

Overview

Pre- vs. Post-Switch

Mixed-Same vs. Mixed-Switch

Pre-Switch vs. Mixed-Same

# SwitchingCues

Created by Ron Pomper

on 3/16/2021

```
sessionInfo()
```

```
## R version 3.6.1 (2019-07-05)
## Platform: x86_64-apple-darwin15.6.0 (64-bit)
## Running under: macOS 10.16
##
## Matrix products: default
## BLAS: /Library/Frameworks/R.framework/Versions/3.6/Resources/lib/libRblas.0.dylib
## LAPACK: /Library/Frameworks/R.framework/Versions/3.6/Resources/lib/libRlapack.dylib
##
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## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
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## attached base packages:
## [1] graphics grDevices utils datasets stats
##      methods base
##
## other attached packages:
## [1] kableExtra_1.2.1 car_3.0-3 dplyr_1.0.2
##      pbkrtest_0.4-7
## [5] AICcmodavg_2.2-2 readr_1.3.1 knitr_1.25
##      beep_1.3
## [9] tidyr_1.0.0 reshape2_1.4.3 plyr_1.8.4
##      lme4_1.1-21
## [13] Matrix_1.2-17 effects_4.1-2 carData_3.0-2
##      lmSupport_2.9.13
## [17] ggplot2_3.2.1 pwr_1.2-2
##
## loaded via a namespace (and not attached):
## [1] nlme_3.1-140 bitops_1.0-6 webshot_0.5.2
## [4] httr_1.4.1 tools_3.6.1 R6_2.4.1
## [7] KernSmooth_2.23-15 DBI_1.0.0 lazyeval_0.2.2
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```

```

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## [19] rvest_0.3.6        xml2_1.2.2        unmarked
_0.12-3
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0.8-71
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0.5.0
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er_1.1.0
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## [73] openxlsx_4.1.0.1    xtable_1.8-4      survey_3
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## [76] survival_2.44-1.1  viridisLite_0.3.0 audio_0.
1-6
## [79] tibble_2.1.3

```

# Overview

5-year-old children completed a modified version of the looking-while-listening (LWL) task from Pomper & Saffran (2016). On each trial, children were shown pictures of two familiar objects and heard a sentence identifying one using either its color or name. Trials were blocked so that there were 8 trials using one dimension (pre-switch), 8 using the other dimension (post-switch), and 16 with both dimensions interspersed (mixed). In the mixed block trials were organized such that 8 were the same dimension as the previous trial (same) and 8 were a different dimension (switch).

In addition to the LWL task, children also completed the DCCS, Flanker, and N-back tasks (from Kaushanskaya, Park, Gangopadhyay, Davidson, & Ellis Weismer, 2017).

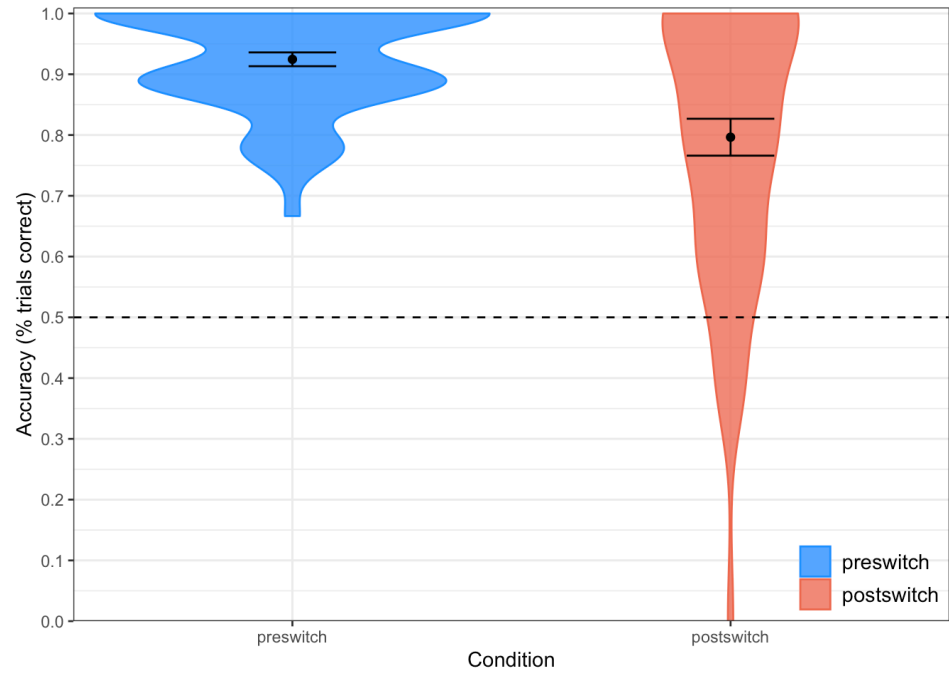
In the DCCS task, there were 4 blocks: training (sort by color, untimed), Preswitch (sort by color), Postswitch (sort by shape), Mixed (sort by both). There were 5 Preswitch, 5 Postswitch, and 30 Mixed trials. Of the 30 Mixed trials, 17 were Same (dimension same as the previous trial) and 13 were Switch (dimension changed from the previous trial).

In the Flanker task, there were 3 trial types: Congruent, Incongruent, Neutral. There were 6 untimed training trials (all types) and 6 timed training trials (all types). There were 48 test trials: 24 Consistent, 12 Inconsistent, and 12 Neutral.

In the 1-back task, there were 6 timed training trials and 40 test trials (10 trials where the shape matched the previous trial; 30 trials where the shape did not match the previous trial).

## EF Data

### Manipulation Check

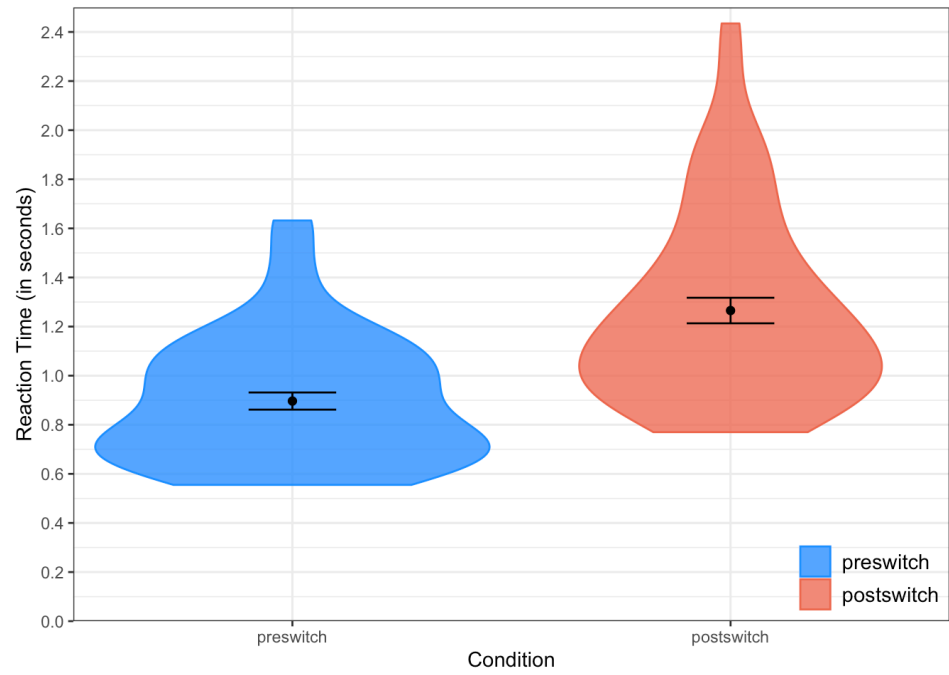


**Figure S1** Children's accuracy on preswitch (blue) and postswitch (red) trials in the DCCS. Data points are accuracies averaged across children. Error bars are  $\pm 1$  SE. Violins show the distribution of accuracies across children.

Condition	Accuracy	min	max	SD	SE
postswitch	0.796	0.000	1	0.227	0.030
preswitch	0.925	0.667	1	0.085	0.011

```
##
## One Sample t-test
##
## data:  stat$Diff
## t = 4.1688, df = 55, p-value = 0.0001093
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  0.06655802 0.18979119
## sample estimates:
## mean of x
## 0.1281746
```

Children were significantly more accurate on preswitch trials ( $M=0.92$ ,  $SD=0.09$ ), compared postswitch trials ( $M=0.8$ ,  $SD=0.23$ ) in the DCCS.



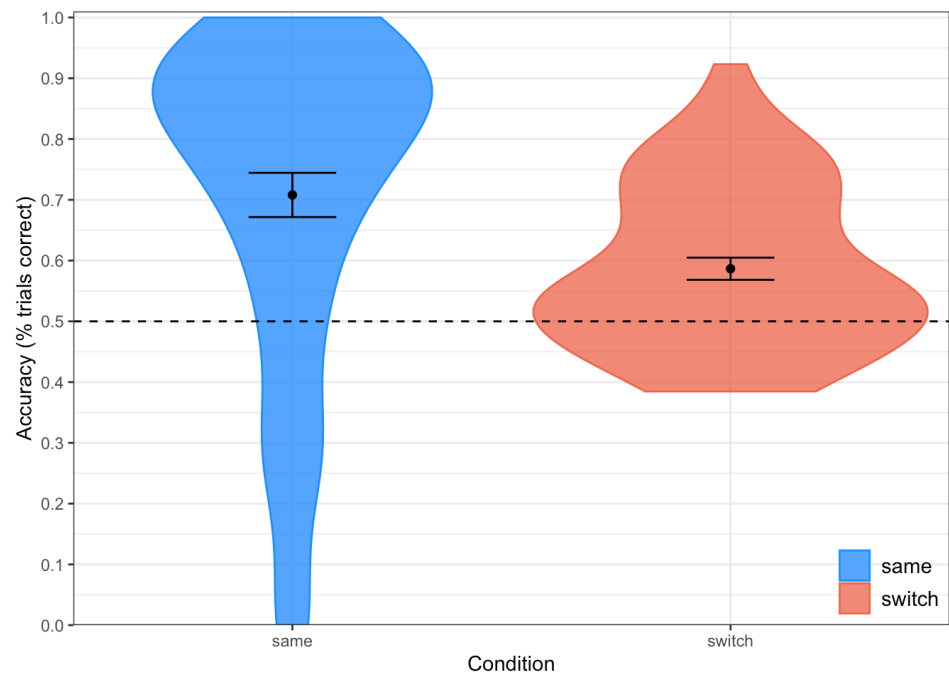
**Figure S2** Children's latency to respond on pre-switch (blue) and post-switch (red) trials in the DCCS. Data points are latencies averaged across children. Error bars are  $\pm 1$  SE. Violins show the distribution of latencies across children.

Note: this only includes RTs for trials where the child answered correctly and RTs that were less than 2 SD below/above the mean for each child.

Condition	RT	min	max	SD	SE
postswitch	1.265	0.770	2.435	0.386	0.052
pre-switch	0.897	0.555	1.632	0.261	0.035

```
##
## One Sample t-test
##
## data:  stat$Diff
## t = 6.57, df = 54, p-value = 0.00000002054
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  0.2559680 0.4807975
## sample estimates:
## mean of x
## 0.3683827
```

Children were also significantly faster on preswitch trials ( $M=0.897$ ,  $SD=0.26$ ) compared postswitch trials in the DCCS ( $M=1.265$ ,  $SD=0.39$ ). One participant (543) is dropped from the analyses, because they did not answer any of the postswitch trials correctly.

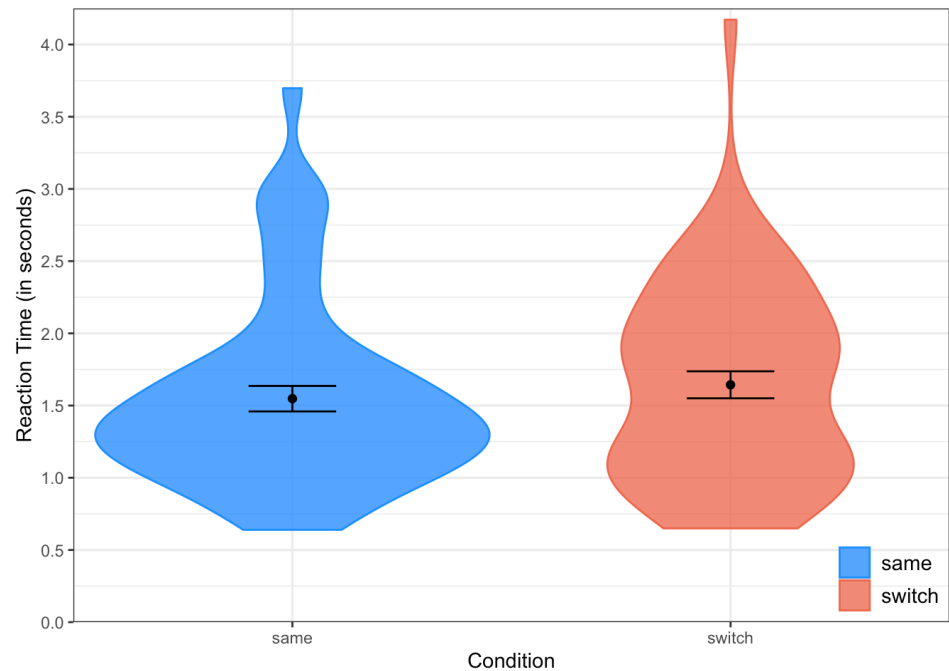


**Figure S3** Children's accuracy on same (blue) and switch (red) trials in the mixed block of the DCCS. Data points are accuracies averaged across children. Error bars are  $\pm 1$  SE. Violins show the distribution of accuracies across children.

Condition	Accuracy	min	max	SD	SE
same	0.708	0.000	1.000	0.273	0.036
switch	0.587	0.385	0.923	0.136	0.018

