

SUPPLEMENTAL MATERIAL FOR
Trecca, F., Bleses, D., Højen, A., Madsen, T. O., & Christiansen, M. H.
When too many vowels impede language processing: An eye-tracking study of Danish-learning children.

Supplemental Material 1:
Stimulus image pairings in the four pseudo-random presentation orders.

	Order 1		Order 2		Order 3		Order 4	
Familiarization	kat (cat)	baby (baby)	baby (baby)	kat (cat)	hund (dog)	bog (book)	ko (cow)	bold (ball)
Familiarization	ko (cow)	bold (ball)	bold (ball)	ko (cow)	bold (ball)	ko (cow)	hund (dog)	bog (book)
Familiarization	bog (book)	hund (dog)	hund (dog)	bog (book)	baby (baby)	kat (cat)	baby (baby)	kat (cat)
Baseline trials	and (duck)	bil (car)	bamse (teddy)	abe (monkey)	bil (car)	and (duck)	abe (monkey)	bamse (teddy)
Baseline trials	abe (monkey)	bamse (teddy)	bil (car)	and (duck)	bamse (teddy)	abe (monkey)	and (duck)	bil (car)
Baseline trials	bil (car)	abe (monkey)	abe (monkey)	bil (car)	abe (monkey)	bil (car)	bil (car)	abe (monkey)
Baseline trials	bamse (teddy)	and (duck)	and (duck)	bamse (teddy)	and (duck)	bamse (teddy)	bamse (teddy)	and (duck)
Filler	bog (book)	bold (ball)	bold (ball)	bog (book)	bold (ball)	bog (book)	kat (cat)	baby (baby)
Baseline trials	and (duck)	bamse (teddy)	abe (monkey)	bil (car)	bamse (teddy)	and (duck)	bil (car)	abe (monkey)
Baseline trials	bil (car)	and (duck)	bil (car)	and (duck)	and (duck)	bil (car)	and (duck)	bil (car)
Baseline trials	bamse (teddy)	abe (monkey)	and (duck)	bamse (teddy)	abe (monkey)	bamse (teddy)	bamse (teddy)	and (duck)
Baseline trials	abe (monkey)	bil (car)	bamse (teddy)	abe (monkey)	bil (car)	and (duck)	abe (monkey)	bamse (teddy)
Filler	baby (baby)	kat (cat)	kat (cat)	baby (baby)	ko (cow)	baby (baby)	bold (ball)	bog (book)
Test trials	and (duck)	bil (car)	bamse (teddy)	abe (monkey)	bil (car)	and (duck)	abe (monkey)	bamse (teddy)
Test trials	abe (monkey)	bamse (teddy)	bil (car)	and (duck)	bamse (teddy)	abe (monkey)	and (duck)	bil (car)
Test trials	bil (car)	abe (monkey)	abe (monkey)	bil (car)	abe (monkey)	bil (car)	bil (car)	abe (monkey)
Test trials	bamse (teddy)	and (duck)	and (duck)	bamse (teddy)	and (duck)	bamse (teddy)	bamse (teddy)	and (duck)
Filler	baby (baby)	ko (cow)	ko (cow)	baby (baby)	kat (cat)	baby (baby)	ko (cow)	baby (baby)
Test trials	and (duck)	bamse (teddy)	abe (monkey)	bil (car)	bamse (teddy)	and (duck)	bil (car)	abe (monkey)

Test trials	bil (car)	and (duck)	bil (car)	and (duck)	and (duck)	bil (car)	and (duck)	bil (car)
Test trials	bamse (teddy)	abe (monkey)	and (duck)	bamse (teddy)	abe (monkey)	bamse (teddy)	bamse (teddy)	and (duck)
Test trials	abe (monkey)	bil (car)	bamse (teddy)	abe (monkey)	bil (car)	and (duck)	abe (monkey)	bamse (teddy)

Supplemental Material 2:
Statistical model specifications

1) M1 (Baseline trials)

Model structure: Proportional Looks $\sim 1 + (1 \mid \text{Child}) + (1 \mid \text{Item})$

