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ORIGINAL PAPER

Early Reading Comprehension Intervention for Preschoolers with Autism Spectrum Disorder and Hyperlexia

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Abstract
Children with autism spectrum disorder (ASD) and hyperlexia (HPL) have both advanced word reading skills and a reading comprehension disorder, alongside impaired oral language. We developed a unique, parent-supported, tablet-based intervention aiming to improve oral and reading comprehension at the word-, phrase- and sentence-level, for preschoolers with ASD and hyperlexia (ASD + HPL). English-speaking preschoolers ($N = 30$) with ASD + HPL ($N = 8$), ASD without HPL ($N = 7$) and typical development ($N = 15$) underwent a 6-week no-intervention period followed by a 6-week intervention period. Findings revealed a significant increase in reading comprehension scores for the group with ASD + HPL as compared to the TD group ($p = .023$). Gains were also found for receptive but not expressive language for all groups. Implications for early intervention for preschoolers with ASD + HPL are discussed.

Keywords Hyperlexia · Autism Spectrum Disorder · Reading comprehension · Intervention

Introduction

Few would disagree that the ultimate goal of reading is to gain meaning from the written text on the page. Through reading we gain knowledge, are entertained, and immersed in different mental worlds. The American author, James Baldwin argued that reading books changed the course of his life by bringing together the "possibilities the books suggested and the impossibilities of the life around me" (Mead & Baldwin, 1971, p. 39). Yet, reading comprehension, the key component to extracting meaning from text, is missing for some children with exceptionalities. Such is the case for those with hyperlexia (HPL), a term first coined by Silberberg and Silberberg (1967), defined as a reading comprehension disorder most commonly associated with Autism Spectrum Disorder (ASD; Ostrolenk et al., 2017). Children with hyperlexia present with poor reading comprehension despite a remarkable strength in early word-level reading and an intense interest in written material (Ostrolenk et al., 2018). But early success in single-word level reading that lacks associated word-level reading comprehension, referred to as lexico-semantic processing, is largely inefficacious. Reading comprehension has been consistently reported as a significant academic challenge for those with ASD (Randi et al., 2010; Ricketts et al., 2013).

Unfortunately, children with hyperlexia's word-level reading is not well supported in preschool or kindergarten (Newman et al., 2007). Parents report that early intervention in schools do not target their children's needs, and children with ASD and hyperlexia can be actively discouraged from engaging in reading, their preferred activity (Newman et al., 2007). These factors may contribute to the later decline viewed in reading skills for older children with ASD and hyperlexia. Studies have found that their advanced word reading appears to decline with increasing age to the point where it reaches the normative average at around age 10 years (Grigorenko et al., 2003; Newman et al., 2007). That is, children with both ASD and hyperlexia under the age of five outperform 5 year-old children with typical development (TD) as well as 10 year-old children with ASD and hyperlexia for single word reading (Newman et al., 2007). It has been proposed that an increasing disinterest in reading

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potentially develops in the absence of appropriate support leading to a plateau of reading skills (Newman et al., 2007).

A lack of early reading support is likely not due to any malintent on the part of teachers but more possibly a lack of understanding and training on how to best manage this special interest. Kindergarten and first grade teachers generally focus on early reading instruction that advances single word decoding, a skill that children with hyperlexia have already acquired despite their struggles with understanding the meaning of these words. Given that the reading comprehension process is not well understood in the context of development prior to formal schooling, even in typical readers (Randi et al., 2010), it is reasonable that preschool teachers and therapists would not address this unfamiliar profile of early reading skills in young children with ASD, and particularly those with hyperlexia. In fact, the difficulties with lexico-semantic processing may even be overlooked given their superior single-word reading ability.

An absence of early, preschool word-level intervention for hyperlexia contrasts starkly with the abundance of research addressing reading comprehension at the sentence and paragraph level with older children with ASD. Several systematic reviews and recent studies have documented strategies such as summarization, graphic organizers, mnemonics, reciprocal teaching and explicit instruction (El Zein et al., 2014; Finnegan & Mazin, 2016; Senokossoff, 2016; Turner et al., 2017) demonstrating varying efficacy at improving sentence- and paragraph-level reading comprehension in older children with hyperlexia. Yet, no study to date has examined the effects of addressing early, word-level reading comprehension abilities in preschool or early school-aged children with ASD and hyperlexia to develop oral and reading comprehension skills during this critical period in the development of language and early literacy skills.

The potential implications of early reading comprehension intervention on both oral language and reading comprehension acquisition for preschool children with ASD and hyperlexia are substantial. Indeed, hyperlexia is frequently accompanied by delayed oral language skills (Grigorenko et al., 2002, 2003; Needleman, 1982) defined as atypical or delayed understanding of spoken language (oral language comprehension) and/or expressive language. A key motive for early intervention is to accelerate development (Landa, 2018) thereby increasing prospects for early academic success and socially appropriate communication exchanges (Landa et al., 2011), in addition to improving oral language skills that are otherwise impaired in ASD but have a critical impact on later academic achievement in reading comprehension (Ricketts et al., 2013). We know from TD children that a strong, bi-directional relationship exists between social and academic competence, whereby poor social skills negatively affect academic achievement; and conversely, weak academic achievement correlates with maladaptive behaviour in the classroom (see Nadeem et al., 2010 for a review). We also know that children with ASD have both social and academic challenges (Brown & Bebko, 2012; Ricketts et al., 2013) that adversely affect their future. Reduced employment and low post-graduate education rates are a few examples of the associated negative career implications post-high school for this group (Autism Society, 2015). Addressing the gap in services focused on early remediation of reading comprehension and oral language, rather than waiting until middle- or upper-elementary school as is common practice, may help alleviate the negative social, academic and vocational issues linked to ASD.

Theoretical Framework: Simple View of Reading and the Dual Coding Theory

The Simple View of Reading (SVR; Hoover & Gough, 1990) has been used to account for the underlying reading comprehension challenges associated with ASD (Ricketts et al., 2013) as well as dyslexia and specific reading comprehension disorders (Catts et al., 2006, 2015). According to the SVR, the product of word decoding and linguistic comprehension determines reading comprehension. Linguistic comprehension is the ability to understand spoken language, while word decoding is the ability to read words via a whole word (orthographic) and/or a sound-based (phonological) route (National Early Literacy Panel, 2008). Given that children with ASD and hyperlexia demonstrate strong word decoding (Atkin & Lorch, 2006; Cardoso-Martins & Ribeiro da Silva, 2010; Grigorenko et al., 2002; Lamonica et al., 2013; Lin, 2014; Mustika et al., 2014; Newman et al., 2007; O'Connor & Hermelin, 1994; Talero-Gutierrez, 2006), in the presence of weak language comprehension (Carlsson et al., 2013), the resulting poor reading comprehension renders the SVR a fitting explanatory model. In fact, both word recognition and language comprehension predicted reading comprehension in adolescents with ASD (Ricketts et al., 2013). Thus, according to the SVR, targeting children's oral language comprehension skills could lead to improved reading comprehension, given their already strong word decoding skills.

Targeting oral language comprehension at the receptive vocabulary level is an appropriate goal for preschoolers with ASD struggling with oral language challenges (Kover et al., 2013). To do so, the Dual Coding Theory (DCT; Sadoski, 2005) provides a framework for accelerating receptive

vocabulary acquisition. The DCT distinguishes between abstract and concrete words, and between two codes: verbal (written words, oral language) and nonverbal (mental imagery, knowledge). While abstract words, like "love", require knowledge of semantic relationships and higher order language skills to specify meaning, concrete words, like "tree", can easily be associated with imagery and thus facilitate earlier acquisition. Hence, according to the DCT, concrete words that have the highest imagery factor are learned more quickly in the presence of the dual code: verbal (written word) plus nonverbal cues (picture). In summary, the DCT provides a scaffolding approach for effectively teaching receptive, concrete vocabulary augmented by orthographic and pictorial cues to improve linguistic comprehension in children with ASD, while the SVR advocates targeting linguistic comprehension as a means to improving reading comprehension.

