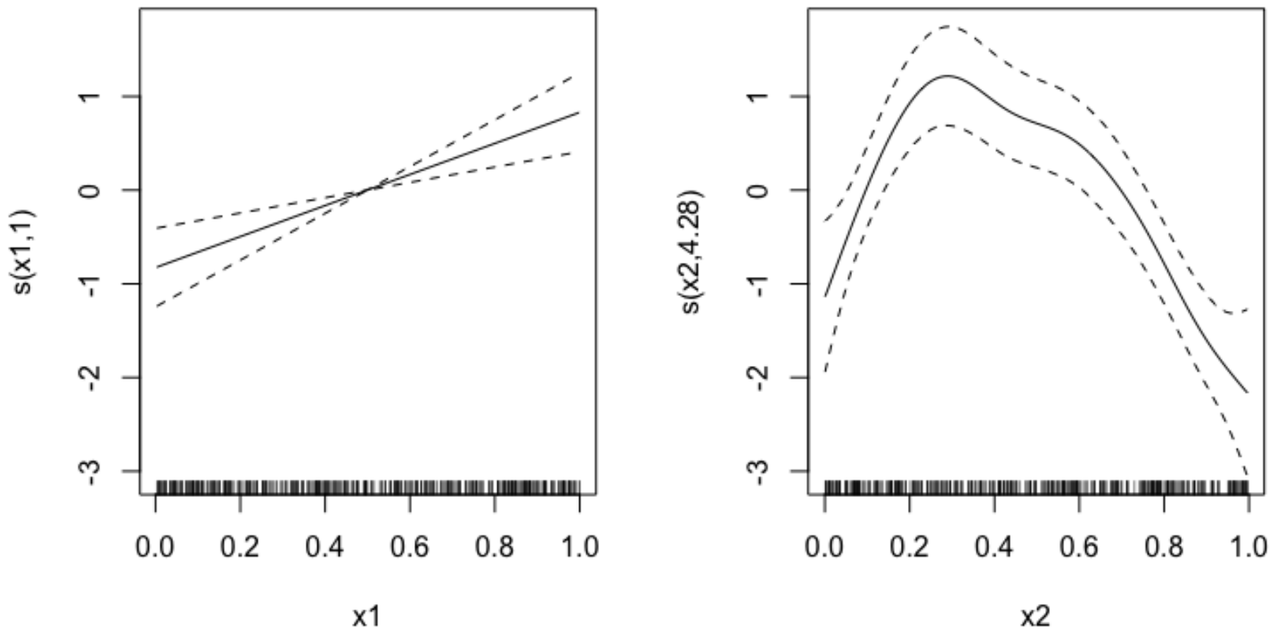
Transforming Scales



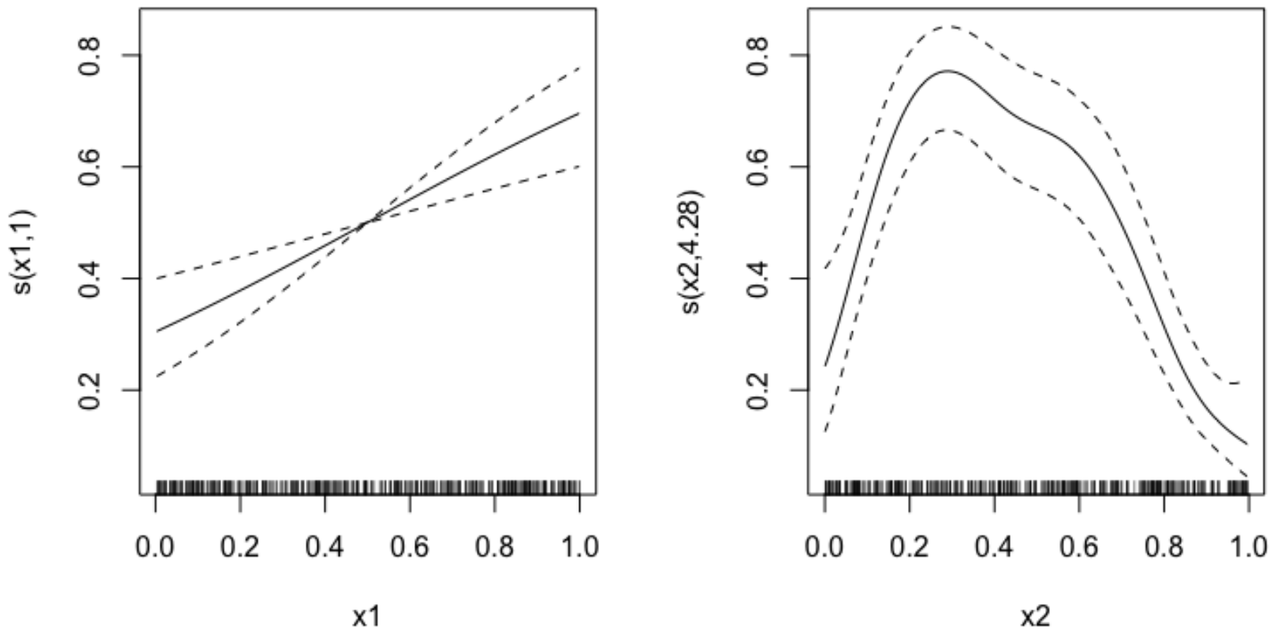
Log-odds plots

```
plot(binom_mod)
