

NONWORD READING AS AN INDICATOR OF
ORTHOGRAPHIC LEARNING IN
THE ID POPULATION

by

SUSAN LOVEALL

A THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Arts
in the Department of Psychology
in the Graduate School of
The University of Alabama

TUSCALOOSA, ALABAMA

2011

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ABSTRACT

Previous research has suggested that individuals with intellectual disability (ID) perform worse in several areas of reading compared to mental age matched peers (see Connors, 2003 for a review of the literature). However, it is unclear how they compare on measures of orthographic processing, the visual aspect of reading. The leading approach to understanding orthographic processing in word identification for typically developing (TD) children is the self-teaching hypothesis (Jorm & Share, 1983; Share, 1995; 1999). The self-teaching hypothesis suggests that word-specific orthographic representations are acquired as a result of phonological recoding. By sounding out words, individuals incidentally pick up on the orthographic layout of those words, achieving orthographic learning. The present study is a first test of the self-teaching hypothesis for children with ID. The results indicate that both groups were able to self-teach. This study has important implications for reading instruction. Specifically, instruction in phonological recoding may have a double benefit for individuals with intellectual disabilities. With more phonological recoding instruction they may be better at recoding and also gain orthographic knowledge in the process.

LIST OF ABBREVIATIONS AND SYMBOLS

<i>F</i>	Fisher's <i>F</i> ratio: a ratio of two variances
<i>M</i>	Mean: the sum of a set of measurements divided by the number of measurements in the set
<i>p</i>	Probability associated with the occurrence under the null hypothesis of a value as extreme as or more extreme than the observed value
<i>r</i>	Pearson product-moment correlation
<i>t</i>	Computed value of <i>t</i> test
<i>n</i>	Sample size for group
<i>SD</i>	Standard deviation
>	Greater than
<	Less than
=	Equal to
ID	Intellectual disability
IQ	Intelligence quotient
KBIT-2	Kaufman Brief Intelligence Test – 2 nd edition
MA	Mental age
REP	Repetition score
SOS	Sound out score
TD	Typically developing
VAS	Visual analysis skill

VMA	Verbal mental age
WA	Word-analysis
WAorth	Word-analysis orthographic choice task
WAspell	Word-analysis spelling test
WS	Word-supply
WSorth	Word-supply orthographic choice task
WSpell	Word-supply spelling test
WISC-R	Weschler Intelligence Scale for Children – Revised
WRMT-R	Woodcock Reading Mastery Test - Revised

ACKNOWLEDGEMENTS

First, I would like to thank my advisor and thesis chairperson, Dr. Frances Connors, for her insightful guidance and continuous support and encouragement. I would also like to thank the other members of my committee, Drs. Ed Merrill and Jason Scofield, for their input and assistance from the initial formulation of the idea and throughout the various stages of the project. In addition to my committee, I would like to thank Dr. Julie Masterson, who allowed me a better project by lending her spelling measure, as well as her time, energy and friendliness. I would also like to thank my family and friends for their unfailing belief in and endless patience with me. Finally, I would like to thank the Tuscaloosa County schools, Crossing Points, the Exceptional Foundation, all of the participants and their families for their help in this research. Their kindness and willingness to participate made this project both possible and enjoyable.

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INTRODUCTION

Just as in the general population, reading ability and motivation to read varies in individuals with intellectual disabilities (ID). Some individuals, especially those with ID, may have a strong desire to read, but struggle a great deal learning to read. While extensive research has examined reading development in typically developing (TD) children (Snow, Burns, & Griffin, 1998), very little research has investigated reading skills within the ID population. However, a call has been made from the President's Commission for People with Disability declaring that the "acquisition of reading skills" in this population should be a top priority (PCPID, 2004). The first step to aid in this intervention is to identify underlying strengths and weaknesses in their reading ability.

Reading Skills in the ID Population

Despite its importance, reading is a difficult skill for children with ID to conquer. A review of the literature (Conners, 2003) suggested that children with ID often match TD children on early emerging reading skills, but show specific difficulty on later emerging reading skills. For example, at a developmental level of 4-6 years, children with ID perform at or above their level of sight word identification, letter identification, and letter sound correspondence (Blake, Aaron, & Westbrook, 1969; Cawley & Parmar, 1995; Gickling, Hargis, & Alexander, 1981).

At a developmental level of 6-8 years, children with ID perform at or below their level, with specific difficulty in phonological recoding and certain comprehension skills (Bos & Tierney, 1984; Cawley & Parmar, 1995; Jenkinson, 1992; Levitt, 1970, 1972), and at a developmental level of 9 years and above, children with ID perform below their level in general (Nagle, 1993; Sheperd, 1967; Wood, Buckhalt, & Tomlin, 1988).