In support of the DCT and SVR, a number of studies and evidence-based intervention programs combine pictures and orthography (written words) to develop various aspects of oral and written language. For example, Ricketts et al. (2015) demonstrated that by using orthographic cues to support oral vocabulary learning (both receptive and expressive), TD children, those with specific language impairment and children with ASD could learn novel or nonwords after only one intervention session. A match-to-sample paradigm (matching a picture to a word) was also effective in teaching emergent language skills (receptive and expressive vocabulary) to 3- to 8-year-old children with ASD (Bejnö et al., 2018), while Still et al. (2015) successfully implemented a tablet-based, text-picture matching task to teach derived requesting (i.e., requesting novel objects) for 3- to 12-year-old children with ASD. Programs such as the Picture Exchange Communication System (PECS; Bondy & Frost, 1985) are also based on pictures to foster communication skills for preschool children with ASD, while the Visualizing and Verbalizing program (Bell, 1991) for older children with ASD teaches lexico-semantic processing (rather than simply sight word reading) using images and text combined. Together, these studies suggest that the technique of word-picture matching, incorporating images and orthography, is a viable means of improving vocabulary acquisition and written language comprehension in young children with ASD. To date, no study has examined the effect of targeting early word reading in preschoolers with ASD and hyperlexia to improve both oral language comprehension and reading comprehension.

Aims and Hypothesis of the Current Study

The current study seeks to harness the strength in early word decoding abilities of preschool children with ASD and hyperlexia to improve both oral language comprehension and reading comprehension. We conduct an intervention study to examine oral language (oral language comprehension and expressive language) and reading comprehension with measurements at three time points. The aim of this study is to evaluate the efficacy of a unique, tablet-based, early reading comprehension intervention program that targets word-picture matching to improve oral language comprehension and reading comprehension (lexico-semantic processing) for preschool children with ASD and hyperlexia. We also assess expressive language skills for associated gains. We hypothesize that preschool children with ASD and hyperlexia (ASD + HPL) will significantly improve their reading comprehension, oral language comprehension and expressive language skills from a pre-intervention period (normal developmental growth) to post-intervention (following exposure to the intervention), as compared to a TD group and a group with ASD without hyperlexia (ASD-HPL).

Method

Participants

We have previously discussed the participants in this study (recruitment, ascertainment criteria, inclusionary and exclusionary criteria, and baseline measures) and their associated characteristics in-depth in an earlier study (Macdonald et al., 2020), which is summarized here. A total of 32 participant pairs (parents and their preschool children between the ages of 3 years, and 5 years and 11 months) were included in the intervention study, $N = 16$ with typical development (TD) and $N = 16$ with ASD. However, two participants (one from the TD group and one from the group with ASD) did not complete the intervention requirements and were removed from the study and their subsequent data were not included in analysis. Thus, $N = 15$ were included in the TD group and $N = 15$ were included in the group with ASD (see Table 1). The group with ASD was further divided into those with hyperlexia (ASD + HPL), $N = 8$ and those without hyperlexia (ASD-HPL), $N = 7$.

There were no significant differences between the groups for age (see Table 1) nor family income between the groups with ASD and TD ($p = 0.33$) and between all three groups ($p = 0.30$). However, the groups did differ significantly for gender. Consistent with previous studies of ASD + HPL

Table 1 Age, FSIQ, VIQ, word reading, ASD and hyperlexia symptoms for all groups before the reading intervention

Variable	ASD + HPL (*N* = 8)		ASD-HPL (*N* = 7)		All ASD (*N* = 15)[d]		TD (*N* = 15)	
	M(SD)	Range	*M(SD)*	Range	*M(SD)*	Range	*M(SD)*	Range
Age (months)	53 (9)	36–65	58 (11)	41–70	55 (10)	36–70	49 (8)	38–61
Full Scale IQ[1] [a**c**]	69 (8)	58–78	82 (10)	67–94	75 (11)	58–94	87 (12)	68–112
Verbal IQ[1] [a**b*c**]	70 (9)	58–85	88 (13)	67–102	79 (14)	58–102	95 (12)	71–111
Word Reading[2a**b**c**]	121 (14)	98–138	93 (17)	72–110	95 (14)	73–119	108 (21)	72–138
Symbol and text representation[3]	96 (26)	51–123	91 (19)	60–115	93 (22)	51–123	98 (10)	82–113
Severity: ADOS-2[4] comparison score	7 (2)	4–10	6 (2)	4–9	7 (2)	4–10	–	–
Severity: SRS-2P[5] [c**]	64 (9)[e]	54–78	74 (7)	63–84	69 (9)	54–84	46 (6)	39-60[f]
Severity: SCQ-L[6] [c**]	13 (6)[g]	3–20	18 (5)	12–24	16 (6)	3–24	8 (9)	1-29 [h]

Data reported in this table (excluding the data on the WJ-IV-ACH PC) were first reported in Macdonald et al. (2020)

[1]Weschler Preschool and Primary Scale of Intelligence–Fourth Edition: Canadian (WPPSI-IV[CDN]; standard scores)

[2]Letter-Word Identification subtest of the Woodcock Johnson Test of Achievement–Fourth edition (WJ-IV-ACH; standard scores)

[3]Passage Comprehension (PC) subtest of the WJ-IV-ACH (standard scores)

[4]Autism Diagnostic Observation Schedule, 2nd edition (ADOS-2)

[5]Social Responsiveness Scale – Second Edition – Preschool Version (SRS-2P; t-scores)

[6]Social Communication Questionnaire – Lifetime (SCQ-L)

Significant difference *$p < .05$, ** $p < .01$ between:

[a]ASD + HPL vs TD,

[b]ASD + HPL vs ASD-HPL,

[c]ASD vs TD

[d]All ASD (n = 15): ASD + HPL (n = 8) plus ASD-HPL (n = 7)

[e]Two participants in the group with ASD + HPL had scores under the cutoff (< 60) on the SRS-2P. Both met criteria for ASD on the ADOS-2 and ADOS-2 comparison score

[f]All participants in the TD group had scores at or under the cut-off score for ASD (*t*-score ≥ 60) on the SRS-2P

[g]Two participants in the group with ASD + HPL had scores below the cutoff (< 10) on the SCQ-L. Both these participants met criteria for ASD on the ADOS-2 and ADOS-2 comparison score

[h]Two participants in the TD group had scores above the cut-off (> 10) on the SCQ-L. Both these participants had scores below the cut-off score for ASD (*t*-score ≥ 60) on the SRS-2P. The range of SCQ-L scores in the TD group without two outliers is from 1–10

(Newman et al., 2007) there were significantly more males in the sample with ASD (93%). The opposite was true for the TD group, composed of significantly more females (73%). Using chi-square analysis, there was no statistically significant difference for paternal education ($p = 0.47$), but all three groups differed significantly on maternal education ($p = 0.04$).

Study and Subgroup Inclusion and ASD Symptoms

All children in the group with ASD had a diagnosis provided by a registered clinical psychologist, paediatrician or psychiatrist, in addition to meeting criteria on the Autism Diagnostic Observation Schedule, 2nd edition (ADOS-2; Lord & Rutter, 2012). ADOS-2 Comparison scores were prioritized for inclusion with a range of 4–10 (low to high severity) required. In addition, the Social Communication Questionnaire – Lifetime (SCQ-L; Rutter et al., 2003) and the Social Responsiveness Scale–Second Edition–Preschool Version (SRS-2P; Constantino, 2012) provided secondary inclusionary measures for the ASD group and exclusionary measures for the TD group. There was a statistically significant group difference (ASD vs TD) for scores on the SCQ-L, $p < 0.006$, and the SRS-2P, $p < 0.001$, in favour of higher scores for the group with ASD (see Table 1) indicating clinically significant symptomology associated with ASD. Participants with ASD + HPL ($N = 3$) who did not meet criteria on either the SRS-2P and/or the SCQ-L were included in the group if they met criteria on the ADOS-2, ADOS-2 comparison score and hyperlexia inclusion. Children with ASD and TD children were included if parents confirmed that their child spoke English at home daily with at least one parent since birth, had an interest in letters, words, and/or an ability to read words. Children with a history of receiving

formal reading instruction were excluded. No child in either group had a documented history of a failed hearing test, nor symptoms of hearing loss during the study.

Hyperlexia Inclusion

As previously discussed in Macdonald et al. (2020), we based inclusion in the ASD hyperlexia group (ASD + HPL) on five criteria according to Needleman (1982) as follows: (a) early word reading before age 5 years, (b) a Full Scale IQ (FSIQ) below 78 as measured on the Weschler Preschool and Primary Scale of Intelligence – Fourth Edition: Canadian, (WPPSI-IV^{CDN}; Wechsler, 2012), (c) a Verbal IQ (VIQ) below 85, as measured on the VIQ scale of the WPPSI-IV^{CDN}, (d) single word reading 2 standard deviations above VIQ and FSIQ as measured on the Letter-Word Identification (LWI) subtest of the Woodcock Johnson Test of Achievement–Fourth edition (WJ-IV-ACH; Mather & Wendling, 2014); hereafter referred to as the WJ LWI), and (e) poor reading comprehension relative to word reading as measured on the Passage Comprehension subtest (PC) of the WJ-IV-ACH (hereafter referred to as the WJ PC). Of the eight participants in the group with ASD + HPL, seven met all five criteria and one met four criteria. The remaining 7 participants with ASD were assigned to the ASD-HPL group.

