Processing of Scalar Implicatures and Question Under Discussion

October 16, 2019

1 Methods

Participants

Participants (US IP Addresses, prior approval rating ¿ 95%) were recruited on Amazon Mechanical Turk and were paid $2.3.

	Before Exclusions			After Exclusions		
	all QUD	any QUD	no QUD	all QUD	any QUD	no QUD
Experiment 1	50	50	50	41	35	38
Experiment 2	50	50	50	37	36	38
Experiment 3	200	200	200	fill	fill	fill
Experiment 4	400	400	400	281	256	313

Procedure and Materials

At the beginning of the experiment, participants in each group were presented with a different cover story. These cover stories were designed to establish an implicit QUD.

all QUD Participants in all QUD group read a story explaining them that they are at a candy store and testing a row of special gumball machines. These gumball machines have 13 gumballs in their upper chambers and when they distribute gumballs, you see a certain number of gumballs move to the lower chamber. These machines also say how many gumballs you got ("You got X gumballs"), but are sometimes faulty in their report. The store worker's boss has threatened to fire him if the gumball machines are left empty and he cannot see the machines from the register and only tell how full they are by their statements. Participants were asked to help the store worker by telling him if this statement is right or wrong by pressing the yes or no key.

Is the machine empty? $\rightarrow$ Did I get all of the gumballs?

any QUD In the any QUD group, participants read the same story except, in their story, the store worker's boss has threatened to fire him if the gumball machines get jammed.

Is the machine jammed? $\rightarrow$ Did I get none of the gumballs?

no QUD Participants in no QUD group didn't read a cover story but instead read instructions that explained that they were going to see a gumball machine filled with gumballs and after a few seconds certain number of gumballs will move to its bottom chamber and the machine will say how many gumballs you got. Participants were asked to say if this statement right or wrong by pressing the yes or no key.

Is the statement correct? $\rightarrow$ No implicit QUD

After reading the cover story, participants went through a scripted demonstration that showed various scenarios and the store worker's reaction to their responses. In the all QUD condition, when all of gumballs dropped from the

upper chamber to the lower chamber and the machine reported "You got all of the gumballs", participants were asked to press the yes key and they read that they let the store worker know that the machine is empty and he therefore knows that he needs to refill the machine. They also read that one time someone got all of the gumballs and was told "You got all of the gumballs", they pressed the no key and the store worker was fired because he didn't refill the machine. In the any QUD condition, participants got no gumballs and the machine reported "You got none of the gumballs". Participants were asked to press the yes key and read that they let the store worker know that the machine is not distributing gumballs and that he needs to fix the machine. They read that one time someone got 0 gumballs and was told "You got none of the gumballs", they pressed the no key and the store worker was fired because he didn't repair the machine. In the no QUD condition, the only feedback that participants got was a sentence that said whether they agreed or disagreed with the statement.

To ensure that participants paid attention to the cover story, participants in all QUD and any QUD conditions were asked a multiple-choice question about when the store worker will be fired. For the all QUD group the correct answer was "when the machines are empty" and for the any QUD group the correct answer was "when the machines jam". When participants answered this question incorrectly they were presented with the cover story again and went through the demonstration. Halfway through the experiment, participants were asked to answer this multiple-choice question again. This time, when they answered incorrectly they were only asked to try again. This was done to prevent the decay of the implicit QUD over time.

There were 4 practice trials with "You got all of the gumballs" and "You got none of the gumballs" statements. On 2 of these trials, the statement was correct, and on 2 of them it was incorrect.

After the practice trials, there were 72 experimental trials. The number of gumballs in the lower chamber (0 to 13 gumballs) and the quantifier in the statement (some, none, all) were varied. On 32 of the trials the expected answer was yes, and on 32 of the trials the expected answer was no. The remaining 8 trials were occurrences of the critical trial and the main focus of this experiment. On these trials, all thirteen of the gumballs dropped to the lower chamber and participants hear the statement "You got some of the gumballs". This statement is true when it's interpreted semantically as "You got some and possibly all of the gumballs" but when it's interpreted pragmatically as "You got some but not all of the gumballs", it's false.

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Experiments differed from each other in the following ways:

Experiment 1. In the critical condition, participants heard "You got some gumballs".

Experiment 2. In the critical condition, participants heard "You got some of the gumballs".

