Uncanny Valley - Child Development

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Method

Participants

240 participants (117 females), 3 to 18 years old, were recruited.

119 children watched human-like robot

120 children watched machine-like robot

234 children watched Nao

Power

With a sample of 240 and 7 predictor variables, you should be able to detect the effect of robot on uncanny responses with a power of 1 (should be greater than .8).

Exploratory Factor Analysis

Alphas

Robot	UV	Agency	Experience
Machine	0.62	0.72	0.73
Human	0.75	0.64	0.85

Model Fit Indices Table

Robot	RMSEA	TLI	Chi.squared	Chi.square. . . p.
Machine	0 (0,0.0698)	1.072	3.6431(7)	0.82
Human	0.071 (0,0.1429)	0.9526	10.5299(7)	0.16

Factor Loadings Table

Factor	Uncanniness	Agency	Experience
Creepy	0.81, 0.99	-0.05, 0.02	0.01, -0.07
Weird	0.57, 0.55	0.13, -0.18	-0.01, 0.12
Choose	0.08, 0.1	0.59, 0.69	0.06, 0.07
Think	-0.01, -0.04	0.77, 0.53	-0.04, 0.34
Moral	-0.14, -0.1	0.66, 0.47	0.02, -0.08
Pain	-0.03, 0.02	-0.02, -0.04	0.93, 0.86
Fear	0.01, 0.03	0.27, 0.03	0.4, 0.82

Hunger	0.03, -0.09	0.27, 0.06	0.51, 0.76
Reliability	0.62, 0.75	0.72, 0.64	0.73, 0.85

Identifying multicollinearity

```
##
##  Pearson's product-moment correlation
##
## data:  UV$Agency.C and UV$Exp.C
## t = 8.5687, df = 236, p-value = 1.381e-15
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.3837318 0.5784542
## sample estimates:
##       cor
## 0.4871239
```

Reason to not use Nao as predictor in regression

```
##
##  Pearson's product-moment correlation
##
## data:  UV$UV2 and UV$UVindex2.Nao
## t = 0.59266, df = 223, p-value = 0.554
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.09160958  0.16956737
## sample estimates:
##        cor
## 0.03965621
```

Results

Regression

	Estimate	Std. Error	t value	Pr(>|t|)
Robot.C	0.1587	0.07561	2.099	0.03693
Age.C	-0.06954	0.09896	-0.7028	0.4829
Mind.C	-0.2527	0.1097	-2.305	0.02214
Robot.C:Age.C	0.1578	0.07597	2.078	0.03892
Age.C:Mind.C	0.1953	0.09591	2.036	0.04298
(Intercept)	1.05	0.09351	11.23	2.178e-23

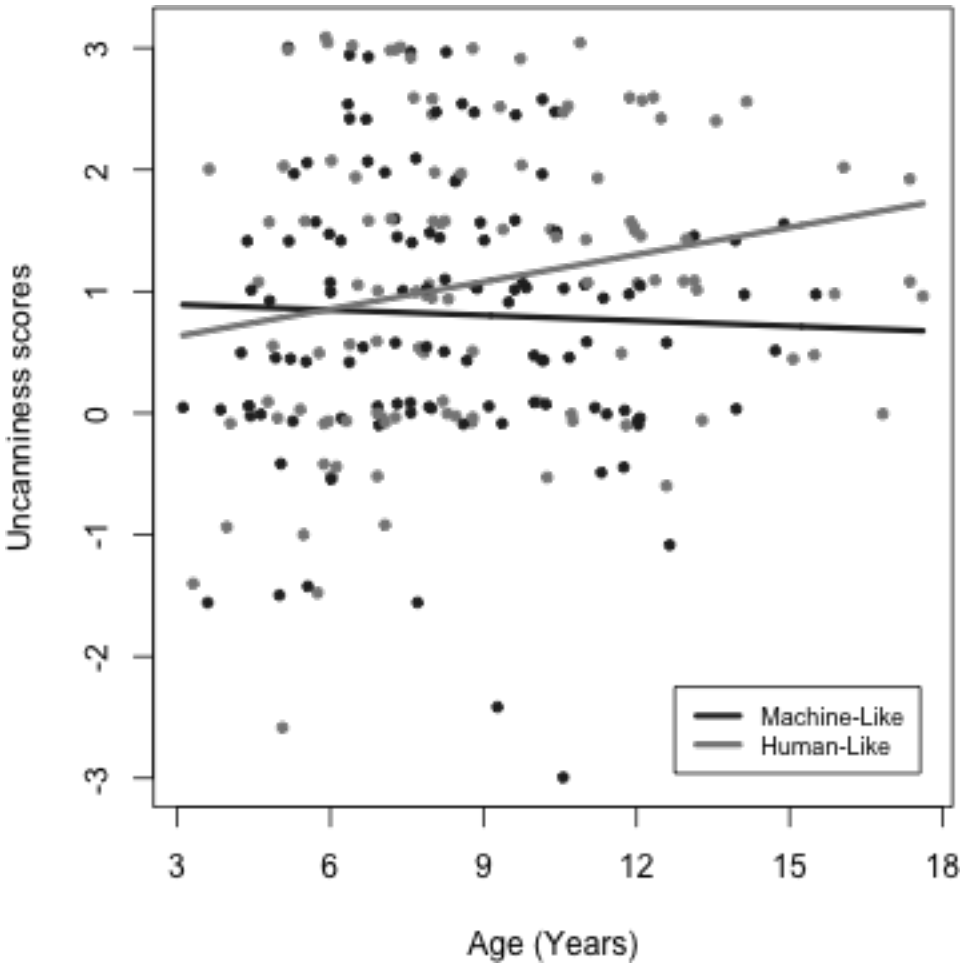
Table 5: Fitting linear model: UV2.diff ~ Robot.C * Age.C + Mind.C * Age.C