```
##
## One Sample t-test
##
## data:  stat$Diff
## t = 3.346, df = 55, p-value = 0.001483
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  0.04870615 0.19418331
## sample estimates:
## mean of x
## 0.1214447
```

Children were significantly more accurate on same trials ( $M=0.71$ ,  $SD=0.27$ ), compared switch trials ( $M=0.59$ ,  $SD=0.14$ ) in the mixed block of the DCCS.



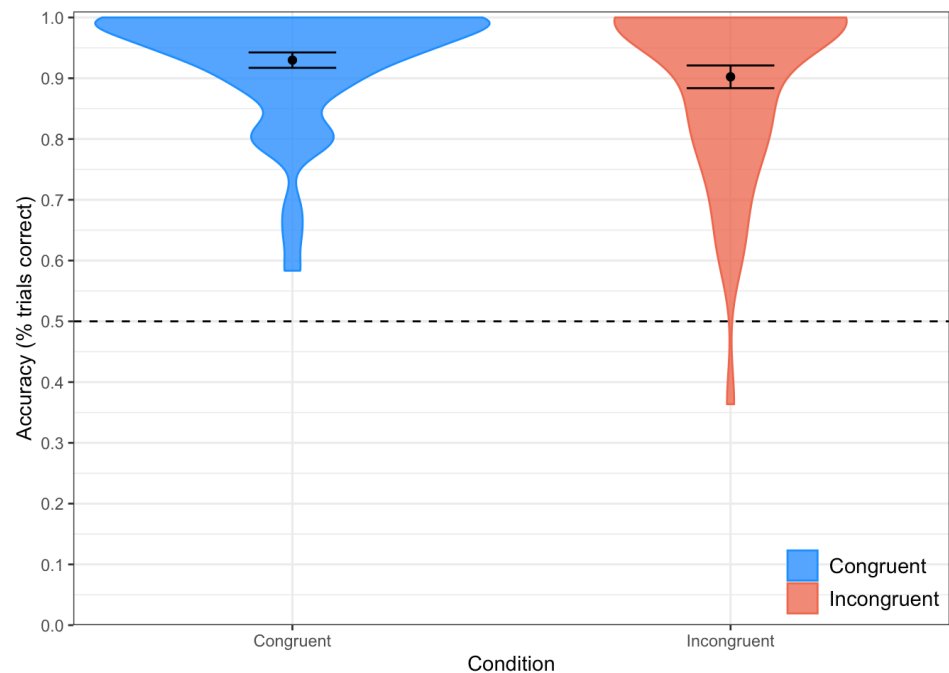
**Figure S4** Children's latency to respond on same (blue) and switch (red) trials in the mixed block of the DCCS. Data points are latencies averaged across children. Error bars are  $\pm 1$  SE. Violins show the distribution of latencies across children.

Note: this only includes RTs for trials where the child answered correctly and RTs that were less than 2 SD above the mean for each child.

Condition	RT	min	max	SD	SE
same	1.548	0.639	3.697	0.649	0.088
switch	1.644	0.649	4.172	0.699	0.093

```
##
## One Sample t-test
##
## data:  stat$Diff
## t = 2.0968, df = 53, p-value = 0.0408
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  0.005507998 0.248211842
## sample estimates:
## mean of x
## 0.1268599
```

Children were also significantly faster on same ( $M=1.55$ ,  $SD=0.65$ ), compared switch trials ( $M=1.64$ ,  $SD=0.7$ ) in the mixed block of the DCCS.



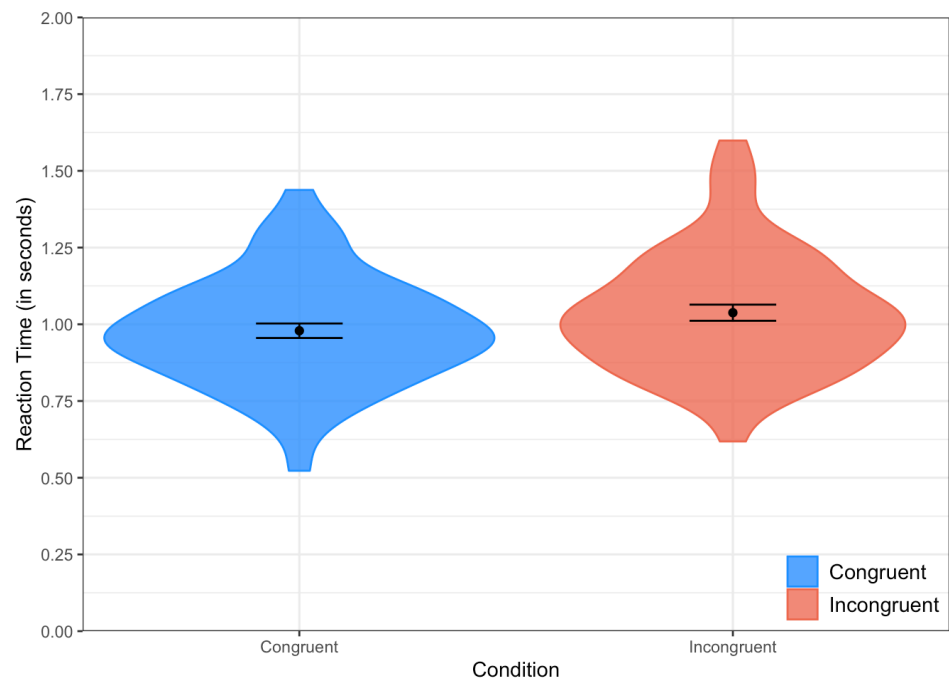
**Figure S5** Children's accuracy on Congruent (blue) and Incongruent (red) trials in the Flanker task. Data points are accuracies averaged across children. Error bars are  $\pm 1$  SE. Violins show the distribution of accuracies across children.

Condition	Accuracy	min	max	SD	SE
Congruent	0.930	0.583	1	0.095	0.013
Incongruent	0.902	0.364	1	0.140	0.019



```
##
## One Sample t-test
##
## data:  stat$Diff
## t = 1.7779, df = 55, p-value = 0.08095
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
## -0.003490799  0.058377522
## sample estimates:
## mean of x
## 0.02744336
```

Children were marginally more accurate on congruent ( $M=0.93$ ,  $SD=0.09$ ) compared to incongruent trials ( $M=0.9$ ,  $SD=0.14$ ) in the Flanker task.



**Figure S6** Children's latency to respond on Congruent (blue) and Incongruent (red) trials in the Flanker task. Data points are latencies averaged across children. Error bars are +/- 1 SE. Violins show the distribution of latencies across children.

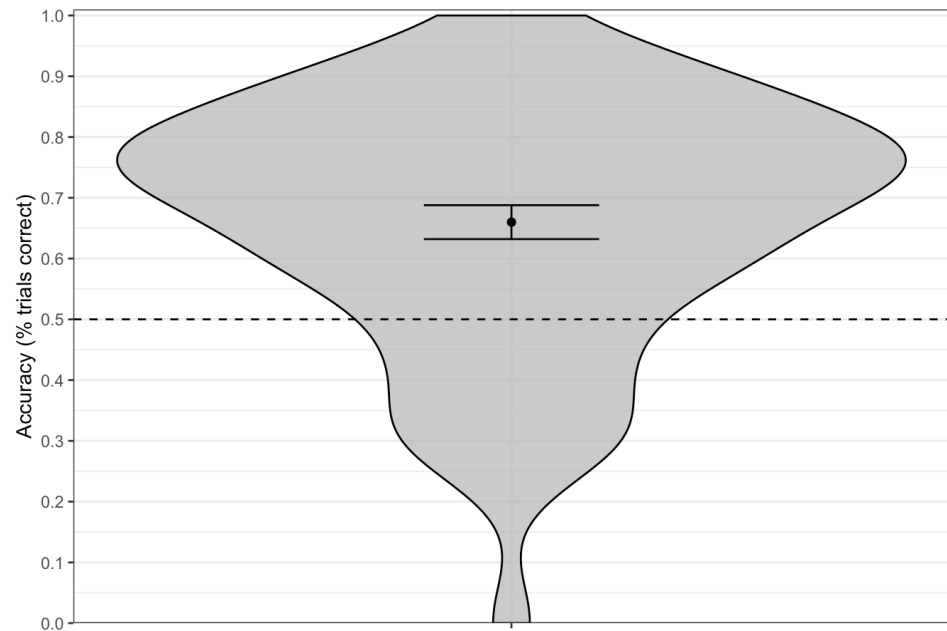
Note: this only includes RTs for trials where the child answered correctly and RTs that were less than 2 SD below/above the mean for each child.

Condition	RT	min	max	SD	SE
Congruent	0.979	0.523	1.438	0.177	0.024

Incongruent 1.038 0.618 1.599 0.197 0.026

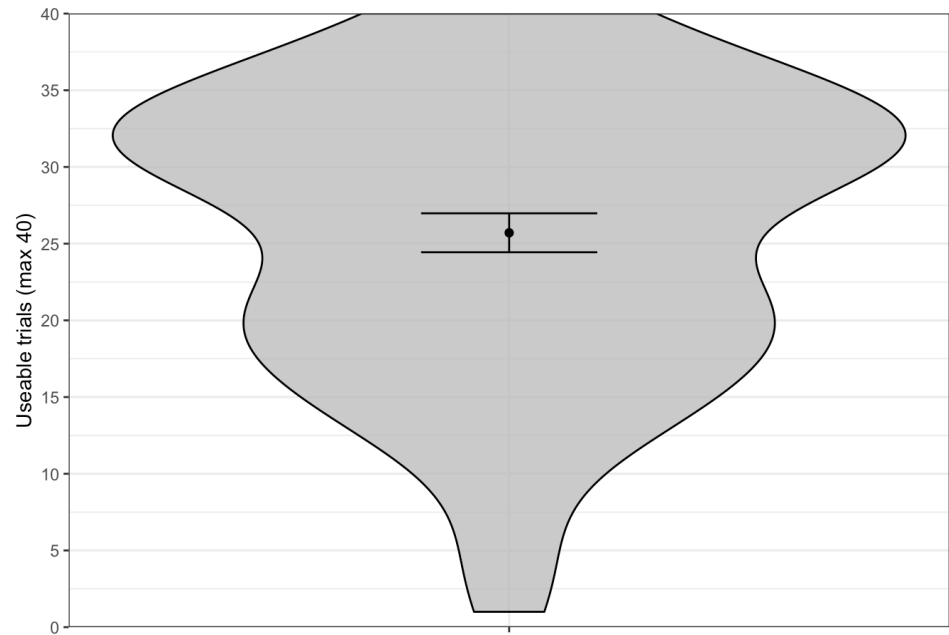
```
##
## One Sample t-test
##
## data:  stat$Diff
## t = 4.1402, df = 55, p-value = 0.0001202
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  0.03031276 0.08718831
## sample estimates:
## mean of x
## 0.05875054
```

Children were significantly faster on congruent ( $M=0.979$ ,  $SD=0.18$ ) compared to incongruent trials ( $M=1.038$ ,  $SD=0.2$ ) in the Flanker task.



**Figure S7** Children's accuracy on all trials in the 1-back task. Data points are accuracies averaged across children. Error bars are  $\pm 1$  SE. Violins show the distribution of accuracies across children.

Accuracy	min	max	SD	SE
0.66	0	1	0.207	0.028

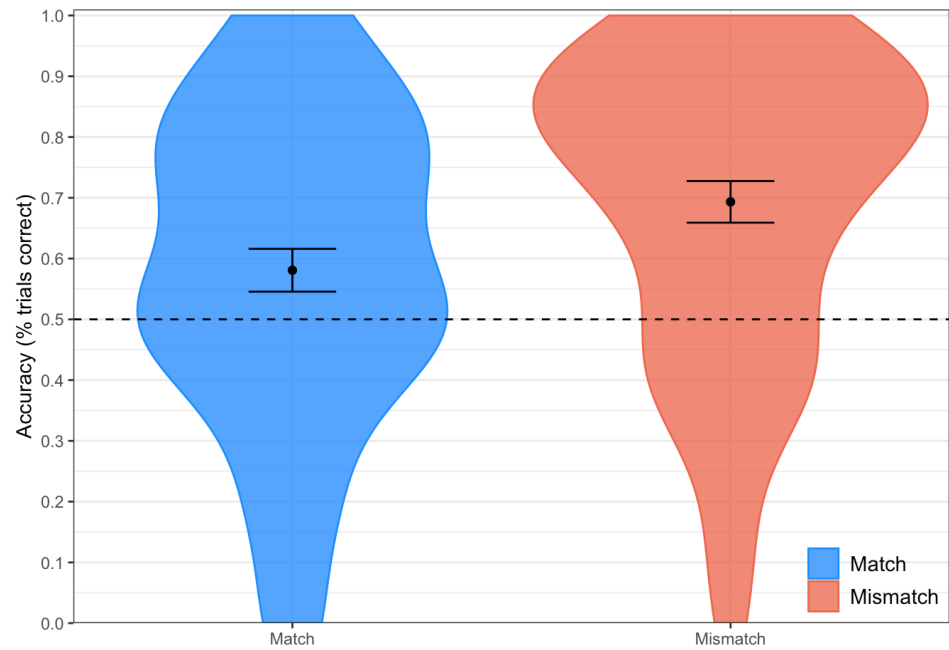


**Figure S8** The proportion of trials with a response in the 1-back task. Data points are proportions averaged across children. Error bars are  $\pm 1$  SE. Violins show the distribution of proportions across children.

On average, children did not respond in time for 14.2909091 trials (35.73%) out of the 40 total test trials.

useable	min	max	SD	SE
25.709	1	40	9.406	1.268

Recall, there are 10 trials that match. 1 subject did not have any useable Match trials (their accuracy was manually coded as 0)



**Figure S9** Children's accuracy on trials that Match (in blue) and Mismatch (in red) the preceding trial stimulus in the 1-back task. Data points are accuracies averaged across children. Error bars are +/- 1 SE. Violins show the distribution of accuracies across children.

	Accuracy	min	max	SD	SE
Match	0.581	0	1	0.261	0.035
Mismatch	0.693	0	1	0.254	0.034

