Research Report:

**Indirect Effects of Task-switching on Reading Comprehension via Decoding Skills among
Adolescents with Autism**

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Abstract

(200 words)

Purpose: We examined whether variation in task-switching indirectly predicted variation in reading comprehension by way of variation in decoding, and furthermore, whether this effect differed among adolescents with ASD compared to an age-matched control group.

Methods: We examined whether the association between task-switching and reading comprehension was mediated by decoding among a sample of autistic adolescents with autism spectrum disorder (ASD; $N = 45$, $M_{age} = 14.9$ years) and an age-matched comparison group ($N = 43$, $M_{age} = 14.3$ years). Analyses were conducted using path models to test for direct effects of decoding and task switching on reading comprehension, as well as indirect effects of task-switching on reading comprehension by way of decoding

Results: Though the indirect effect did not significantly differ between the ASD and comparison groups, the indirect effect of task-switching on reading comprehension via decoding was only significant among adolescents with ASD. This suggest that task-switching plays a particularly prominent role in decoding and reading comprehension among adolescents with ASD.

Conclusion: Though further work is necessary to replicate this effect, the findings may have implications for interventions that may target improvements in word reading abilities as a means for improving reading comprehension outcomes among youth with ASD.

keywords:

task-switching; executive functions; decoding; reading comprehension; Autism Spectrum Disorder; adolescent

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Introduction

Youth with autism spectrum disorder (ASD) show impairments in oral language (Tager-Flusberg & Joseph, 2003) and in reading skills (McIntyre et al., 2017a; Nally et al., 2018). Yet, some research has found that youth with ASD are also very capable of reading at or above age level (Turkeltaub et al., 2004). In particular, children and adolescents with ASD may struggle with reading comprehension, even though more basic reading skills, such as reading words and nonwords accurately and fluently, remain relatively unimpaired (Nation et al., 2006). However, more recent research has suggested that word reading abilities may indeed be impaired among children with ASD (Davidson, 2021; McIntyre et al., 2017b). Lower-level language and reading abilities may mediate the associations between ASD symptomatology and reading comprehension outcomes. While youth with more severe ASD symptomatology may perform worse on measures of reading comprehension compared to typically developing peers, there is some evidence that this association is mediated by variation in oral language skills (McIntyre et al., 2017a).

Aside from oral language, individual differences in other foundational processes implicated in word reading may also help to explain variation in reading comprehension abilities among youth with ASD. According to the *Reading Systems Framework* (Perfetti & Stafura, 2014), the knowledge and identification of words are especially significant in predicting differences in reading comprehension skills. Before words are assembled into

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meaningful messages, words are identified through a process of decoding (Ehri, 2005). The process of decoding text into speech sounds is a foundational aspect of reading that contributes to the knowledge and identification of words. Decoding involves the application of grapheme-phoneme rules while reading unfamiliar words and rapid retrieval of familiar words aided by lexical and semantic knowledge systems (Coltheart, 2006). Among autistic youth, decoding appears to be relatively unimpaired though deficits emerge in other areas of reading (Nally et al., 2018).

The ability to switch between the application of grapheme-phoneme rules and a mental lexicon of familiar words may be associated with general task-switching abilities (Cartwright, 2012). Task-switching is an important aspect of executive function skills that have been found to be moderately associated with reading abilities (Butterfuss & Kendeou, 2018; AUTHOR, 2020). The construct of task-switching involves the flexible application of rulesets and is thought to be essential for the serial processing of both phonological and semantic information while reading (Cartwright et al., 2017). Though much of the research on task-switching and reading abilities has focused on early reading skill development, significant associations between task-switching and reading abilities have also been found among adolescents, particularly with respect to basic phonological memory processes (Schaeffner et al., 2020) and lower-level reading skills such as nonword decoding (AUTHOR, 2019). Compared with typically developing youth, autistic youth may be more likely to exhibit impairments in task-switching (Corbett et al., 2009). By contrast, other studies have found that relative to youth with known reading difficulties, autistic youth have task-switching abilities similar to those of typically developing peers (Poljac et al., 2007). Some evidence has shown that when controlling for differences in social communication, autistic youth do not perform significantly differently

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on measures of inhibition (Ellis Weismer et al., 2018). These findings point towards variability of task-switching abilities across the autism spectrum that may explain variation in reading skills.

