INLFLUENCE OF SOCIOECONOMIC STATUS ON RHYTHM PERCEPTION IN CHILDREN WITH AND WITHOUT DYSLEXIA

by

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Submitted in partial fulfillment of the
requirements for Departmental Honors in
the Department of Psychology
Texas Christian University
Fort Worth, Texas

May 3, 2021

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ABSTRACT

Development of strong reading skills takes years of practice and instruction, but such skills are critical for future success academically, vocationally, and in everyday life. In spite of the early start to reading instruction in the United States, up to 15 percent of children fail to learn to read and approximately 21 percent of adults meet the Department of Education's criteria for low English literacy. One risk factor for poor reading outcomes is the child's socioeconomic status (SES). Previous research has demonstrated a significant and positive relationship between children's SES and their reading abilities, such that children from more advantaged backgrounds develop better reading skills. Interestingly, reading skills may also be correlated with rhythm perception. Children who struggle to acquire reading also appear to struggle in the ability to detect slight changes in rhythmic patterns. It is currently unknown why these two skills are related and whether SES impacts the development of rhythm perception. The goal of the current study was to examine the SES-rhythm relationship in children from a range of reading abilities. We recruited typically developing children (TD, N = 36) and children with dyslexia (DYS, N = 25) to complete a series of virtual reading assessments. Information about the child's history and home environment was collected from the parents. Children then completed a rhythm matching task in which they heard two patterns and reported whether they were the same or different. Contrary to our expectation, we found no relationship between SES and rhythm processing. This suggests that the different cognitive functions used in rhythm processing and reading are differentially influenced by SES, and that rhythmic processing may be more resilient to environmental influences. If our findings were replicated in a larger sample, they would support the use of rhythmic interventions to improve reading in children at risk for poor literacy based on their family's SES.

Introduction

The development of strong reading skills is important in nearly every aspect of daily life, not only for academic and vocational success, but also for the navigation of simple tasks. Applying for any job, for example, requires the ability to read and fill out a form. In spite of the necessity of reading expertise and access to free education through public schools from an early age, many individuals struggle with literacy. Data collected by the U.S Department of Education found that 18% of American adults score at or below the minimum standards for literacy (McFarland et al., 2017) and up to 15% of the American population is diagnosed with dyslexia (Peterson & Pennington, 2012), a neurodevelopmental disorder characterized by difficulty reading in individuals with otherwise normal intelligence and access to adequate instruction.

There are two categories of risk that contribute to poor reading; biological and environmental. Genetics play a notable role, as dyslexia is thought to be approximately 40-60% heritable (Fulker et al., 1987; Fisher & DeFries, 2002; Gialluisi et al., 2020). Research has also found several risk loci for dyslexia mapped on many chromosomes, further supporting this link between genetics and reading ability (for review, see Becker et al., 2017). Importantly, several genes of interest have been linked with reading skills in a variety of populations (Fisher et al., 2002; Galaburda et al., 2006; Marino et al., 2004). Scerri & Schulte-Körne (2010) for example, reported that genome-wide screens have identified several regions of dyslexia susceptibility on several chromosomes, with further research on many of the regions yielding promising information on the specific candidate genes. While the biological basis of dyslexia is well-established, dyslexia is not determined by genetics alone, and there is no single causal gene for dyslexia (Grigorenko, 2001; Gayán & Olsen, 2001). A large body of research has demonstrated that environmental risk factors heavily influence poor literacy, even in those without a formal

dyslexia diagnosis. The most consistently replicated environmental risk factor is low socioeconomic status (SES), which is often quantified using metrics of household income and parental education.

Multiple studies have reported a positive relationship between SES and reading skills such as phoneme identification, rapid letter naming, and word recognition (Fung & Chung, 2020; Chiu & Chow, 2015; Chung et al., 2017, Hecht et al., 2000). This result has been found consistently, even when controlling for other factors such as IQ (Bowey, 1995). In fact, Corso et al. (2016) reported that nonverbal IQ had no effect on reading comprehension. Romeo et al. (2018) reported that neurological differences are also present, with children from lower SES backgrounds exhibiting reduced cortical thickness (as measured with magnetic resonance imaging) when compared to children from higher SES backgrounds. Research on these influences is critical for improving intervention options for children at risk for low literacy, with some findings supporting the use of reading interventions. Romeo et al. (2018) for example, found that children from lower-SES backgrounds exhibited increased cortical volume, which was associated with better reading performance, in response to an intensive summer reading intervention program (Romeo et al., 2018), suggesting that individuals from low SES homes can benefit from intervention. Simos et al. (2007) found that an intensive phonological awareness program was accompanied by an increase in neurophysiological activity in areas of the brain associated with verbal processing, as shown by MSI brain scans, further supporting the use of interventions. If the achievement gap is to be effectively reduced, this research must be put to practical use in the education system in the form of widespread reading interventions.

