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A Statistical Replication of the Relationship Between Dimension-Switch and Language Comprehension in Young Children

by

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Abstract

This paper is a statistical replication of Pomper and Saffran’s 2016 study and examines how dimensional switches affect children’s language comprehension with levels of executive function (EF) as an interaction variable. The dataset from the original study is used to replicate the mean accuracy and growth curve analyses. The results of the replication corroborate the findings of the original study that children with participants with higher EF generally perform better on tests on accuracy of language comprehension. However, contrary to hypotheses, those with higher EF have lower levels of accuracy in post-switch conditions. Children with lower EF do not display much of a difference in accuracy between pre-switch and post-switch conditions. It is found that fixation on the correct target increases as time increases for both low and high executive function participants. In fact, high EF participants have the lowest amount of time fixated on the correct target immediately post-switch, and do not reach the peak amount of fixation in other conditions. Further research should investigate older, school-aged children with more advanced levels of EF, to explore the differences in processing mechanisms between children with high EF and low EF, and their impact on educational learning styles and needs.

(199 words)

Introduction

Dimensional switch and language comprehension

Pomper and Saffran's study in 2016 explored whether children, who have low executive functioning (EF) skills compared to adults, would have accuracy problems in a card sorting task after the labeling dimension was switched from by color to by names or vice versa. They hypothesized that children, given their lower EF abilities, may have trouble shifting dimensions when comprehending speech. Interestingly, they found that accuracy increased as time exposed to the dimensional switch increased. These findings were significant because it provided preliminary evidence that children may experience difficulty with language comprehension after having to change the focus of their attention. This research has implications for understanding how children develop deep and multi-dimensional meaning in their vocabulary.

A dimensional switch task requires one to flexibly shift their attention between two or more domains (e.g., labeling objects by shape and then by color). This ability relies on the prefrontal cortex, which mediates executive functions, including planning, attention, working memory, and multitasking. Inability to perform dimensional switches can result in inability to sort through lexical ambiguities as one grows up, and is a significant indicator of the strength of a subject's executive functioning.

Previous research has demonstrated that children perform worse than adults on EF tasks, but within children there was a lot of variability. For example, EFs increase with age, and research has investigated EF-related abilities within childhood. Older children aged 9-10, who have higher EF abilities, exhibited increased ability to complete bi-dimensional sorting tasks compared to 5-6 years olds, who have lower EF abilities. This shows that as children age, their ability to shift their attention across dimensions and comprehend words flexibly also increases, which was a pertinent finding to our replication paper, as it provides insight into longer term development of childrens' executive function past the parameters of our study. Another variable that was responsible for EF ability variability in children is whether they were monolingual or multilingual. Past research has shown that bilingual children exhibit stronger inhibitory skills (an important aspect of EF), which leads to better performance in dimensional switch tasks since they were able to block the language they were not currently using (Kalina et al., 2019). Beyond age and multilingualism, many other factors can impact the development of executive functioning skills in children, including maternal care-giving and adverse childhood experiences, which associate negatively with levels of executive functioning (Cuevas et al., 2014).

The original study

The original study, conducted by Pomper and Saffran (2016), aimed to test whether children's performance on a language comprehension dimensional switch task would be worse after a switch compared to before. They hypothesized that performance would be worse after the dimensional switch compared to before. Furthermore, they hypothesized that performance would be most impaired directly after the switch, and that performance would increase with time. Lastly, they hypothesized that children with lower EF abilities would have more impaired performance after the switch compared to children with higher EF abilities.

To test their hypotheses, Saffran and Pomper's research team presented children (M = 3 years and 8 months) with a task in which they were instructed to identify objects shown on cards, based on two labelling dimensions--either their name or color (e.g., “where is the banana?” “where is the yellow one?’). The accuracy of the children's language comprehension ability was assessed by their looking behavior. Specifically, they measured the proportion of time spent looking at the target object. In addition, all children completed the Dimensional Change Card Sort (DCCS), which is a measure of EF (Pomper & Saffran, 2016). Lastly, children's receptive vocabulary was assessed using the Fourth Edition Peabody Picture Vocabulary Test, which required the children to match a spoken word to one of four line drawings.