Research Aims

We examine the indirect effect of task-switching ability on reading comprehension by way of decoding skills among a sample of adolescents with and without known cases of ASD. First, we anticipated that better task-switching performance would be associated with better decoding abilities, which in turn would be positively associated with better reading comprehension. Second, we anticipated an indirect association of task-switching and reading comprehension by way of decoding ability. Third, we expected this indirect effect would be significantly stronger in the ASD group.

Methods

Participants

During the spring of 2018, middle and high school students were recruited to participate in studies conducted in a university research lab. Participants were recruited from programs designed to serve adolescents with ASD who are in classrooms with general education students. Institutional Review Board approval was granted to allow the researchers to conduct the study. Prior to any data collection, and in order to be eligible for the study, all participants completed parental consent and assent documentation.

Participants ($N_{total}=88$) ranged from 11 to 18 years of age. About half ($N=45$, $Mean_{age}=14.9$ years, $SD_{age}=2.21$, $N_{male}=41$) of the sample recruited were receiving accommodations for ASD, while the other half of participants ($N=43$, $Mean_{age}=14.3$ years, $SD_{age}=1.84$, $N_{male}=25$) consisted of adolescents across a range of abilities, some of whom may

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have been at risk for ADHD or a learning disability, based on teacher report. Participants identified as Hispanic/Latinx (44.3%), White/European American (31.8%), Black/African American (10.2%), North African/Middle Eastern descent (4.5%), American Indian (1.1%), and the remainder identified as a member of another group. Race/ethnicity did not substantially differ between the two samples.

Materials

All measures were administered in English given that it was the primary language of instruction for all participants. As a measure of task-switching, a standardized version of the Dimensional Change Card Sort (DCCS; Zelazo, 2006) was administered through a custom-designed online study administration platform developed within the [...] Lab.¹ The DCCS instructs participants to identify a series of stimuli according to one of two dimensions; first according to one dimension (e.g., color), and then according to the other (e.g., shape). The DCCS NIH score (range: 0-10), which considers both accuracy and speed, was derived (Zelazo et al., 2014). To provide some convergent validity for the DCCS score, a 10-item computerized matrix reasoning task was also administered (*McDonald's* $\omega_{total} = .62$). Like *Cronbach's a*, another indicator of internal consistency, values of *McDonald's* ω_{total} that are closer to 1 generally reflect better internal consistency (McNeish, 2018). Past research has shown that task-switching is distinct yet highly associated with fluid intelligence (Deák & Wiseheart, 2015).

Reading tasks were administered to the participants to gauge abilities with respect to reading comprehension and decoding². The reading tasks, in addition to a short demographic survey, were administered through the online survey platform Qualtrics. The reading

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¹ Name of research lab withheld for blind review.

² See associated Open Science Framework (OSF) repository for details, including copies of the measures: https://osf.io/7hea2/?view_only=241169944c924db1a7555950f14da171

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comprehension task consisted of a 10-item CLOZE procedure embedded within a passage describing a fictionalized first-person narrative (*McDonald's* $\omega_{total} = .83$). The 5-item nonword decoding task instructed participants to select a nonword that if read aloud would sound most similar to a target word (*McDonald's* $\omega_{total} = .65$). Scores were calculated as the average of correct responses.

Results

We examined the indirect effect of task-switching on adolescents' reading comprehension abilities by way of decoding skills. Descriptives for all included measures are shown in Table 1.

Table 1. *Descriptive statistics* (N=88).

	<i>Mean</i>	<i>SD</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>	<i>Skew</i>	<i>Kurtosis</i>
Age (Years)	14.46	2.03	14.92	11.00	18.00	-0.26	-1.23
Matrix Reasoning Score	0.77	0.09	0.83	0.50	0.83	-1.44	1.34
DCCS NIH Score	7.50	1.18	7.66	2.13	9.29	-1.96	5.59
Nonword Decoding Score	0.68	0.22	0.80	0.20	1.00	-0.50	-0.46
Reading Comprehension Score	0.98	0.05	1.00	0.80	1.00	-1.88	2.69

As a preliminary step, we examined correlations between measures (see Table 2). With Bonferroni corrections applied, nonword decoding was moderately and positively associated with reading comprehension. This is to be expected given both tasks measure aspects of reading ability. Task-switching (DCCS) and fluid intelligence (matrix reasoning) were also significantly and moderately correlated with one another, a finding expected given both tasks measure general cognitive functioning. To a lesser extent, task-switching was also positively associated with nonword decoding.