Priors: Intercept = $N(0, 10)$, SD = $N(0, 0.2)$

Family: zero-one inflated Beta distribution with logit link

Model fit summary:

Group-Level Effects:

~Sound (Number of levels: 9)

	Estimate	Est.Error	I-95% CI	u-95% CI	Eff.Sample	Rhat
sd(Intercept)	0.11	0.08	0.00	0.29	4533	1.00

~SubjectID (Number of levels: 22)

	Estimate	Est.Error	I-95% CI	u-95% CI	Eff.Sample	Rhat
sd(Intercept)	0.21	0.11	0.01	0.43	2181	1.00

Population-Level Effects:

	Estimate	Est.Error	I-95% CI	u-95% CI	Eff.Sample	Rhat
Intercept	0.50	0.10	0.29	0.70	5656	1.00

Family Specific Parameters:

	Estimate	Est.Error	I-95% CI	u-95% CI	Eff.Sample	Rhat
phi	5.31	0.71	4.04	6.84	5161	1.00
zoi	0.17	0.03	0.12	0.24	13074	1.00
coi	0.88	0.06	0.73	0.98	14097	1.00

2) M1 (Test trials)

Model structure: Proportional Looks $\sim 1 + (1 \mid \text{Child}) + (1 \mid \text{Item})$

Priors: Intercept = $N(0, 10)$, SD = $N(0, 0.2)$

Family: zero-one inflated Beta distribution with logit link

Model fit summary:

Group-Level Effects:

~Sound (Number of levels: 9)

	Estimate	Est.Error	I-95% CI	u-95% CI	Eff.Sample	Rhat
sd(Intercept)	0.11	0.08	0.00	0.30	5533	1.00

~SubjectID (Number of levels: 22)

	Estimate	Est.Error	I-95% CI	u-95% CI	Eff.Sample	Rhat
sd(Intercept)	0.28	0.12	0.04	0.50	2170	1.00

Population-Level Effects:

	Estimate	Est.Error	I-95% CI	u-95% CI	Eff.Sample	Rhat
Intercept	0.48	0.11	0.26	0.72	5450	1.00

Family Specific Parameters:

	Estimate	Est.Error	I-95% CI	u-95% CI	Eff.Sample	Rhat
phi	5.21	0.78	3.85	6.85	3925	1.00
zoi	0.17	0.03	0.11	0.24	10293	1.00
coi	0.91	0.06	0.77	0.99	11475	1.00

3) M2a (Baseline trials)

Model structure: Proportional Looks $\sim \text{Target Word} + (1 + \text{Target Word} \mid \text{Child}) + (1 \mid \text{Item})$

Priors: Intercept = $N(0, 10)$, beta = $N(0, 10)$, SD = $N(0, 0.2)$, $\text{cor}^1 = \text{LKJ}(5)$

Family: zero-one inflated Beta distribution with logit link

Model fit summary:

Group-Level Effects:

¹ Correlations between random effects

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~Sound (Number of levels: 11)
      Estimate Est.Error l-95% CI u-95% CI Eff.Sample Rhat
sd(Intercept)  0.08   0.06   0.00   0.23   5892 1.00

~SubjectID (Number of levels: 22)
      Estimate Est.Error l-95% CI u-95% CI Eff.Sample Rhat
sd(Intercept)    0.18   0.10   0.01   0.38   2180 1.00
sd(TargetWordVowel)  0.21   0.12   0.01   0.46   2598 1.00
cor(Intercept,TargetWordVowel)  0.02   0.30  -0.54   0.59   7966 1.00

Population-Level Effects:
      Estimate Est.Error l-95% CI u-95% CI Eff.Sample Rhat
Intercept    0.31   0.11   0.09   0.52   10149 1.00
TargetWordVowel  0.09   0.15  -0.19   0.39   10039 1.00

Family Specific Parameters:
      Estimate Est.Error l-95% CI u-95% CI Eff.Sample Rhat
phi    8.55   1.23   6.33  11.18   6311 1.00
zoi    0.13   0.03   0.08   0.18  15383 1.00
coi    0.84   0.08   0.65   0.96  15435 1.00

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4) M2b (Test trials)

