Inter-reading timing

Tyler Peckenpaugh

April 7, 2019

Contents

1 Inter reading time

This document examines the inter-reading time (IRT) from the study. Subjects were asked to read each sentence twice, once with no preview at all (reading 1, a cold reading), and then again after unlimited preview (reading 2, a previewed reading). Inter-reading time (IRT) is a measure of the amount of time between when a subject stops speaking after a cold reading and when they begin speaking for a previewed reading. IRT was measured over 1500 recordings: 32 participants, 48 items = 1536 recording pairs (reading 1 and reading 2), with 36 missing pairs.

1.1 IRT measurement

IRT was measured using a Python script and Google's WebRTC Voice Activity Detection (VAD) over 44.1kHz WAV files downsampled to 8kHz via SOX[1]. This VAD system uses Gaussian Mixture Models to make probabilistic decisions on whether a given audio frame is speech or noise (see (Falk and Chan 2006) for a complete explanation). Google's implementation takes one paramater, which they call aggressiveness: a 4-tier setting for the level of confidence necessary to call a gvien frame speech. I call this "rejection rate", where a higher rejection rate means that the model requires a high level of confidence before assuming a frame is speech, i.e. it is more likely to label something noise than speech. The implementation codes this setting as 0-3,

[1] Google's VAD API only accepts WAV files with sample rates that are a multiple of 8kHz. It ultimately downsamples all files to 8kHz, regardless of the input rate.

	No HPF	HPF at 200Hz	HPF at 400Hz
Lowest rejection rate	0	0	1
...	4	0	1
...	460	43	0
Highest rejection rate	1387	1175	5

Table 1: Rejection rate and HPF values

where 0 is the most lenient (most likely to label a frame as speech) and 3 is the most stringent (most likely to label a frame as noise).

The recordngs vary in the volume of the speaker's voice and the amount of background noise present. An algorothm was constructed to allow for the most stringent measurement of the least modified data that gave plausible measurements. Specifically, each file was measured using the highest possible rejection rate for the VAD algorithm and no modification of the file. If the timings detected were not plausible, the timings were re-measured with the same rejection rate, but after the recording had undergone a 200Hz high-pass filter[2] (HPF). If that still failed, a 400Hz HPF was used. After a further failure, the rejection rate for the VAD was lowered, and the whole thing was tried again (0, 200Hz, 400Hz); and that process was itself repeated until the lowest possible rejection rate was tried of the four possible settings.

Plausible timings had to meet the following criteria:

1. An utterance length between 2s and 10s[3], where utterance timing is the longest contiguous span in the recording that VAD reports as phonation, with breaks in phonation of less than 1s[4] not breaking contiguity.

2. A leading silence (delay) length of more than 120ms[5] and less than 95% of the entire recording's duration.

3. A trailing silence length of less than 95% of the entire recording's duraton.

Of the 3097 recordings subjected to this treatment, 3076 resulted in plausible timings. For those that were successfull, the breakdown of HPF and rejection rate used is reported in Table 1.

2 *Distribution of IRT*

The raw IRTs including fillers and before any outliers are trimmed are distributed as shown in Figure 1. Overall mean IRT of these data (n = 1500), is 6.5s. The longest is 35.8s and the shortest 6ms. Median IRT is 5.9s.

IRTs below 250ms (2) and above 25s (5) are (assumed to be implausible) omitted. Experimental data were then Winsorized by participant to bring data in the 5th and 95th percentile of data to the value

[2] The exact algorithm is available at github (URL: bit.ly/2uMrcrG)

[3] Stimuli range from 18-22 syllables in length. If we assume a speeach rate of 3 to 7 syllables per second (Jacewicz et al. 2010) we would expect utterances between 2.5s and 7.3s. Conservative thresholds higher and lower than the expected were used, especially on the higher end to allow for any processing or fluency difficulty.

[4] Goldman-Eisler (1961) found that a large majority (82.5 to 87%) of pauses in fluent speech are less than 1s.