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Table 2. *Zero-order Pearson correlations between variables (N=88).*

	1.	2.	3.	4.	5.
1. Age (Years)		.395	.035	.805	.054
2. Matrix Reasoning Score	.09		<.001	.099	.034
3. DCCS NIH Score	.23	.44*		.002	.006
4. Nonword Decoding Score	-.03	.18	.32*		.001
5. Reading Comprehension Score	.21	.23	.29	.36*	

Note: Lower diagonal reflects Pearson correlation coefficients. Upper diagonal reflects *p*-value.

* indicated correlation is significant with Bonferonni corrected *p*-value (with $\alpha = .05$) = .005.

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Table 3. *Standardized estimates of regression parameters in the mediation model (N=88).*

<i>Regression Parameter</i>	ASD Sample (N=45)						Comparison Sample (N=43)					
	<i>Estimate</i> (B)	<i>Std.</i> <i>Error</i>	<i>Std.</i> <i>Estimate</i> (β)	<i>z</i>	<i>p</i>		<i>Estimate</i> (B)	<i>Std.</i> <i>Error</i>	<i>Std.</i> <i>Estimate</i> (β)	<i>z</i>	<i>p</i>	
<i>Y ~ X</i>												
Reading Comprehension ~												
Nonword Decoding	0.056	0.022	0.266	2.587	0.010	*	0.084	0.043	0.325	1.947	0.052	.
Task-switching	0.010	0.008	0.217	1.189	0.234		0.005	0.006	0.118	0.817	0.414	
Age	0.006	0.002	0.267	2.380	0.017	*	0.002	0.004	0.073	0.568	0.570	
Nonword Decoding ~												
Task-switching	0.117	0.025	0.546	4.622	0.000	***	0.034	0.023	0.211	1.468	0.142	
Age	-0.019	0.015	-0.194	-1.281	0.200		-0.013	0.016	-0.107	-0.765	0.444	
Task-switching ~												
Age	0.160	0.071	0.351	2.258	0.024	*	0.083	0.077	0.113	1.078	0.281	
Indirect Effect	0.007	0.003	0.145	2.312	0.021	*	0.003	0.002	0.069	1.218	0.223	.
Total (Indirect + Direct) Effect	0.016	0.009	0.362	1.872	0.061	.	0.008	0.005	0.187	1.545	0.122	

*** $p < .001$, ** $p < .01$, * $p < .05$, . $p < .10$

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We compared the two groups and did not find apparent differences with respect to age, $t(86)=.81, p=.42, d=.17$ $p=.57$, task-switching (DCCS), $t(86)=.56, d=.12$, fluid intelligence, $t(86)=1.52, p=.13, d=.33$, nonword decoding score, $t(86)=1.20, p=.23, d=.26$, or reading comprehension score, $t(86)=1.51, p=.14, d=.32$.

Figure 1. (a) Path model for ASD subgroup with standardized estimates shown. (b) Path model for non-ASD subgroup with standardized estimates shown.

Analyses were conducted on the two subsamples to examine the extent to which task-switching abilities were indirectly associated with differences in reading comprehension abilities via decoding skills and included age as a covariate. Figure 1 shows the direct model paths and Table 3 shows the estimates for all direct, indirect, and total effects. The models were fit using the *lavaan* package in *R* (Rosseel, 2012). Multiple fit indices were considered when evaluating the overall model fit against recommended thresholds of $CFI > .95$, $TLI > .95$, $RMSEA < .06$, $SRMR < .08$ (Hu & Bentler, 1999).