Single Word Reading, Reading Comprehension, FSIQ and VIQ

As previously shown in (Macdonald et al., 2020; see Table 1), statistically significant differences were found between all three groups for single word reading on the WJ LWI, $F(2,23) = 10.46$, $p < 0.001$, with significantly higher mean word reading scores for the group with ASD + HPL as compared to both the TD group ($p = 0.001$) and the group with ASD-HPL group ($p = 0.004$). The WJ LWI subtest first assesses knowledge of single letters (items 1–6) followed by letter naming (items 7–10), then single word reading progressing from single syllable words to 2-, 3- and 4-syllable words (items 11–78). In addition, there were statistically significant group differences for both FSIQ, $F(2,27) = 7.43$, $p = 0.003$, and VIQ, $F(2, 27) = 11.83$, $p < 0.001$, with significantly higher mean FSIQ ($p = 0.002$) and VIQ ($p < 0.001$) for the TD group as compared to the ASD + HPL group, and higher VIQ for the group with ASD-HPL as compared to the ASD + HPL group ($p = 0.021$). In contrast, there were no significant differences among groups for the distribution of scores on reading comprehension (symbol and text representation) on the WJ PC before the intervention $\chi^2(2,30) = 0.703$, $p = 0.704$.

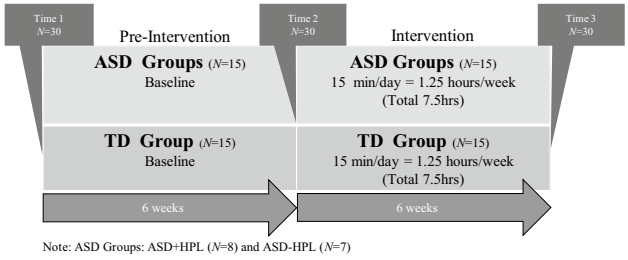

Fig. 1 Study design

Design

In this repeated-measures A-B design (see Fig. 1), parent and child dyads with ASD ($N = 15$), and TD ($N = 15$) completed baseline measures at Time 1.

Following Time 1 assessment, parent–child dyads underwent a pre-intervention period for 6 weeks (from Time 1–2). This initial pre-intervention period was designed to serve as a measure of normal developmental growth that occurs in the absence of intervention, representing normal maturation. Thus, each participant served as their own pre-intervention control. During this period, parents were instructed to interact with their child as they normally did at home. After this six-week period, children were reassessed (Time 2). The tablet-based reading intervention period then lasted 6 weeks (from Time 2–3) in the participants' homes where parents supported their child's use of the tablet intervention for 15 min per day, 5 days per week, for a maximum of 7.5 h of intervention (See Fig. 1). Parents were instructed to conduct the intervention with their child at a time that worked for their daily schedules. Parents were asked to sit with their child during the intervention time and interact as they would when reading a book, as well as to provide praise and encouragement. Subsequent to the intervention period, children completed Time 3 assessments (post-intervention).

Intervention

The first author and a team of professional developers at BrandJaws (https://www.brandjaws.com) through UpWork (https://www.upwork.com) designed and built the reading comprehension intervention application on an iOS platform with a web-based backend to collect data. The intervention implemented a forced-choice, two-option, text-to-picture matching activity (see Fig. 2 and Appendix Figure 6) with stimuli that consisted of 145 concrete nouns, 100 verbs, 48

Fig. 2 Sequence of screen displays with the tablet-based reading comprehension and oral language intervention

adjectives, 24 concepts and 11 pronouns organized from early to later developing words, based on the MacArthur-Bates Communicative Development Inventories Wordbank (Frank et al., 2017).

All children began at the first item, with concrete nouns of short word shapes (e.g., Consonant Vowel Consonant; CVC), like *cat*, and progressed to longer noun word shapes (e.g., CCVC or CVCC) like "slip" or "park". There were three levels: word-, phrase-, sentence-picture matching tasks, and two phases: Oral Language Comprehension and Reading Comprehension (see Appendix Figure 7 and 8).

The screen display, in both the Oral Language Comprehension and Reading Comprehension phases, was identical; each presented a written word (e.g., bed; see Fig. 2 and Appendix Figure 6). The only difference between the two phases was audio (the spoken word) accompanied the written word along with an ear icon in the Oral Language Comprehension phase, while no accompanying audio and a book icon appeared during the Reading Comprehension phase. In the Oral Language Comprehension phase, the participant heard the oral word when touching the written word, (e.g., the participant heard and saw the word "bed" simultaneously). In each phase, the child heard the verbal prompt (via a synthesized iPad female voice) to "Touch the word" to initially help with training. However, there was an available option in the settings to replace the verbal prompt with a nonverbal green arrow pointing to the word. After the initial training session, the nonverbal option was selected, and parents were counselled not to change this setting to avoid encouraging echolalic responses. After the child touched the word, two images appeared on the screen (the corresponding image and a distractor image) above the same written word (see Fig. 2 and Appendix Figure 7). The child then chose the picture that corresponded to the written and auditory word in the Oral Language Comprehension phase or to

the written word in the Reading Comprehension phase by touching the image.

When a child touched the correct picture, they heard a rewarding sound (ascending tones; differential reinforcement; default setting) or verbal reinforcement (That's right! or well done!) depending on the chosen settings. The correct image appeared alone, highlighted in green and the 'next' arrow appeared, which the child selected to advance to the next word. When the child chose the incorrect word (distractor), a corresponding "incorrect" sound (descending tones; default setting) or verbal prompt option, "Try again" played and the same two pictures in the same orientation were repeated. If the child chose the incorrect image a second time, that image faded and only the correct image was available for selection. On a new trial, the target image remained the same with the position randomly varying between left and right and the distractor image randomly alternating between three different images. There were over 200 unique distractor images. Some distractor images did appear as target words and vice versa. Each trial always ended with the child choosing the correct picture and receiving positive verbal or auditory reinforcement. However, only when a child correctly chose the target word on the first attempt of 2/3 trials (see Outcomes of Scenarios 1, 2 and 3 in Appendix Figure 7) was the word considered "acquired" and the same word was presented in the reading comprehension phase. When the word was not acquired (see Outcome Scenario 4 in AppendixFigure 7), a novel target word was presented and the unacquired target word reappeared after approximately 3–4 trials.

The intervention incorporated a number of reward systems to maintain motivation. For example, during the intervention a small sunshine icon appeared every 3 min for a total of 5 icons over the 15-min session (see Fig. 2). At the end of each 15-min session, a link to PBS kids' games appeared. However, parents were also encouraged to provide their own form of reward if they did not want their child to play iPad games. Finally, at the completion of 5 days of intervention a message appeared on the screen with a present icon congratulating the child on their work and letting them know they had earned a gift. It was left up to the discretion of the parent as to whether the child would choose his/her own gift, or whether the parent would provide them with one. Gifts provided to parents for their child included pens, colouring sets, bubbles, toy cars, etc. This was repeated each week for the 6-week period (for a total of 6 gifts throughout the intervention period).

Data Collection

We used standardized tests at Times 1, 2, 3 to assess outcome measures of reading comprehension (symbol and text representation) and oral language (receptive and expressive) during the intervention period (from Time 2–3), as compared to a pre-intervention period (from Time 1–2; see Table 2). Baseline measures, including the ADOS-2, SRS-2P, SCQ-L, WPPSI-IV^{CDN} and the WJ LWI, were collected at Time 1.

Standardized Outcome Measures (Time 1, 2 and 3)

Reading Comprehension (Symbol and Text Representation) The primary outcome measure used to assess reading comprehension was the WJ PC. Since we also assessed TD preschoolers who were not yet reading, we refer to this task as symbol and text representation (see Table 2). The WJ PC subtest measures symbol, single word and sentence comprehension within a multiple-choice paradigm. The first four items of the test begin with matching one of two, then one of three, black and white rebus symbols to a single colour image (e.g., chair, cat, book). Following the symbol matching, participants match written words or phrases to one of four pictures, then progress to completing sentences (fill-in the blank) initially accompanied by a picture cue but progressing to sentences without pictures. At Time 1, the majority of participants in the TD group (87%) and in the group with ASD-HPL (86%) were able to match symbols but were not able to match written words or phrases to pictures. Versions B and C of the WJ-IV-ACH were randomly assigned and then alternated (B-C-B or C-B-C) to ensure counterbalance of the presentation order across Time 1, 2 and 3 and to control for practice effects. Of the 145 nouns used in the intervention, only three single vocabulary items and three fill-in-the-blank sentences on the WJ PC subtest contained overlapping items (man, book, car, chair, table, soup). Raw scores for the WJ subtests were used for consistency in analysis given that standard scores are not available for children younger than 5 years of age on the B version of the OWLS-II Listening Comprehension and Oral Expression Scales.