[5] Human reaction time should not permit a smaller delay.

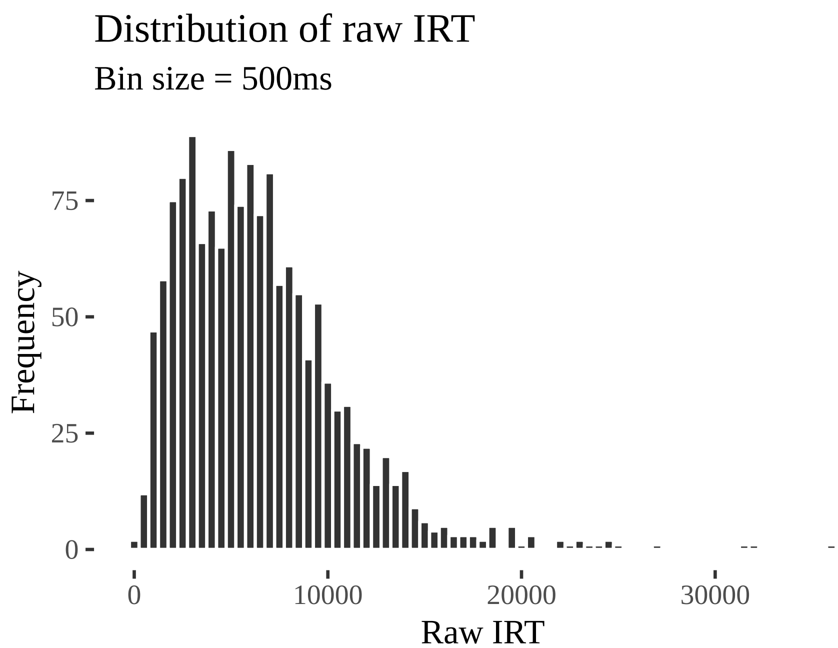


Figure 1: Distribution of raw IRT

Condition	-Q	+Q
-GP	6.20	6.56
+GP	6.67	6.94
Increase	0.47	0.39

Table 2: Means (s) by condition

at those tresholds. The resulting measure is referred to as wIRT and is distribued as shown in Figure 2 (n = 495). Overall mean for wIRT is 6.6s. The longest IRT is 22.8s and the shortest is 737ms. Median wIRT is 6.1s.

For the purposes of regression analysis, a common log transformation reduces the skew in the data. This distribution is seen in Figure 3.

3 Means by condition

Table 2 shows the mean wIRT by experimental condition. The top left cell represents the mean wIRT for the declaritive controls ("-Q -GP"). The bottom row shows the increase in IRT across the garden path condition.

The difference in the effect of ±GP across ±Q is 82ms. This difference is in the direction that supports the hypothesis.