Thus, Conners' (2003) review of the literature suggested that certain aspects of reading may be more problematic than others for the ID population. For example, phonological recoding appears to be one area of specific difficulty for children with ID. Phonological recoding is reading by sounding out, a process sometimes called word attack. Even when building blocks, such as letter-sound correspondences, are in place, children with ID seem to have difficulty with phonological recoding (see Conners, Rosenquist, Sligh, Atwell, & Kiser, 2006). Strong relationships have been found between performances on phonological recoding and overall reading skill. Further, Wagner and Torgesen (1987) found that phonological awareness, which develops at the same time or slightly before reading, plays a causal role in the acquisition of reading skills.

Although there has been some attention to the study of phonological recoding in children with ID, there has been little if any attention to orthographic recoding. Along with phonological recoding, orthographic recoding is one of the main subskills of word identification. Orthographic recoding is a visual component of reading. It involves recognizing specific letter patterns that correspond to specific words, and requires knowledge of how letters tend to combine in one's language. Without much research on orthographic recoding in the ID population, it is difficult to determine if this is an area of difficulty for children with ID. Thus, the purpose of the present study is to examine orthographic recoding by children with ID.

Self-teaching Hypothesis

The leading approach to understanding orthographic recoding in word identification for TD children is the self-teaching hypothesis (Jorm & Share, 1983; Share, 1995; 1999). The self-teaching hypothesis suggests that word-specific orthographic representations are acquired as a result of phonological recoding. By sounding out words, individuals incidentally pick up on the orthographic layout of those words, achieving orthographic learning. The present study is a test of the self-teaching hypothesis for children with ID.

The self-teaching hypothesis has been supported in several empirical studies. In a classic study, Share (1999) showed that when children sounded out words during reading, they learned the orthographic features of those words. Share had second graders read aloud short texts (94-170 words) with embedded nonword targets. Three days later, the children completed three orthographic learning measures. The first was an orthographic choice test in which the participants were to choose the learned nonword target from among four options. The three alternate options included a homophone foil, a visually similar foil in which one letter was replaced with another that looked very similar, and a transposition foil, in which two adjacent letters were transposed. The second orthographic learning measure was a rapid naming test in which the participants had to identify a series of words presented on a computer screen, some of which were the nonword targets. The other words included homophones of the nonword targets and real words. The third orthographic learning measure was a spelling test in which the participants were to spell the nonword targets. In the orthographic choice task, participants chose the nonword targets more often than alternate homophone, visually similar and transposition foils.

In the rapid naming task, participants read the nonword targets more quickly than homophones and real words, and in the spelling test, participants spelled the nonword targets more accurately than alternate homophones.

In follow-up studies, Share (1999) showed that it was phonological recoding, and not mere visual exposure to nonwords, that was essential to orthographic learning. Over multiple experiments Share created conditions that limited opportunity for phonological recoding. He presented the nonword targets very briefly (300 milliseconds) and had participants vocalize concurrently by saying “DUBBA” over and over while the nonword target was presented. When conditions of phonological recoding were diminished, participants’ orthographic learning, as measured by orthographic choice, rapid naming and spelling tests, was significantly reduced.

The self-teaching hypothesis has since been tested across a wider age range with a wider variety of conditions and stimuli. Studies including children in grades one through five have supported the self-teaching hypothesis (Cunningham, 2006; Share, 2004). Further, studies using both nonword and real word targets have supported the hypothesis (Bowey & Miller, 2007; Cunningham, 2006; de Jong & Share, 2007; Kyte & Johnson, 2005; Nation, Angell, & Castles, 2006), whether targets were presented in isolation or embedded within text (Nation et al., 2006), and whether read aloud or silently (Bowey & Muller, 2005; de Jong & Share, 2007). Share (2004) found that a single exposure of a target provided orthographic learning that was maintained for up to a month. Individual-differences have also been found in self-teaching. More advanced phonological recoders performed better on real word reading than poorer phonological recoders, and the relation between phonological recoding and real word reading was partially mediated by orthographic knowledge (Connors, Loveall, Moore, Hume and Maddox, 2011).

In spite of the overwhelming evidence in favor of the self-teaching hypothesis, two limitations have been noted by researchers. First, orthographic recoding may not be entirely dependent on phonological recoding. Cunningham, Perry, Stanovich, and Share (2002; also Cunningham, 2006; Share, 1999) found that previous general orthographic knowledge contributed to orthographic learning after the influence of phonological recoding of the target nonwords was removed. A second factor that could contribute to orthographic learning is semantic information. Ouellette and Fraser (2009) found that fourth graders recognized and spelled nonwords more accurately when they were presented in context with semantic information than when they were presented in isolation.