Experiment 3. Participants were prescreened for age. Only participants aged between 18 and 25 and participants older than 45 were recruited.

Experiment 4. Participants had 4 seconds to respond after they heard the statement.

*Both in Experiment 3 and 4 participants heard "You got some of the gumballs" in the critical condition.

2 Results

Exclusions The exclusion criteria and the number of participants excluded with each criterion are given below:

1. non-native English speakers

2. participants who get at least two practice trials wrong
3. participants who get the audio check wrong more than one once
4. participants who get the second comprehension question wrong more than twice
5. participants with accuracy of lower than 85% on non-critical trials
6. response times that are 2.5 standard deviations above the mean for that condition or that are faster than the onset of the quantifier.

	experiment 1	experiment 2	experiment 3*	experiment 4
1	0	3	13	37
2	32	24	23**	93**
3	0	0	1	5
4	0	1	0	15
5	4	7	26	200***
total	**36**	**35**	**62**	**350**

*7 participants were excluded because their age didn't match the age they reported in prescreening.
**Criterion was changed to only exlude participants who got more than two practice trials wrong.
**Criterion was changed to only exclude participants with accuracy lower than 85% on non-critical trials with quantifiers "some", "all", "none", and numbers below 6.

Judgements

In all four experiments, in the critical condition, participants in the all QUD group gave more pragmatic responses than the participants in the any QUD

group and participants in the any QUD group gave more pragmatic responses than the no QUD group.

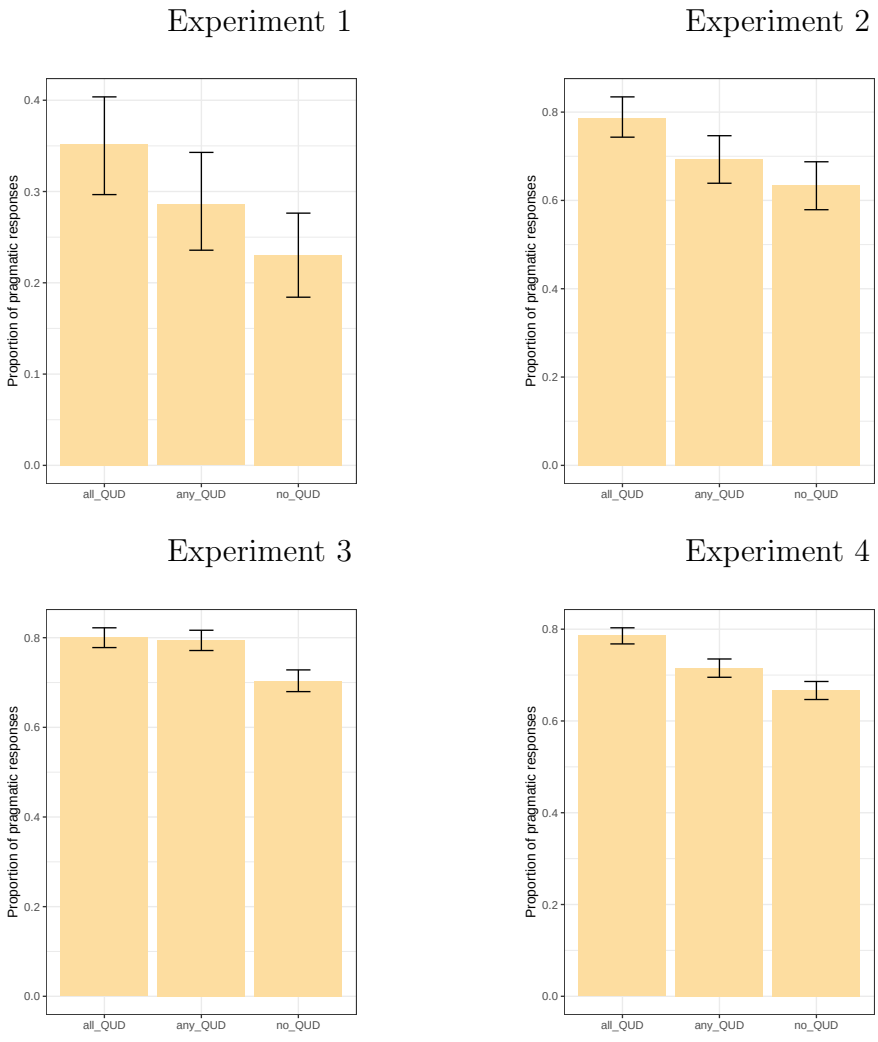

Figure 1: Proportion of pragmatic responses on critical trials for all four experiments