Model structure: Proportional Looks ~ Target Word + (1 + Target Word | Child) + (1 | Item)

Priors: Intercept = N(0, 10), beta = N(0, 10), SD = N(0, 0.2), cor = LKJ(5)

Family: zero-one inflated Beta distribution with logit link

Model fit summary:

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Group-Level Effects:
~Sound (Number of levels: 9)
      Estimate Est.Error l-95% CI u-95% CI Eff.Sample Rhat
sd(Intercept)  0.20   0.11   0.01   0.44   2772 1.00

~SubjectID (Number of levels: 22)
      Estimate Est.Error l-95% CI u-95% CI Eff.Sample Rhat
sd(Intercept)    0.16   0.10   0.01   0.37   2662 1.00
sd(CarrierPhraseVocoid)    0.19   0.12   0.01   0.44   2928 1.00
sd(TargetWordVowel)    0.13   0.10   0.01   0.37   4972 1.00
sd(CarrierPhraseVocoid:TargetWordVowel)    0.15   0.11   0.01   0.42   6486 1.00
cor(Intercept,CarrierPhraseVocoid)    0.06   0.27  -0.47   0.57   9144 1.00
cor(Intercept,TargetWordVowel)   -0.02   0.28  -0.54   0.51  14502 1.00
cor(CarrierPhraseVocoid,TargetWordVowel)    0.01   0.27  -0.52   0.54  11408 1.00
cor(Intercept,CarrierPhraseVocoid:TargetWordVowel)   -0.00   0.28  -0.54   0.53  15405 1.00
cor(CarrierPhraseVocoid,CarrierPhraseVocoid:TargetWordVowel)   -0.00   0.28  -0.53   0.53  11517 1.00
cor(TargetWordVowel,CarrierPhraseVocoid:TargetWordVowel)    0.00   0.28  -0.53   0.54  10582 1.00

Population-Level Effects:
      Estimate Est.Error l-95% CI u-95% CI Eff.Sample Rhat
Intercept    0.66   0.22   0.23   1.10   5766 1.00
CarrierPhraseVocoid  -0.32   0.28  -0.86   0.26   5113 1.00
TargetWordVowel   -0.19   0.31  -0.82   0.41   4474 1.00
CarrierPhraseVocoid:TargetWordVowel  0.26   0.43  -0.55   1.16   4254 1.00

Family Specific Parameters:
      Estimate Est.Error l-95% CI u-95% CI Eff.Sample Rhat
phi    8.22   1.26   5.97  11.00   5989 1.00
zoi    0.11   0.03   0.07   0.17  18972 1.00
coi    0.88   0.08   0.68   0.98  18260 1.00

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5) M3a (Baseline trials)

Model structure: Looks at Target ~ Target Word × (Linear Time + Quadratic Time + Cubic Time) + (1 + Target Word | Child) + (1 | Item)

Priors: Intercept = N(0, 10), beta = N(0, 10), SD = N(0, 0.2)

Family: Bernoulli distribution with logit link

Model fit summary:

Group-Level Effects:

~Sound (Number of levels: 11)

	Estimate	Est.Error	I-95% CI	u-95% CI	Eff.Sample	Rhat
sd(Intercept)	0.29	0.06	0.19	0.44	2930	1.00

~SubjectID (Number of levels: 22)

	Estimate	Est.Error	I-95% CI	u-95% CI	Eff.Sample	Rhat
sd(Intercept)	0.63	0.06	0.52	0.76	2345	1.00
sd(BoundaryN_V)	0.76	0.07	0.63	0.92	1969	1.00
cor(Intercept,BoundaryN_V)	-0.73	0.08	-0.86	-0.55	1740	1.00

Population-Level Effects:

	Estimate	Est.Error	I-95% CI	u-95% CI	Eff.Sample	Rhat
Intercept	-0.27	0.45	-1.13	0.62	3787	1.00
TargetWordVowel	-1.34	0.50	-2.32	-0.39	2547	1.00
ot1	-9.84	9.16	-27.68	8.13	5429	1.00
ot2	6.61	5.75	-4.63	17.77	3367	1.00
ot3	25.59	3.37	18.88	32.22	3572	1.00
TargetWordVowel:ot1	-13.29	9.15	-31.38	4.29	3848	1.00
TargetWordVowel:ot2	21.97	6.40	9.62	34.51	3715	1.00
TargetWordVowel:ot3	7.51	4.07	-0.42	15.57	3716	1.00