```
##
## One Sample t-test
##
## data:  stat$Diff
## t = 2.6012, df = 53, p-value = 0.01201
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  0.02623085 0.20293164
## sample estimates:
## mean of x
## 0.1145812
```

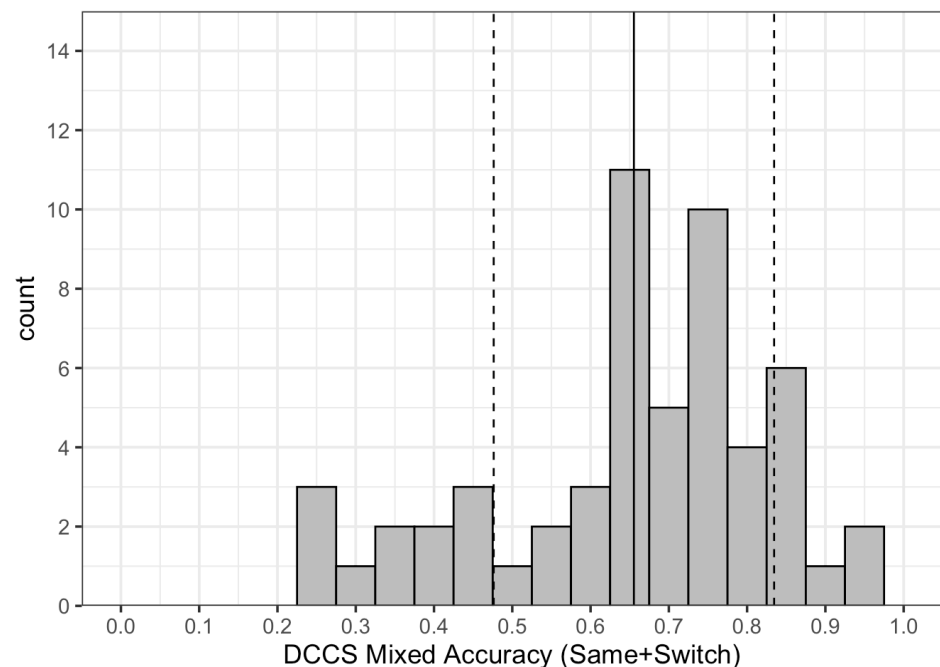
Children were significantly more accurate in correctly identifying Mismatch trials ( $M=0.69$ ,  $SD=0.25$ ), compared to Match trials ( $M=0.58$ ,  $SD=0.26$ ) in the 1-back.

## Indices

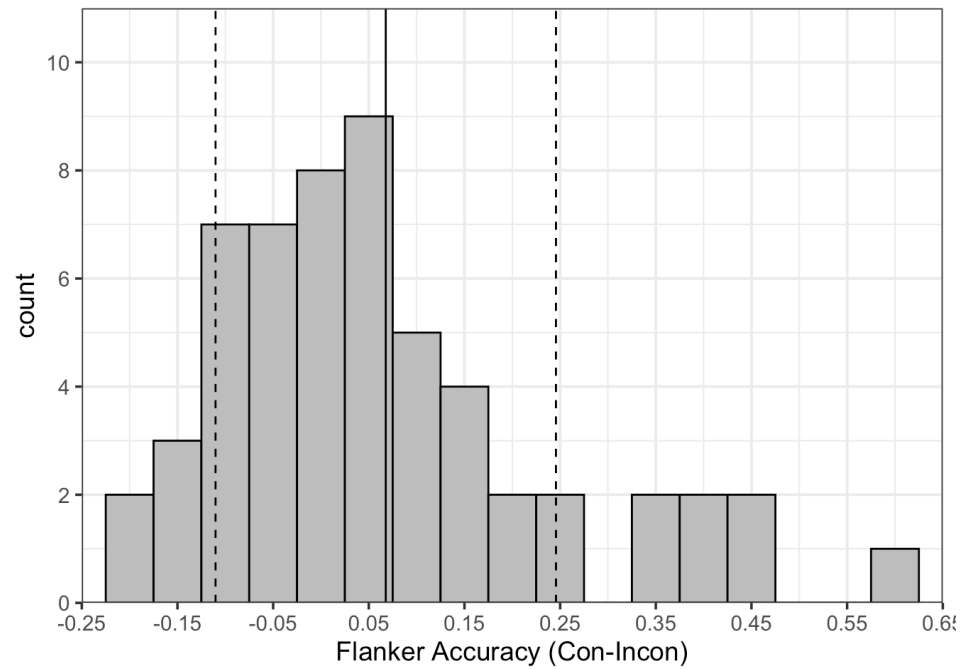
For each of the offline tasks, there were several trial types and response measures (i.e., accuracy vs. RT). Therefore, there are multiple indices of EF that could be used. For each measure, we chose an index that was approximately normally distributed and conceptually relevant (i.e., comparing the change in children's on Incongruent compared to Congruent trials in the Flanker task).

- For **DCCS**, children's accuracy on all trials (Same+Switch) in the Mixed block
- For **Flanker**, children's accuracy difference between Incongruent compared to Congruent trials (Incon-Con)
- For the **1-back**, there is nothing, because the task was too difficult for this age range (trials advanced too quickly) and many children did not respond in time.

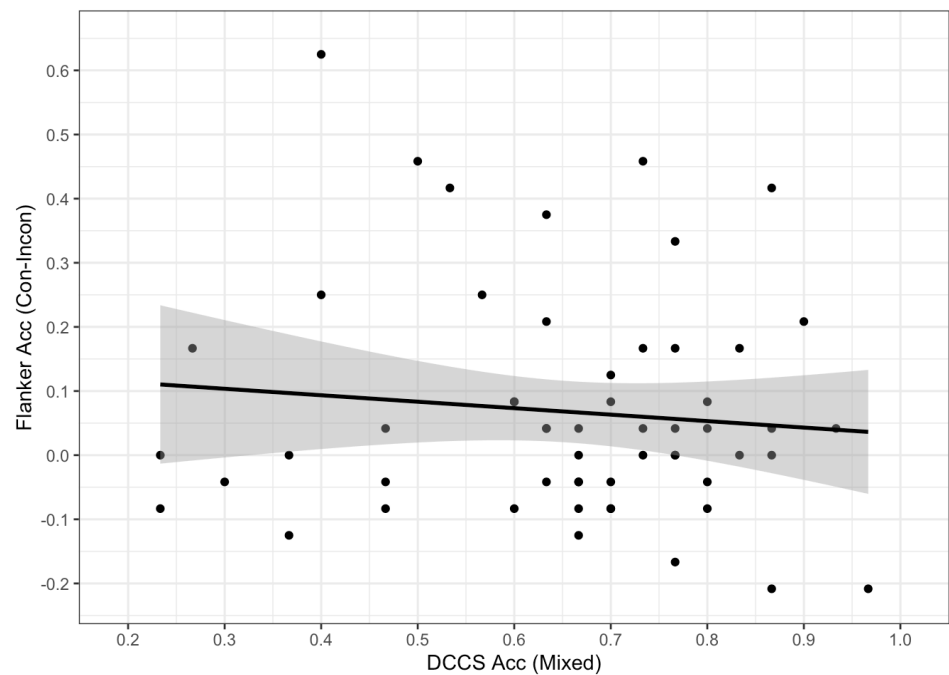
Below are plots of 1) distribution of the different indices and 2) correlations between the indices.



**Figure S10** Histogram plotting the distribution of accuracies in the Mixed Block of the DCCS across children. The solid vertical line is the group average and the dashed vertical lines are +/- 1 SD. Note: we use these levels -1 SD, 0 SD, +1 SD above the mean when plotting effects of DCCS on children's language comprehension (GCAs below)



**Figure S11** Histogram plotting the distribution of differences in accuracy on Congruent vs. Incongruent trials in the Flanker task across children. The solid vertical line is the group average and the dashed vertical lines are  $\pm 1$  SD. Note: we use these levels  $-1$  SD,  $0$  SD,  $+1$  SD above the mean when plotting effects of DCCS on children's language comprehension (GCAs below)



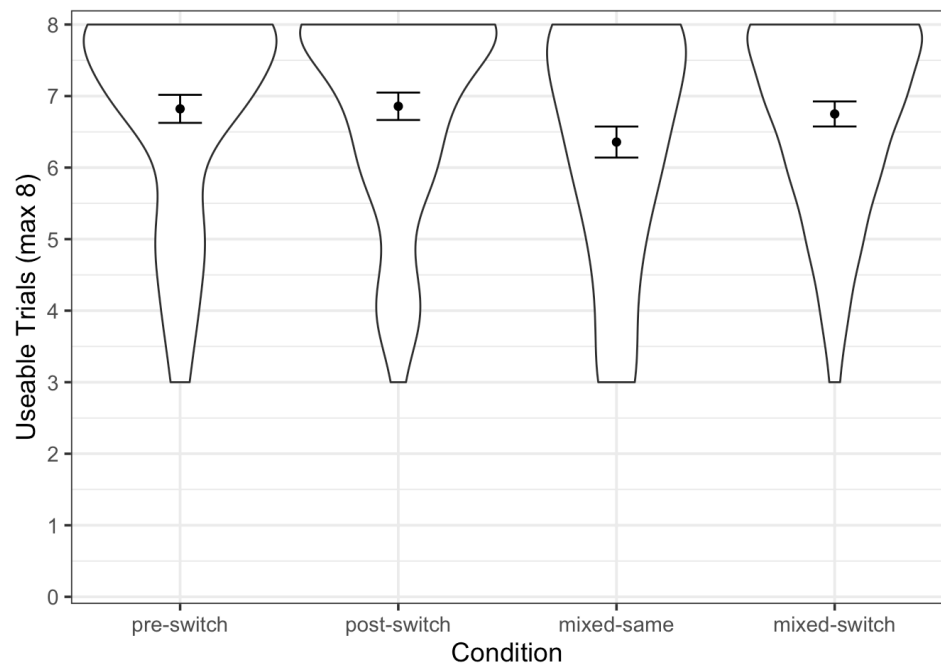
**Figure S12** Children's performance on the Flanker task as a function of their performance on the DCCS task. The solid black line represents the linear fit with gray ribbons  $\pm 1$  SE. Individual data points for each

child are plotted in black.

The different indices of EF are not highly correlated, which indicates that we are capturing different sources of variance in children's EF (i.e., different components of EF like shifting and inhibition). This also means we can include multiple indices of EF without problems due to colinearity.

## LWL Data

Although there were 8 trials in each condition (pre-switch, post-switch, mixed-same, mixed-switch), we filtered to remove trials where children were not looking at either object for more than 50% of the critical window (300 to 1800ms). Here are the number of trials after filtering:



**Figure S13** Number of useable trials per condition after filtering to remove trials where children were inattentive (i.e., not fixating either image for more than half of the critical window). Data points are the number of trials averaged across children. Error bars are  $\pm 1$  SE. Violins show the distribution of number of useable trials across children.

Condition	meanN	min	max	SD	SE
pre-switch	6.821	3	8	1.466	0.196
post-switch	6.857	3	8	1.432	0.191

mixed-same	6.357	3	8	1.623	0.217
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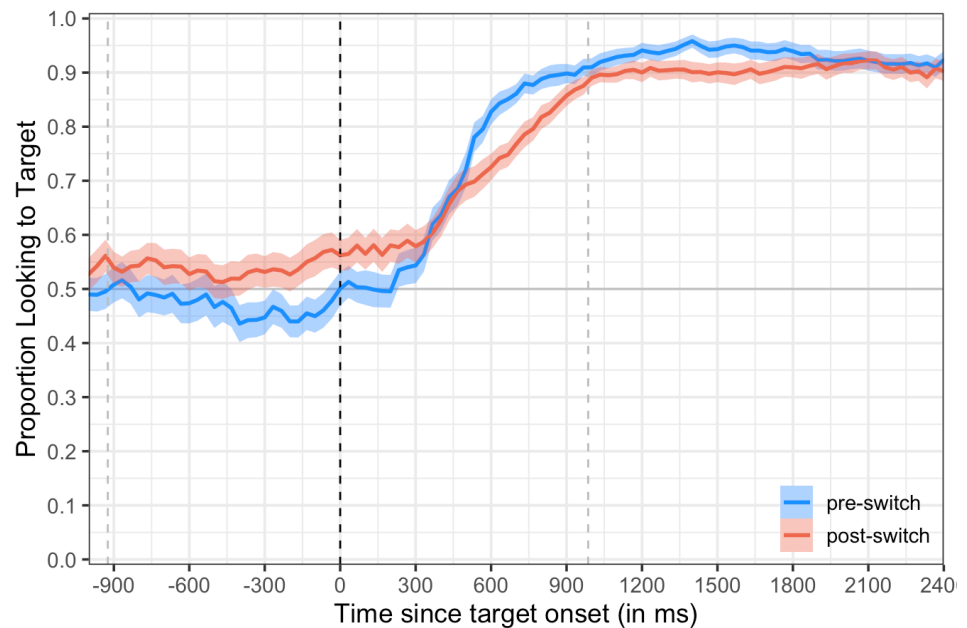
mixed-switch	6.750	3	8	1.311	0.175
--------------	-------	---	---	-------	-------

Note: one participant was dropped from the final sample, because after filtering this participant did not have any useable trials. Thus, our final sample includes 56 participants.