A large body of research has investigated possible interventions to improve literacy in children and adults with reading difficulties (Saine et al., 2011; Hatcher et al., 2006; Zhou et al.,

2019). One branch of research focuses on the role of home literacy environment (HLE) – parental support of reading and access to books in the home – on early reading development. Zuilkowsky et al. (2019) reported that access to reading materials in the home was a strong predictor of early reading among children, with children from lower SES households benefitting from increased access to in-home reading materials, suggesting that interventions involving book and tablet donations may be effective. Carroll et al. (2019) found that preschoolers' literacy interest is positively related to reading levels, while controlling for SES and HLE. This indicates that interventions focused on increasing children's interest in reading for its own sake may help them overcome negative environmental factors to achieve strong reading scores. Others have tested the effectiveness of small-group phonological training interventions, with Hatcher et al. (2006) finding them moderately successful.

In spite of this promising work, no intervention is 100% successful, highlighting the need for additional options for improving reading and reducing the risk of dyslexia. A growing body of work suggests a link between reading skills and rhythm processing, such that better rhythmic processing is associated with higher reading scores (Flaugnacco et al., 2014; Ozernov-Palchik et al., 2018; Strait et al., 2011). This suggests that musical or rhythmic interventions may be an effective option. Overy (2000), for example, found that rhythmic interventions may be helpful for children with dyslexia and potentially other children with reading difficulties. By improving children's rhythm processing skills, it may be possible to improve their reading skills as well. Hallam (2019) found that children with lower-than-average reading scores showed significant improvements in reading accuracy and comprehension after a 10-week intervention involving clapping, stomping, and chanting to a beat.

Because research suggests that rhythm and reading are related, some have suggested that the accurate perception of metrical structure is critical for phonological development, as children with dyslexia struggle to both match rhythms (Huss et al., 2011) and mimic audible beats (Thomson & Goswami, 2008). Further, Overy et al. (2003) reported that difficulties in tapping along with a rhythmic pattern were correlated with spelling difficulties in dyslexic children. Given this link between rhythm and reading outcomes, it may be possible to identify children at risk for low reading skills before they are old enough to begin reading. Carr et al. (2014) found that preschoolers who exhibit poor beat synchronization also exhibited deficits in encoding of temporal speech modulations, which is important for reading acquisition. The preliterate preschoolers who struggled with replicating a beat also showed poorer phonological processing, auditory short-term memory, and rapid letter naming (Carr et al., 2014).

While these studies have consistently found relationships between reading and rhythm perception and relationships between reading and SES, there has been very little research on the relationship between SES and rhythm perception. Understanding the interactions between rhythm processing, reading, and SES is essential for developing effective reading interventions for children from low SES households. Given the relationship between rhythm perception and reading, we hypothesized that children with poor reading skills would also exhibit reduced accuracy on rhythm perception tasks and that children with deficits in these skills would be more likely to come from low SES backgrounds. We recruited native English-speaking children with dyslexia (DYS) and without (typically developing; TD) and measured their performance on a variety of tasks in a fully virtual study environment.

Methods

Participants

For this study, 61 participants from around the United States were recruited for a fully virtual study. All were between 7 and 12 years old and were native English speakers. Parents of participants were sent an online Qualtrics questionnaire prior to an online assessment session. The demographics and health questions covered their child's race, gender, gestation length, current medications, developmental delays, and handedness. The questionnaire also included a section assessing parents' socioeconomic status (SES). This section asked parents to report household income, parental occupation, and parental level of education. All study activities were previously approved by the Texas Christian University Institutional Review Board. Electronic consent and verbal assent were obtained from parents and children, respectively, prior to the start of the experiment. Children received a $20 Amazon gift card in exchange for their participation.