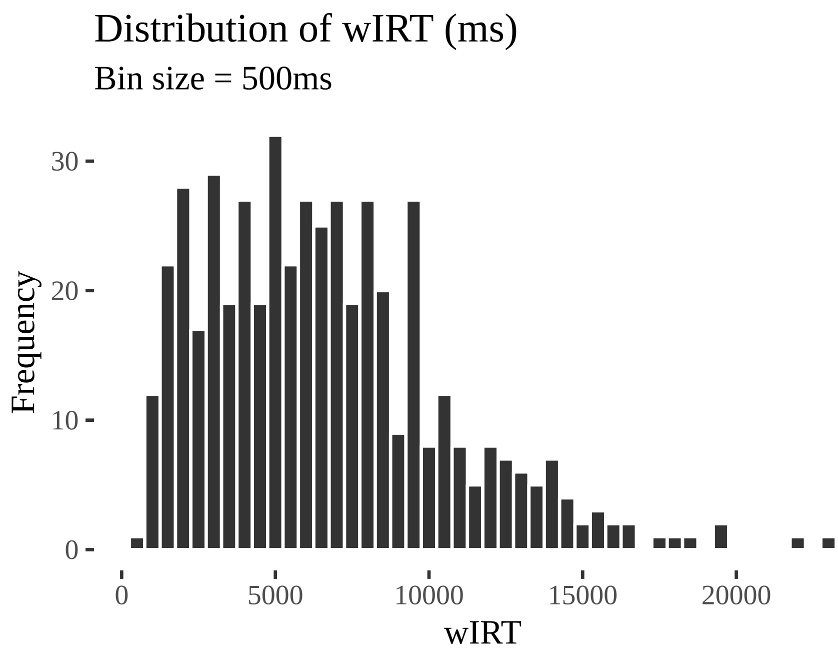


Figure 2: Distribution of wIRT

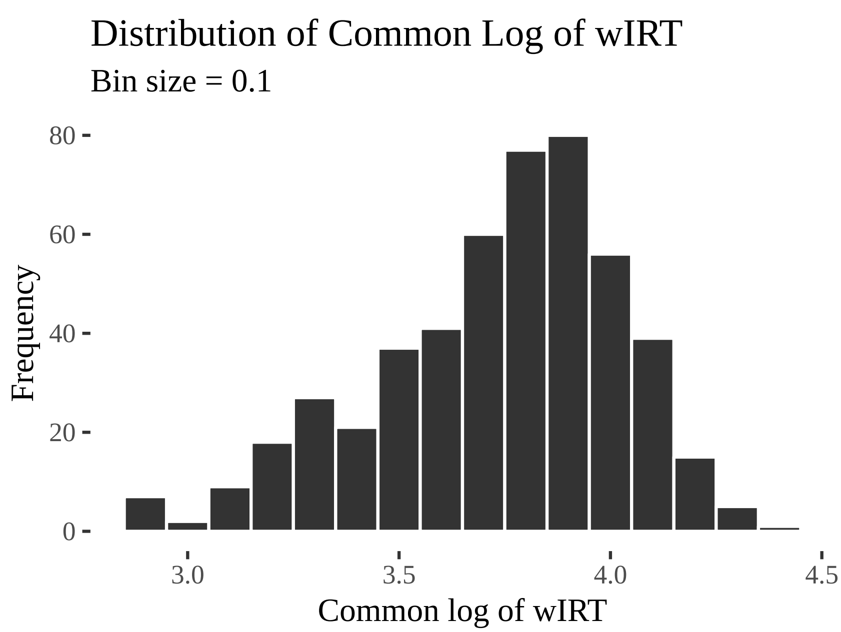


Figure 3: Common log of wIRT

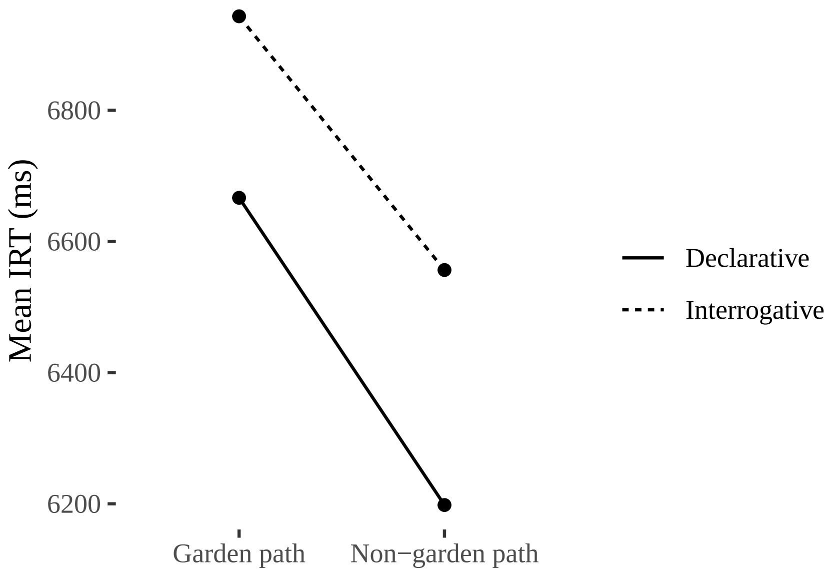


Figure 4: Mean IRT by condition

4 Regression models

The models with random slopes for participant and item did not converge, so the tables in this section show models with no random slopes.