## Pre- vs. Post-Switch

### Time Course

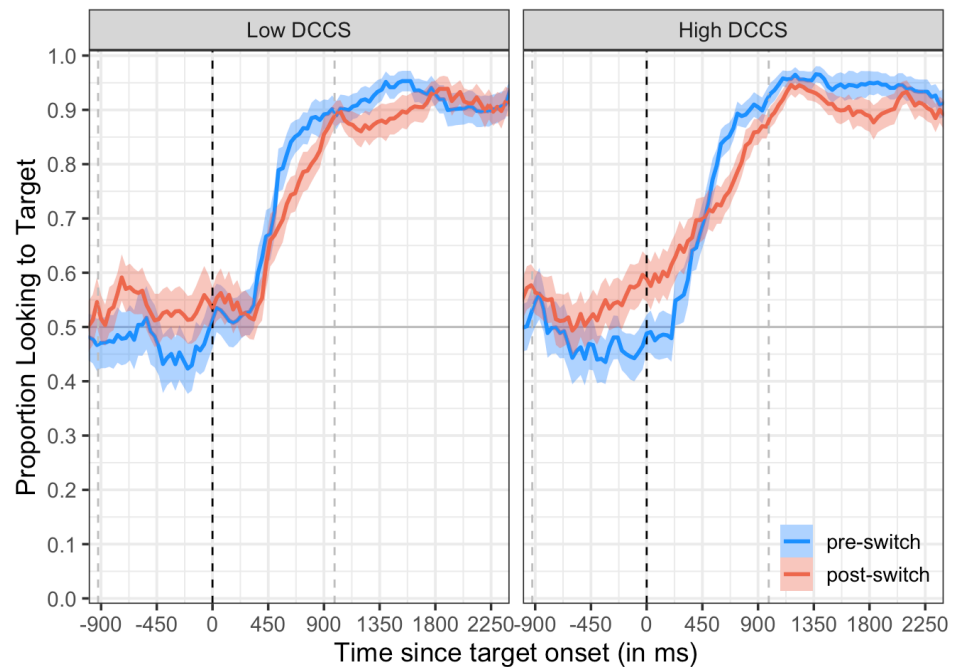
Here are time course plots of the changes in children's accuracy over time on trials in the Pre-Switch and Post-Switch blocks of the LWL task. These raw data are plotted for the entire group, median split based on the DCCS, and median split based on the Flanker.



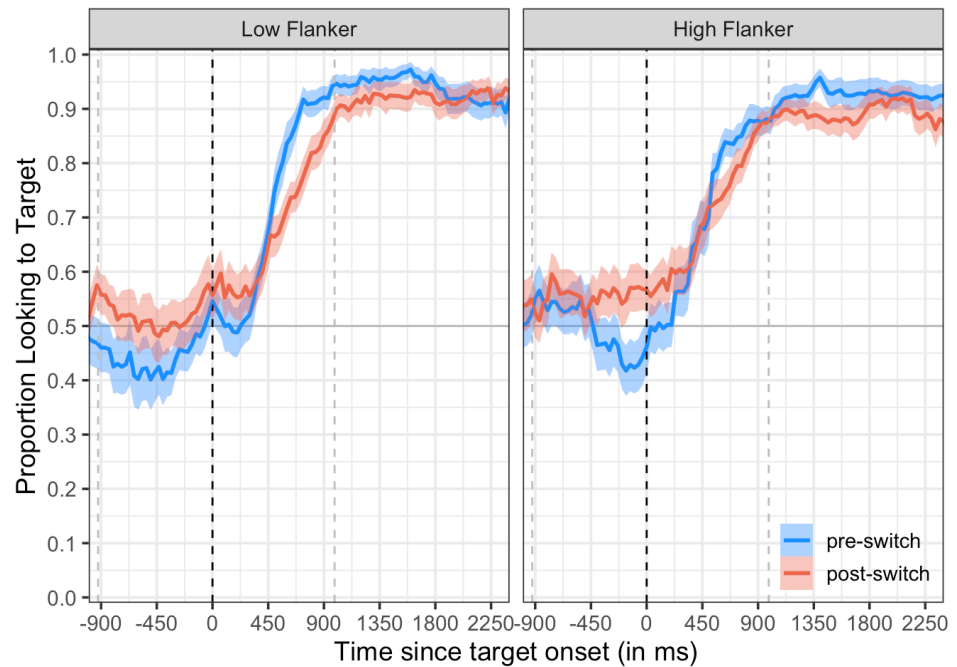
**Figure S14** Time course of changes in children's accuracy in fixating the target object over time for trials in the pre-switch (blue) and post-switch (red) blocks. Solid lines are children's accuracy in fixating the target image for each time frame (i.e., every 33 ms) averaged across trials within a condition and across children. Ribbons around the solid lines are  $\pm 1$  SE. The gray vertical dashed line at -924 ms indicates the onset of the carrier phrase (e.g., "Find the"), the black vertical



dashed line at 0 ms indicates the onset of the target word (e.g., “Sock”), and the gray vertical dashed line at 986 ms indicates the offset of the target word.



**Figure S15** Time course of changes in children’s accuracy in fixating the target object over time for trials in the pre-switch (blue) and post-switch (red) blocks. Children whose accuracy on the DCCS was below the median (0.68) are plotted in the left panel and children whose accuracy was above the median are plotted in the right panel. Solid lines are children’s accuracy in fixating the target image for each time frame (i.e., every 33 ms) averaged across trials within a condition and across children. Ribbons around the solid lines are  $\pm 1$  SE. The gray vertical dashed line at -924 ms indicates the onset of the carrier phrase (e.g., “Find the”), the black vertical dashed line at 0 ms indicates the onset of the target word (e.g., “Sock”), and the gray vertical dashed line at 986 ms indicates the offset of the target word.



**Figure S16** Time course of changes in children's accuracy in fixating the target object over time for trials in the pre-switch (blue) and post-switch (red) blocks. Children whose difference in accuracy on Congruent vs. Incongruent trials in the Flanker task was below the median (0.04) are plotted in the left panel and children whose difference in accuracy was above the median are plotted in the right panel. Solid lines are children's accuracy in fixating the target image for each time frame (i.e., every 33 ms) averaged across trials within a condition and across children. Ribbons around the solid lines are  $\pm 1$  SE. The gray vertical dashed line at -924 ms indicates the onset of the carrier phrase (e.g., "Find the"), the black vertical dashed line at 0 ms indicates the onset of the target word (e.g., "Sock"), and the gray vertical dashed line at 986 ms indicates the offset of the target word.

## GCA

Growth Curve Analysis (GCA) was used to quantify changes in the timecourse of children's word recognition accuracy during a critical window 300 to 1800 ms after the onset of the target word. Children's accuracy in fixating the target object was calculated as the empirical log odds of fixations to the target over fixations to the distractor at each time point (i.e., every 33 ms).

Time course changes were measured using the following orthogonal polynomial time terms:

- **intercept**, which quantifies overall accuracy (i.e., average across

the entire window)

- **linear**, which quantifies the average increase (i.e., slope of the line connecting accuracy from the onset to offset)
- **quadratic**, which quantifies the steepness of the peak in accuracy (i.e., more negative value means sharper inverted u-shape)
- **cubic**, which quantifies asymptotes in accuracy at the tails (i.e., delayed increase from chance at onset and maintained peak accuracy at offset)

Here is the full model specification:

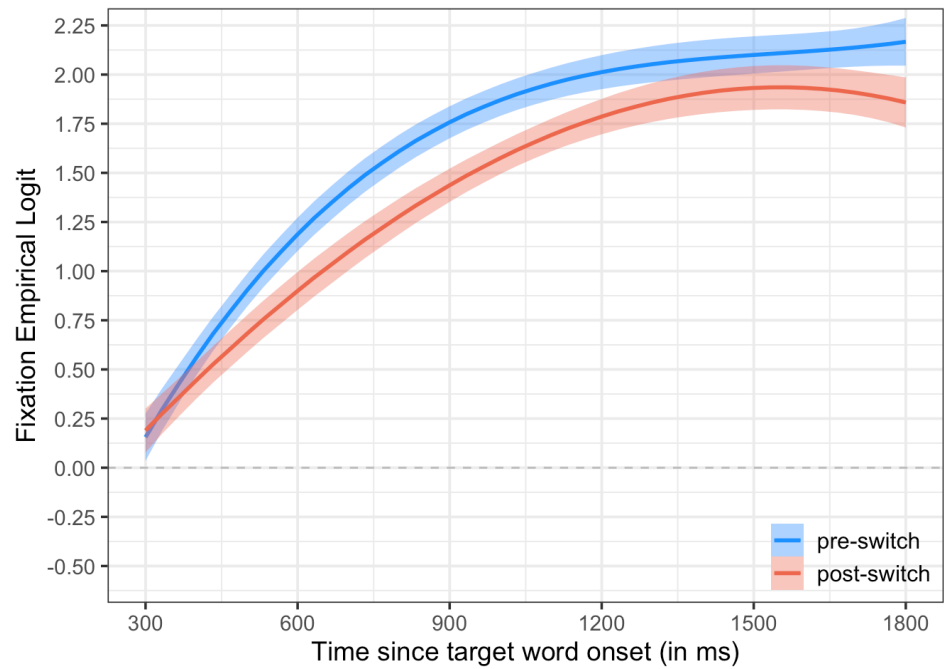
```
##
## pre-switch  -0.5
## post-switch  0.5
```