6) M3b (Test trials)

Model structure: Looks at Target ~ Carrier Phrase × Target Word × (Linear Time + Quadratic Time + Cubic Time) + (1 + Carrier Phrase × Target Word | Child) + (1 | Item)

Priors: Intercept = N(0, 10), beta = N(0, 10), SD = N(0, 0.2)

Family: Bernoulli distribution with logit link

Model fit summary:

Group-Level Effects:

~Sound (Number of levels: 9)

	Estimate	Est.Error	I-95% CI	u-95% CI	Eff.Sample	Rhat
sd(Intercept)	0.43	0.10	0.26	0.64	6709	1.00

~SubjectID (Number of levels: 22)

	Estimate	Est.Error	I-95% CI	u-95% CI	Eff.Sample	Rhat
sd(Intercept)	0.28	0.09	0.10			
sd(CarrierPhraseVocoid)	0.50	0.10	0.32			
sd(TargetWordVowel)	0.63	0.10	0.44			
sd(CarrierPhraseVocoid:TargetWordVowel)	0.49	0.17	0.10			
cor(Intercept,CarrierPhraseVocoid)	0.29	0.30	-0.30			
cor(Intercept,TargetWordVowel)	-0.20	0.26	-0.64			
cor(CarrierPhraseVocoid,TargetWordVowel)	-0.30	0.22	-0.71			
cor(Intercept,CarrierPhraseVocoid:TargetWordVowel)	-0.06	0.32	-0.69			
cor(CarrierPhraseVocoid,CarrierPhraseVocoid:TargetWordVowel)	0.08	0.30	-0.48			
cor(TargetWordVowel,CarrierPhraseVocoid:TargetWordVowel)	0.03	0.28	-0.46			
	u-95% CI	Eff.Sample	Rhat			
sd(Intercept)	0.47	2997	1.00			
sd(CarrierPhraseVocoid)	0.70	3441	1.00			
sd(TargetWordVowel)	0.85	4186	1.00			
sd(CarrierPhraseVocoid:TargetWordVowel)	0.79	997	1.01			
cor(Intercept,CarrierPhraseVocoid)	0.84	2003	1.00			
cor(Intercept,TargetWordVowel)	0.36	1622	1.00			
cor(CarrierPhraseVocoid,TargetWordVowel)	0.15	2321	1.00			
cor(Intercept,CarrierPhraseVocoid:TargetWordVowel)	0.56	2249	1.00			
cor(CarrierPhraseVocoid,CarrierPhraseVocoid:TargetWordVowel)	0.67	3770	1.00			
cor(TargetWordVowel,CarrierPhraseVocoid:TargetWordVowel)	0.61	3449	1.00			

Population-Level Effects:

	Estimate	Est.Error	I-95% CI	u-95% CI	Eff.Sample	Rhat
Intercept	-0.01	0.57	-1.13	1.09	6923	1.00
CarrierPhraseVocoid	-1.40	0.65	-2.69	-0.13	4681	1.00
TargetWordVowel	0.47	0.69	-0.90	1.85	4814	1.00
ot1	-8.17	9.33	-26.35	10.40	11984	1.00
ot2	10.04	6.96	-3.71	23.61	6357	1.00
ot3	22.88	4.88	13.12	32.26	6222	1.00
CarrierPhraseVocoid:TargetWordVowel	0.90	0.81	-0.71	2.50	4228	1.00
CarrierPhraseVocoid:ot1	-9.73	9.31	-27.61	8.59	9260	1.00
CarrierPhraseVocoid:ot2	15.45	7.43	1.28	29.99	6708	1.00
CarrierPhraseVocoid:ot3	10.42	5.53	-0.21	21.45	6015	1.00