cover story → implicit QUD → likelihood of pragmatic responses → scaler

implicature

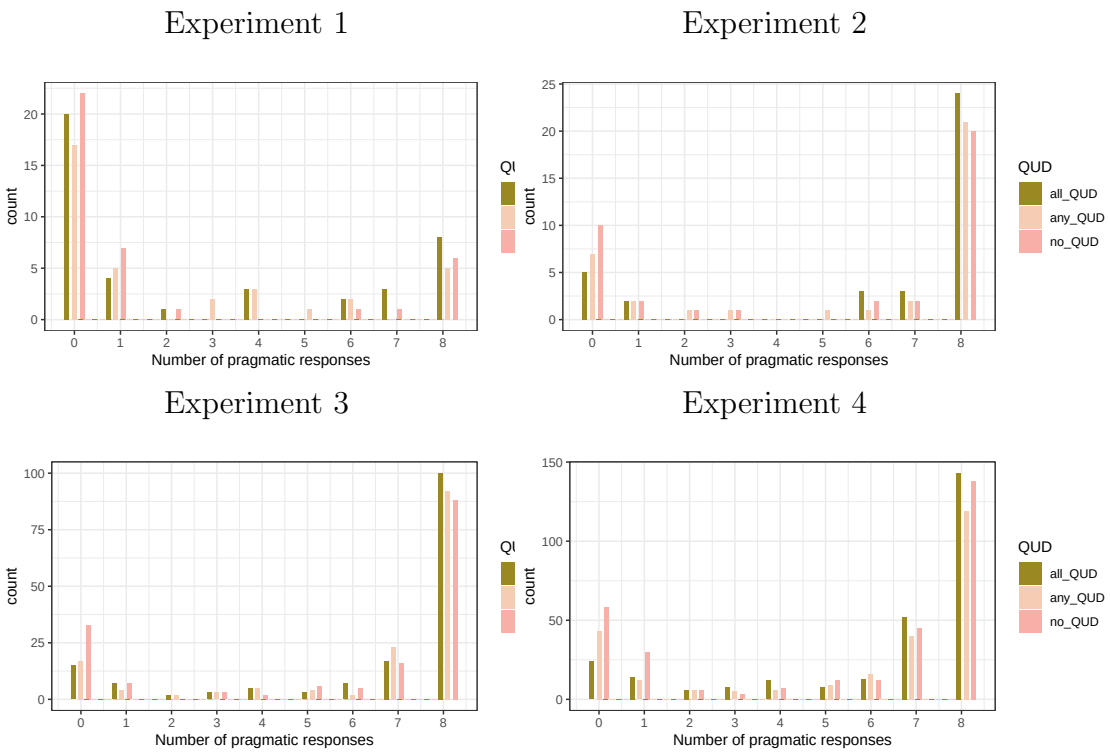

Figure 2: Distribution of participants over number of pragmatic responses on critical trials