```
# m <- lmer(eolog ~ (ot1+ot2+ot3)*Condition*DCCS + (ot1
+ot2+ot3)*Condition*Flanker + ((ot1+ot2+ot3)*Condition
/Sub.Num), data=d.gca, weights=1/wts, control=lmerCont
rol(optimizer='bobyqa'),REML=FALSE)
```

Because it is computationally and theoretically difficult to estimate the degrees of freedom in mixed-effects models, we analyzed t-scores by assuming a Gaussian distribution; therefore, t-values  $> \pm 1.96$  are considered significant.

For ease in interpretability, we have separated the model results into different subsections with plots illustrating the significant or non-significant results.

## Effect of Condition



**Figure S17** (Figure 1 in manuscript) Time course of changes in children's accuracy in fixating the target object over time for trials in the pre-switch (blue) and post-switch (red) blocks. Solid lines are the growth curve model fits for a child with an average DCCS and Flanker score. The ribbons around the lines represent  $\pm 1$  SE. The dashed horizontal line at 0 is chance (i.e., equal likelihood of fixating to the target and the distractor object).

	Estimate	Std..Error	t.value	p.value	sig
(Intercept)	1.538	0.040	38.768	0.000	•
ot1	3.426	0.282	12.134	0.000	•
ot2	-1.442	0.185	-7.774	0.000	•
ot3	0.187	0.139	1.347	0.178	
Condition	-0.230	0.096	-2.399	0.016	•
ot1:Condition	-0.052	0.474	-0.109	0.914	
ot2:Condition	0.299	0.298	1.000	0.317	
ot3:Condition	-0.463	0.316	-1.463	0.144	

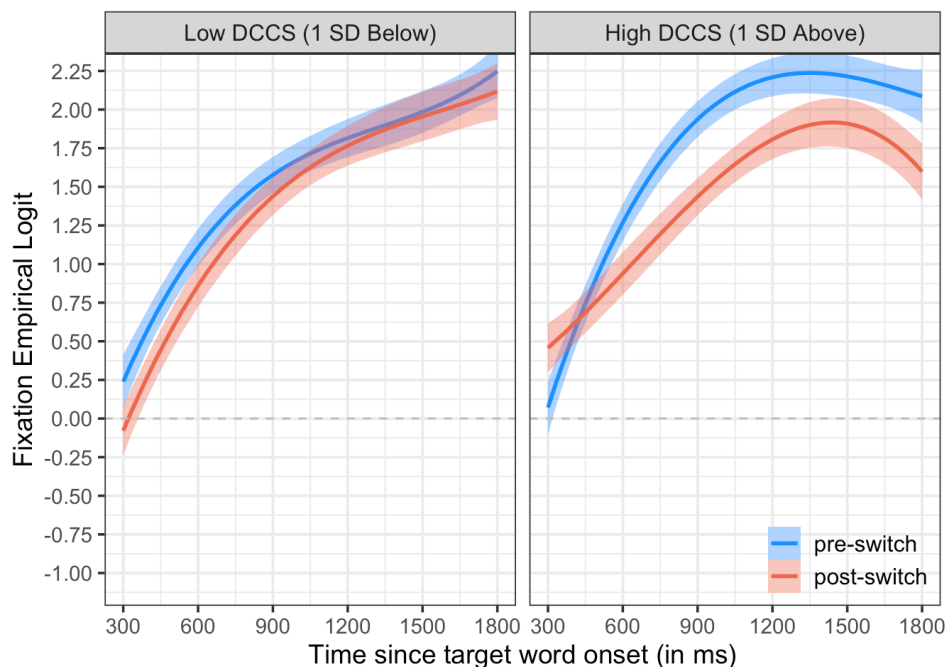
There's a significant effect of **Condition** on the following time terms:

- *intercept*,  $b=-0.23, p=0.016$

But not on any of the other time terms,  $p$ 's > 0.144

Children have overall higher accuracy in fixating the target object on trials before the dimensional switch (pre-switch  $b= 1.653$ ), compared to after the dimensional switch (post-switch  $b= 1.423$ ) trials.

## DCCS Moderation



**Figure S18** Time course of changes in children's accuracy in fixating the target object over time for trials in the pre-switch (blue) and post-switch (red) blocks. Solid lines are the growth curve model fits plotted in the left panel for a child with an average Flanker score and below average DCCS score (1 SD below mean, 0.48) and in the right panel for a child with average Flanker score and above average DCCS score (1 SD above mean, 0.83). The ribbons around the lines represent  $\pm 1$  SE. The dashed horizontal line at 0 is chance (i.e., equal likelihood of fixating to the target and the distractor object).

	Estimate	Std..Error	t.value	p.value	sig
DCCS	0.306	0.225	1.362	0.173	
ot1:DCCS	-1.371	1.600	-0.857	0.392	
ot2:DCCS	-1.699	1.051	-1.616	0.106	
ot3:DCCS	-1.140	0.788	-1.446	0.148	

Condition:DCCS	-0.522	0.542	-0.964	0.335
ot1:Condition:DCCS	-3.509	2.690	-1.305	0.192
ot2:Condition:DCCS	3.261	1.693	1.926	0.054
ot3:Condition:DCCS	-1.761	1.795	-0.982	0.326

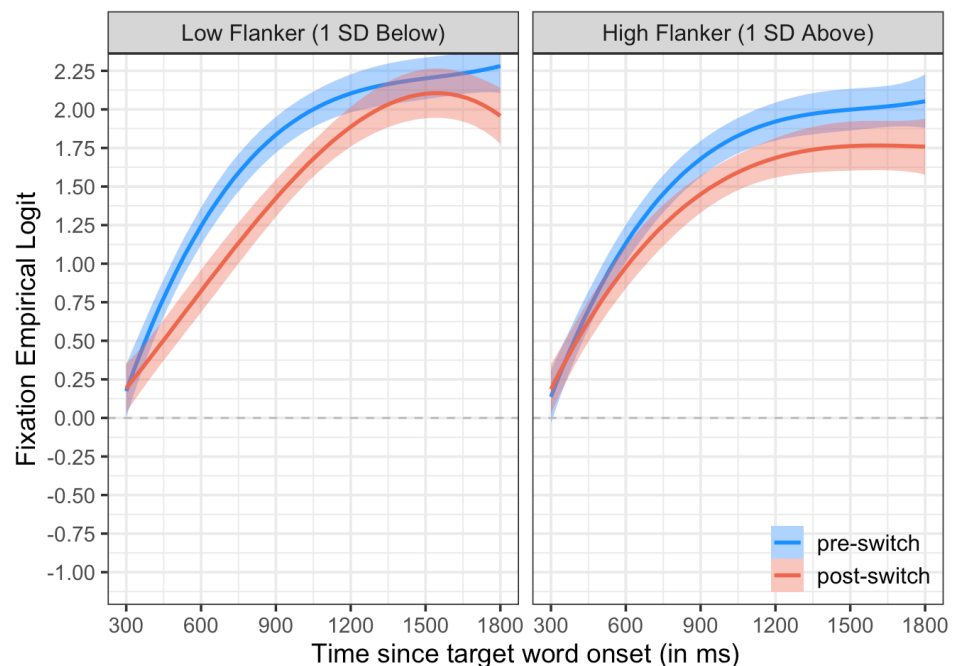
There is *NOT* a significant effect of **DCCS** for any of the time terms ( $p$ 's > 0.106).

Nor is the effect of **Condition moderated by DCCS** for any of the time terms ( $p$ 's > 0.054).

There is a marginal effect of **ot2:Condition:DCCS**,  $b=3.261$ ,  $p=0.054$ . The peak in children's accuracy is steeper (i.e., more negative) for pre-switch -1.5915 compared to post-switch -1.2925 trials, although this effect of Condition on quadratic time is *not* significant at the group level,  $b=0.299$ ,  $p=0.317$ . The marginal effect of the three-way interaction suggests that the effect of Condition on quadratic time is larger for children with stronger EFs ( $b=0.8831833$ ) compared to children with weaker EFs ( $b=-0.2851833$ ).

Individual differences in children's ability to shift their attention (measured using the DCCS) are *not* associated with their word recognition accuracy nor are they associated with the degree to which their word recognition accuracy is affected by a dimensional shift.

## Flanker Moderation



**Figure S19** Time course of changes in children's accuracy in fixating the target object over time for trials in the pre-switch (blue) and post-switch (red) blocks. Solid lines are the growth curve model fits plotted in the left panel for a child with an average DCCS score and below average Flanker score (-0.11) and in the right panel for a child with average DCCS score and above average Flanker score (0.25). The ribbons around the lines represent +/- 1 SE. The dashed horizontal line at 0 is chance (i.e., equal likelihood of fixating to the target and the distractor object).

	Estimate	Std..Error	t.value	p.value	sig
Flanker	0.351	0.226	1.553	0.120	
ot1:Flanker	2.050	1.609	1.274	0.203	
ot2:Flanker	-0.065	1.057	-0.062	0.951	
ot3:Flanker	-0.707	0.791	-0.894	0.371	
Condition:Flanker	-0.182	0.545	-0.334	0.738	
ot1:Condition:Flanker	2.211	2.704	0.818	0.414	
ot2:Condition:Flanker	0.321	1.701	0.189	0.850	
ot3:Condition:Flanker	-1.604	1.802	-0.890	0.374	

There is *NOT* a significant effect of **Flanker** for any of the time terms ( $p$ 's > 0.12).

Nor is the effect of **Condition moderated by DCCS** for any of the time terms ( $p$ 's > 0.374).

Individual differences in children's ability to inhibit their attention (measured using the Flanker) are *not* associated with their word recognition accuracy nor are they associated with the degree to which their word recognition accuracy is affected by a dimensional shift.

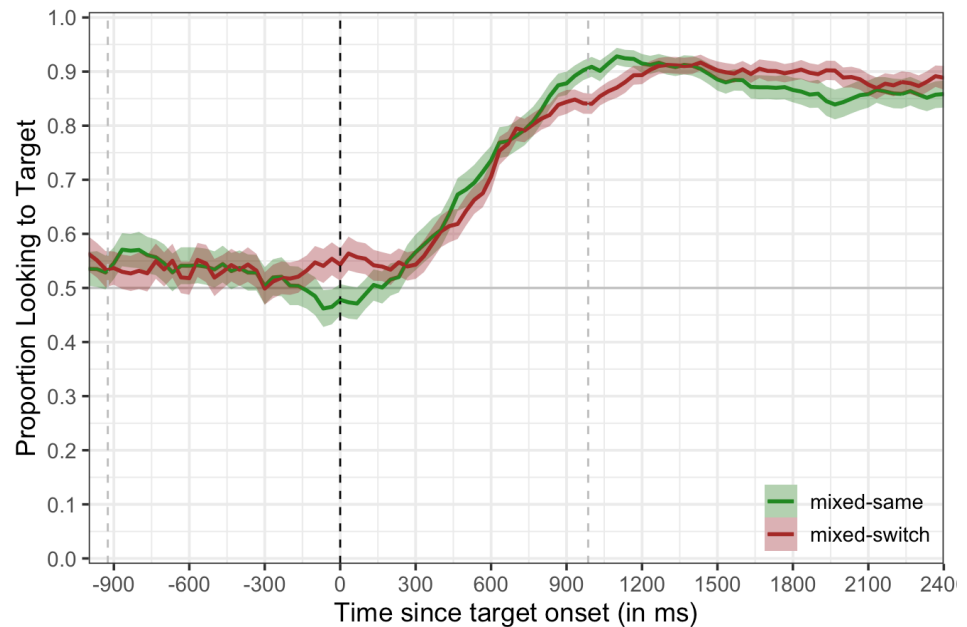
## Summary

Taken together, these results indicate that children are less accurate on post-switch, compared to pre-switch trials. However, this does not seem to be associated with individual differences in EF.

## Mixed-Same vs. Mixed-Switch

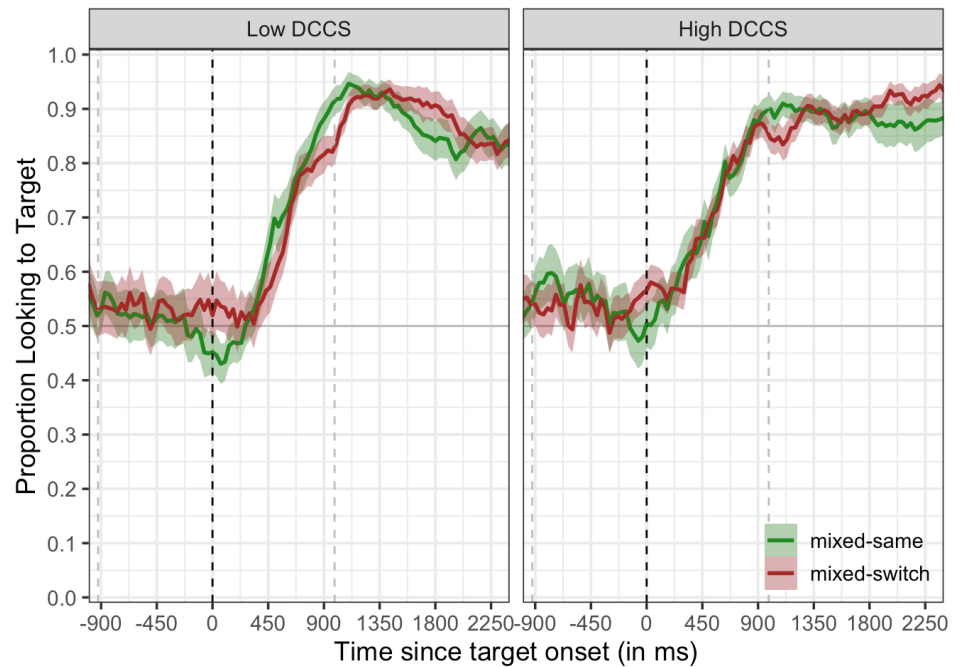
## Time Course

Here are time course plots of the changes in children's accuracy over time on trials in the Mixed Block of the LWL task, both when the dimension was the same as the previous trial (Mixed-Same) and when it switched (Mixed-Switch). These raw data are plotted for the entire group, median split based on the DCCS, and median split based on the Flanker.

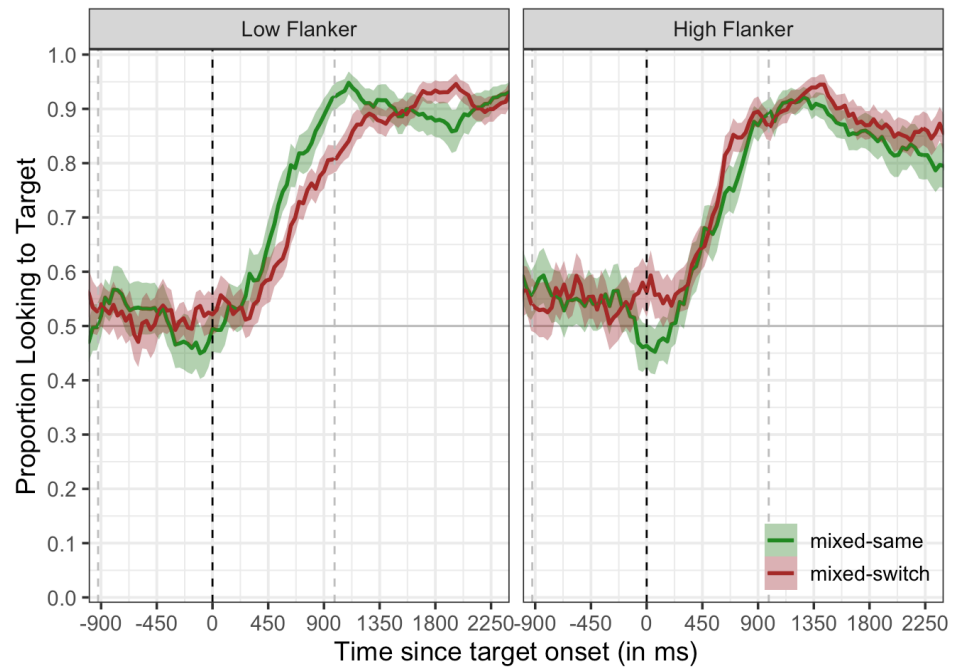


**Figure S20** Time course of changes in children's accuracy in fixating the target object over time for trials where the dimension is the same as the preceding trial (mixed-same; green) and different from the preceding trial (mixed-switch; brown) in the Mixed block. Solid lines are children's accuracy in fixating the target image for each time frame (i.e., every 33 ms) averaged across trials within a condition and across children. Ribbons around the solid lines are  $\pm 1$  SE. The gray vertical dashed line at -924 ms indicates the onset of the carrier phrase (e.g., "Find the"), the black vertical dashed line at 0 ms indicates the onset of the target word (e.g., "Sock"), and the gray vertical dashed line at 986 ms indicates the offset of the target word.





**Figure S21** Time course of changes in children's accuracy in fixating the target object over time for trials where the dimension is the same as the preceding trial (mixed-same; green) and different from the preceding trial (mixed-switch; brown) in the Mixed block. Children whose accuracy on the DCCS was below the median (0.68) are plotted in the left panel and children whose accuracy was above the median are plotted in the right panel. Solid lines are children's accuracy in fixating the target image for each time frame (i.e., every 33 ms) averaged across trials within a condition and across children. Ribbons around the solid lines are  $\pm 1$  SE. The gray vertical dashed line at -924 ms indicates the onset of the carrier phrase (e.g., "Find the"), the black vertical dashed line at 0 ms indicates the onset of the target word (e.g., "Sock"), and the gray vertical dashed line at 986 ms indicates the offset of the target word.



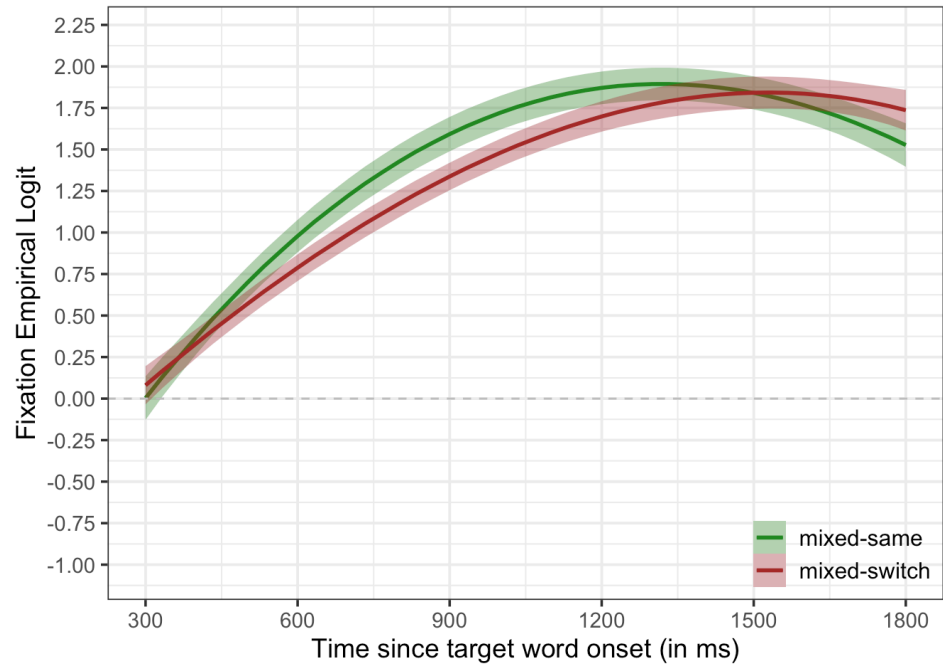
**Figure S22** Time course of changes in children's accuracy in fixating the target object over time for trials where the dimension is the same as the preceding trial (mixed-same; green) and different from the preceding trial (mixed-switch; brown) in the Mixed block. Children whose difference in accuracy on Congruent vs. Incongruent trials in the Flanker task was below the median (0.04) are plotted in the left panel and children whose difference in accuracy was above the median are plotted in the right panel. Solid lines are children's accuracy in fixating the target image for each time frame (i.e., every 33 ms) averaged across trials within a condition and across children. Ribbons around the solid lines are  $\pm 1$  SE. The gray vertical dashed line at -924 ms indicates the onset of the carrier phrase (e.g., "Find the"), the black vertical dashed line at 0 ms indicates the onset of the target word (e.g., "Sock"), and the gray vertical dashed line at 986 ms indicates the offset of the target word.

## GCA