Observations	Residual Std. Error	R^2	Adjusted R^2
224	1.119	0.1165	0.09627

Observations	Residual Std. Error	R^2	Adjusted R^2

Robot.C	Age.C	Mind.C	Robot.C:Age.C	Age.C:Mind.C
0.1351	-0.05972	-0.2148	0.1343	0.1677

Robot Type x Age interaction



	Estimate	Std. Error	t value	Pr(>|t|)
AgeYears	-0.1041	0.0863	-1.206	0.2289

`**Order**` `-0.529` `0.473` `-1.118` `0.2647`

AgeYears:Order 0.08935 0.05175 1.726 0.08566

(Intercept) 1.466 0.773 1.896 0.05926

Table 8: full sample regression

Observations	Residual Std. Error	R^2	Adjusted R^2
225	1.163	0.03542	0.02233

AgeYears	Order	AgeYears:Order
-0.2716	-0.2253	0.2331

Tests of Simple Slopes

```
##
## Call:
## lm(formula = UV2.diff ~ Robot + Age.C + Mind.C + RobotXAge +
##     MindXAge, data = UV)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.8691 -0.7580 -0.0285  0.7943  2.7985
##
## Coefficients:
##                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)         1.20888    0.12018  10.059   <2e-16 ***
## Robot Machine-like -0.31746    0.15121  -2.099   0.0369 *
## Age.C              -0.06954    0.09896  -0.703   0.4829
## Mind.C             -0.25270    0.10965  -2.305   0.0221 *
## RobotXAge           0.15783    0.07597   2.078   0.0389 *
## MindXAge            0.19526    0.09591   2.036   0.0430 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.119 on 218 degrees of freedom
##   (15 observations deleted due to missingness)
## Multiple R-squared:  0.1165, Adjusted R-squared:  0.09627
## F-statistic: 5.751 on 5 and 218 DF,  p-value: 5.228e-05
```

```
## lavaan (0.5-23.1097) converged normally after  15 iterations
##
##                                                   Used       Total
##   Number of observations                          224         239
##
##   Estimator                                         ML
##   Minimum Function Test Statistic                0.000
##   Degrees of freedom                                 0
##   P-value (Bollen-Stine Bootstrap)               1.000
##
## Parameter Estimates:
##
##   Information                                 Observed
##   Standard Errors                            Bootstrap
##   Number of requested bootstrap draws             1000
##   Number of successful bootstrap draws            1000
```