To test their first hypothesis, data from this task was analyzed with a linear mixed-effects model based on the children's accuracy in each trial type (pre- or post-switch) to see if children performed worse in the post-switch phase compared to the pre-switch phase. The results demonstrate that children were indeed significantly less accurate in the post-switch trials compared to the pre-switch trials. These findings suggest that children's ability to recognize a word is disrupted after children were prompted to switch their attention to a new labelling dimension.

To test their second hypothesis--that performance would be most impaired immediately after the dimensional switch--results from both pre- and post-switch tasks were split into 2 blocks each (pre-switch block 1, pre-switch block 2, post-switch block 1, post-switch block 2). Through regression analysis of mean accuracy in each block, it was found that the decrease in children's accuracy was significant in the post-switch block 1, but in the post-switch block 2, the children's accuracy had improved again.

To test their final hypothesis--that children with high EF would be less affected by the dimensional switch--data was analyzed to compare performance between low and high EF children. Specifically, using a median split, children were placed into 2 groups (low and high EF). Their performance was then analyzed using mean accuracy and growth curve analysis of fixations. Interestingly, in contrast to their hypothesis, their results suggest that children with higher EF were actually more adversely impacted by the dimensional switch than children with lower EF. This analysis was advised to be taken with caution because the DCCS taps into multiple components of EF, differing to the language comprehension task due to the presence of conflict.

In our replication of this experiment, we will replicate the analyses used to test all 3 of their hypotheses.We will replicate the analyses used to determine whether performance is worse in the post-switch task compared to the pre-switch task (hypothesis 1), whether performance is most impaired immediately after the dimensional switch (hypothesis 2), and whether children with higher EF were less impacted by a dimensional switch compared to children with lower EF (hypothesis 3). By replicating this study, we can test if these results still stand.

Methods

Participants

This paper used the dataset from the original study. The sample was made up of 56 children with a mean age of 3 years and 8 months with a range of 3 years and 5 months to 3 years and 11 months. For the original study, all parents provided written consent and children provided oral assent. All of the parents of the children reported that the children had normal hearing and vision, were free of ear infections, and heard less than 10 hours per week of a language other than English. However, by the end of the original study, 5 participants had to be excluded from the final data because of either a technical error, inability to read eye movement as a result of glare from glasses, failure to fully complete tasks, or side bias, where a child would fixate on one side of the screen for 80% of the time even prior to word onset. All of these procedures for the original study were approved by the University of Wisconsin-Madison Institutional Review Board (Pomper & Saffran, 2016).

Materials

The data materials used in this replication is the same data used from the original study, accessed from the Plos One open access journal, and is used as archival data. The original data materials consist of data on children's accuracy between trial types. Children's accuracy was determined by the amount of time that was spent looking at the object out of the total time during the critical window, measured using the eye tracker. The trial types were the pre-switch trials and post-switch trials. Data was also collected on the children's fixations on target objects and eye movements, which contributed to accuracy analyses between the pre-switch and post-switch block. The data collected on time spent looking at the target object were then averaged and used to create mean accuracy analysis and categorized between the different blocks. The data on the time course of children's fixations on the target objects between pre-switch and post-switch blocks were demonstrated by growth curve analysis to demonstrate the effects of the dimensional switch.

Procedures

In order to replicate the study's analysis, we obtained the original data from the original paper, and procured the original R script from the author. The original study conducted data analysis through mean accuracy and growth curve analysis, so we did the same in our replication. We altered some of the original code to better fit our needs.