```
##
## mixed-same    -0.5
## mixed-switch   0.5
```

```
# m.mixed <- lmer(elog ~ (ot1+ot2+ot3)*Condition*DCCS
+ (ot1+ot2+ot3)*Condition*Flanker + ((ot1+ot2+ot3)*Con
dition/Sub.Num), data=d.gca, weights=1/wts, control=lme
rControl(optimizer='bobyqa'),REML=FALSE)
```

## Effect of Condition



**Figure S23** (Figure 2 in manuscript) Time course of changes in children's accuracy in fixating the target object over time for trials where the dimension is the same as the preceding trial (mixed-same; green) and different from the preceding trial (mixed-switch; brown) in the Mixed block. Solid lines are the growth curve model fits for a child with an average DCCS and Flanker score. The ribbons around the lines represent  $\pm 1$  SE. The dashed horizontal line at 0 is chance (i.e., equal likelihood of fixating to the target and the distractor object).

	Estimate	Std..Error	t.value	p.value	sig
(Intercept)	1.372	0.052	26.221	0.000	•
ot1	3.189	0.244	13.068	0.000	•
ot2	-1.733	0.203	-8.544	0.000	•
ot3	-0.006	0.113	-0.049	0.961	
Condition	-0.099	0.093	-1.070	0.285	

ot1:Condition	0.484	0.451	1.074	0.283
ot2:Condition	0.785	0.354	2.218	0.026 •
ot3:Condition	-0.160	0.267	-0.600	0.548

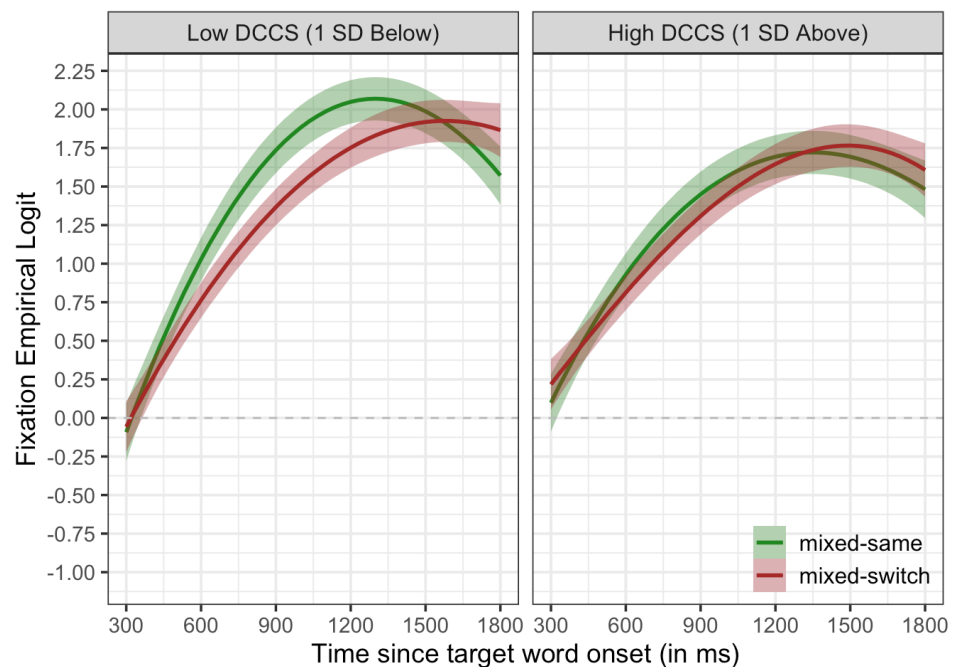
There's a significant effect of **Condition** on the following time terms:

- *quadratic*,  $b=0.785, p=0.026$

But not on any of the other time terms,  $p$ 's > 0.283

Children have a steeper peak asymptote in fixations on trials in the mixed block where the dimension remains the same (mixed-same  $b=-2.1255$ ), compared to when the dimension switched (mixed-switch  $b=-1.3405$ ). But children's overall accuracy is the same in both conditions.

## DCCS Moderation



**Figure S24** Time course of changes in children's accuracy in fixating the target object over time for trials where the dimension is the same as the preceding trial (mixed-same; green) and different from the preceding trial (mixed-switch; brown) in the Mixed block. Solid lines are the growth curve model fits plotted in the left panel for a child with an average Flanker score and below average DCCS score (0.48) and in the right panel for a child with average Flanker score and above average DCCS score (0.83). The ribbons around the lines represent  $\pm 1$  SE. The dashed horizontal line at 0 is chance (i.e., equal likelihood of fixating to the target and the distractor object).

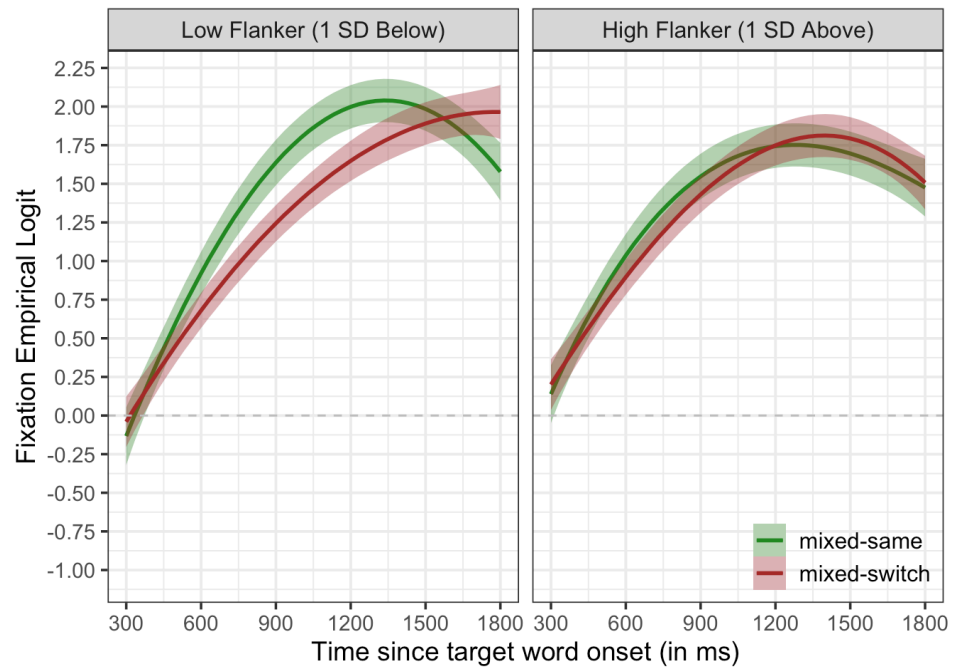
	Estimate	Std..Error	t.value	p.value	sig
DCCS	-0.356	0.296	-1.200	0.230	
ot1:DCCS	-2.025	1.383	-1.464	0.143	
ot2:DCCS	1.418	1.150	1.233	0.217	
ot3:DCCS	-0.181	0.643	-0.282	0.778	
Condition:DCCS	0.415	0.525	0.791	0.429	
ot1:Condition:DCCS	-0.628	2.555	-0.246	0.806	
ot2:Condition:DCCS	-1.725	2.008	-0.859	0.390	
ot3:Condition:DCCS	-0.576	1.520	-0.379	0.705	

There is *NOT* a significant effect of **DCCS** for any of the time terms ( $p$ 's > 0.143).

Nor is the effect of **Condition moderated by DCCS** for any of the time terms ( $p$ 's > 0.39).

Individual differences in children's ability to shift their attention (measured using the DCCS) are *not* associated with their word recognition accuracy nor are they associated with the degree to which their word recognition accuracy is affected by a dimensional shift in the mixed block (when same and switch trials are equally unpredictable).

## Flanker Moderation



**Figure S25** Time course of changes in children's accuracy in fixating the target object over time for trials where the dimension is the same as the preceding trial (mixed-same; green) and different from the preceding trial (mixed-switch; brown) in the Mixed block. Solid lines are the growth curve model fits plotted in the left panel for a child with an average DCCS score and below average Flanker score (i.e., greater advantage for Congruent compared to Incongruent trials, 0.25) and in the right panel for a child with average DCCS score and above average Flanker score (-0.11). The ribbons around the lines represent +/- 1 SE. The dashed horizontal line at 0 is chance (i.e., equal likelihood of fixating to the target and the distractor object).

	Estimate	Std..Error	t.value	p.value	sig
Flanker	0.038	0.298	0.128	0.898	
ot1:Flanker	3.215	1.391	2.311	0.021	•
ot2:Flanker	-0.015	1.156	-0.013	0.990	
ot3:Flanker	-0.146	0.643	-0.227	0.820	
Condition:Flanker	-0.429	0.528	-0.812	0.417	
ot1:Condition:Flanker	0.262	2.570	0.102	0.919	
ot2:Condition:Flanker	3.141	2.017	1.557	0.120	
ot3:Condition:Flanker	1.139	1.523	0.748	0.455	

There is a significant effect of **Flanker** on:

- *linear*,  $b=3.215, p=0.021$

But not on any of the other time terms,  $p's > 0.82$ ).

The effect of **Condition is not moderated by Flanker** for any of the time terms ( $p's > 0.12$ ).