Oral Language The primary outcome measures used to assess oral language skills were the Oral and Written Language Scales (OWLS-II; Carrow-Woolfolk, 2011a) Listening Comprehension Scale (OWLS-II LC) for oral language comprehension (receptive language), and the Oral Expression (OWLS-II OE) Scale for expressive language (see

Table 2 Mean Raw Scores on Outcome Measures at Time Points 1, 2, and 3 for the ASD + HPL, ASD-HPL, and TD groups

Variable	Symbol and Text Representation[1] *M(SD)* Range	Receptive Language[2] *M(SD)* Range	Expressive Language[3] *M(SD)* Range
ASD + HPL			
Time 1	6.12 (4) 0–13	23.62 (10) 10–45	8.88 (5) 2–18
Time 2	7.75 (5) 1–14	23.25 (14) 4–43	14.25 (6) 6–24
Time 3	10.13 (4) 5–18	32.5 (17) 14–66	13.0 (7) 5–26
ASD-HPL			
Time 1	5.0 (3) 3–11	36.14 (18) 5–52	21.71 (10) 8–38
Time 2	5.0 (1) 4–6	36.86 (12) 16–49	25.0 (8) 12–35
Time 3	6.28 (2) 3–9	44.57 (17) 23–73	28.43 (11) 17–45
TD			
Time 1	4.6 (1) 4–8	36.2 (21) 16–87	23.6 (12) 7–44
Time 2	4.6 (2) 0–8	41.13 (20) 14–87	26.73 (13) 9–46
Time 3	5.73 (2) 2–10	45.00 (21) 19–90	28.73 (12) 12–48

The above variables were assessed using the following:

[1]Passage Comprehension subtest of the Woodcock Johnson Test of Achievement – Fourth Edition (WJ-IV ACH PC)

[2]Listening Comprehension Scale of the Oral and Written Language Scales – Second Edition (OWLS-II LC)

[3]Oral Expression Scale of the Oral and Written Language Scales – Second Edition (OWLS-II OE)

Table 2). The LC scale involves matching a spoken word by pointing to one of 4 coloured pictures. The OE scale requires picture naming, often after a model prompt has been provided, e.g., This is a little ball and this is a _____ (picture of a big ball). Items are presented in an increasing order of difficulty, matched to age of acquisition in TD children, and assess different linguistic structures, including lexical/semantic, syntactic, and supralinguistic (e.g., inferences) for the LC scale, with the addition of pragmatic language for the OE scale (Carrow-Woolfolk, 2011b). Versions A and B of the OWLS-II were also randomly assigned to ensure counterbalance of the presentation order across Time 1, 2 and 3. Raw scores for the OWLS-II subtests were used in analysis as noted.

Web-based Data Collection

A web-based database securely and anonymously collected information on performance and usage including date, number of sessions spent on the intervention, number of correct and incorrect words choices, total daily score on each of the Oral Language Comprehension and Reading Comprehension phases of intervention, and final level attained (see Table 3). There was no significant difference between the three groups in mean number of sessions spent on the intervention ($p = 0.074$; ASD + HPL, $M = 22$; ASD-HPL, $M = 21$; TD, $M = 16$).

Compliance and/or Intervention Fidelity Participants were required to complete the intervention five days per week. Parents were sent friendly reminders via email or contacted directly if the weekly goals were not met. For example, any participant who missed three consecutive days or who failed to complete the entire 15 min on three consecutive days, was contacted to offer assistance or troubleshoot with the family. If a child did not complete five days in any two weeks of the study, they were removed from the study; this was the case for two participants who were not included in the final sample of 30 participants as noted.

Settings

Assessment activities were conducted either at McGill University or a clinical psychology office. Occasionally, assessments were conducted in the participants' homes. Some children were able to complete all Time 1 measures during the same session, while others required two separate sessions. Child participants received a small gift following each assessment session. All intervention sessions were conducted in the families' homes by the parents after receiving instructions and a demonstration with their child. Parents received a $25 gift card for their participation. Families who did not own an iPad were lent one for the 6-week intervention period.

Table 3 Distribution of Participants' Final Level Attained (Word, Phrase, Sentence) for Oral Language and Reading Comprehension by Group

Level	ASD + HPL*		ASD-HPL		TD	
	Oral	Reading	Oral	Reading	Oral	Reading
Word	0	0	3	3	3	3
Phrase	2	2	2	2	6	6
Sentence	6	6	2	2	6	6
Total	8	8	7	7	15	15

Significant difference*$p < .05$

Statistical Analyses

Data were coded to ensure anonymity and entered into SPSS statistical software version 25 and analyzed in version 26. We aimed to evaluate whether the intervention significantly improved reading comprehension, oral language comprehension and expressive language scores from the initial pre-intervention period (Time 1–2) as compared to the intervention period (Time 2–3). Data screening was performed prior to analysis. Assumption checks for the two-way mixed ANOVA revealed a number of extreme outliers in the data, as evidenced by inspection of box plots. Floor effects were noted for the TD group on symbol and text representation on the WJ PC. Normality was assessed using the Shapiro–Wilk test, where a significance of $p < 0.001$ was used to identify data that were not normally distributed. The assumption of homogeneity of variances was violated for the symbol and text representation variable (assessed via WJ PC) for Time 1 and 2. The assumption of homogeneity of covariances was violated as evidenced by a significant Box's test ($p = 0.010$).

Given the violations of assumptions we elected to run Friedman's nonparametric repeated measures ANOVA for the reading comprehension (symbol and text representation) variable at the three time points, adjusting for multiple comparisons using Bonferroni correction. We used the Kruskal–Wallis tests for the group comparisons at two time points (Time 2 and 3), adjusting for multiple comparisons using Bonferroni correction. We also examined the improvement in change scores from Time 2–3, while controlling for change scores from Time 1–2, using linear regression to obtain unstandardized residuals and compared these between the two groups (ASD + HPL and TD) using the Independent-Samples Mann–Whitney U test. When all assumptions were met, we used a two-way mixed ANOVA to assess if there was a two-way interaction among the between-subjects factor (groups: ASD + HPL, ASD-HPL, TD) and the within-subjects factor (Time 1, 2, and 3) on the dependent variables (oral language comprehension and expressive language) adjusting for multiple comparisons using Bonferroni correction when pairwise comparisons followed significant findings.

Results

Reading Comprehension (Symbol and Text Representation)

Friedman's nonparametric repeated measures test revealed a statistically significant difference in the distribution of scores for symbol and text representation across the three different time points, $\chi^2(2,30) = 16.796$, $p < 0.001$, $\eta^2 = 0.28$ (see Table 2, Fig. 3), as measured on the WJ PC subtest. Pairwise comparisons with Bonferroni correction indicated no significant difference from Time 1–2, $p = 1.00$, but significant improvements in performance from Time 1–3, $p = 0.002$, and from Time 2–3, $p = 0.007$. These results indicate that scores on reading comprehension (symbol and text representation) were significantly higher following the intervention period (at Time 3) as compared to the pre-intervention period (at Time 1 and at Time 2) for all groups.

The Kruskal–Wallis test was run to examine differences between the three groups at Times 2 and 3. The distribution of symbol and text representation scores was significantly different among the three groups at Time 3 $\chi^2(2,30) = 7.783$, $p = 0.020$, $\eta^2 = 0.14$, but not at Time 2, $\chi^2(2,30) = 4.203$, $p = 0.122$. Pairwise comparisons of group with Bonferroni correction indicated that these differences were between the TD group and the group with ASD + HPL, $p = 0.017$, but not between the TD group and the group with ASD-HPL, $p = 1.00$, nor between the groups with ASD + HPL and ASD-HPL, $p = 0.208$ (see Fig. 3, Table 2). Thus, the group with ASD + HPL had significantly higher mean scores in symbol and text representation post-intervention (Time 3) as compared to the TD group, but not compared to the group with ASD-HPL.