Assessment and Eligibility

As this research was conducted during the COVID-19 pandemic, all reading assessments were given virtually via Zoom (Zoom Video Communications, San Jose, CA). Researchers shared their screen with participants via Zoom, and participants gave their answers aloud. Audio was recorded, with participant consent, to allow for offline scoring. The assessment battery consisted of eight assessments measuring nonverbal intelligence (Matrices subtest of the KBIT, Kauffman, 1990), word identification (WI) and non-word identification (WA) subtests of the Woodcock Reading Mastery Test (WRMT, Woodcock, 1987), sight word efficiency (SWE) and phonemic (non-word) decoding efficiency (PDE) subtests of the Test of Word Reading Efficiency (TOWRE, Torgesen et al., 1999), rapid digit naming (RDN) and rapid letter naming (RLN, Wagner et al., 1999), and non-word repetition task (NWR, Dolloghan and Campbell, 1998). Each assessment was first- and second-scored by experienced researchers and raw scores were then converted to age-normalized standard scores. Participants who scored lower than a

standard score of 85 on the nonverbal IQ assessment did not qualify for the remainder of the study.

To qualify as typically developing, a child had to score 85 or higher on nonverbal IQ (Matrices subtest of the KBIT, Kauffman, 1990) and score 90 or higher on each reading assessment. To qualify for the dyslexia group, the child must score an 85 or higher on nonverbal IQ and below 90 on two or more of the reading assessments. In our sample of 61 children, 36 were typically developing and 25 qualified as having dyslexia.

Rhythm Perception Task

Upon completion of the Zoom reading assessment battery, participants received a link to the rhythm task, which was coded and administered on PsyToolKit (Stoet, 2010; Stoet, 2017). Participants listened to 36 pairs of pre-recorded rhythmic patterns and were instructed to indicate whether the two rhythms were the same or different (Huss et al., 2011). To create differences in the rhythms, a single accented beat was elongated by either 166 ms or 100 ms, and one of these differences was present in 50% of the randomly presented trial pairs. Children completed 4 practice trials with feedback and 32 trails with no feedback. Accuracy and reaction time data were recorded for offline analysis.

Data Analysis Plan

Descriptive statistics for the reading assessment measures are presented as (M ± SD). Rhythm task performance is reported as (M ± SD). Performance on reading assessments and the rhythm task were analyzed for possible group differences using two-tailed independent samples *t*-tests. Correlations between SES and reading and between SES and rhythm were quantified by Pearson's *r*.

Results

Standard Assessment Scores

We first utilized two-tailed independent samples *t*-tests to quantify the baseline assessment scores to verify that our participant groups were matched on age and IQ but differed on reading ability (Table 1). There were no group differences in either age (t (59) = .53, p = .60) or nonverbal IQ (t (59) = 1.62, p = .12). As expected, TD children outperformed DYS children on untimed measures of reading, as measured by Word Identification (t (59) = 6.93, p = < .001) and Word Attack measures (t (59) = 5.54, p = < .001). Also, as expected, TD children outperformed DYS children on timed reading measures, as measured by the Sight Word Efficiency (t (59) = 6.34, p = < .001) and Phonemic Decoding Efficiency subtests (t (59) = 7.38, p = < .001). Finally, children in the TD group outperformed the DYS group on the Rapid Digit Naming (t (59) = 2.41, p = .02) and Rapid Letter Naming (t (59) = 3.98, p = < .001). Descriptive statistics are presented as M ± SD in Table 1.

No group differences in rhythm perception

Scores on the rhythm task were analyzed using a two-tailed independent-samples *t*-test. There were no group differences between the TD group (.62 ± .02) and the DYS group (.58 ± .03) on accuracy; (t (59) = 1.12, p = .27). Further, there were no group differences between the TD group (2.12 ± .23 sec) and the DYS group (2.25 ± .28 sec) on time to respond to trials (t (59) = .36, p = .72; Figure 1).

No significant correlations between household income parental education and reading

Familial SES was measured by household income and parental education and we utilized Pearson's *r* to evaluate the relationship between each SES metric and reading, given prior research suggesting that SES is risk factor for dyslexia (Becker et al., 2017). In the TD group,

there was a trend in the relationship between income and performance on a timed pseudoword decoding task (r = .31, p = .08), but this same trend was not seen for education and performance on the task (ps > .73). No other correlations between either income or education and reading measures were close to significance (ps > .13). In the DYS group, all correlations were nonsignificant (ps > .39; Table 2).

No correlations between household income and parental education and rhythm perception

To determine whether familial SES impacted rhythm perception, we utilized Pearson's r to evaluate the relationship between two SES metrics, household income and parental education, and performance on the rhythm task. In the TD group, no correlations emerged between either SES as measured by parental education or household income and rhythm accuracy (ps > .10). A similar pattern of results was seen in the DYS group, such that all correlations were nonsignificant (ps > .43; Table 3).