For the first model, fixed effects of ±GP and ±Q as well is the interaction between them were included, along with random effects of participant and item. The second model removes the interaction, but keeps both main effects.

A model with no fixed effects was also run, here it is shown beside the interaction model from the previous table.

5 Delay comparison for cold vs. previewed readings

A comparison of the delay for cold readings compared with that of previewed readings can lend insight into the extent to which subjects followed task instructions.

“Delay” here is the amount of time after the start of a recording until the beginning of phonation of the target sentence. Cold readings are also called “reading 1”, while previewed readings are the same as “reading 2”. Implausible delays of >15s are excluded in the data shown here.

	Dependent variable:	
	Winsorized IRT	
	(1)	(2)
+GP	362.077	367.485*
	(285.543)	(202.990)
+Q	458.456	463.912**
	(286.773)	(202.953)
+GP +Q	10.939	
	(406.230)	
Constant	6,279.529***	6,276.827***
	(595.388)	(586.867)
Observations	495	495
Log Likelihood	−4,583.130	−4,583.131
Akaike Inf. Crit.	9,180.261	9,178.262
Bayesian Inf. Crit.	9,209.693	9,203.489
Note:	*p<0.1; **p<0.05; ***p<0.01	

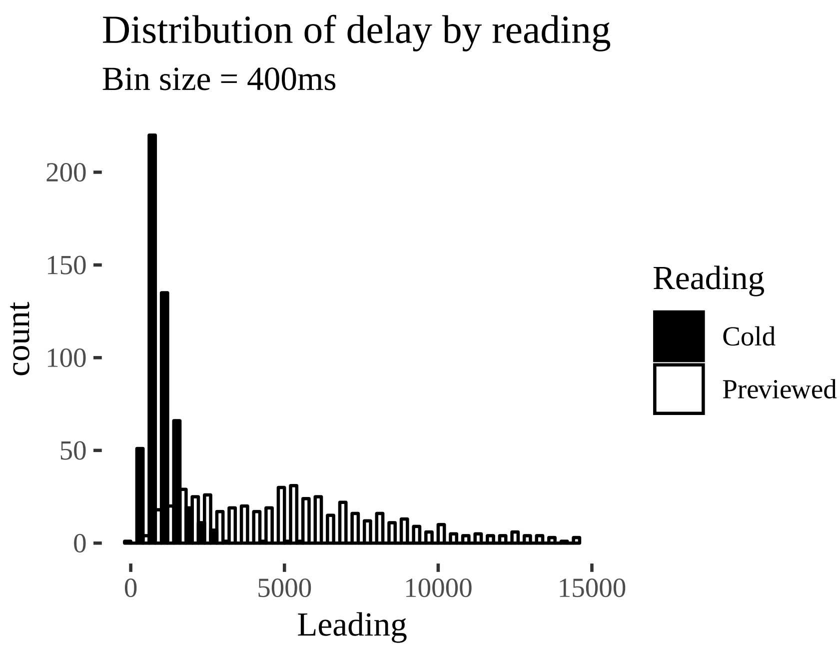
Table 3: Interaction vs. non-interaction model

Table 4: Interaction vs. no fixed effects

	Dependent variable:	
	Winsorized IRT	
	(1)	(2)
+GP	362.077	
	(285.543)	
+Q	458.456	
	(286.773)	
+GP +Q	10.939	
	(406.230)	
Constant	6,279.529***	6,689.403***
	(595.388)	(568.522)
Observations	495	495
Log Likelihood	−4,583.130	−4,587.332
Akaike Inf. Crit.	9,180.261	9,182.664
Bayesian Inf. Crit.	9,209.693	9,199.482
Note:	*p<0.1; **p<0.05; ***p<0.01	