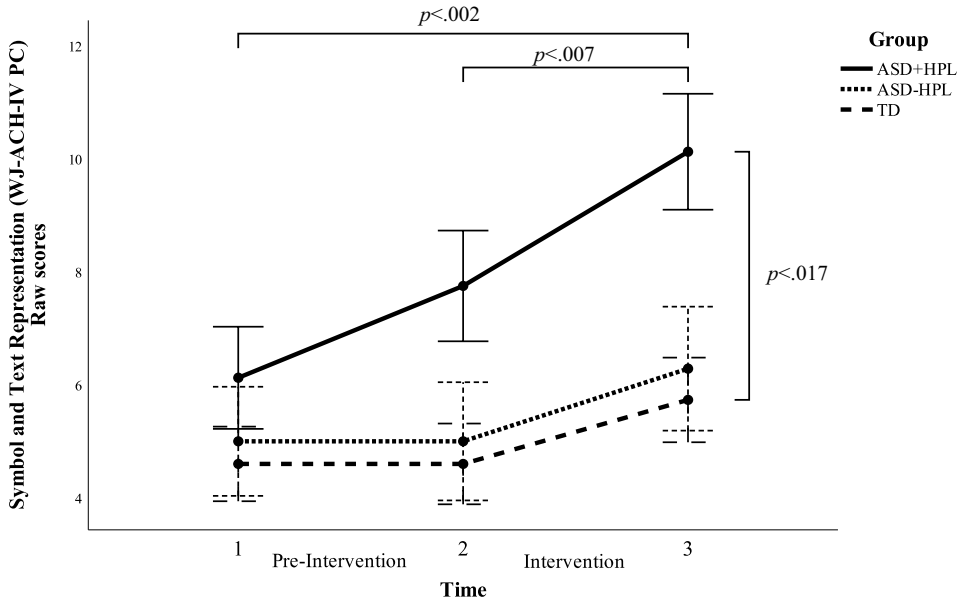

Fig. 3 Mean reading comprehension (symbol and text representation) a time points 1, 2, and 3 for ASD + HPL, ASD-HPL and TD groups (error bars = ± 1 SE)

To further examine improvement in scores noted from Time 2–3 for all groups, and higher scores at Time 3 for the ASD + HPL group compared to the TD group, we regressed the change in scores from Time 1–2 (Δ 1–2) out of the change in scores from Time 2–3 (Δ 2–3) for both groups and compared the unstandardized residuals across groups using an Independent-Samples Mann–Whitney U test. Results showed again that the group with ASD + HPL (mean rank = 16.31) had significantly greater gains in scores from Time 2–3 as compared to the TD group (mean rank = 9.87), $U = 94.5$, $p = 0.023$, $\eta^2 = 0.23$ when controlling for the change in scores from Time 1–2. These results indicate greater improvement in reading comprehension (grasp of symbol and text representation) associated with the intervention from Time 2–3 for the ASD + HPL group compared to the TD group.

Oral Language

Language Comprehension

A two-way mixed ANOVA was run to examine oral language comprehension (see Fig. 4, Table 2). There was no significant group x time interaction, $F(4, 54) = 0.725$, $p = 0.579$. The main effect of group was not statistically significant, $F(2,27) = 1.887$, $p = 0.171$. However, the main effect of time showed a statistically significant difference in mean oral language comprehension at the different time points, $F(2,54) = 14.138$, $p < 0.001$, $\eta^2 = 0.34$. Pairwise comparisons with Bonferroni correction revealed no significant difference from Time 1–2, $p = 0.929$, with significant improvement in performance from Time 1–3, $p < 0.001$, and from Time 2–3, $p = 0.002$. This finding indicates that the mean oral language comprehension scores were higher post-intervention (at Time 3) as compared to pre-intervention (at Time 1 and Time 2) and that this was the case for all three groups taken together.

Expressive Language

A two-way mixed ANOVA was conducted to examine expressive language. There was no significant group x time interaction, $F(4,54) = 1.182$, $p = 0.329$ (see Fig. 5, Table 2). There was a significant main effect of group, $F(2,27) = 5.773$, $p = 0.008$, $\eta^2 = 0.30$. Pairwise comparisons with Bonferroni correction revealed a significant difference between the TD group and the group with ASD + HPL, $p = 0.008$, with the TD group demonstrating higher mean expressive language scores throughout the pre-intervention and intervention periods. The difference between the groups with ASD + HPL and ASD-HPL approached significance, $p = 0.053$, revealing the group with ASD-HPL to trend towards having higher mean scores for expressive language throughout the pre-intervention and intervention periods as compared to the group with ASD + HPL. The main effect of time was also significant, $F(2,54) = 20.208$, $p < 0.001$, $\eta^2 = 0.43$. Pairwise comparisons with Bonferroni correction indicated significant differences in oral expression from Time 1–2, $p < 0.001$ and from Time 1–3, $p < 0.001$, but not from Time 2–3, $p = 0.414$. Thus, the intervention did not

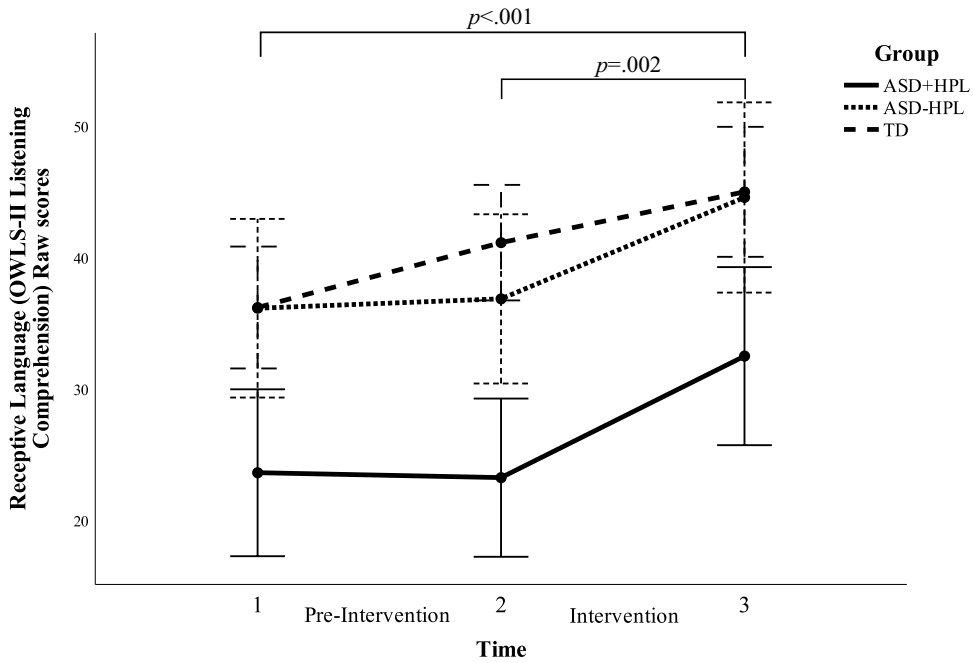

Fig. 4 Mean receptive language measured on the OWLS-II Listening Comprehension Scale at time points 1, 2 and 3 for the ASD + HPL, ASD-HPL and TD groups (error bars = ± 1 SE)

appear to significantly affect change in oral expression skills in the group with ASD + HPL nor did it affect change in oral expression differently from one group to another.

Discussion

This study is the first to report on a successful early intervention for preschoolers with ASD + HPL targeting their strength in early word reading to improve areas of challenge in word-, phrase- and sentence-level reading comprehension and oral language comprehension. Results demonstrated that significant improvements in reading comprehension (symbol and text-representation) and oral language comprehension can be achieved at the preschool level with very young children with ASD + HPL. This study adds to other successful, parent-supported, tablet-based language interventions for young children with ASD (Dunn et al., 2017; Still et al., 2015), in addition to contributing to previous findings of existing intervention programs that use visuals to support language development (Bell, 1991; Bondy & Frost, 1985) and studies that have effectively used word-picture matching (Bejnö, et al., 2018; Still et al., 2015) and orthography (Ricketts et al., 2009, 2015) to teach language skills to children with ASD.

Our hypothesis stated that preschoolers with ASD + HPL would improve their reading comprehension and oral language skills (both comprehension and expression) from pre-intervention (Time 1–2) to post-intervention (Time 2–3) as compared to the two comparison groups (TD and ASD-HPL). Our findings support this hypothesis for reading comprehension for the group with ASD + HPL, whose reading comprehension scores significantly increased from pre- to post-intervention on the WJ PC subtest measuring symbol and text representation, as compared to the TD group (see Fig. 3). These results suggest that there is no need to delay intervention until later primary school to affect change in reading comprehension.