TargetWordVowel:ot1	4.57	9.64	-14.39	23.35	8813	1.00
TargetWordVowel:ot2	-4.85	7.68	-19.54	10.14	8104	1.00
TargetWordVowel:ot3	-16.42	5.73	-27.63	-5.20	7137	1.00
CarrierPhraseVocoid:TargetWordVowel:ot1	4.90	9.61	-13.94	23.82	9526	1.00
CarrierPhraseVocoid:TargetWordVowel:ot2	-10.82	8.09	-26.51	5.09	7903	1.00
CarrierPhraseVocoid:TargetWordVowel:ot3	6.95	6.36	-5.55	19.69	7029	1.00

7) M4

Model structure: Shift ~ Carrier Phrase × Target Word × First Image + (1 + Carrier Phrase × Target Word × First Image | Child) + (1 | Item)

Priors: Intercept = N(0, 10), beta = N(0, 10), SD = N(0, 0.2), cor = LKJ(5)

Family: Bernoulli distribution with logit link

Model fit summary:

Population-Level Effects:

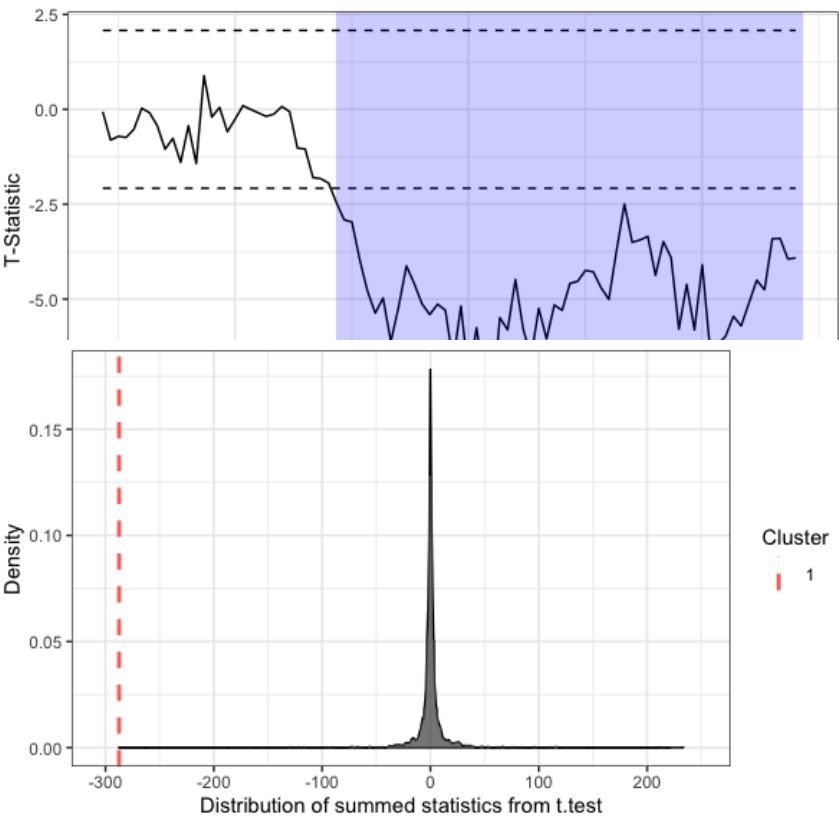
	Estimate	Est.Error		
Intercept	0.49	0.20		
CarrierPhraseVocoid	-0.68	0.28		
TargetWordVowel	-0.31	0.30		
FirstImageTarget	-1.69	0.24		
CarrierPhraseVocoid:TargetWordVowel		0.37	0.44	
CarrierPhraseVocoid:FirstImageTarget		1.15	0.32	
TargetWordVowel:FirstImageTarget		0.16	0.36	
CarrierPhraseVocoid:TargetWordVowel:FirstImageTarget	-0.44	0.55		
I-95% CI u-95% CI				
Intercept	0.11	0.88		
CarrierPhraseVocoid	-1.23	-0.13		
TargetWordVowel	-0.91	0.28		
FirstAOILookAtTarget	-2.19	-1.22		
CarrierPhraseVocoid:TargetWordVowel		-0.51	1.21	
CarrierPhraseVocoid:FirstAOILookAtTarget		0.53	1.77	
TargetWordVowel:FirstAOILookAtTarget		-0.54	0.86	
CarrierPhraseVocoid:TargetWordVowel:FirstAOILookAtTarget	-1.54	0.60		
Eff. Sample Rhat				
Intercept	4431	1.00		
CarrierPhraseVocoid	3544	1.00		
TargetWordVowel	3439	1.00		
FirstAOILookAtTarget	4039	1.00		
CarrierPhraseVocoid:TargetWordVowel		3002	1.00	
CarrierPhraseVocoid:FirstAOILookAtTarget		3620	1.00	
TargetWordVowel:FirstAOILookAtTarget		3747	1.00	
CarrierPhraseVocoid:TargetWordVowel:FirstAOILookAtTarget		3290	1.00	