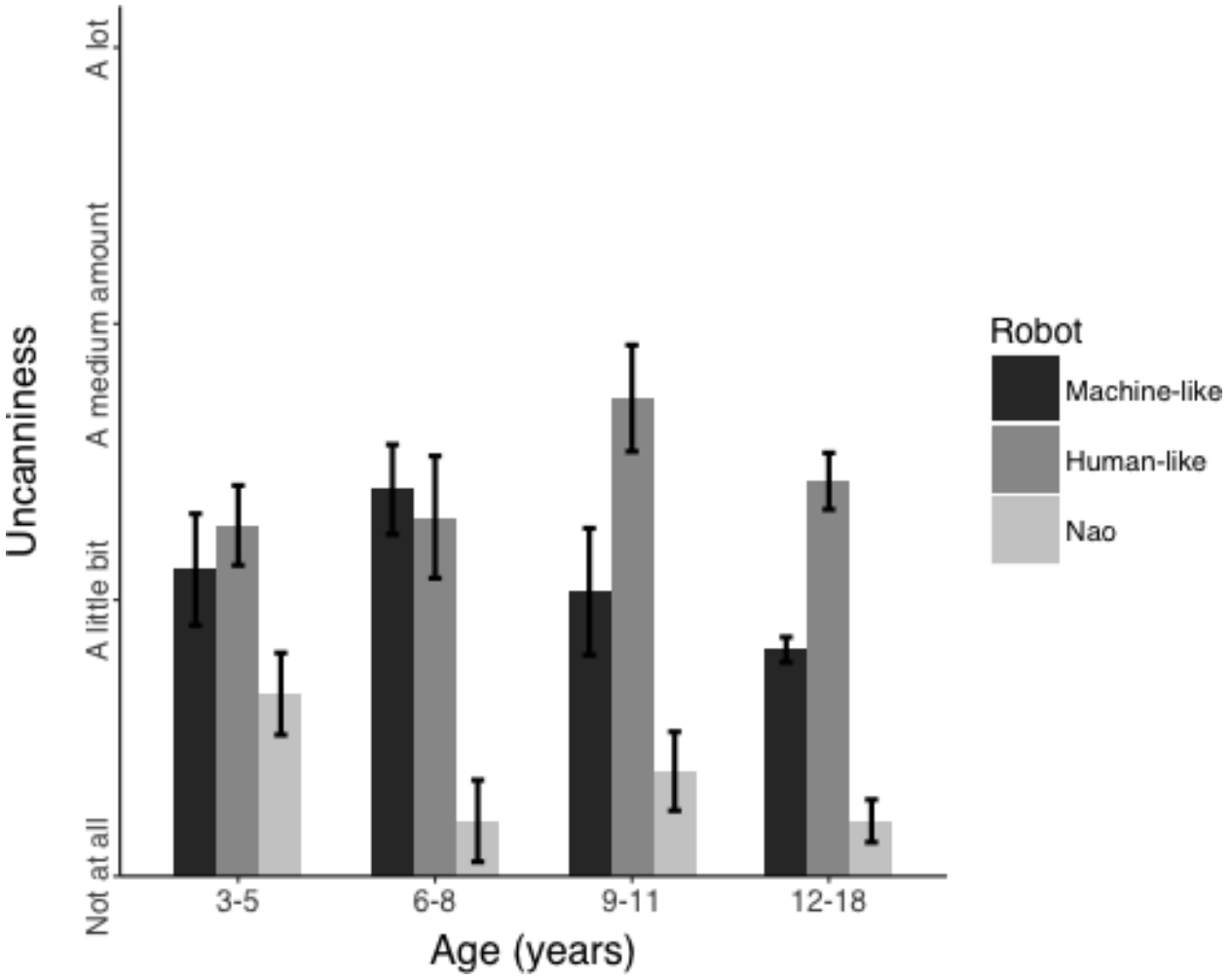
```
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   UV2.diff ~
##     Robot.C   (c1)    0.159    0.076    2.101    0.036    0.159    0.135
##     Age.C     (c2)   -0.070    0.093   -0.751    0.453   -0.070   -0.060
##     Mind.C    (c3)   -0.253    0.106   -2.378    0.017   -0.253   -0.215
##     RobotXAge (c4)    0.158    0.070    2.240    0.025    0.158    0.135
##     MindXAge  (c5)    0.195    0.086    2.277    0.023    0.195    0.153
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##    .UV2.diff          1.219    0.124    9.811    0.000    1.219    0.883
##
## R-Square:
##                    Estimate
##     UV2.diff          0.117
##
## Defined Parameters:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##     rob.4years       -0.081    0.139   -0.586    0.558   -0.081   -0.070
##     rob.6years        0.023    0.103    0.224    0.823    0.023    0.019
##     rob.8years        0.127    0.079    1.611    0.107    0.127    0.108
##     rob.9years        0.179    0.075    2.381    0.017    0.179    0.152
##     rob.10years       0.231    0.078    2.941    0.003    0.231    0.197
##     rob.12years       0.335    0.102    3.278    0.001    0.335    0.286
##     rob.14years       0.435    0.137    3.186    0.001    0.435    0.371
##     rob.16years       0.545    0.180    3.034    0.002    0.545    0.466
##     mind.4years      -0.549    0.117   -4.706    0.000   -0.549   -0.448
##     mind.6years      -0.421    0.092   -4.577    0.000   -0.421   -0.347
##     mind.8years      -0.292    0.098   -2.976    0.003   -0.292   -0.246
##     mind.9years      -0.228    0.112   -2.029    0.042   -0.228   -0.196
##     mind.10years     -0.164    0.131   -1.249    0.212   -0.164   -0.145
##     mind.12years     -0.035    0.177   -0.197    0.844   -0.035   -0.044
##     mind.14years      0.089    0.225    0.395    0.693    0.089    0.053
##     mind.16years      0.225    0.281    0.801    0.423    0.225    0.160
```

```
##             lhs op            rhs        label    est    se      z pvalue
## 1      UV2.diff  ~        Robot.C           c1  0.159 0.076  2.101  0.036
## 2      UV2.diff  ~          Age.C           c2 -0.070 0.093 -0.751  0.453
## 3      UV2.diff  ~        Mind.C            c3 -0.253 0.106 -2.378  0.017
## 4      UV2.diff  ~      RobotXAge           c4  0.158 0.070  2.240  0.025
## 5      UV2.diff  ~       MindXAge           c5  0.195 0.086  2.277  0.023
## 6      UV2.diff ~~       UV2.diff               1.219 0.124  9.811  0.000
## 7       Robot.C ~~        Robot.C               1.000 0.000     NA     NA
## 8       Robot.C ~~          Age.C               0.091 0.000     NA     NA
## 9       Robot.C ~~        Mind.C                0.041 0.000     NA     NA
## 10      Robot.C ~~      RobotXAge               0.024 0.000     NA     NA
## 11      Robot.C ~~       MindXAge              -0.049 0.000     NA     NA
## 12        Age.C ~~          Age.C               1.018 0.000     NA     NA
## 13        Age.C ~~        Mind.C               -0.588 0.000     NA     NA
## 14        Age.C ~~      RobotXAge               0.190 0.000     NA     NA
## 15        Age.C ~~       MindXAge               0.025 0.000     NA     NA
## 16       Mind.C ~~        Mind.C                0.998 0.000     NA     NA
```