Table 5: Interaction vs. no random effects

	Dependent variable:	
	Winsorized IRT	
	linear mixed-effects	*OLS*
	(1)	(2)
+GP	362.077	358.335
	(285.543)	(487.048)
+Q	458.456	468.453
	(286.773)	(489.024)
+GP +Q	10.939	−81.632
	(406.230)	(692.298)
Constant	6,279.529***	6,198.129***
	(595.388)	(344.395)
Observations	495	495
R^2		0.005
Adjusted R^2		−0.001
Log Likelihood	−4,583.130	
Akaike Inf. Crit.	9,180.261	
Bayesian Inf. Crit.	9,209.693	
Residual Std. Error		3,850.452 (df = 491)
F Statistic		0.793 (df = 3; 491)
Note:		*p<0.1; **p<0.05; ***p<0.01



For cold readings, n = 514 and for previewed, n = 497.

5.1 Difference in delay across paired readings

Overall, each recording pair (n = 497) has a mean difference in delay (DelDif = previewed delay - cold delay) of 4.3s (sd = 3.3s), with a minumum of -1.9s and a max of 13.4s. The median DelDif is 3.9s. The distribution DelDif is shown in Figure 5.

If we calculate the mean delay difference by participant, we find a mean participant DelDef of 4.4s. Each participant's DelDif is 386ms and 10.2s, with a median of 3.97s. Table 6 shows these values.

Table 6: Delay differences by participant

	Participant	Mean difference in delay (ms)
1	1	386
8	8	702
23	203	938
28	208	1183
29	209	1290
24	204	1502
22	201	1584
32	214	1604
26	206	2582
33	215	2814
20	21	2908
17	17	3139

31	212	3167
7	7	3682
9	9	3816
30	210	3908
21	22	3973
27	207	3988
12	12	4303
2	2	4369
4	4	4798
3	3	4841
11	11	4845
15	15	5961
10	10	6358
25	205	6858
14	14	7157
5	5	7838
13	13	8051
19	20	8685
16	16	9105
18	19	9537
6	6	10184

The distribution of the participants' DelDifs can be found in Figure 6.

6 *Individual variation*

Individuals vary with regard to the effect of the garden path condition on IRT. For 18 of 32, the increase in IRT for garden paths is greater for interrogatives than it is for declaratives.

Table 7: Mean wIRT (ms) by condition and participant

Participant	-Q -GP	-Q +GP	+Q -GP	+Q +GP
12	5436.092	5236.717	6146.935	7347.062
17	3725.878	6283.250	5736.560	5128.127
1	2723.095	2764.875	3165.468	3061.438
10	9072.500	9416.155	8734.438	9630.157
11	8635.833	9030.440	5688.040	12075.837
13	10779.875	11638.595	9410.875	11132.593
14	7180.315	8851.722	8443.062	12052.435
15	9673.310	7771.158	9463.500	5764.438

16	12583.907	9725.440	9352.470	15201.440
19	8780.500	14237.875	17076.783	16161.185
2	6077.595	7088.435	4410.845	6398.435
20	9963.565	9211.125	12225.282	10081.030
201	1396.033	4249.562	2533.628	2206.812
203	1451.470	1501.438	1909.753	2472.343
204	3164.688	3173.847	2792.125	1676.000
205	6456.967	11925.468	7450.278	11345.407
206	3736.810	3707.875	3223.593	4985.440
207	5083.280	6428.315	6700.748	5199.312
208	2612.250	3449.810	2482.940	3263.970
209	2126.185	3625.500	2563.718	2967.907
21	5035.065	5748.627	6117.688	7204.748
210	5690.440	6105.592	6664.688	5098.160
212	4699.658	5192.250	4647.190	5065.035
214	3628.378	4118.707	5185.467	2026.030
215	4432.130	4132.312	5207.998	5075.938
22	5066.752	4134.533	5006.845	7975.283
3	5655.472	8400.845	6056.405	7267.347
4	7993.717	5457.905	10609.750	7010.720
5	13082.620	10694.565	9437.685	12188.125
6	12848.093	10828.407	13018.030	14695.872
7	5208.465	5864.283	6291.778	4918.595
9	6234.815	6632.685	6386.938	6484.312

References

Falk, Tiago H, and Wai-Yip Chan. 2006. "Nonintrusive Speech Quality Estimation Using Gaussian Mixture Models." *IEEE Signal Processing Letters* 13 (2): 108–11.