```



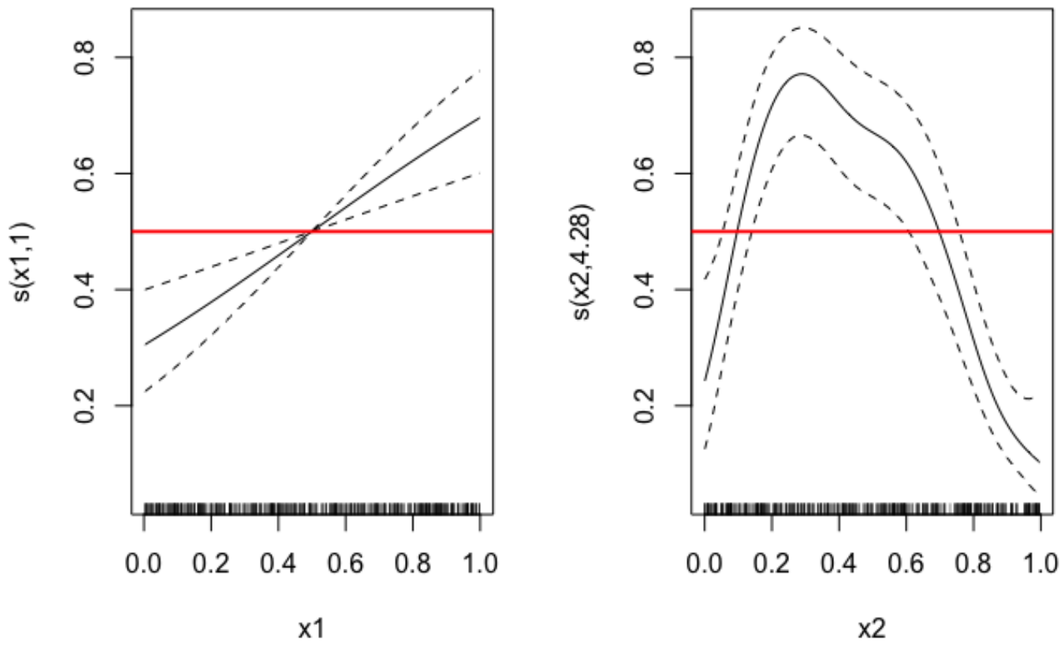
Converting partial effects

```
plot(binom_mod, pages = 1, trans = plogis)
```