For oral language comprehension, our hypothesis proved to be correct for all groups, not solely the group with ASD + HPL as we had originally hypothesized. That is, there were significantly higher language comprehension scores following the intervention period, as opposed to the pre-intervention period, for all groups taken together. Increased oral language comprehension post-intervention support and extend findings of Ricketts et al. (2009, 2015) by showing that orthography plus imagery can improve receptive language, not just oral vocabulary, for preschool children with ASD. Moreover, given the strong link between vocabulary development and reading success (Carlson et al., 2013; Perfetti et al., 2008), with a correlation of 0.81 between vocabulary knowledge and reading comprehension in the general population of school-age children (Biemiller, 2003), improving receptive vocabulary is key to accelerating reading comprehension.

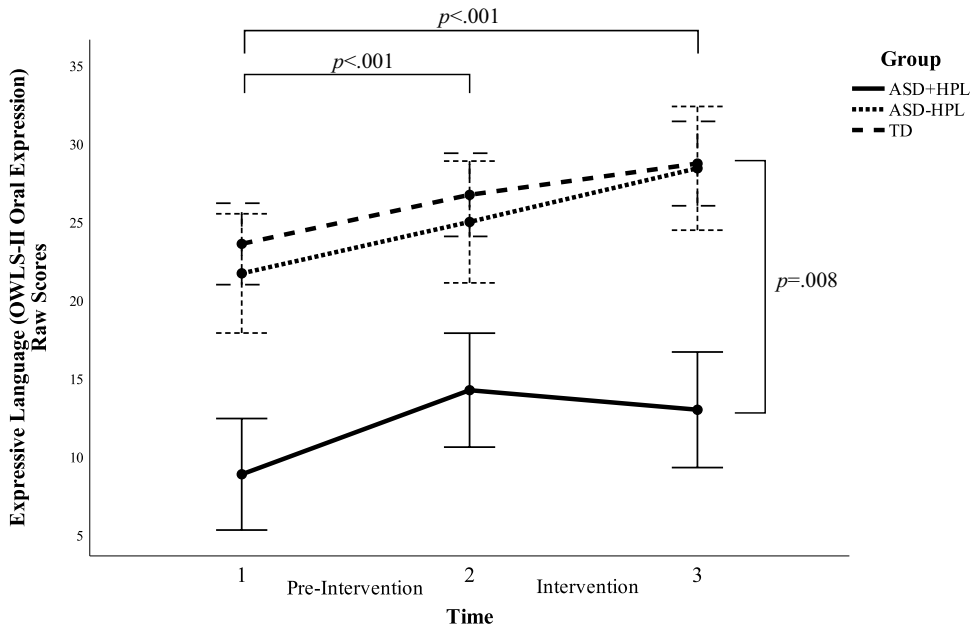

Fig. 5 Mean expressive language measured on the OWLS-II Oral Expression Scale at time points 1, 2 and 3 for the ASD + HPL, ASD-HPL and TD groups (error bars = ± 1 SE)

For oral expressive language skills, neither the group with ASD + HPL, nor the control groups demonstrated significant gains following the intervention period (see Fig. 5). Although we had hypothesized that all aspects of oral language (comprehension and expressive language), would be favourably impacted by the intervention, this was not the case. Yet, these results may shed light on the nature of language acquisition in children with ASD. Post-intervention, all groups showed a similar pattern of acquisition, with gains in receptive language but not expressive language. In TD children, receptive language typically precedes expressive language acquisition (Brown, 1973; Carrow-Woolfolk, 2011a; Lahey, 1988). While it is commonly held that preschool children with ASD demonstrate more severe deficits in receptive vocabulary (Kover et al., 2013) than expressive language (Davidson & Ellis Weismer, 2014), a recent meta-analysis of 74 studies did not support this finding, showing instead a similar level of impairment across both receptive and expressive language (Kwok et al., 2014).

Our findings for young children with ASD + HPL are consistent with these meta-analytic findings supporting weaker development in both language domains as compared to control groups, and contrast with previous studies of ASD + HPL where language was on par with non-hyperlexic and TD groups (Grigorenko et al., 2002; Newman et al., 2007). Thus, higher receptive language gains in our study, as compared to the poorer outcomes in expressive language profile across all groups may reflect a more typical rather than atypical language acquisition pattern for children with ASD. However, in light of the known heterogeneity in ASD (Baio et al., 2018) and in ASD + HPL for language acquisition across studies (Grigorenko et al., 2002; Newman et al., 2007), in combination with the variation in criteria used to define hyperlexia (Ostrolenk et al., 2017), more studies are required to examine this pattern of linguistic development in preschoolers with ASD + HPL.

The findings of this intervention also strengthen the application of the Simple View of Reading (SVR) to reading comprehension intervention for preschoolers with ASD + HPL. The notion of targeting linguistic comprehension to improve reading comprehension when word decoding is intact has been supported by the results of this intervention. Moreover, the improvements in receptive language comprehension also provide support for the use of the Dual Coding Theory (DCT) as an effective strategy, to not only teach vocabulary to preschoolers with ASD + HPL, but to support reading comprehension. By incorporating concrete, high imagery vocabulary terms and their written correlates as targets, Sadoski (2005) maintains that learning and semantic memory are enhanced, similar to a mnemonic effect, via the connection of verbal (visual language–writing) modalities and nonverbal (mental representations of an object) modalities. "Without the activation of mental representations, no meaning can be present; the potential in the cognitive system lies dormant." (Sadoski, 2005, p. 50).

Children with ASD + HPL may require an orthographic mental representation of a written word for reading comprehension to occur but be dependent on support or training to achieve such mental images. In fact, when people with ASD perform word reading tasks, the inferior frontal

gyrus (IFG or Broca's area), which is involved in semantic processing, shows decreased activation (Harris et al., 2006) and decreased functional connectivity with the left inferior occipital gyrus, an area implicated in visual processing (Bednarz et al., 2017). In addition, the TD adult control group included in the Harris et al. (2006) study showed stronger differential activation than the ASD group for concrete compared to abstract words. That is, participants with ASD did not show significant activation of the medial frontal gyrus (semantic processing in controls) and showed less pronounced activation of the left parahippocampal gyrus (a memory area) for concrete vs. abstract words. Bednarz et al. (2017) conclude that neural differences in semantic processing contribute to poor reading comprehension for ASD. Thus, targeting concrete words and imagery in individuals with ASD may strengthen semantic processing at both an oral language and reading comprehension (lexico-semantic) level, as evidenced by the results of this intervention.

Future Considerations

This novel reading comprehension intervention was designed and built to capitalize on the special interests of the population with ASD + HPL. As these children's interest in reading is already high, parents reported no challenges in soliciting their participation on a daily basis. However, this was not the case for the TD participants, as well as some participants with ASD-HPL. Although there was no statistically significant difference across groups for mean number of sessions spent on the intervention, anecdotally parents reported more challenges with compliance in the group with ASD-HPL and TD group. This was likely due to multiple factors.

Firstly, less than half the TD children (30%) and those with ASD-HPL (42%) were reading, and so were less successful and consequently, less motivated by a reading app. Second, there were very few "bells and whistles" built into this app as potential distractions. Previous research has shown that certain features of an app in e-books can distract from the task, particularly with language-impaired children, and lead to an increase in management-type dialogue on the part of parents (Rees et al., 2017), as compared to preferred narrative-type dialogue that focuses on the content of the story. To avoid this scenario with children with ASD + HPL, the app was developed to minimize distracting features. In doing so, however, the TD children and those with ASD-HPL, were potentially less motivated to participate, especially with lower reading skills and less interest in letters and words than their peers with ASD + HPL.

Furthermore, as noted in Macdonald et al. (2020), children with ASD + HPL are likely not reading via a phonological approach but rather using a more sight word technique. The DCT is aligned with a sight word reading approach and comprehension was potentially facilitated by this focus. However, this was likely not the case for the TD children. The whole word/orthographic reading approach adopted in this app was not best practice for teaching word reading to TD children who benefit from a phonological or phonics-based reading approach (Brady et al., 2011). In fact, neither the TD group, nor the group with ASD-HPL significantly improved their word reading skills from Time 2 to Time 3. Although this was not the focus of the intervention, it may have been a byproduct had the approach been more aligned with their needs.

Therefore, the TD child's potential frustration in combination with their preference for other activities associated with the digital device, may have contributed to poorer outcomes for the TD group in reading comprehension. This app is likely more appropriate for the TD group once they have begun to read or might support word reading and reading comprehension in children who do not respond to a phonological approach to reading. However, findings of improved scores for oral language comprehension indicate that despite any lack of engagement, there were still benefits to the TD group as well as the group with ASD-HPL. Future studies should adapt and explore this intervention with TD children and those with ASD who are reading, or with young children with a reading impairment in comprehension or decoding.