Response Times

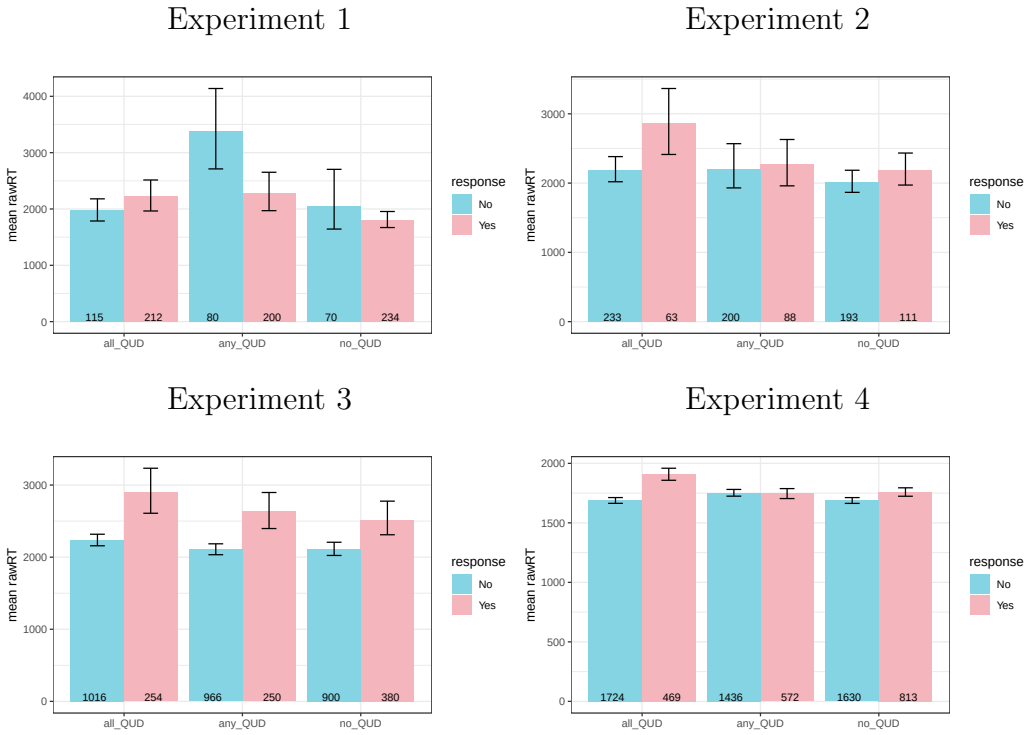

Figure 3: Mean response times for semantic and pragmatic responses on critical trials as a function of QUD

For semantic and pragmatic responders

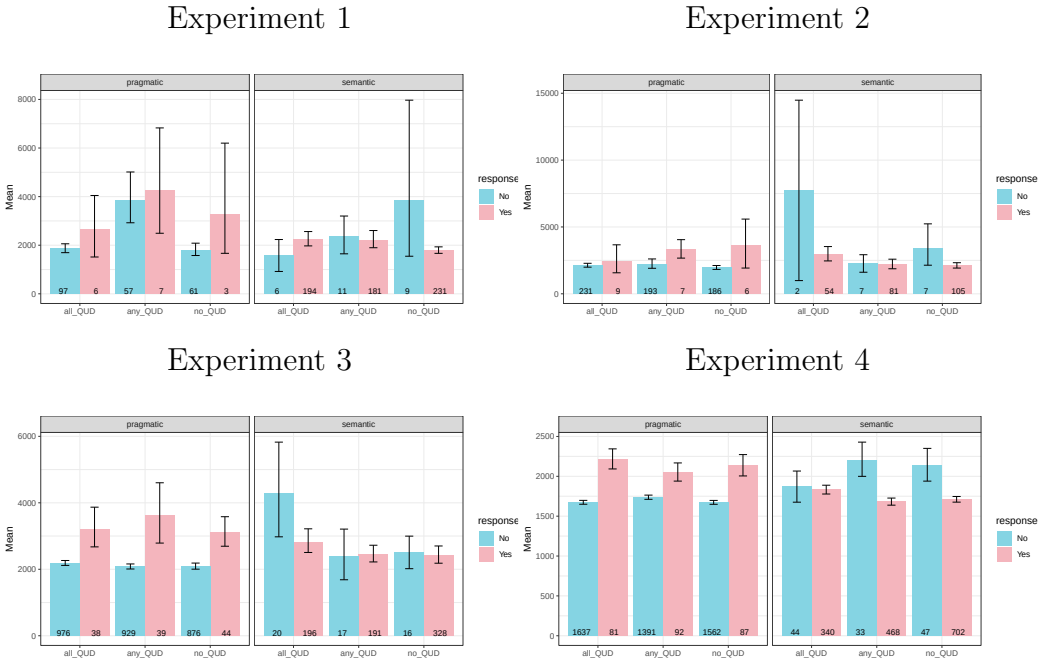

Figure 4: Mean response times for semantic and pragmatic responders (inconsistent responders excluded)