Data Analysis Plans

In our data analysis, we utilized the code from the original R Script and the data set from the original study to perform our own data analysis in R. The replication analyzes mean accuracy arranged by condition as well as executive function levels, and also examines growth curve analysis, arranged by executive function levels. Since the publication of the original paper in 2016, the lmer package has been updated. The lme4 package used in the original study uses modern, efficient linear algebra methods, and was used since it fits linear mixed-effects models. This may have an impact on the results of our data analysis.

Results

Mean Accuracy

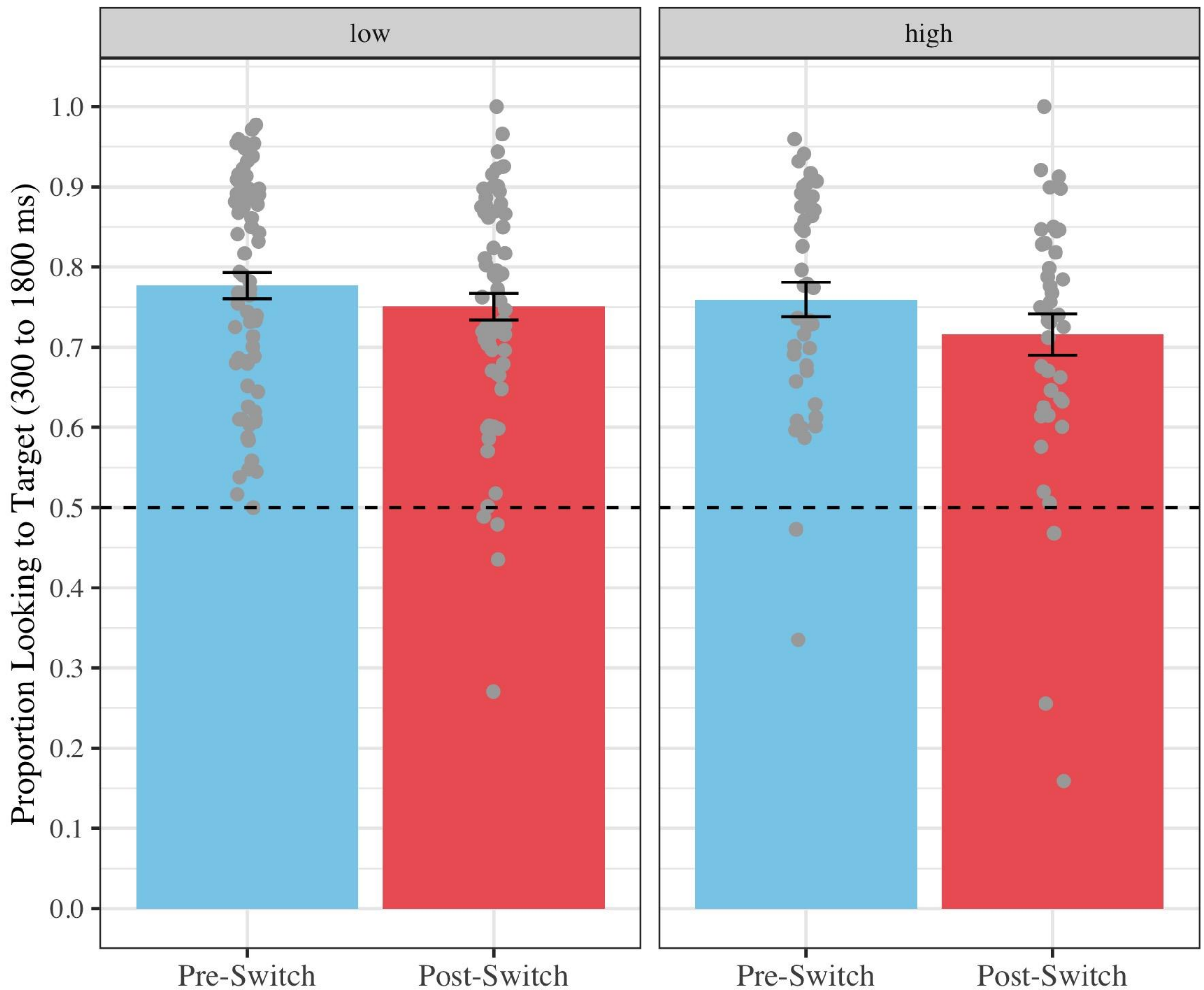

Figure 1: Mean accuracy by trial blocks by EF levels

The two experimental groups were made up of a group of high EF children and a group of low EF children. This figure shows the amount of time (on average) that each group of children spent looking at the target pre and post dimension switch. Each block represents either the pre or post switch condition, and how long on average the children in that group spent looking at the target. The graph shows that the low EF group spent longer staring at the object than the higher EF group, but both the low and high EF group had delayed comprehension and therefore fixation post switch. The high EF group did not perform better on the comprehension task than the low EF group (p >.05), which replicated the original study.