An additional, yet critical factor particularly relevant to children with ASD centers on generalization, beyond the intervention tasks themselves and the assessment measures, to functional reading. Notwithstanding the small sample size, and the lack of post-intervention measures obtained beyond Time 3, there is potential for generalization based on improvements in test items on the standardized measures. For example, items on both the OWLS-LC and OWLS-OE Scales progress in difficulty within 4 linguistic categories of lexical semantic, syntactic, supralinguistic (e.g., inferences) and pragmatics (Carrow-Woolfolk, 2011b). This suggests that increasing scores demonstrate increasingly complex linguistic acquisition, although no measure of construct validity is provided. Similarly, the WJ PC subtest assesses both literal and inferential reading comprehension (Mather & Wendling, 2014). Literal comprehension is the most basic level of comprehension, tapping meaning that is directly stated in the text. In contrast, inferential comprehension is increasingly complex, as it is less explicit and requires the reader to understand relationships among the various elements (Alonzo et al., 2009).

The WJ-IV states that fill-in-the-blank questions likely demand more inferential type comprehension (Mather & Wendling, 2014), therefore, items 1–10 represent literal comprehension, while the remaining 42 questions are

inferential (out of a total of 52 items in the subtest). Examination of individual test item scores from Time 1 to Time 3 for the group with ASD + HPL revealed that 38% demonstrated acquisition of literal comprehension items initially and progressed to inferential items by the end of the study; 50% made progress within the literal comprehension section, and 12% within the inferential section. In summary, despite the lack of available construct validity data for these measures, the test items reflect reading comprehension and linguistic competencies that are applicable to functional reading and communication beyond the context in which they have been assessed, suggesting progress in these domains may transfer to real-life contexts. However, future studies should examine if gains continue post-intervention and if long-term benefits can be achieved (Landa & Kalb, 2012).

Finally, there are a number of ways that gains in reading comprehension may have been fostered by this intervention for the group with ASD + HPL that warrant further investigation. For example, it is unclear to what degree parental support influenced outcomes. A recent review of early intervention for children under five years old, at-risk or diagnosed with ASD (Landa, 2018) concluded that "equipping parents to implement development-enhancing strategies while engaged with their child is a vital intervention component" (pp. 34–35). This may be partially due to the fact that daily intervention supported by a parent can closely follow a distributed practice learning schedule (short, daily sessions with frequent, regular practice) that has been shown to be a superior learning paradigm over massed practice (e.g., conducting all trials on one day) for preschool and school-age children with ASD (Haq et al., 2015).

Similarly, it is uncertain to what extent outcomes are dependent on the delivery of the intervention using a tablet. The tablet's touch screen afforded the use of a simple pointing response. It has been noted that an abstract gesture (touching the screen) tied to the underlying concept of the task (in this case identifying an object by pointing) that avoids irrelevant features of the real-world task, can result in a greater degree of generalization (McEwen & Dubé, 2017). Additionally, contingent responses in the form of touching the screen and hearing the word or touching a "next" button to proceed to the next page, permitted child-control of the device or activity in contrast to adult-control. Child-control has been shown to improve TD preschool children's visual attention and interest while playing an early reading computer game (Calvert et al., 2005), which is relevant to our ASD + HPL sample given they found that boys, and those with better reading skills, made more attempts to control the game. Thus, future studies might examine the impact of these factors for children with ASD as well as investigate their associated effect on generalization.

Clinical and Educational Implications

The positive effects of early intervention for children with ASD are well documented (see Landa, 2018 for a current review of the literature). Our study not only demonstrated significant benefits for the children, but also suggests additional benefits for parents, therapists and teachers of young children with ASD + HPL. For example, parents can successfully implement this intervention at home at the first signs of hyperlexia. Given the rising prevalence of ASD (Baio et al., 2018), the lengthy wait times for early intervention of upwards of a year (Brian, et al., 2019; Gordon-Lipkin et al., 2016), and the current movement to include children with ASD into mainstream elementary schools (United Nations, 2016; Vakil et al., 2009), addressing early reading skills of preschool children with ASD and hyperlexia in a timely manner is essential.

Furthermore, as the cost of daily therapy can be prohibitive for families or access to therapy can be disrupted, or limited for those in remote areas, a tablet-based format offers a relatively cost-effective method of service delivery to preschoolers with ASD while awaiting available services. Finally, encouraging and providing support for their child's special interest for written material early on may help alleviate the later decline found in reading interests and skills around 10 years of age (Grigorenko et al., 2002; Newman et al., 2007) while simultaneously accelerating growth in both oral and reading comprehension.

For educators and clinicians, findings of this study also demonstrate that there is no reason to wait until late primary school to begin working on reading comprehension. Teachers, learning specialist, and clinicians can recommend (to parents) or implement this program themselves in kindergarten as part of the general curriculum, or in a clinical or special education setting, with no additional training required and minimal support. Similarly, clinicians can include this intervention as an adjunct to their intervention that can easily be carried over at home. This has significant implications for children with ASD + HPL in both clinical and academic settings, as oral language comprehension and reading comprehension are essential components of most academic subjects and are primary targets for clinical therapy. Moreover, as social impairments of adolescents with ASD are a significant predictor of reading comprehension (Ricketts et al., 2013), the need for evidence-based measures that strengthen academic skills like reading comprehension for preschoolers with ASD + HPL is clear. Consequently, we

argue that there is a lack of evidence to support postponing reading comprehension therapy until the child is older in favour of sentence- and paragraph-level comprehension therapy. Rather, early intervention of lexico-semantic processing (word-level comprehension) at the first signs of hyperlexia, seems promising for advancing the development of both reading comprehension and oral language comprehension.

Early interventions, such as this one, are also a significant step toward establishing best practices for young children with ASD + HPL. In an earlier study, Macdonald et al. (2020) suggest that preschoolers with ASD + HPL do not likely benefit from the same early reading instructional model as their TD peers given their alternative, non-phonological approach to word reading. The current study indicates that focusing on vocabulary development and reading comprehension are viable, alternate early reading intervention routes that can represent best practices for preschoolers with ASD + HPL.

Conclusion

This early reading comprehension intervention represents a paradigm shift in the current method of teaching reading comprehension. Instruction has typically been delivered in later grade school and beyond at the sentence- and paragraph-level. The results of this study suggests that early intervention for lexico-semantic processing, beginning at the single-word level, as opposed to paragraph-level, might offer a valuable language learning opportunity for a child with ASD and support early language and academic skills. Our study is the first to report on a successful, parent-supported, strength-based, single-word approach targeting reading comprehension for very young children with ASD + HPL, although future studies with larger sample sizes are required to confirm these benefits. Early reading and language comprehension intervention holds the potential to mitigate the social and academic challenges that children with ASD face (Brown & Bebko, 2012; Ricketts et al., 2013). Improving employment and post-graduate education rates and reversing the negative career and academic outcomes post-high school that have been documented for this group (Autism Society, 2015) are key motives in developing earlier interventions to improve academic and functional skills including reading comprehension. Ultimately, and most importantly, early reading-based intervention may permit children with ASD + HPL to apply their strength in, and love of reading to develop language and reading comprehension in parallel so that reading becomes a rich and meaningful experience, one that can positively influence the personal, academic and professional course of their lives.

Appendix

Figures 6, 7 and 8

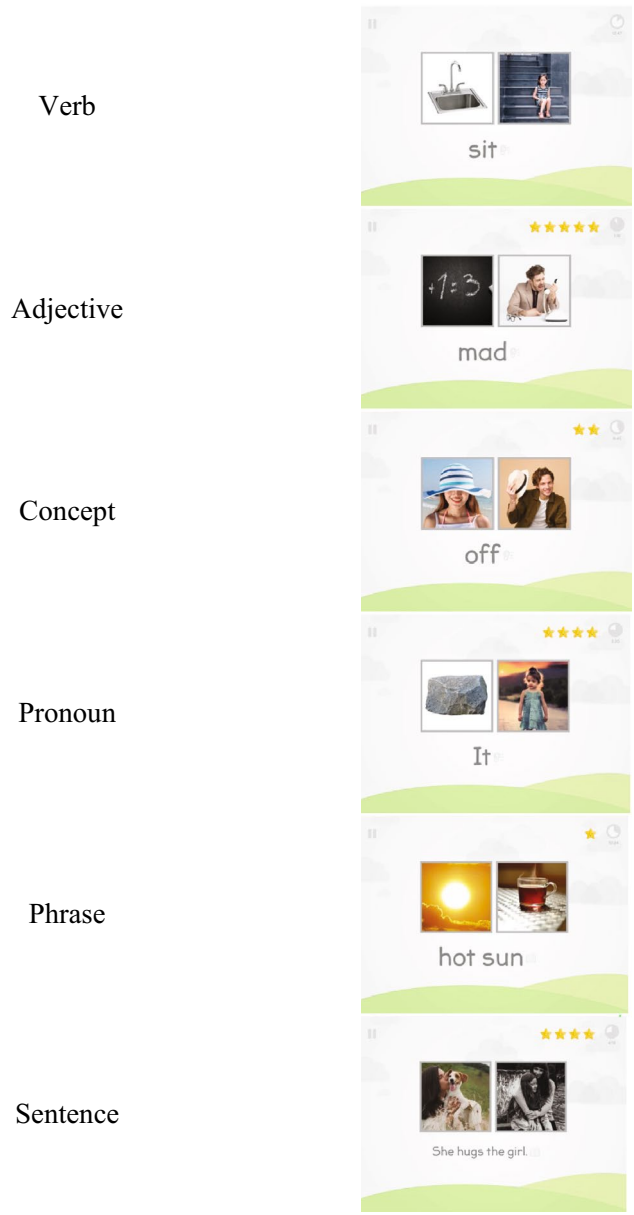

Fig. 6 Examples of verbs, adjectives, pronouns, concepts, phrases and sentences used in the intervention