Age Effect

Age, response type, QUD

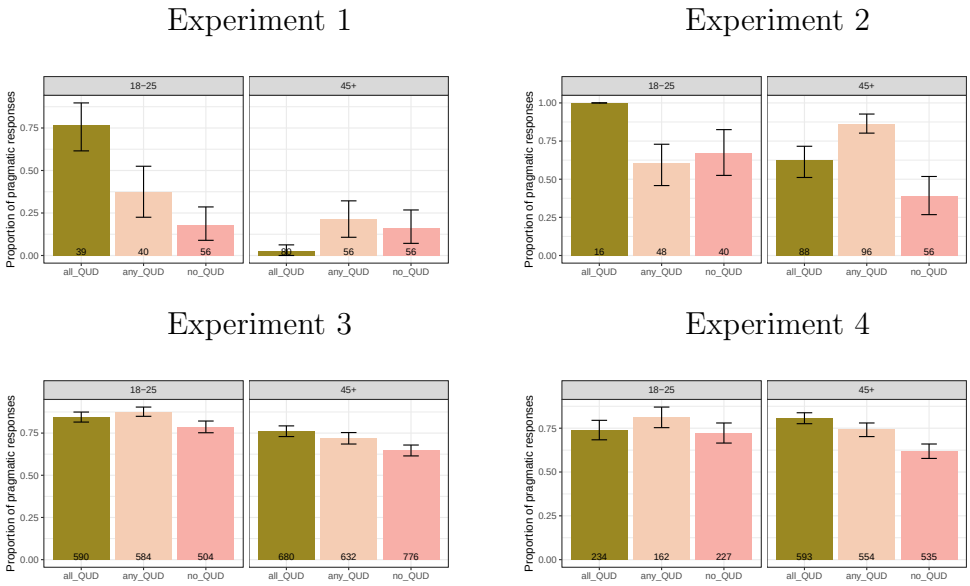

Figure 5: Proportion of pragmatic responses as a function of age and QUD

Age, response time, QUD

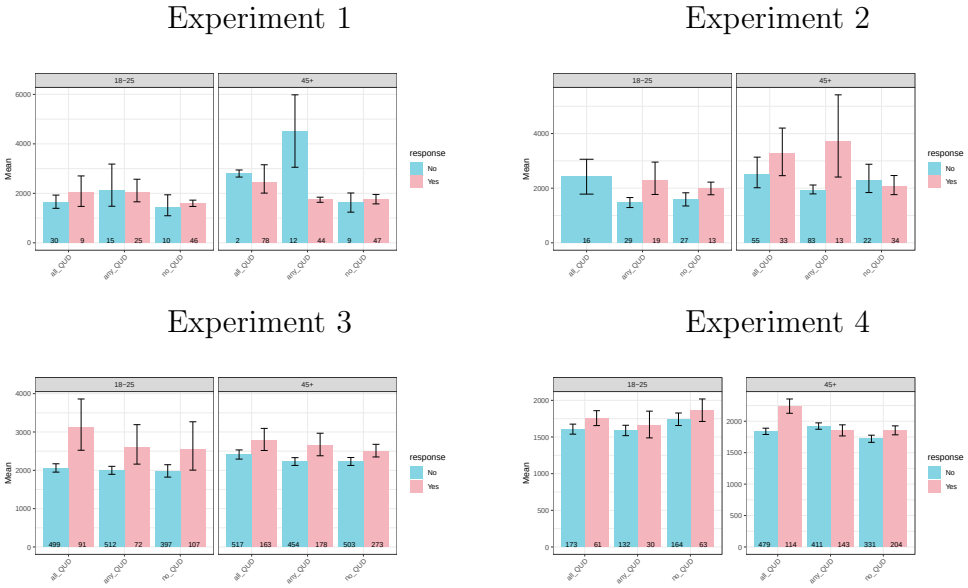

Figure 6: Mean response times for semantic and pragmatic responses as a function of age and QUD

NOT SURE ABOUT THESE GRAPHS?

Age, responder type, response type, QUD

Age, responder type, response time, QUD

Models - for experiment 4 (time pressure)