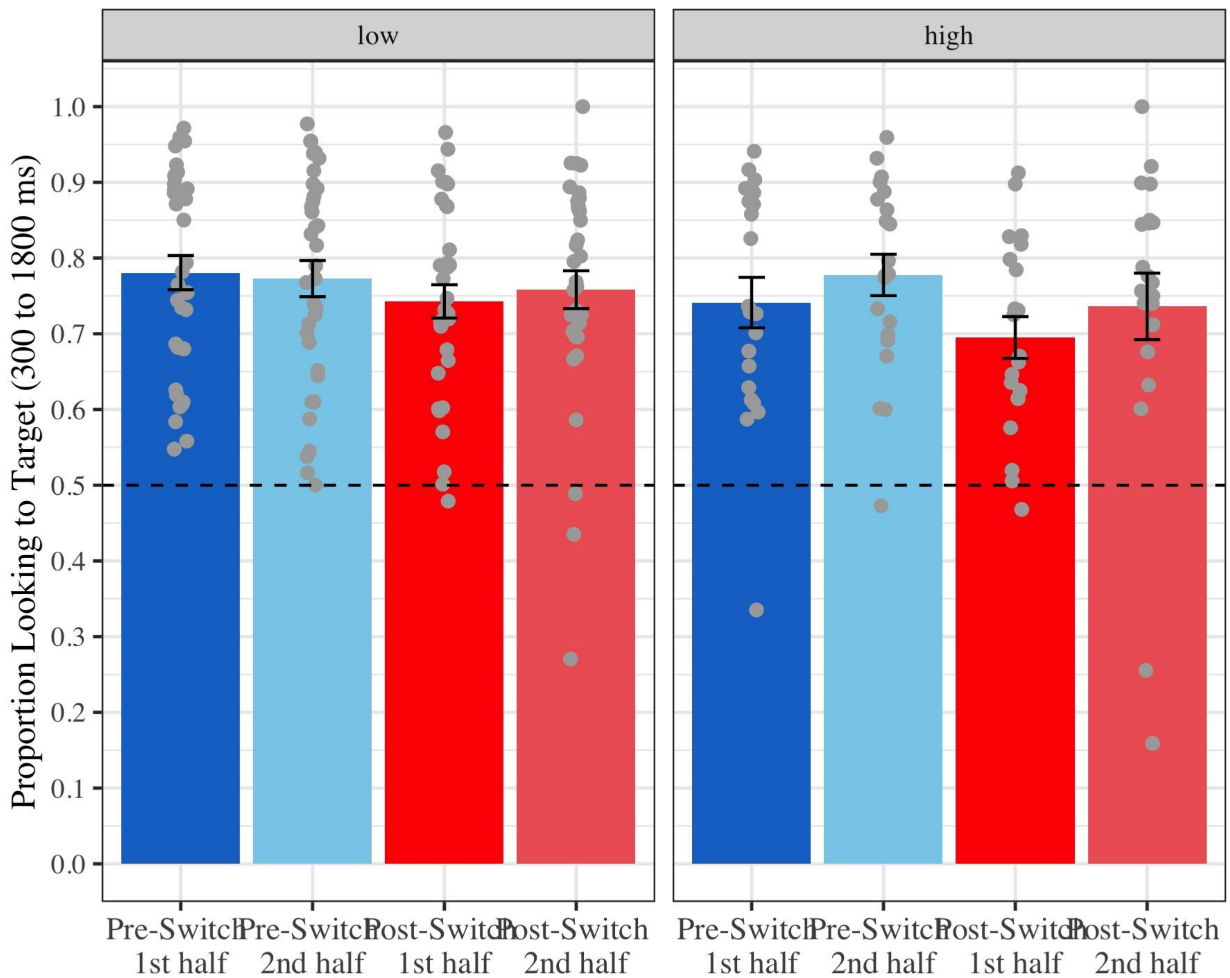

Figure 2: Mean accuracy by trial blocks halves by EF levels

Mean accuracy was also conducted by blocks halves by EF on the experimental groups. This figure shows the contrast between the first and second half in each pre-switch and post-switch block between groups with low and high EF and how the participants' accuracy changed throughout the duration of each time block. We examined how executive function affects the children's mean accuracy in looking at the target object and also observed whether or not executive function mitigated the temporary effect of the first half and second half of trials in both Pre-Switch and Post-Switch blocks. The mean accuracy generally increased between the first and second half before and after the dimensional switch in both the low EF and high EF group, except for the slight decrease in mean accuracy for the low EF group during the Pre-Switch block, although the results were not statistically significant ($p > .05$). In both Pre-Switch and Post-Switch blocks, the experimental groups were generally more accurate and spent more time looking at the target object during the second half of both Pre-Switch and Post-Switch blocks, similar to the original study.