```
## 17       Mind.C ~~      RobotXAge              -0.049 0.000     NA     NA
## 18       Mind.C ~~       MindXAge              -0.412 0.000     NA     NA
## 19    RobotXAge ~~      RobotXAge               1.010 0.000     NA     NA
## 20    RobotXAge ~~       MindXAge              -0.039 0.000     NA     NA
## 21     MindXAge ~~       MindXAge               0.849 0.000     NA     NA
## 22   rob.4years :=    c1+c4*-1.52   rob.4years -0.081 0.139 -0.586  0.558
## 23   rob.6years :=     c1+c4*-.86   rob.6years  0.023 0.103  0.224  0.823
## 24   rob.8years := c1+c4*-.203051   rob.8years  0.127 0.079  1.611  0.107
## 25   rob.9years :=  c1+c4*.125849   rob.9years  0.179 0.075  2.381  0.017
## 26  rob.10years := c1+c4*.4547489  rob.10years  0.231 0.078  2.941  0.003
## 27  rob.12years :=    c1+c4*1.116  rob.12years  0.335 0.102  3.278  0.001
## 28  rob.14years :=     c1+c4*1.75  rob.14years  0.435 0.137  3.186  0.001
## 29  rob.16years :=    c1+c4*2.448  rob.16years  0.545 0.180  3.034  0.002
## 30  mind.4years :=    c3+c5*-1.52  mind.4years -0.549 0.117 -4.706  0.000
## 31  mind.6years :=     c3+c5*-.86  mind.6years -0.421 0.092 -4.577  0.000
## 32  mind.8years := c3+c5*-.203051  mind.8years -0.292 0.098 -2.976  0.003
## 33  mind.9years :=  c3+c5*.125849  mind.9years -0.228 0.112 -2.029  0.042
## 34 mind.10years := c3+c5*.4547489 mind.10years -0.164 0.131 -1.249  0.212
## 35 mind.12years :=    c3+c5*1.116 mind.12years -0.035 0.177 -0.197  0.844
## 36 mind.14years :=     c3+c5*1.75 mind.14years  0.089 0.225  0.395  0.693
## 37 mind.16years :=    c3+c5*2.448 mind.16years  0.225 0.281  0.801  0.423
##    ci.lower ci.upper
## 1     0.007    0.309
## 2    -0.237    0.119
## 3    -0.457   -0.028
## 4     0.035    0.310
## 5     0.031    0.367
## 6     0.960    1.473
## 7     1.000    1.000
## 8     0.091    0.091
## 9     0.041    0.041
## 10    0.024    0.024
## 11   -0.049   -0.049
## 12    1.018    1.018
## 13   -0.588   -0.588
## 14    0.190    0.190
## 15    0.025    0.025
## 16    0.998    0.998
## 17   -0.049   -0.049
## 18   -0.412   -0.412
## 19    1.010    1.010
## 20   -0.039   -0.039
## 21    0.849    0.849
## 22   -0.380    0.173
## 23   -0.192    0.212
## 24   -0.028    0.279
## 25    0.027    0.329
## 26    0.075    0.395
## 27    0.144    0.545
## 28    0.182    0.730
## 29    0.224    0.950
## 30   -0.776   -0.310
## 31   -0.605   -0.230
## 32   -0.477   -0.090
```

```
## 33   -0.447    0.014
## 34   -0.416    0.112
## 35   -0.369    0.332
## 36   -0.330    0.553
## 37   -0.297    0.799
```