Discussion

In the current study, we tested the hypothesis that SES is positively related to rhythm perception in TD and DYS children. Previous research has found a positive relationship between SES and reading skills and a positive relationship between rhythm perception and reading skills (Chiu & Chow, 2015; Flaugnacco et al., 2014) and though our study did not replicate these findings, our findings may have implications for the development of rhythmic interventions to improve reading skills in children from low SES households. No significant relationships were found between performance on rhythm perception tasks and participant SES, as measured by parental income or parental education level. These findings do not support our hypothesis that low SES is a risk factor for poor rhythm perception in children. This lack of relationship between

SES and rhythm could provide insight into the neurobiological interactions between SES and reading skills and how cognitive systems are differentially influenced by environmental factors.

Reading and SES

Decades of research have established a significant correlation between SES and reading comprehension, mediated by factors such as home literacy environment (HLE), access to after-school programs, and parental involvement (Zuilkowski et al., 2019; Fung & Chung, 2020; Bowey, 1995; Korat et al., 2013). In contrast to these prior findings, we did not observe a significant relationship between SES and reading comprehension. This may be due to a lack of variability in our participants' SES, as most participants came from middle and upper-middle class households and there were no participants from low SES households, as defined by the Census Bureau, which compares family income to poverty threshold for number of family members (United States Census Bureau, 2020). It is likely that our lack of variability is at least partially attributable to the methods used to recruit participants. Recruitment was done online due to the restrictions imposed by the COVID-19 pandemic. Thus, we were likely unable to reach those from lower SES households who may not have a home computer or internet service. Further, because all research was conducted during the COVID-19 pandemic, all assessments were given virtually through Zoom. Participation in the study itself required the use of a home computer with a stable internet connection, or at least reliable access to a computer in a quiet environment. It is possible that any low SES households would have had difficulty participating even if they had been recruited.

Rhythm and SES

In the current study, we found no significant correlations between SES and performance on either rhythm accuracy or rhythm matching tasks for either DYS or TD children, which contradicted our hypothesis. This may also be partially attributable to the lack of variability in participant SES, or it may indicate a true lack of relationship between these two variables. Reading and musical ability differ in some important respects, and thus may be impacted differently by SES. Rhythm perception, for example, emerges very early in life, with some research indicating that it is present at birth (Provasi et al., 2014). This is much earlier than the emergence of reading ability and may, therefore, be less impacted by environmental influences. Reading skills, on the other hand, are consistently shown to be influenced by environmental factors (Little et al., 2019; Carroll et al., 2019). Research suggests that both reading skills and musicality are heritable (Centanni et al., 2019; Tosto et al., 2017; Ullén et al., 2014) but genetic and environmental factors often overlap and intertwine, making it difficult to separate the two influences. The influence of low SES on reading may be mediated by home literacy environment, for example, but parents' low SES may be due to poor academic achievement resulting from dyslexia, which their children may in turn inherit. Musicality, on the other hand, may frequently be passed on and encouraged over generations due to family pride in the skill, despite low SES.

Furthermore, it is possible that the separate cognitive functions used in reading and rhythm perception are influenced differently by environmental factors. Rhythm perception may be a more resilient function than reading skills, and thus less likely to be negatively impacted by poorer environments associated with low SES. This would provide support for musical and rhythmic interventions for very young children from low SES households. These children are at risk for poor literacy, and prior research suggests rhythmic interventions are associated with

improved reading outcomes in children whose literacy is below average (Overy, 2000; Hallam, 2019). Given these findings, it may be helpful for pre-readers from low SES households to begin such interventions as soon as possible to capitalize on their less-impacted rhythm perception skills in order to proactively combat poor literacy. This would also suggest that older children who have already begun to struggle with reading could also be helped by interventions that improve their current rhythm perception abilities, which may be less impacted than their reading skills. If future research supports these concepts, the inclusion of free music courses in all high school curricula may be beneficial to children with dyslexia and those from lower-income households. Fitzpatrick (2006) for example, found significant relationships between instrumental music participation and test scores in elementary and high school children, but also emphasized the overall benefit of musical courses to all students, aside from any effect on test scores. On the other hand, both Fitzpatrick (2006) and Swaminathan et al. (2018) suggested that the relationship between reading skills and musical involvement was mediated by cognitive or academic ability, such that those who were better students to begin with were also more likely to choose involvement in musical classes. This factor must also be considered when developing musical interventions, so that the children most in need (those from lower-SES backgrounds and those with lower academic achievement) are encouraged to join. More research, however, is needed on the subject in order to understand the interaction between these three variables of reading, SES, and rhythm perception, providing valuable information for those designing effective interventions to reduce the achievement gap created by low SES.