Children with lower inhibition as measured by Flanker (i.e., a larger than average increase in Accuracy on Congruent compared to Incongruent trials) have a larger monotonic increase in accuracy during the critical window ( $b=3.7610921$ ), compared to children with higher inhibition ( $b=2.6169079$ ). But their overall accuracy is the same. This could reflect the fact that children with low inhibition do not focus on a specific dimension during the mixed block, which is adaptive, because which dimension will be used is unpredictable. If this is the case...we'd expect to see an interaction b/w Flanker and the decrease in children's accuracy on Mixed-Same vs. Pre-Switch trials (next section). This effect should be interpreted with caution, however, because it is likely driven in part by baseline differences at the onset of the target window (i.e., children with higher Flanker scores are starting with their accuracy above chance).

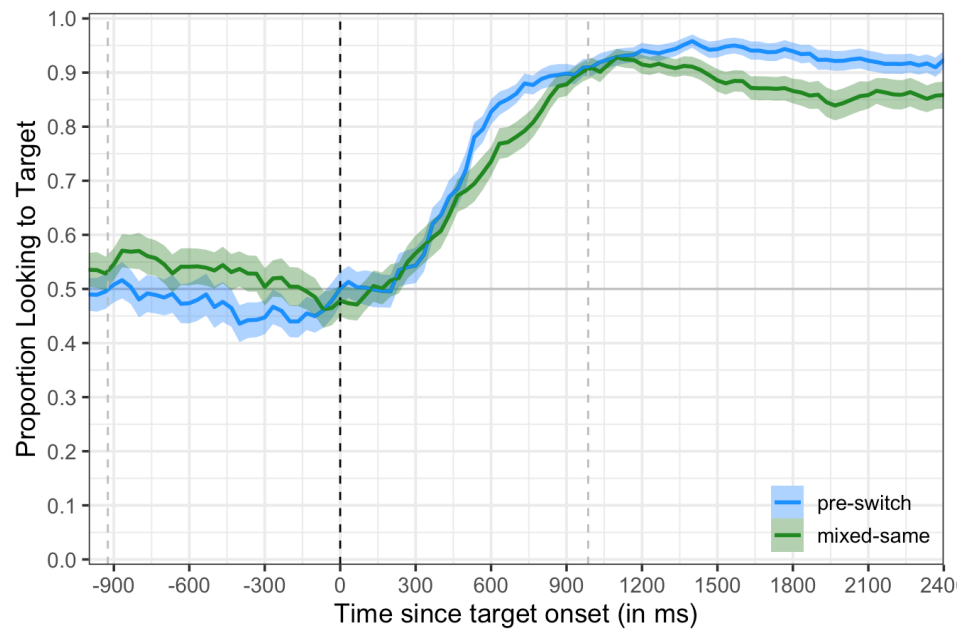
## Summary

Taken together, these results suggest that children have the same overall accuracy in word recognition both when there is and is not a switch in dimensions and each condition is equally unpredictable. The increase in children's accuracy is steeper, however, when there is no change in dimensions (Mixed-Same), compared to when there is a change in dimensions (Mixed-Switch). This effect does not seem to be associated with individual differences in EF.

# Pre-Switch vs. Mixed-Same

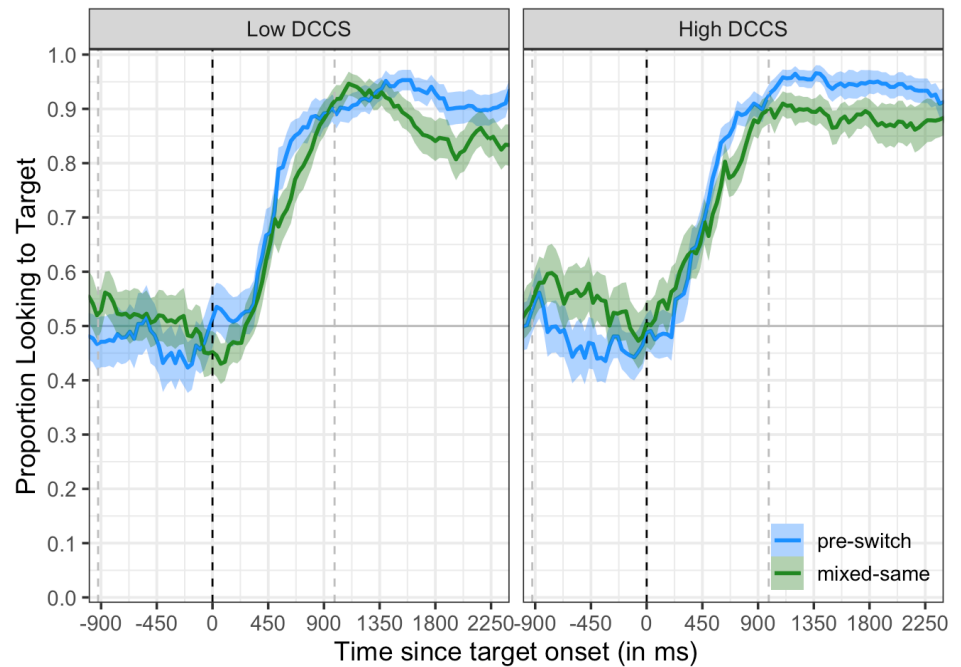
## Time Course

Here are time course plots of the changes in children's accuracy over time on trials when the dimension was the same as the previous trial, both when dimension was consistent within the block and therefore predictable (Pre-Switch) and when dimension was inconsistent within the block and therefore unpredictable (Mixed-Switch). These raw data are plotted for the entire group, median split based on the DCCS, and median split based on the Flanker.

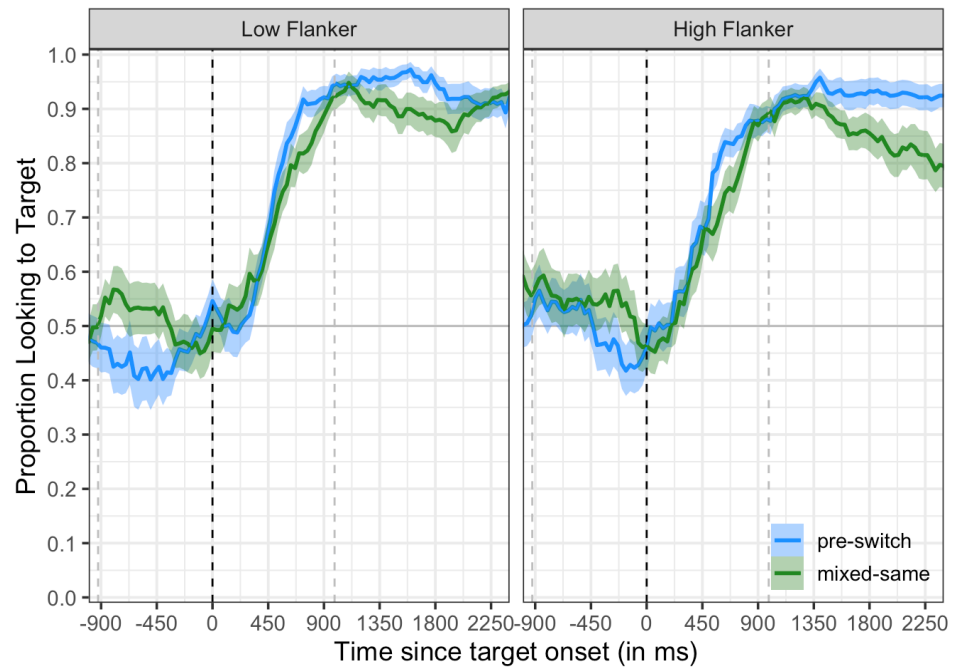


**Figure S26** Time course of changes in children’s accuracy in fixating the target object over time for trials where the dimension is the same as the preceding trial in the pre-switch block (blue) and mixed block (green). Solid lines are children’s accuracy in fixating the target image for each time frame (i.e., every 33 ms) averaged across trials within a condition and across children. Ribbons around the solid lines are  $\pm 1$  SE. The gray vertical dashed line at -924 ms indicates the onset of the carrier phrase (e.g., “Find the”), the black vertical dashed line at 0 ms indicates the onset of the target word (e.g., “Sock”), and the gray vertical dashed line at 986 ms indicates the offset of the target word.





**Figure S27** Time course of changes in children’s accuracy in fixating the target object over time for trials where the dimension is the same as the preceding trial in the pre-switch block (blue) and mixed block (green). Children whose accuracy on the DCCS was below the median (0.68) are plotted in the left panel and children whose accuracy was above the median are plotted in the right panel. Solid lines are children’s accuracy in fixating the target image for each time frame (i.e., every 33 ms) averaged across trials within a condition and across children. Ribbons around the solid lines are  $\pm 1$  SE. The gray vertical dashed line at -924 ms indicates the onset of the carrier phrase (e.g., “Find the”), the black vertical dashed line at 0 ms indicates the onset of the target word (e.g., “Sock”), and the gray vertical dashed line at 986 ms indicates the offset of the target word.



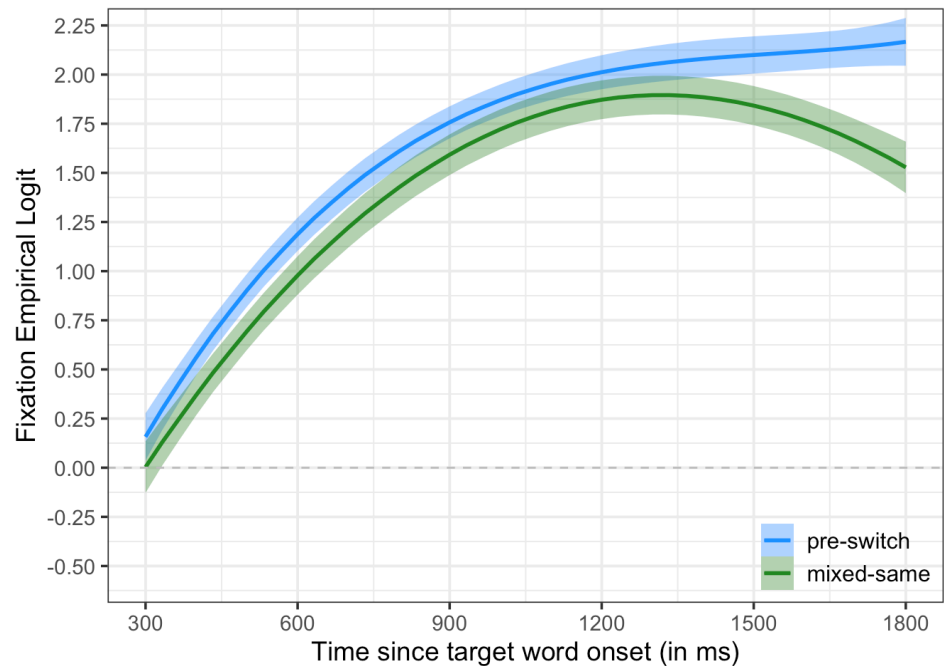
**Figure S28** Time course of changes in children's accuracy in fixating the target object over time for trials where the dimension is the same as the preceding trial in the pre-switch block (blue) and mixed block (green). Children whose difference in accuracy on Congruent vs. Incongruent trials in the Flanker task was below the median (0.04) are plotted in the left panel and children whose difference in accuracy was above the median are plotted in the right panel. Solid lines are children's accuracy in fixating the target image for each time frame (i.e., every 33 ms) averaged across trials within a condition and across children. Ribbons around the solid lines are  $\pm 1$  SE. The gray vertical dashed line at -924 ms indicates the onset of the carrier phrase (e.g., "Find the"), the black vertical dashed line at 0 ms indicates the onset of the target word (e.g., "Sock"), and the gray vertical dashed line at 986 ms indicates the offset of the target word.

## GCA