Supplemental Material 3:
Bootstrapped cluster-based permutation analyses

1) Average looks in Baseline trials vs. chance level (with noise term)

Test Type: t.test
Predictor: Predictor
Formula: Prop ~ Predictor
Null Distribution =====
Mean: 0.263
2.5%: -23.8212
97.5%: 27.1357
Summary of Clusters =====

Cluster	Direction	SumStatistic	StartTime	EndTime	Probability
1	Negative	-281.5226	1216.91	2217.11	p < 0.001



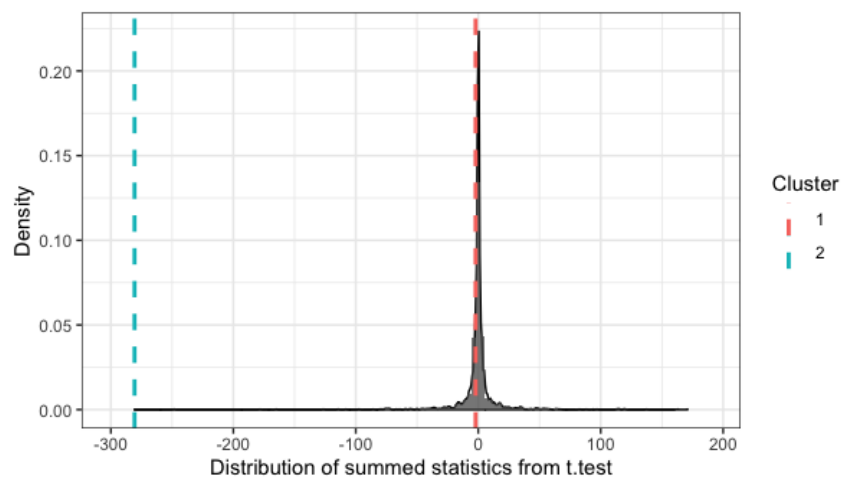
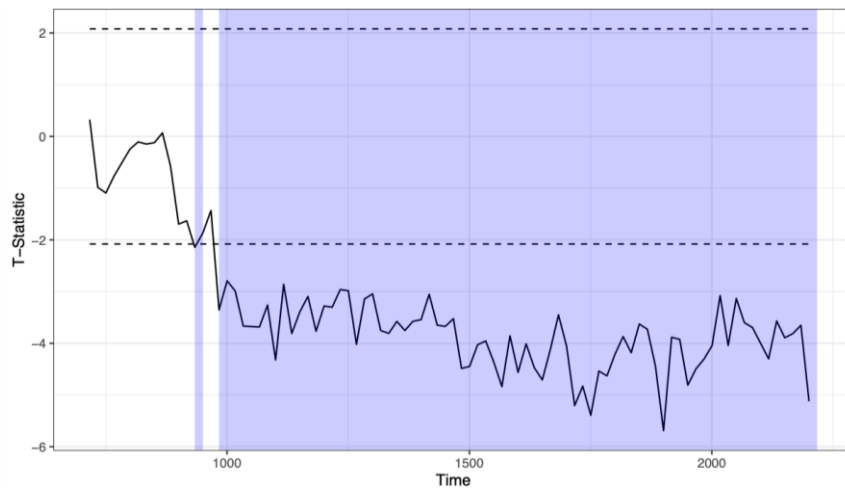
2) Average looks in Test trials vs. chance level (with noise term)