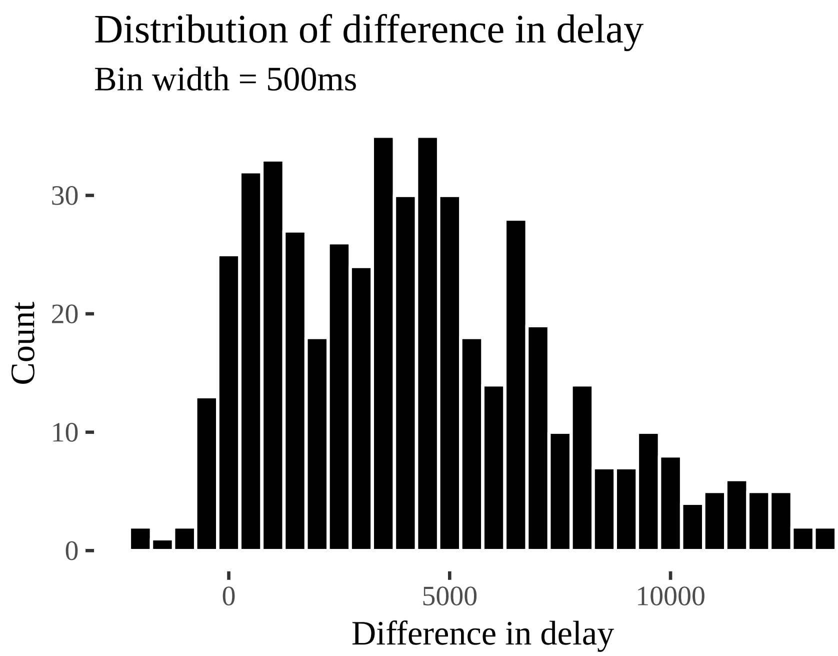


Figure 5: Distribution of DelDif

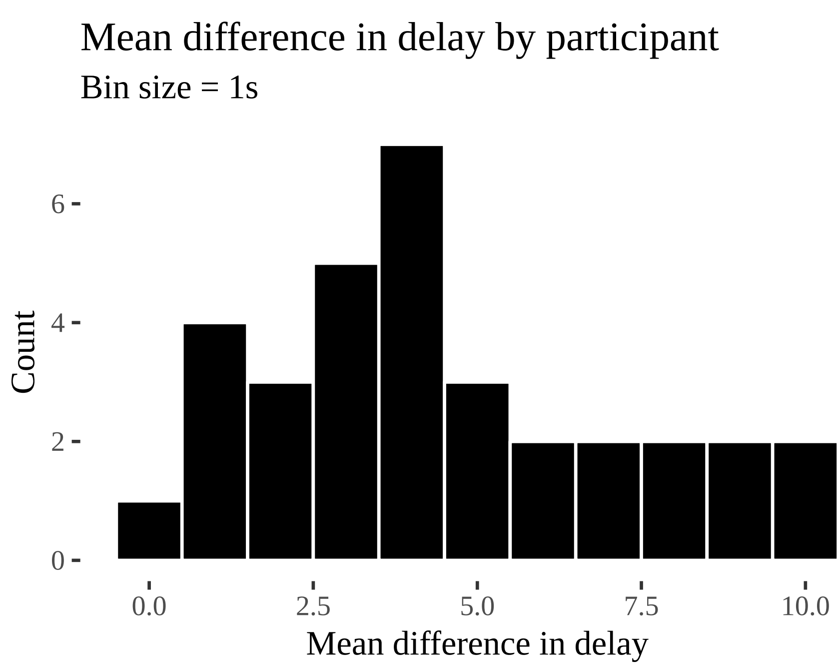


Figure 6: Mean difference in delay by participant