```
##
## pre-switch -0.5
## mixed-same 0.5
```

```
# m.predict <- lmer(e log ~ (ot1+ot2+ot3)*Condition*DCC
S + (ot1+ot2+ot3)*Condition*Flanker + ((ot1+ot2+ot3)*C
ondition/Sub.Num), data=d.gca, weights=1/wts, control=
lmerControl(optimizer='bobyqa'),REML=FALSE)
```

## Effect of Condition



**Figure S29** Time course of changes in children’s accuracy in fixating the target object over time for trials where the dimension is the same as the preceding trial in the pre-switch block (blue) and mixed block (green). Solid lines are the growth curve model fits for a child with an average DCCS and Flanker score. The ribbons around the lines represent +/- 1 SE. The dashed horizontal line at 0 is chance (i.e., equal likelihood of fixating to the target and the distractor object).

	Estimate	Std..Error	t.value	p.value	sig
(Intercept)	1.537	0.050	30.680	0.000	•
ot1	3.201	0.273	11.733	0.000	•
ot2	-1.857	0.182	-10.192	0.000	•
ot3	0.245	0.120	2.033	0.042	•
Condition	-0.231	0.091	-2.546	0.011	•
ot1:Condition	-0.497	0.451	-1.101	0.271	
ot2:Condition	-0.536	0.359	-1.494	0.135	
ot3:Condition	-0.345	0.287	-1.203	0.229	

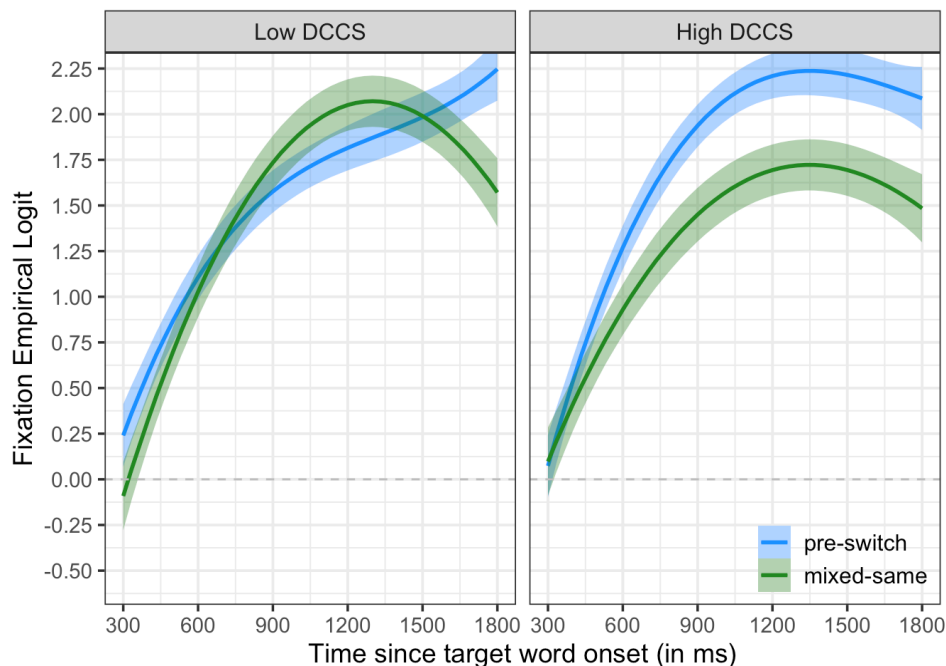
There's a significant effect of **Condition** on the following time terms:

- *intercept*,  $b=-0.231, p=0.011$

But not on any of the other time terms,  $p$ 's > 0.135

Children have overall higher accuracy in fixating the target object on trials where the dimension does not change and this is predictable (pre-switch  $b= 1.6525$ ), compared to trials where the dimension does not change and this is unpredictable (mixed-same  $b= 1.4215$ ) trials.

## DCCS Moderation



**Figure S30** (Figure 3 in manuscript) Time course of changes in children's accuracy in fixating the target object over time for trials where the dimension is the same as the preceding trial in the pre-switch block (blue) and mixed block (green). Solid lines are the growth curve model fits plotted in the left panel for a child with an average Flanker score and below average DCCS score (0.48) and in the right panel for a child with average Flanker score and above average DCCS score (0.83). The ribbons around the lines represent  $\pm 1$  SE. The dashed horizontal line at 0 is chance (i.e., equal likelihood of fixating to the target and the distractor object).

	Estimate	Std..Error	t.value	p.value	sig
DCCS	0.003	0.284	0.012	0.990	
ot1:DCCS	-0.666	1.545	-0.431	0.666	

ot2:DCCS	-0.520	1.031	-0.504	0.614	
ot3:DCCS	-0.063	0.683	-0.092	0.927	
Condition:DCCS	-1.130	0.513	-2.204	0.028	•
ot1:Condition:DCCS	-2.104	2.557	-0.823	0.411	
ot2:Condition:DCCS	5.599	2.032	2.755	0.006	•
ot3:Condition:DCCS	0.385	1.627	0.237	0.813	

There is not a significant effect of **DCCS** for any of the time terms,  $p$ 's  $> 0.614$ ).

The effect of **Condition** was significantly moderated by **DCCS** for the following time terms:

- *intercept*,  $b = -1.13, p = 0.028$
- *quadratic*,  $b = 5.599, p = 0.006$

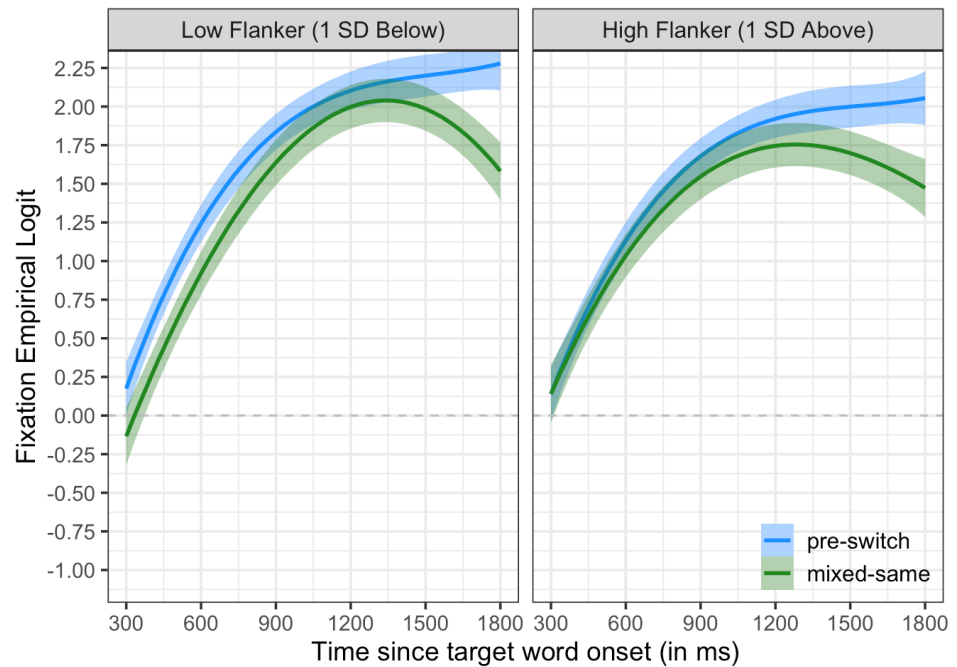
But not on any of the other time terms,  $p$ 's  $> 0.411$

The effect of predictability on children's word recognition accuracy ( $b = -0.231$ ) is significantly greater for children with stronger switching abilities (measured by the DCCS),  $b = -0.433$ , compared to children with weaker switching abilities,  $b = -0.029$ ).

Although there is not an overall effect of predictability on quadratic time ( $b = -0.536, p = 0.135$ ), this effect is moderated by DCCS. Children with stronger shifting skills had a shallower peak in accuracy on mixed-same compared to pre-switch trials  $b = 0.467$ , while children with weaker switching skills had a steeper peak accuracy on mixed-same compared to pre-switch trials  $-1.539$ .

These **Condition:DCCS** interactions are further explored below (see DCCS Simple Effects)

## Flanker Moderation



**Figure S31** Time course of changes in children's accuracy in fixating the target object over time for trials where the dimension is the same as the preceding trial in the pre-switch block (blue) and mixed block (green). Solid lines are the growth curve model fits plotted in the left panel for a child with an average DCCS score and below average Flanker score (-0.11) and in the right panel for a child with average DCCS score and above average Flanker score (0.25). The ribbons around the lines represent +/- 1 SE. The dashed horizontal line at 0 is chance (i.e., equal likelihood of fixating to the target and the distractor object).

	Estimate	Std..Error	t.value	p.value	sig
Flanker	0.346	0.286	1.213	0.225	
ot1:Flanker	2.008	1.555	1.291	0.197	
ot2:Flanker	-0.909	1.038	-0.875	0.382	
ot3:Flanker	-0.293	0.686	-0.428	0.669	
Condition:Flanker	-0.188	0.516	-0.364	0.716	
ot1:Condition:Flanker	2.156	2.573	0.838	0.402	
ot2:Condition:Flanker	-1.326	2.046	-0.648	0.517	
ot3:Condition:Flanker	-0.779	1.635	-0.477	0.634	

There is *NOT* as significant effect of **Flanker** for any of the time terms,  $p$ 's > 0.197.

Nor is there an effect of **Condition:Flanker** on any of the time terms ( $p$ 's > 0.402).

Individual differences in children's ability to inhibit their attention (measured using the Flanker) are *not* associated with their word recognition accuracy nor are they associated with the degree to which their word recognition accuracy is affected by differences in predictability.

## DCCS Simple Effects

To further examine the interaction of **Condition:DCCS**, the model was re-centered and refit for each condition.

```
## [1] "ERROR: ContrastMatrix columns do not sum to ZERO"
##
## pre-switch 0
## mixed-same 1
```

	Estimate	Std..Error	t.value	p.value	sig
DCCS	0.569	0.326	1.743	0.081	•
ot1:DCCS	0.386	1.993	0.194	0.846	
ot2:DCCS	-3.319	1.366	-2.430	0.015	•
ot3:DCCS	-0.255	1.181	-0.216	0.829	

When centered on the **Pre-Switch** condition, there is a significant (or marginally significant) effect of **DCCS** on the following time terms:

- *intercept*,  $b=0.569, p=0.081$
- *quadratic*,  $b=-3.319, p=0.015$

But not on any of the other time terms,  $p$ 's > 0.829).

Children's overall (i.e., average) accuracy on Pre-Switch trials (intercept  $b= 1.653$ ) is marginally higher for children with higher DCCS scores (+1 SD above mean, intercept  $b=1.755$ ), compared to children with lower DCCS scores (-1 SD above mean, intercept  $b=1.551$ ).

The peak asymptote on Pre-Switch trials (quadratic  $b=-1.589$ ) is significantly steeper for children with higher DCCS scores (+1 SD above mean, quadratic  $b=-2.184$ ), compared to children with lower DCCS scores (-1 SD above mean, intercept  $b=-0.994$ ).

```
## [1] "ERROR: ContrastMatrix columns do not sum to ZERO"
##
## pre-switch 1
## mixed-same 0
```

	Estimate	Std..Error	t.value	p.value	sig
DCCS	-0.562	0.431	-1.302	0.193	
ot1:DCCS	-1.718	2.018	-0.851	0.395	
ot2:DCCS	2.280	1.525	1.494	0.135	
ot3:DCCS	0.130	0.929	0.140	0.889	

When centered on the **Mixed-Same** condition, there is a *not* a significant effect (marginal or otherwise) of **DCCS** on any of the time terms:  $p$ 's  $>0.135$ ).

```
##
## pre-switch -0.5
## mixed-same 0.5
```

	Estimate	Std..Error	t.value	p.value	sig
Condition	-0.028	0.129	-0.218	0.828	
ot1:Condition	-0.120	0.644	-0.186	0.852	
ot2:Condition	-1.539	0.512	-3.008	0.003	•
ot3:Condition	-0.414	0.410	-1.011	0.312	

For children with low accuracy on the DCCS task (i.e., 0.48, 1 SD below mean), there is a significant effect of Condition on quadratic time:  $b=-1.539$ ,  $p=0.003$

But not on any of the other time terms,  $p$ 's  $>0.312$ ).



The peak in accuracy -1.764 for children with weak EFs (shifting) is steeper for trials in the mixed block -2.5335 than trials in the pre-switch block -0.9945. This result, however, is likely driven by changes in children's accuracy at the end of the critical window where for children with weak EFs accuracy dips on mixed-same trial and increases on pre-switch trials.

	<b>Estimate</b>	<b>Std..Error</b>	<b>t.value</b>	<b>p.value</b>	<b>sig</b>
Condition	-0.433	0.129	-3.358	0.001	•
ot1:Condition	-0.874	0.642	-1.360	0.174	
ot2:Condition	0.467	0.511	0.914	0.361	
ot3:Condition	-0.276	0.408	-0.677	0.499	

For children with high accuracy on the DCCS task (i.e., 0.83, 1 SD below mean), there is a significant effect of Condition on the intercept:  $b=-0.433$ ,  $p=0.001$

But not on any of the other time terms,  $p$ 's  $>0.174$ ).

Overall accuracy 1.538 for children with stronger EFs (shifting) is lower for trials in the mixed block 1.3215 than trials in the pre-switch block 1.7545.

## Summary

Taken together, these findings reveal that children are overall more accurate on trials where there is no switch in dimensions and this is predictable (pre-switch), compared to when this is unpredictable (mixed-same). This effect is stronger for children with stronger switching abilities (DCCS) compared to children with weaker switching abilities. This differential effect is driven by changes in children's word recognition accuracy in predictable contexts (i.e., association between pre-switch accuracy and DCCS), but not in unpredictable contexts.