We first examined the mediation in adolescents with ASD only (see Figure 1a). The mediation model demonstrated good fit, $\chi^2(df=6)=26.78$, $CFI=1.0$, $TLI=1.0$, $RMSEA < .001$, $SRMR < .001$. Within the subgroup of adolescents with ASD, decoding was found to predict reading comprehension, $\beta=.27$, $z=2.59$, $p=.01$. Task-switching, $\beta=.55$, $z=4.62$, $p < .001$ predicted differences in decoding but not reading comprehension, $\beta=.22$, $z=1.19$, $p=.23$. The indirect effect of task-switching on reading comprehension via decoding was significant, $\beta=.15$,

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$z=2.31, p=.02$.

The mediation model was then tested on the group without ASD (see Figure 1b). The model likewise demonstrated good model fit, $\chi^2(df=6)=8.47$, $CFI=1.0$, $TLI=1.0$, $RMSEA < .001$, $SRMR < .001$. The indirect effect was not significant, $\beta=.07$, $z=1.22$, $p=.22$, suggesting that task-switching was not associated with variation in reading comprehension abilities by way of differences in nonword decoding abilities. In spite of a moderate effect size, decoding skill was not found to significantly predict variation in reading comprehension, $\beta=.33$, $z=1.95$, $p=.05$, and no other direct effects were significant.

As we had found the indirect effect was significant in the ASD group and not the comparison group, we wanted to determine whether indirect effects may differ between the two groups. We thus compared a model in which all regression parameters were constrained between the groups against a model in which they were relaxed. We did not find a significant difference between the two models, $\Delta\chi^2(\Delta df=2)=1.18$, $p=.57$.

Discussion

In this current investigation, we sought to uncover the indirect effects of task-switching on reading comprehension by way of differences in decoding ability. We found that task-switching was associated with decoding, and decoding was associated with reading comprehension in adolescents with known cases of ASD, but not the comparison group. While differences in task-switching are indirectly associated with reading comprehension skills by way of decoding ability in the ASD group, this indirect effect does not appear to emerge in a sample of adolescents not diagnosed as such. However, we did not find sufficient evidence to conclude that the indirect effect was stronger among the ASD group.

Limitations

There are several obvious limitations of the present study. First, since the categorization of the sample relied on reports of student teachers rather than a diagnostic measure administered by the researchers, there are likely to be large differences in reading and general cognitive skills within and between the two subgroups in this study. Second, we note that the ASD and comparison group samples are not balanced according to certain key demographic variables, most obviously, in terms of gender. This appears to reflect a population norm, with some estimates suggesting that male youth are three times as likely to meet clinical criteria for ASD compared with females (Loomes et al., 2017). Third, many of the tasks were nonstandardized and also very concise, thus explaining the low internal consistency estimates. As past research has shown, reading comprehension measures may vary considerably based on the target skill assessed (Keenan et al., 2008), and thus it is difficult to make generalizations in contexts where different measures of reading comprehension may be used. Fourth, even for a relatively simple moderated mediation analysis, the present sample size is small and thus likely underpowered. While we found a significant indirect effect among the ASD group and not the comparison group, the moderation analysis failed to yield a significant effect. Replicating these findings with a larger sample may uncover a significant difference in the indirect effect. Finally, individual differences in the non-ASD sample may not have been fully captured with the variables entered into the analyses. This may explain why the regression parameters are insignificant based on data from the comparison group.

Implications

Despite these limitations, these findings point towards one possible route by which task-switching may predict differences in reading skills among youth with autism. While many

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diagnosed with ASD have language impairments that negatively affect linguistic comprehension, reading abilities tend to be unimpaired. These findings suggest that improved decoding abilities in autistic youth may buffer delays in reading comprehension. Furthermore, decoding skills appear to mediate the association between task-switching and reading comprehension among autistic youth, thus implicating task-switching as a route by which variability in certain executive functions, such as task-switching, are associated with differences in higher-level reading comprehension skills. Though these skills are presumed to be mastered early on in literacy acquisition (Chall, 1983), research suggests there is a considerable development in decoding well into adolescence (Foorman et al., 2020) and possibly even adulthood (Greenberg et al., 1997). Supporting the development of task-switching may support the development of reading fluency, particularly for youth with ASD.

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