Growth Curve Analysis

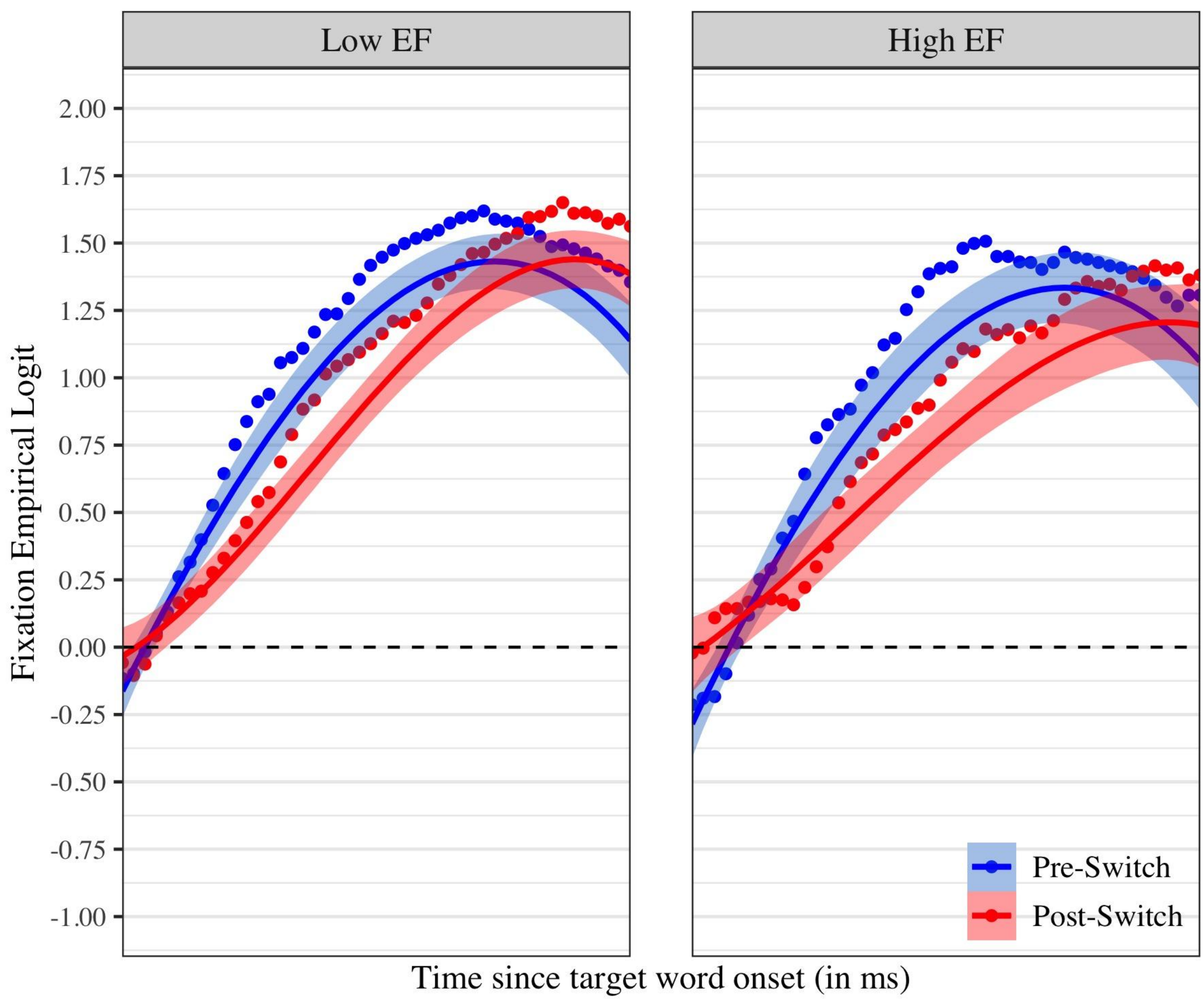

Figure 3: Time course of fixations by trial blocks by EF levels

We conducted growth curve analysis to measure the time course of fixations to the target object in different experimental conditions, namely, in trials with children with high and low EF in pre-switch and post-switch trials. The experiment was conducted by tracking children's eye movements and fixations on the target both before the dimension switch and after the dimension switch, and the fixations were measured over time. We see that children with high EF took more time to recover in the post-switch condition as compared to the children with low EF. In both groups, word recognition decreased following the dimensional switch, but this trend was temporary. Overall, in both groups, following the dimensional switch, word recognition was slower than in the pre-switch condition, but the results were not statistically significant ($p > .05$).