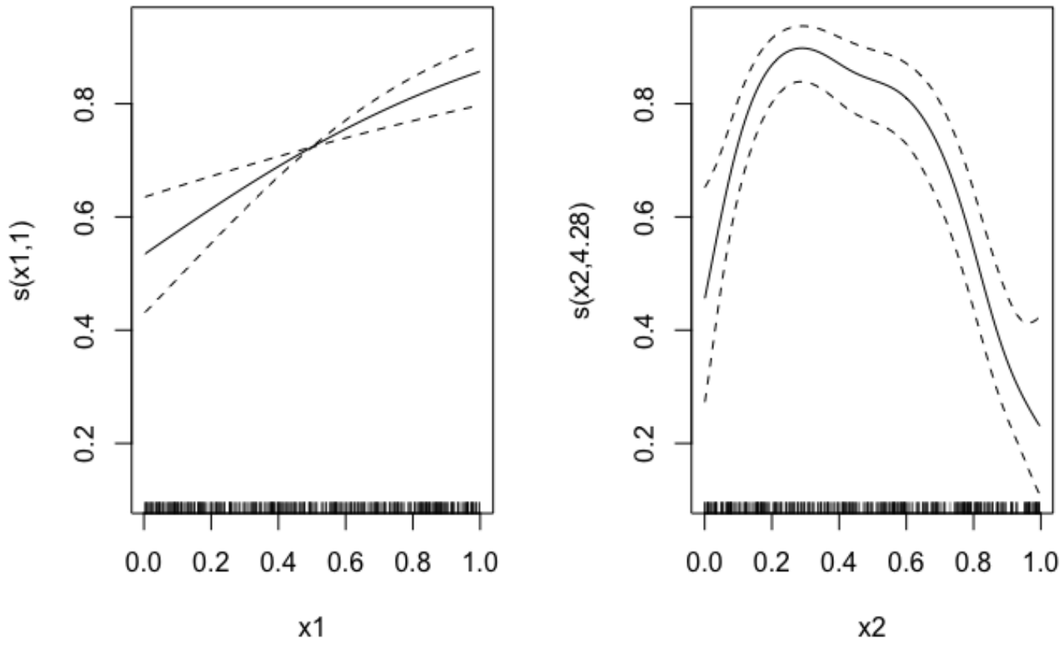
Converting partial effects (2)

```
plot(binom_mod, pages = 1, trans = plogis)
```



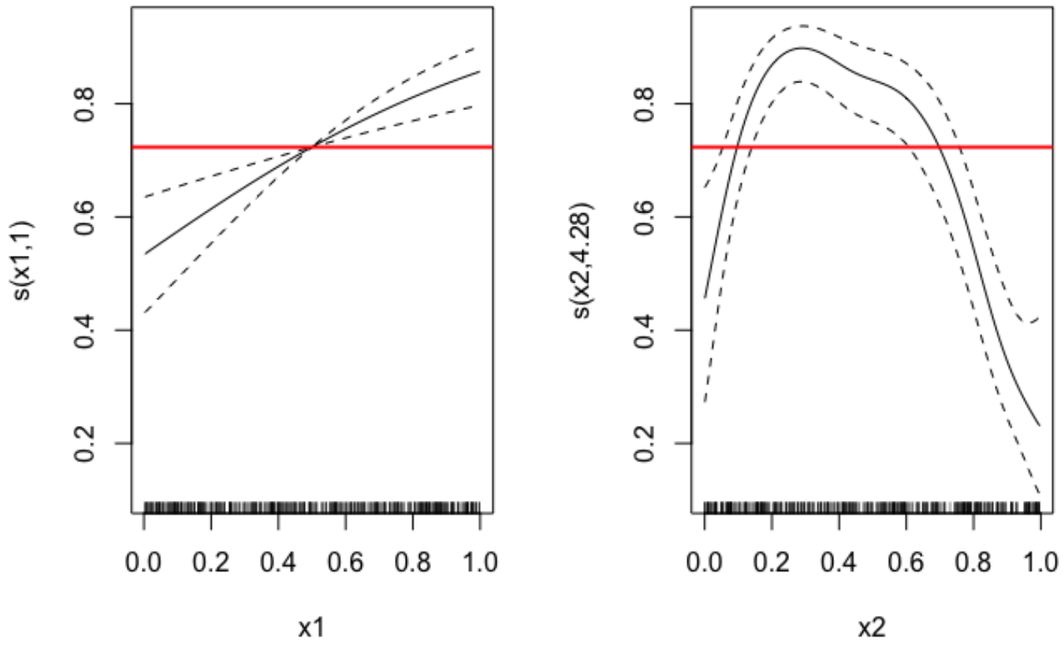
Adding an intercept

```
plot(binom_mod, pages = 1, trans = plogis,
     shift = coef(binom_mod)[1])
```