Test Type: t.test
Predictor: Predictor
Formula: Prop ~ Predictor
Null Distribution =====

Mean: 0.9017
2.5%: -28.6136
97.5%: 39.0625

Summary of Clusters =====

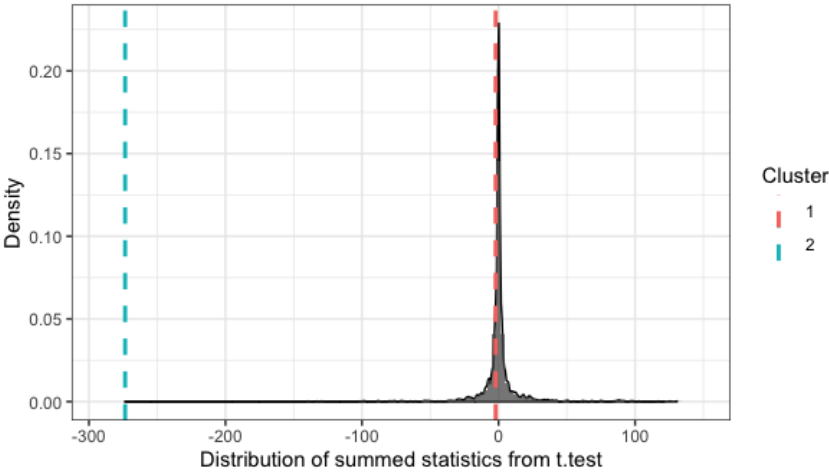
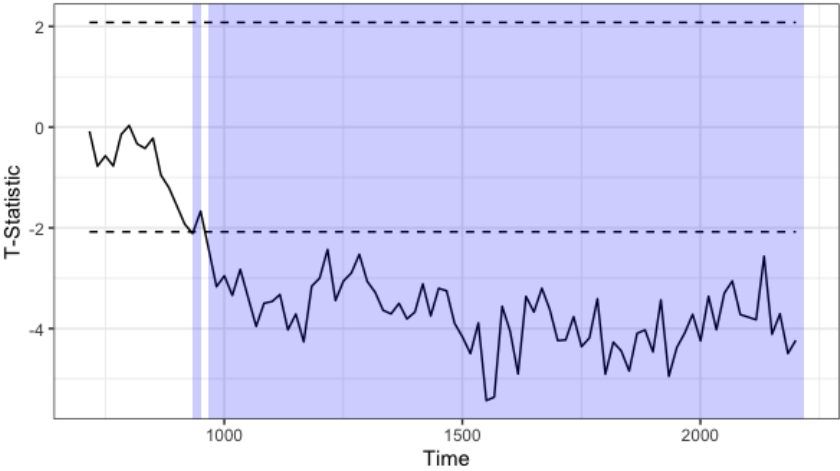
Cluster	Direction	SumStatistic	StartTime	EndTime	Probability
1	Negative	-278.1717	966.86	2217.11	$p < 0.001$



3) Average looks in Test trials vs. chance level (with noise term)

Test Type: t.test
Predictor: Predictor
Formula: Prop ~ Predictor
Null Distribution =====
Mean: 0.4912
2.5%: -24.3181
97.5%: 32.1918
Summary of Clusters =====

Cluster	Direction	SumStatistic	StartTime	EndTime	Probability
1	Negative	-2.112689	933.52	950.19	p = 0.512
2	Negative	-273.491493	966.86	2217.11	p < 0.001



4) Average looks in Baseline trials between conditions (C#C vs. (C#V)