Limitations

The greatest limitation to our study was a lack of variability in participant SES, as most participants came from middle- to upper-middle-class households, as mentioned earlier

(household income for all participants was $40,000 a year or greater). Participants also resided in several different states, which have varying cost-of-living expenses. Similar incomes may reflect different SES levels in states with great differences in the cost-of-living. These differences were not controlled for, which may have influenced our findings. Future research should control for cost-of-living differences when analyzing SES in participants from different communities.

Another noteworthy obstacle to our research was the COVID-19 pandemic, during which the entirety of our study was conducted. Health concerns necessitated solely virtual assessments, rather than typical in-person assessments. Due to pandemic-related disruptions in regular school schedules, teaching methods, and peer interaction, some children with average reading skills may also be performing more poorly than normal. Furthermore, children who struggle to maintain attention over Zoom calls may have performed more poorly than they would have if the assessments had been conducted in person. Increased distractions during assessments as parents and siblings work and study from home may have also impacted participant scores. Future research should be conducted in person, circumstances allowing.

Additionally, the rhythm task was not overseen by a researcher as the reading assessments were, but rather sent to the participant as a link with instructions to be completed on their own. This lack of supervision opens the door for many difficulties that may have negatively impacted participants' scores. Participants may not have understood the instructional video, for example, or may not have paid much attention. Researchers also had no way of knowing if participants experienced connection issues, poor audio quality, or environmental distractions during this task, all of which could influence scores.

Future research should ensure that participants span a wide range of household income by recruiting within public schools, in addition to recruiting online. Once the pandemic becomes

less dangerous, there will likely be more opportunities for in-person assessments as well, minimizing problems stemming from faulty internet connections, distractions, etc. In-person assessments will also provide an opportunity to participate for those from low SES households that do not own personal computers or have an internet connection. More research is needed on the subject to understand the relationship between SES and rhythm perception.

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Tables

Table 1

Summary of participant demographics. Data presented as mean ± SD

English Assessment	Typically Developing Children (TD; *n* = 36)	Children with Dyslexia (DYS; *n* = 25)	T-Statistic
Age	9.82 ± 1.51	10.02 ± 1.38	.53
KBIT-2 Matrices	112.89 ± 12.71	107.92 ± 10.37	1.62
WRMT-3 Word Identification	115.31 ± 10.86	92.84 ± 14.46	6.93*
WRMT-3 Word Attack	110.75 ± 10.40	93.24 ± 14.31	5.54*
TOWRE-2 Sight Word Efficiency	107.67 ± 14.84	84.28 ± 13.11	6.34*
TOWRE-2 Phonemic Decoding Efficiency	106.39 ± 12.38	82.40 ± 12.62	7.38*
Rapid Digit Naming	103.56 ± 11.97	95.32 ± 14.59	2.41*
Rapid Letter Naming	102.64 ± 11.15	89.84 ± 13.92	3.98*

Note. KBIT = Kauffman Brief Intelligence Test; WRMT = Woodcock Reading Mastery Test; TOWRE = Test of Word Reading Efficiency.

*$p < 0.05$

Table 2

Household income and reading tasks by group. Data presented as mean ± SD

Correlation	Typically Developing Children (TD; *n* = 36)	Children with Dyslexia (DYS; *n* = 25)
Income vs.:		
Word Identification	r = .23, p = .19	r = .16, p = .46
Nonword Identification	r = .27, p = .13	r = .19, p = .39
Sight Word Efficiency	r = .26, p = .14	r = .03, p = .90
Phonemic Decoding Efficiency	r = .31, p = .08	r = -.12, p = .59
Education vs.:		
Word Identification	r = .06, p = .71	r = .19, p = .36
Nonword Identification	r = .22, p = .20	r = .20, p = .33
Sight Word Efficiency	r = .04, p = .81	r = .01, p = .98
Phonemic Decoding Efficiency	r = .06, p = .73	r = .22, p = .30

Table 3

Household income and parental education and rhythm accuracy by group.

Correlation	Typically Developing Children (TD; *n* = 36)	Children with Dyslexia (DYS; *n* = 25)
Income to Rhythm Accuracy	r = .15, p = .39	r = -.17, p = .43
Education to Rhythm Accuracy	r = -.28, p = .10	r = .02, p = .92

Figures

Figure 1

Rhythm accuracy (A) and reaction time (B) by group. There were no significant differences across groups in either metric (ps >.36).