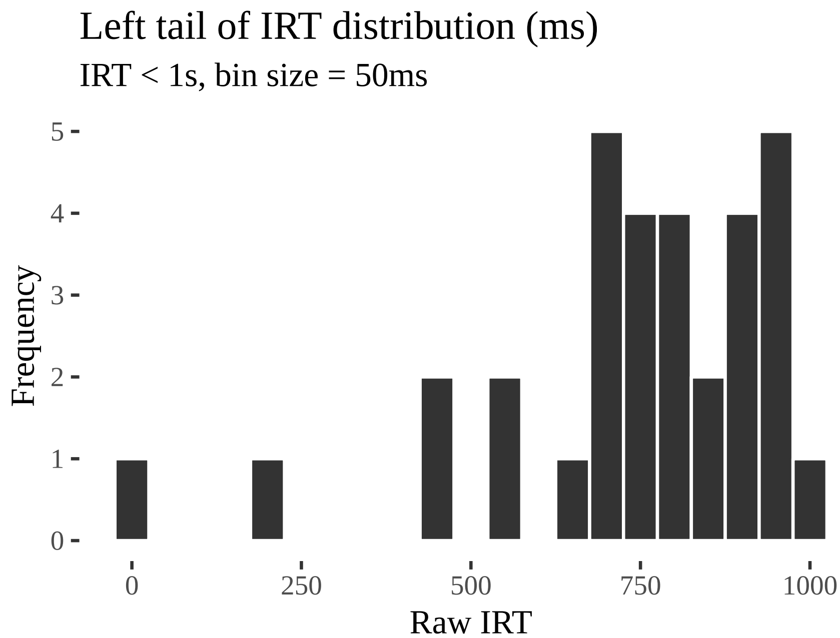


Figure 7: Left tail of raw IRT distribution

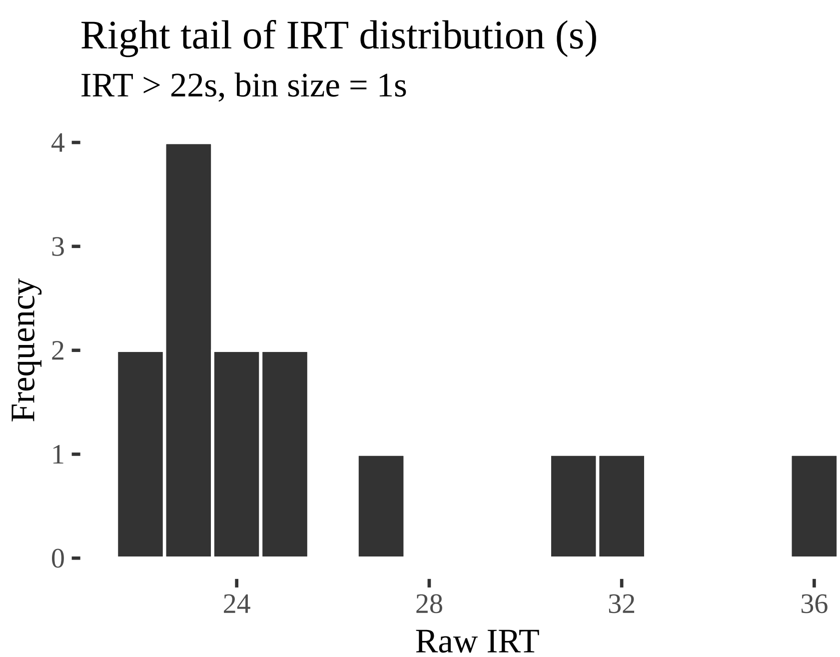


Figure 8: Right tail of raw IRT distribution