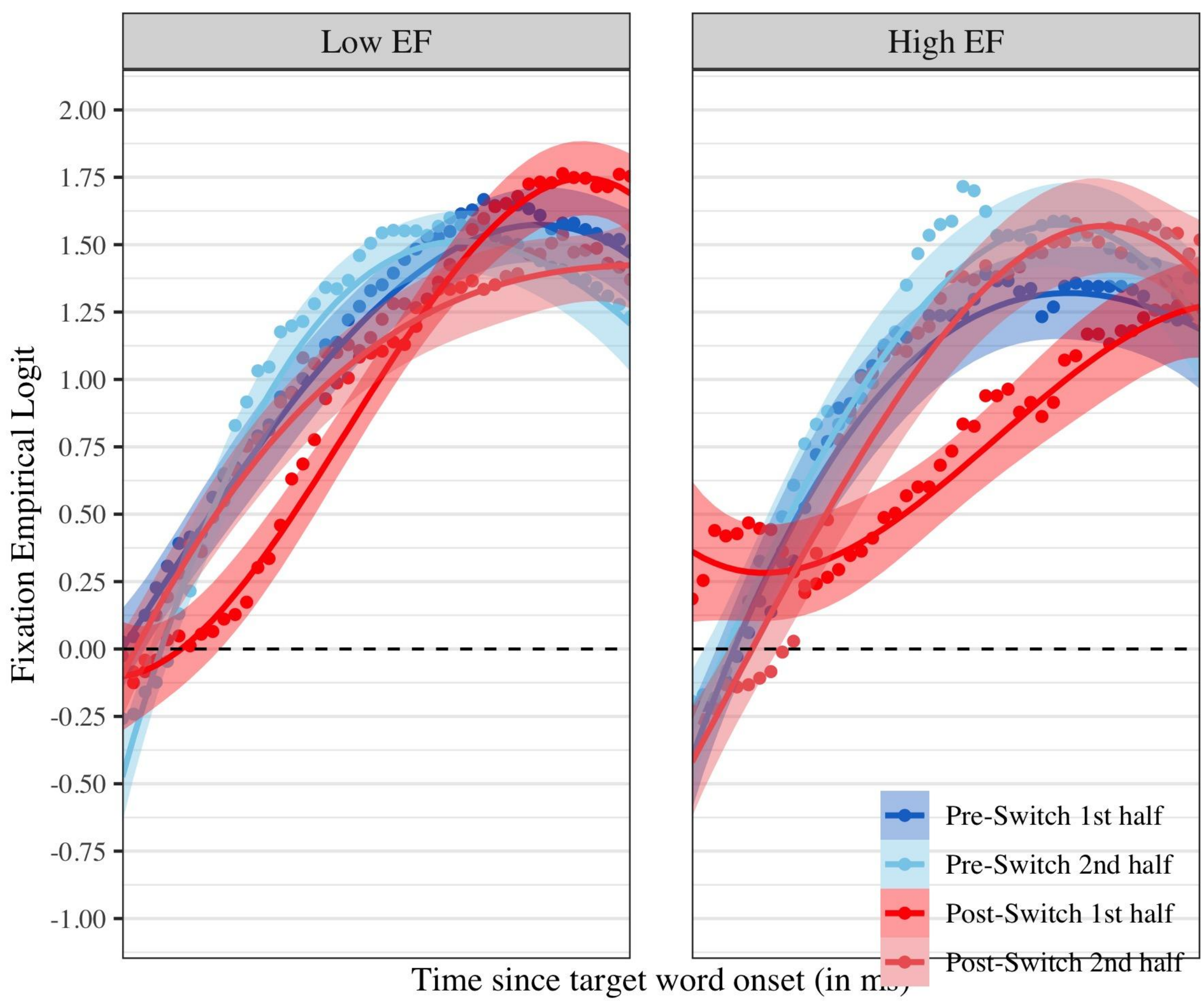

Figure 4: Time course of fixations by trial block halves by EF levels

We conducted a growth curve analysis of the time course of fixations on the target object on trials in the first and second halves of the pre-switch and post-switch blocks. The experiment was carried out by tracking the children's eye movements and the amount of time fixated on each object before and after the dimension switch. Children with low EF were plotted in the left panel and children with high EF were plotted on the right panel. Over time, both groups showed an increase in fixation on the correct target. Children with low EF achieved the peak of fixation on the correct target in the first half of the post switch, before fixation decreased a bit in the second half of the post-switch, closely resembling both halves of the pre-switch block. Children with high EF, however, demonstrated the lowest fixation on the correct target during the first half of the post-switch block, which improved back to pre-switch levels during the second half of the post-switch block. Children with low EF fixated on the correct target more than those in the high EF group, especially post-switch, and the results were statistically significant ($p < .05$). This replicated the original study, and was unexpected given the hypothesis about EFs and dimensional switch tasks.

Discussion

The goal for this study was to replicate an experiment completed by Pomper and Saffron in 2016 that sought to investigate how dimension switching impacts the ability of low or high EF individuals to comprehend speech. The results indicated that children were better in a pre-switch than post-switch, and that performance is worse immediately after a switch, and surprisingly, there is no significant difference between low and high EF individuals in speech comprehension, they both struggled with target fixation in the post-switch condition. However, it should be noted that lower EF individuals tended to have a longer average fixation time as baseline compared to the higher EF individuals.