	Trial 1	Trial 2	Trial 3	Outcome
Scenario 1 - 2/3 correct (on first attempt)				
Attempt 1 Attempt 2 Attempt 3	dog	dog		Word acquired! Proceed to Reading Comprehension Phase for the target word DOG.
Scenario 2 - 2/3 correct (on first attempt)				
Attempt 1 Attempt 2 Attempt 3	dog dog dog	dog	dog	Word acquired! Proceed to Reading Comprehension Phase for the target word DOG.
Scenario 3 - 2/3 correct (on first attempt)				
Attempt 1 Attempt 2 Attempt 3	dog	dog dog	dog	Word acquired! Proceed to Reading Comprehension Phase for the target word DOG.
Scenario 4 - 1/3 correct (on first attempt)				
Attempt 1 Attempt 2 Attempt 3	dog dog dog	dog dog dog	dog	Word not acquired Proceed to a new Learning Opportunity for a new target word. The target word DOG will appear in a novel pairing in a new Learning Opportunity at a later time.

Participant's Selection Incorrect | Participant's Selection Correct | Option Selectable | Option Only Selectable | Option NOT Selectable

◂**Fig. 7** Successful or Unsuccessful Acquisition of a Target Word in 2/3 Trials in a Learning Opportunity: Three Possible Avenues. Note: Acquisition of an oral or written word is determined when a child chooses the correct image for the corresponding auditory and/or written word combination on the first attempt of at least two of the three trials in a learning opportunity. Although a child has 3 attempts within one trial to correctly choose the corresponding image, only the first attempt counts towards determination of acquisition. That is, each target word will be presented in three novel pairings or learning opportunities. If a child has been exposed to three novel trials for a target word and has not met the criteria for 2/3 correct selection on the first attempt of a trial, the unacquired target word remains in a general bank of vocabulary to be targeted for receptive language acquisition (up to two more learning opportunities or 6 more trials); after which the word will no longer be presented. Therefore, there are a total possibility of 9 trials per word dependent on performance. Progression from the Oral Language to the Reading Comprehension phase occurs automatically when the Oral Language phase has been confirmed for an individual target word. The process for the Reading Comprehension phase is identical, without the auditory support. It is important to note that a child can be working at both phases simultaneously for different words. That is, words at the Oral Language phase and the Reading Comprehension phase are integrated, depending on performance. Once a word has been acquired in the Oral Language phase, it will be presented immediately in the Reading Comprehension phase, interspersed (every second word) with an Oral Language trial, to maximize written word exposure, as reading comprehension is the goal of the application.

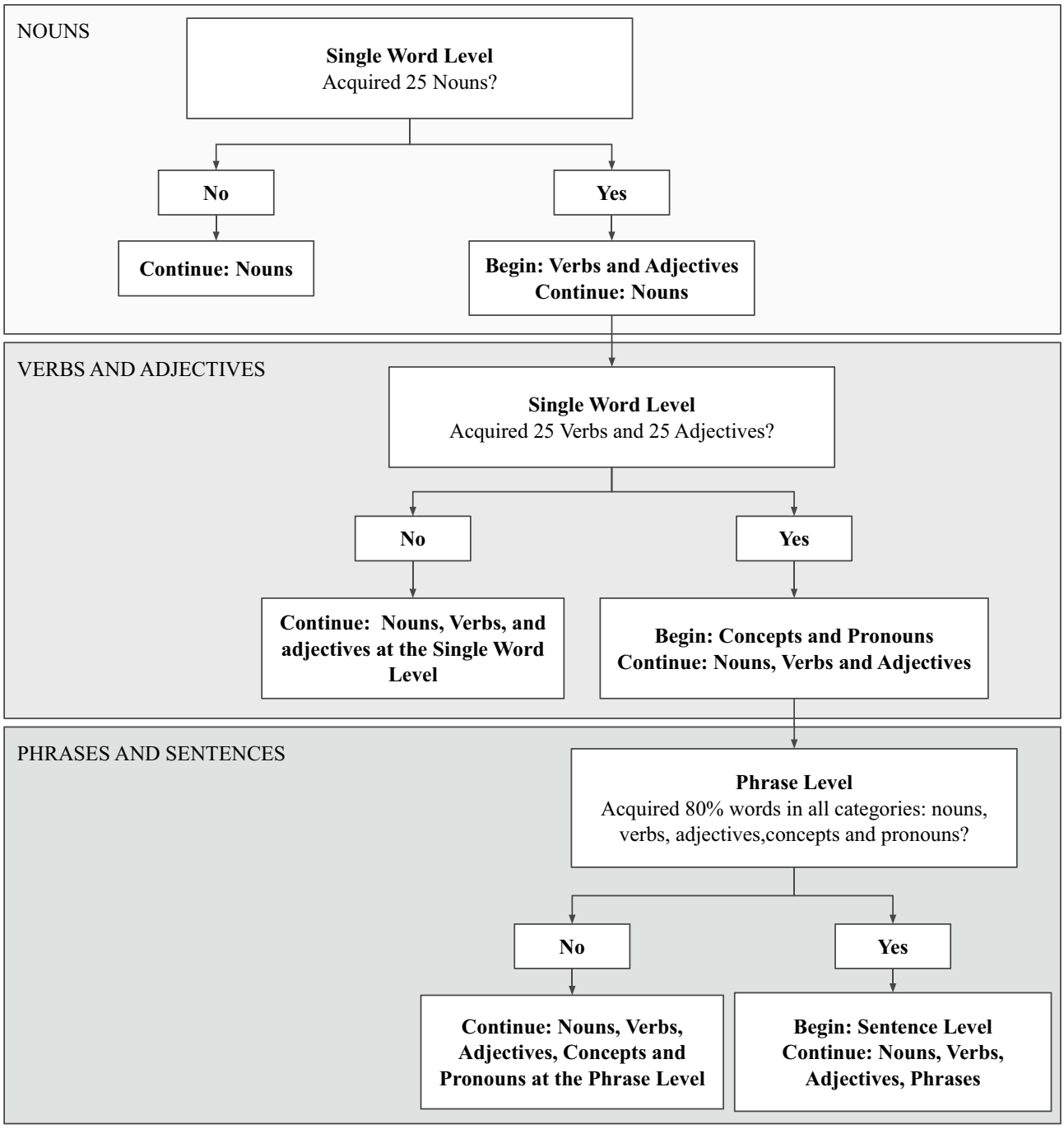

Fig. 8 Movement from single word to phrase to sentence level. Note: Introduction of verbs and adjectives is based on acquisition of 25 nouns. Progression from Word level to Phrase level is dependent on acquisition of 25 nouns, plus 25 verbs and 25 adjectives, which is in agreement with typical language development (Brown, 1973). Progression from Phrase to Sentence level is dependent on 80% acquisition in each category (noun, verb, adjective, concept, pronouns) for a total of approximately 260 words. The same content used at the word-level, e.g., dog is incorporated at the phrase-level, e.g., dog runs, and at the sentence-level, e.g., The dog runs fast, as the child acquires verbs and adjectives, adverbs and pronouns. Similarly, once a phrase or sentence has been established at the Oral Language phase, using the same criteria, the phrase is practiced at the Reading Comprehension phase. As with the Oral Language and Reading Comprehension phases, a child may work at a number of different levels simultaneously, dependent on acquisition rates, as the transition from a word to a phrase is seamless. Movement from Phrase Level to Sentence Level occurs when the child has acquired 80% of words in all categories.

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