1. Mixed effects logistic regression predicting response type with random by-participant intercepts, from fixed effects of QUD
   Prediction: Main effect of QUD such that there are more pragmatic responses for all-QUD compared to any-QUD and no-QUD

```
Generalized linear mixed model fit by maximum likelihood (Laplace
Approximation) ['glmerMod']
 Family: binomial  ( logit )
Formula: key ~ Answer.condition + (1 | workerid)
   Data: critical

     AIC      BIC   logLik deviance df.resid
  4163.1   4190.3  -2077.5   4155.1     6640

Scaled residuals:
     Min       1Q   Median       3Q      Max
-2.41404 -0.08493 -0.07524  0.17266  2.82575

Random effects:
 Groups   Name        Variance Std.Dev.
 workerid (Intercept) 29.23    5.407
Number of obs: 6644, groups:  workerid, 847

Fixed effects:
                        Estimate Std. Error z value             Pr(>|z|)
(Intercept)              -5.2821     0.5325  -9.920 < 0.0000000000000002 ***
Answer.conditionany_QUD   1.4246     0.5498   2.591             0.009564 **
Answer.conditionno_QUD    2.0248     0.5277   3.837             0.000125 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
                (Intr) Answr.cndtnny_QUD
Answr.cndtnny_QUD -0.405
Answer.cndtnn_QUD -0.467  0.406
```

2. Mixed effects linear regression model with random by-participant intercepts predicting log-transformed response time from fixed effects of QUD, response type and their interaction

   Prediction: Interaction of QUD and response such that the more relevant the alternative, the faster the pragmatic responses become and the slower the semantic responses become

```
Linear mixed model fit by REML ['lmerMod']
Formula: logRT ~ Answer.condition * key + (1 | workerid)
   Data: critical

REML criterion at convergence: 959.3

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.0117 -0.6114 -0.1004  0.5219  4.2777

Random effects:
 Groups   Name        Variance Std.Dev.
 workerid (Intercept) 0.02670  0.1634
 Residual             0.05511  0.2348
Number of obs: 6644, groups:  workerid, 847

Fixed effects:
                              Estimate Std. Error t value
(Intercept)                   7.390869   0.011648 634.513
Answer.conditionany_QUD       0.030851   0.017173   1.796
Answer.conditionno_QUD       -0.005469   0.016559  -0.330
keyYes                        0.117455   0.018031   6.514
Answer.conditionany_QUD:keyYes -0.102870   0.025684  -4.005
Answer.conditionno_QUD:keyYes  -0.062684   0.024409  -2.568

Correlation of Fixed Effects:
                  (Intr) Answr.cndtnny_QUD Answer.cndtnn_QUD keyYes
Answr.cndtnny_QUD:Y
Answr.cndtnny_QUD   -0.678
Answer.cndtnn_QUD   -0.703  0.477
keyYes              -0.333  0.226             0.234
Answr.cndtnny_QUD:Y  0.234 -0.376            -0.165            -0.702
Answr.cndtnn_QUD:kY  0.246 -0.167            -0.396            -0.739  0.519
```

3. Mixed effects logistic regression predicting response type with random by-participant intercepts, from fixed effects of QUD, responder type and their interaction
   Prediction: Prediction

4. Mixed effects linear regression model with random by-participant intercepts predicting log-transformed response time from fixed effects of QUD, response type, responder type and their interaction
   Prediction: Prediction

Models - for experiment 3 (age groups)

1. Mixed effects logistic regression predicting response type with random by-participant intercepts, from fixed effects of QUD, age and their interaction

   Prediction: Interaction of QUD and age such that in the younger age group(18-25) there are more pragmatic responses for all-QUD compared to any-QUD and no-QUD

```
Generalized linear mixed model fit by maximum likelihood (Laplace
Approximation) ['glmerMod']
 Family: binomial  ( logit )
Formula: key ~ Answer.condition * age + (1 | workerid)
   Data: critical

     AIC      BIC   logLik deviance df.resid
  1971.4   2015.1   -978.7   1957.4     3759

Scaled residuals:
     Min       1Q   Median       3Q      Max
-2.51819 -0.02373 -0.01571 -0.01198  2.76561

Random effects:
 Groups   Name        Variance Std.Dev.
 workerid (Intercept) 89.98    9.486
Number of obs: 3766, groups:  workerid, 471

Fixed effects:
                             Estimate Std. Error z value         Pr(>|z|)
(Intercept)                 -9.02687    1.28109  -7.046 0.00000000000184 ***
Answer.conditionany_QUD     -0.49401    1.78415  -0.277            0.782
Answer.conditionno_QUD      -0.15382    1.85277  -0.083            0.934
age                          0.01952    0.02848   0.685            0.493
Answer.conditionany_QUD:age  0.01739    0.04172   0.417            0.677
Answer.conditionno_QUD:age   0.02524    0.04445   0.568            0.570
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Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
                  (Intr) Answr.cndtnny_QUD Answer.cndtnn_QUD age
Answr.cndtnny_QUD:
Answr.cndtnny_QUD  -0.666
Answer.cndtnn_QUD  -0.652  0.457
age                -0.870  0.632            0.607
Answr.cndtnny_QUD:  0.613 -0.920           -0.418           -0.679
Answr.cndtnn_QUD:g  0.599 -0.408           -0.922           -0.634  0.441
```