This study has an important influence in understanding children's language comprehension and executive function. By focusing on dimensional switch and its impact, this study will demonstrate the gaps and struggles that children have with language comprehension and broaden our understanding of how children process and learn words. The results of this study have the potential to impact education systems and curriculum and shape the way children gain language comprehension and acquisition.

The pre- and post-switch conditions indicated the average time the participants fixated on the target before and after the dimensional change. This study shows that dimension switching similarly impacts low and high EF individuals in terms of comprehension ability. High EF individuals do not have a significantly easier time in adjusting to dimension switches in speech and as such should not be taught any differently than their lower EF peers. While there might be some educational activities where low and high EF children may benefit from a more individualized approach suited to their abilities, vocabulary and speech comprehension doesn't seem to be one of them. Mean accuracy was further investigated between the groups with low executive function and high executive function and how they performed during the pre-switch and post-switch blocks. Possible indications suggest that children have a difficult time with adjusting to switching between dimensions and being able to immediately adapt and this can make comprehending language more difficult.

Growth curve analysis was used to measure the children's accuracy over the course of time, both pre-dimension switch and post-dimension switch, separated into two groups, low EF and high EF. Children had a difficult time with accuracy in the post-switch block, but with more time spent in the post-switch block, the accuracy of the children's fixations improved and recovered. This phenomenon was observed in both children with high EF as well as low EF, with the high EF group experiencing a marginally slower recovery as compared to the low EF group. These results suggest that young children with both high levels of EF as well as low levels of EF both struggle to shift between dimensions when comprehending speech. This may suggest that in regards to language comprehension, high EF levels may not directly correlate to a stronger ability to switch between dimensions.

Our study analyzed how well young children performed on a language comprehension task, both before and after a dimension switch. We used mean accuracy and growth curve analysis to analyze and measure fixations to the target objects in both the pre and post-switch conditions, similarly to the original Pomper and Saffron study. By comparing children with high EF and children with low EF in these dimension switching tasks, we may have a more holistic understanding of the role that EF plays in dimension switching, specifically in language comprehension.

This study has the ability to inform future research in drawing connections between language comprehension and flexibility in young children with executive functioning levels, which could impact language acquisition and educational outcomes. While this study used Dimensional Change Card Sort to measure EF, future studies could utilize other tasks or assessments and potentially shape additional understandings of children's EF. Some potential limitations of this study lie in a disregard for confounding factors like socioeconomic status and discrepancies in the childrens' home environments. As seen in the Corrinne Bower study, children with lower socioeconomic status may be at an automatic disadvantage and thus socioeconomic status may have affected some childrens' scores in our study, resulting in them being unfairly classified as Low EF. Furthermore, differences in childrens' home environments, such as cultural differences or home education, may impact the child's EF development and may prime them to have stronger associations with certain words more than others. Small discrepancies may have important effects on the study because the children were in the early stages of their cognitive development and as such, their brains were affected greatly by their environments. Future research and studies could focus on these limitations to expand our current understanding of the factors that impact children's language development.

References

Cuevas, K., Deater-Deckard, K., Kim-Spoon, J., Watson, A. J., Morasch, K. C., & Bell, M. A. (2014). What's mom got to do with it? Contributions of maternal executive function and caregiving to the development of executive function across early childhood. *Developmental Science*, *17*(2), 224–238. https://doi.org/10.1111/desc.12073

Kalia, V., Daneri, M. P., & Wilbourn, M. P. (2019). Relations between vocabulary and executive functions in Spanish–English dual language learners. *Bilingualism: Language and Cognition*, *22*(1), 1–14. https://doi.org/10.1017/S1366728917000463

Pomper, R., & Saffran, J. R. (2016). Roses Are Red, Socks Are Blue: Switching Dimensions Disrupts Young Children's Language Comprehension. *PLOS ONE*, *11*(6), 1–19. https://doi.org/10.1371/journal.pone.0158459