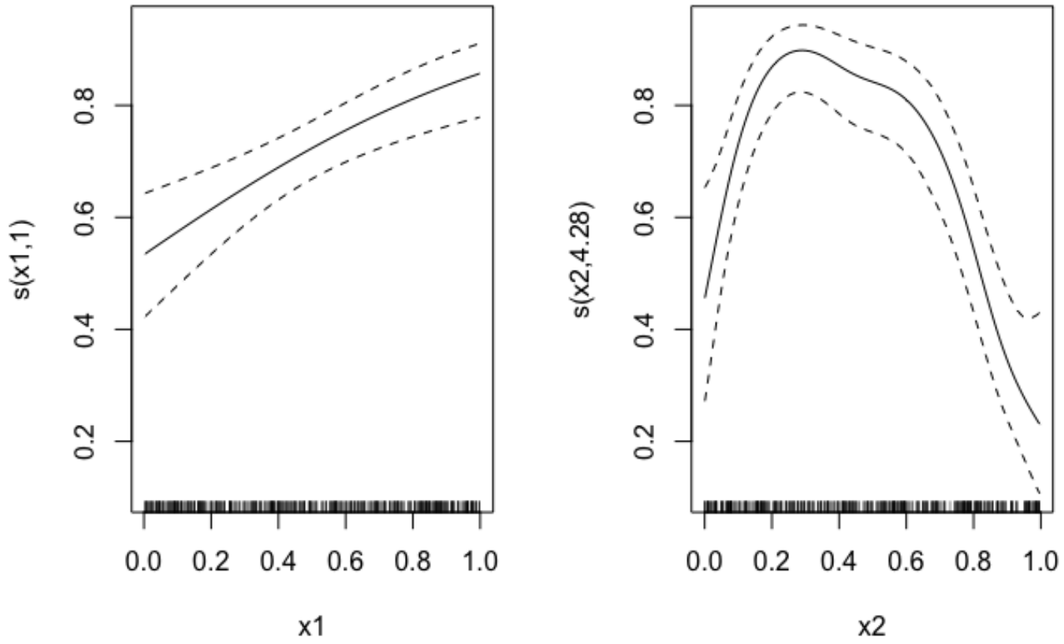
Adding an intercept (2)

```
plot(binom_mod, pages = 1, trans = plogis,
     shift = coef(binom_mod)[1])
```



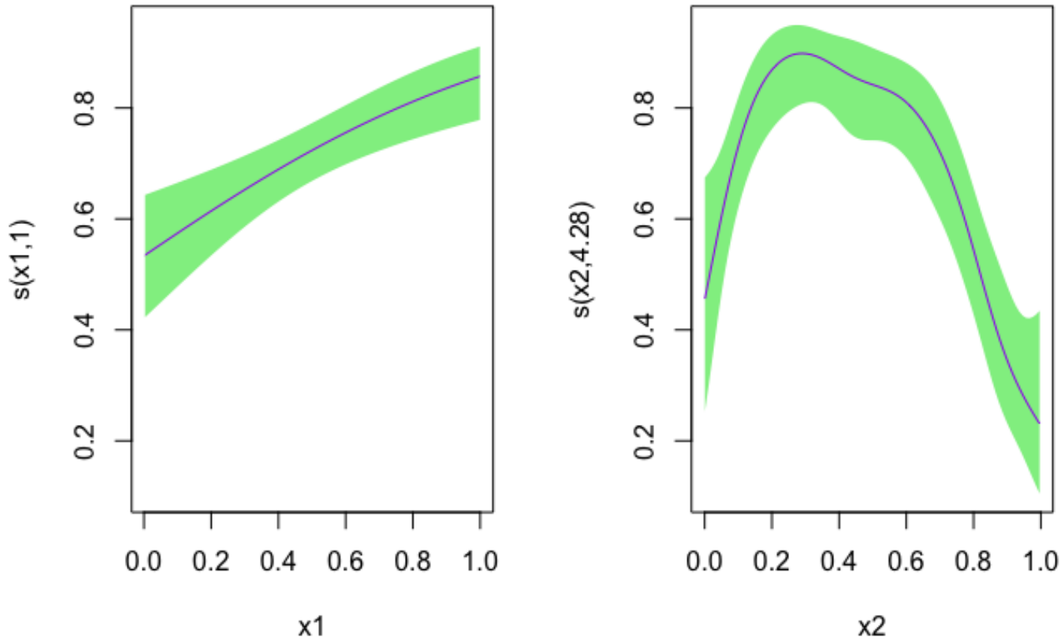
Incorporating intercept uncertainty

```
plot(binom_mod, pages = 1, trans = plogis,
     shift = coef(binom_mod)[1],
     seWithMean = TRUE)
```