Uncanniness Bar Plot



Nao as baseline

Comparing uncanny responses between Nao and other robots

```
## Linear mixed-effects model fit by REML
##  Data: UV.back.mixed
##        AIC      BIC    logLik
##   820.3078 843.2814 -404.1539
##
## Random effects:
##  Formula: ~1 | SubID
```

```
##         (Intercept)  Residual
## StdDev:  0.09901863 0.7647308
##
## Fixed effects: value ~ variable * Age.C
##                                 Value  Std.Error  DF   t-value p-value
## (Intercept)                 2.1569199 0.07160258 230 30.123495  0.0000
## variableUVindex2.Nao       -0.8176215 0.08755043 110 -9.338863  0.0000
## Age.C                      -0.1099205 0.07796836 230 -1.409809  0.1599
## variableUVindex2.Nao:Age.C  0.0136106 0.09270930 110  0.146809  0.8836
##  Correlation:
##                            (Intr) vrUV2.N Age.C
## variableUVindex2.Nao       -0.811
## Age.C                       0.094 -0.077
## variableUVindex2.Nao:Age.C -0.079  0.057  -0.835
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -1.7430316 -0.5055382 -0.3392539  0.3736017  3.5251947
##
## Number of Observations: 344
## Number of Groups: 232
```

```
## Linear mixed-effects model fit by REML
##  Data: UV.front.mixed
##       AIC      BIC   logLik
##   856.736 879.7097 -422.368
##
## Random effects:
##  Formula: ~1 | SubID
##         (Intercept) Residual
## StdDev:   0.2101351 0.786098
##
## Fixed effects: value ~ variable * Age.C
##                                 Value  Std.Error  DF   t-value p-value
## (Intercept)                 2.3894192 0.07537368 229  31.70098  0.0000
## variableUVindex2.Nao       -1.0498311 0.09068826 111 -11.57626  0.0000
## Age.C                       0.1024107 0.06933757 229   1.47699  0.1411
## variableUVindex2.Nao:Age.C -0.1991004 0.08556147 111  -2.32699  0.0218
##  Correlation:
##                            (Intr) vrUV2.N Age.C
## variableUVindex2.Nao       -0.804
## Age.C                      -0.078  0.064
## variableUVindex2.Nao:Age.C  0.063 -0.061  -0.779
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -1.9804274 -0.4746835 -0.3282174  0.4249674  3.2321150
##
## Number of Observations: 344
## Number of Groups: 231
```

Comparing differences in responses to Nao depending on which robot was shown first

```
##
```

```
##  Welch Two Sample t-test
##
## data:  UVindex2.Nao by Robot
## t = -0.53442, df = 224.25, p-value = 0.5936
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.2276360  0.1305086
## sample estimates:
##   mean in group  Human-like mean in group  Machine-like
##                     1.313043                     1.361607
```

```
##           Robot UVindex2.Nao
## 1    Human-like     1.313043
## 2  Machine-like     1.361607
```

```
##           Robot UVindex2.Nao
## 1    Human-like    0.6736288
## 2  Machine-like    0.6949296
```

Creepy-Weird Interview