2. Mixed effects linear regression model with random by-participant intercepts predicting log-transformed response time from fixed effects of QUD, response type, age and their interaction

   Prediction: Interaction of QUD, response and age such that in the younger age group(18-25) the more relevant the alternative, the faster the pragmatic responses become and the slower the semantic responses become.

```
Linear mixed model fit by REML ['lmerMod']
Formula: logRT ~ Answer.condition * key * age + (1 | workerid)
   Data: critical

REML criterion at convergence: 3809.5

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.1473 -0.5983 -0.2022  0.3986  6.8816

Random effects:
 Groups   Name        Variance Std.Dev.
 workerid (Intercept) 0.04525  0.2127
 Residual             0.13357  0.3655
Number of obs: 3766, groups:  workerid, 471

Fixed effects:
                                  Estimate Std. Error t value
(Intercept)                       7.4036308  0.0528456 140.099
Answer.conditionany_QUD           0.0043546  0.0751020   0.058
Answer.conditionno_QUD           -0.0600827  0.0799914  -0.751
keyYes                            0.3645351  0.0949647   3.839
age                               0.0054746  0.0012682   4.317
Answer.conditionany_QUD:keyYes   -0.1191993  0.1406982  -0.847
Answer.conditionno_QUD:keyYes    -0.2512632  0.1420774  -1.768
Answer.conditionany_QUD:age      -0.0015265  0.0017930  -0.851
Answer.conditionno_QUD:age       -0.0003154  0.0018603  -0.170
keyYes:age                       -0.0056486  0.0021715  -2.601
Answer.conditionany_QUD:keyYes:age  0.0036201  0.0031431   1.152
Answer.conditionno_QUD:keyYes:age   0.0055638  0.0031141   1.787

Correlation of Fixed Effects:
                  (Intr) Answr.cndtnny_QUD Answer.cndtnn_QUD keyYes age
Answr.cndtnny_QUD -0.704
Answer.cndtnn_QUD -0.661  0.465
keyYes            -0.331  0.233             0.218
age               -0.916  0.645             0.605            0.320
Answr.cndtnny_QUD:Y  0.223 -0.298           -0.147           -0.675 -0.216
Answr.cndtnn_QUD:kY  0.221 -0.156           -0.379           -0.668 -0.214
Answr.cndtnny_QUD:   0.648 -0.915           -0.428           -0.227 -0.707
Answr.cndtnn_QUD:g   0.625 -0.440           -0.923           -0.218 -0.682
keyYes:age           0.337 -0.237           -0.223           -0.917 -0.391
Answr.cndtnny_QUD:Y: -0.233  0.306            0.154            0.634  0.270
Answr.cndtnn_QUD:kY: -0.235  0.165            0.378            0.640  0.272
                  Answr.cndtnny_QUD:Y Answr.cndtnn_QUD:kY
Answr.cndtnny_QUD:
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```
Answr.cndtnny_QUD
Answer.cndtnn_QUD
keyYes
age
Answr.cndtnny_QUD:Y
Answr.cndtnn_QUD:kY   0.451
Answr.cndtnny_QUD:    0.284               0.151
Answr.cndtnn_QUD:g    0.147               0.355               0.482
keyYes:age            0.619               0.613               0.276
Answr.cndtnny_QUD:Y: -0.923              -0.424              -0.354
Answr.cndtnn_QUD:kY: -0.432              -0.930              -0.193
                     Answr.cndtnn_QUD:g kyYs:g Answr.cndtnny_QUD:Y:
Answr.cndtnny_QUD
Answer.cndtnn_QUD
keyYes
age
Answr.cndtnny_QUD:Y
Answr.cndtnn_QUD:kY
Answr.cndtnny_QUD:
Answr.cndtnn_QUD:g
keyYes:age            0.266
Answr.cndtnny_QUD:Y: -0.184             -0.691
Answr.cndtnn_QUD:kY: -0.418             -0.697  0.482
```