Improving the plot

```
plot(binom_mod, pages = 1, trans = plogis, shift = coef(binom_mod)[1],
     seWithMean = TRUE, rug = FALSE, shade = TRUE, shade.col = "lightgreen",
     col = "purple")
```



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Making predictions

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mgcv's predict() function

```
predict(log_mod2)
```

```
             1              2              3              4
-0.8672827973 -2.9135420237 -0.4839780158 -0.1996086132
             5              6              7              8
-0.4416783066 -1.2351679544 -0.6148559122 -2.9135420237
...
```

Prediction types

```
predict(log_mod2, type = "link")
```

```
                1                 2                 3
-0.8672827973 -2.9135420237 -0.4839780158 -0.1
                5                 6                 7
-0.4416783066 -1.2351679544 -0.6148559122 -2.9
...
```

```
predict(log_mod2, type="response")
```

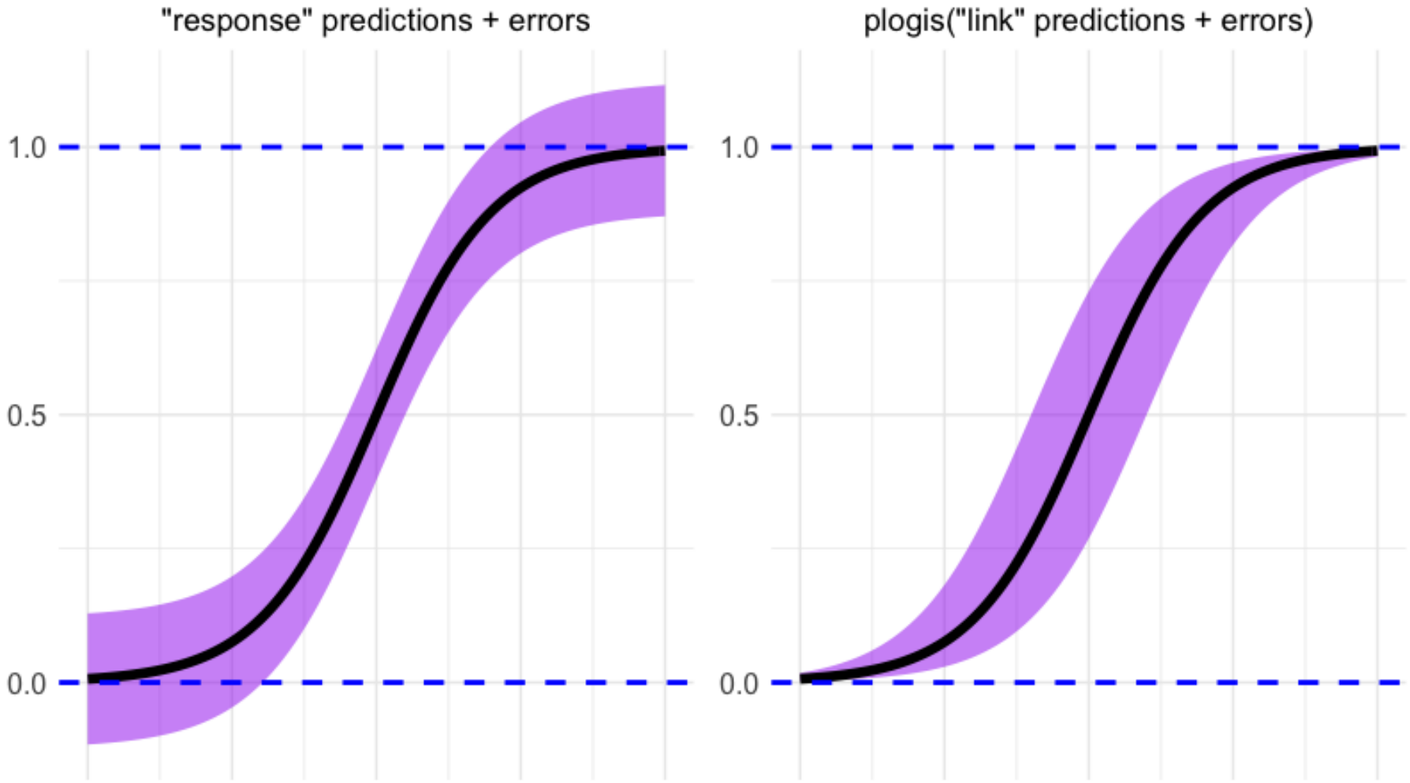
Standard errors

```
predict(log_mod2, type = "link", se.fit = TRUE
```

```
$fit
         1          2          3          4
-0.8672828 -2.9135420 -0.4839780 -0.1996086
         5          6          7          8
-0.4416783 -1.2351680 -0.6148559 -2.9135420

$se.fit
         1          2          3          4
0.2850848 0.1646090 0.2299404 0.2159088
         5          6          7          8
0.2767443 0.7601131 0.2454877 0.1646090
```