Test Type: t.test

Predictor: Boundary

Formula: Prop ~ Boundary

Null Distribution =====

Mean: 0.2403

2.5%: -36.3871

97.5%: 36.3079

Summary of Clusters =====

Cluster	Direction	SumStatistic	StartTime	EndTime	Probability
0	NA	NA	NA	NA	NA

5) Average looks in Test trials: C#C vs. C#V

Test Type: t.test

Predictor: Predictor

Formula: Prop ~ Predictor

Null Distribution =====

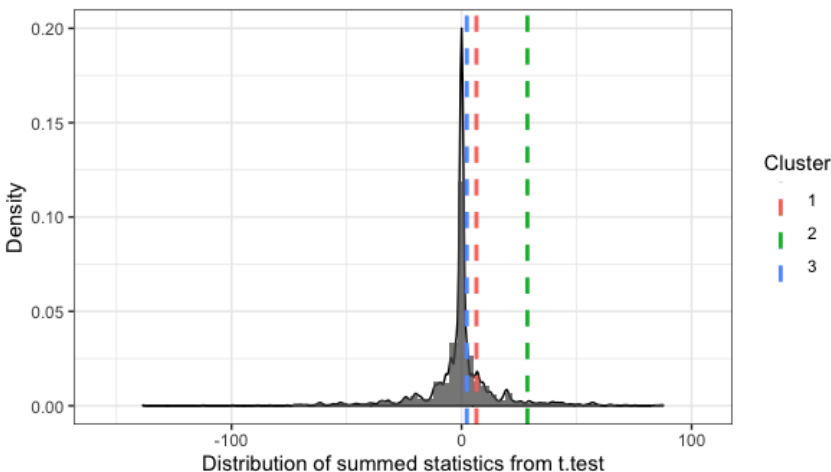
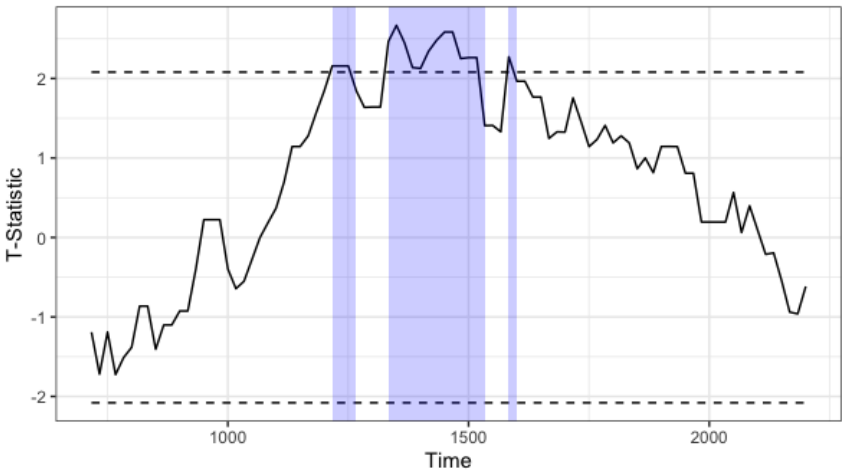
Mean: -0.5465

2.5%: -42.5542

97.5%: 40.1769

Summary of Clusters =====

Cluster	Direction	SumStatistic	StartTime	EndTime	Probability
1	Positive	6.471832	1216.91	1266.92	p = 0.3645
2	Positive	28.617204	1333.60	1533.64	p = 0.0940
3	Positive	2.272300	1583.65	1600.32	p = 0.5355



6) Average looks in Test trials: V#C vs. V#V

Test Type: t.test

Predictor: Predictor

Formula: Prop ~ Predictor

Null Distribution =====

Mean: 0.9017

2.5%: -28.6136

97.5%: 39.0625

Summary of Clusters =====

Cluster	Direction	SumStatistic	StartTime	EndTime	Probability
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7) Average looks in Test trials: C#V vs. V#C

Test Type: t.test

Predictor: Predictor

Formula: Prop ~ Predictor

Null Distribution =====

Mean: 0.9017

2.5%: -28.6136

97.5%: 39.0625

Summary of Clusters =====

Cluster	Direction	SumStatistic	StartTime	EndTime	Probability
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8) Average looks in Test trials: C#V vs. V#V

Test Type: t.test

Predictor: Predictor

Formula: Prop ~ Predictor

Null Distribution =====

Mean: 0.9017

2.5%: -28.6136

97.5%: 39.0625

Summary of Clusters =====

Cluster	Direction	SumStatistic	StartTime	EndTime	Probability
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