Standard errors (2)



Predictions on new data

```
trained_model <- gam(response ~ s(predictor),
                     data = train_df,
                     family = binomial,
                     method = "REML")
```

```
# Test data
test_predictions <- predict(trained_model,
                            type = "response",
                            newdata = test_df)
```

Explaining predictions by terms

```
predict(log_mod2, type = "terms")
```

```
      s(n_acts) s(bal_crdt_ratio) s(avg_prem_b
1     1.2115213       0.3327855673         -0.13
2    -0.8850186      -0.4058818961         -0.13
3     0.5693622       0.2972364048         -0.13
4     0.8974704       0.3827671103         -0.13
5     0.8974704      -0.0727464938         -0.13
6    -0.6228781       0.1936974771         -0.13
7     0.3642246       0.3377181800         -0.13
8    -0.8850186      -0.4058818961         -0.13
9     1.0209905       0.3604064595          0.31
10    1.7675666      -0.4533384774          0.34
```

Explaining predictions by terms (2)

```
predict(log_mod2, type = "terms")[1, ]
```

```
          s(n_acts)    s(bal_crdt_ratio)
         1.21152126           0.33278557
 s(avg_prem_balance) s(retail_crdt_ratio)
        -0.13592053           0.06789949
  s(avg_fin_balance)      s(mortgage_age)
        -0.04057249          -0.29183903
       s(cred_limit)
        -0.37055621
```

```
plogis(
  sum(predict(log_mod2, type = "terms")[1, ]) + coef(log_mod2)[1]
)
```

```
[1] 0.29582
```

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Doing more with GAMs

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Course review

Chapter 1

- GAM theory
- Fitting GAMs
- Mixing linear and nonlinear terms

Chapter 2

- Interpreting GAMs
- Visualizing GAMs
- Model-checking and concurvity

Chapter 3

- 2-D Interactions and spatial data
- Interactions with different scales
- Continuous-categorical interaction

Chapter 4

- Logistic GAMs
- Plotting logistic outputs
- Making predictions

GAMs and the Tidyverse

```
library(broom)

augment(gam_model)
tidy(gam_model)
glance(gam_model)
```

```
library(caret)

train(x, y, method = "gam", ...)
```

Other types of smooths

```
?smooth.terms
```

Other types of outcomes/distributions

```
?family.mgcv
```

See Generalized Linear Models

Variable selection

```
?gam.selection
```

Complex model structures

```
?gam.models
```

See Hierarchical and Mixed Effects Models

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Thank You!