A second limitation is that there appears to be a difference in self-teaching in shallow versus deep orthographies. In shallow orthographies, such as Hebrew, there is a direct mapping from letter to sound, and sounding out is very straightforward. In deep orthographies, such as English or Dutch, the letter-sound mapping is more complex, and letter sounds can vary depending on context (e.g., in English the letter c makes different sounds in cat, cell, and chop). Although self-teaching is evident as early as first grade in deep orthographies, it may not emerge until around the third grade in shallow orthographies (Share, 2004). This may be because in shallow orthographies, letters always correspond to the same sound despite their placement in a word. Since letters always make the same sound, individuals learning shallow orthographies do not depend on orthographic knowledge as much as individuals learning deep orthographies; therefore they may develop orthographic knowledge later than those who learn deep orthographies.

The self-teaching hypothesis might predict that children with ID are particularly impaired in orthographic learning because of their extreme difficulty with phonological recoding. Some

support for this idea was provided by Cunningham et al. (2002) and Share (1999). Cunningham and colleagues found that target word recoding was positively correlated with orthographic learning in TD 2nd grade children. As mentioned previously, Share (1999) experimentally manipulated the level of recoding accuracy in 20 second grade children by only briefly flashing targets (300 ms) and by using irrelevant concurrent vocalization (participants repeated “DUBBA” out loud until the target strings were replaced by a mask onscreen) during a lexical decision task. Results showed that when recoding accuracy was reduced, orthographic learning declined.

Although there is no research on the self-teaching hypothesis involving children with ID, there are a few studies involving children with specific reading disability. As a group, these children also have extremely poor phonological recoding. Thus, findings related to this group may be relevant to children with ID. Contrary to the self-teaching hypothesis, some research has shown that when compared to younger reading-level matched controls, older children with reading disability tend to have equivalent or even superior orthographic recoding in spite of their inferior phonological skills (Siegel, Share, & Geva, 1995; Share & Shalev, 2004; Stanovich & Siegel, 1994).

Share and Shalev (2004) examined this apparent paradox within the self-teaching paradigm. They developed two competing hypotheses to test against the self-teaching hypothesis for children with reading disability. The *compensatory processing hypothesis* predicts better orthographic skills in disabled readers than would be expected based on their level of phonological recoding. This ability could be the result of a basic processing advantage in the visual domain or an acquired processing style.

In other words, the compensatory processing hypothesis suggests that some other kind of strength related to orthographic learning compensates for a weakness in phonological recoding.

The *dissociation hypothesis* predicts poorer orthographic learning in children with reading disability than would be expected from their level of phonological recoding. It suggests that the relationship between phonological recoding ability and orthographic learning may be weaker for disabled readers than for normal readers. Therefore, a given level of recoding among disabled readers does not result in as much orthographic learning as the same level of recoding would in normal readers. Research by Ehri and Saltmarsh (1995) is consistent with this hypothesis.

Ehri and Saltmarsh (1995) found that children with reading disability may perform more poorly in orthographic learning than younger TD readers who are similar in phonological recoding ability. Participants were taught to read simplified spellings of words (e.g. CRADL) in a list format, allowing practice between 10 and 12 times over a two day period. Three days later the participants were asked to name the original spellings (CRADL), homophonic spellings (KRADL) and non-homophonic spellings (KRATL). They found that even though the two groups were equivalent in phonological recoding, the children with reading disability needed more trials to learn the simplified spelling. In addition, the typical readers read the target spellings faster than the homophonic foils indicating good orthographic learning, while the older disabled readers did not.

Share and Shalev (2004) tested the self-teaching hypothesis vs. the compensatory processing hypothesis and the dissociation hypothesis using four groups of children - dyslexics, garden-variety poor readers, a chronologically matched control group (all in grades 4-6) and a reading level/mental age matched control group (Grade 2). Participants read aloud short stories

that contained embedded nonwords. Three days later, the participants completed three post-tests evaluating orthographic learning. In support of the self-teaching hypothesis, dyslexics and garden variety poor readers performed worse in orthographic learning than same-age typical readers, and this difference was fully explained by differences in target word recoding accuracy. However, in contrast to the self-teaching hypothesis, dyslexics and garden variety poor readers performed better in orthographic learning than reading-level controls even though their target word recoding accuracy was lower. None of the three hypotheses fully explained the data, so Share and Shalev proposed a hybrid *orthographic sensitivity* hypothesis. The orthographic sensitivity hypothesis proposes that given a critical volume of print experience, fundamental changes in orthographic sensitivity can take place, leading children to acquire a specialized print-specific processing skill. In this way, after years of print exposure, even disabled readers may develop sensitivity to orthography of words, and when compared to younger, beginner readers, they may show some advantage in orthographic learning of new words in spite of poorer phonological recoding.

Thus, Ehri and Saltmarsh (1995) and Share and Shalev (2004) came to different conclusions about orthographic learning by children with reading disability. Ehri and Saltmarsh showed worse orthographic learning compared with typical readers who were similar in phonological recoding; Share and Shalev showed better. The difference in study outcomes may be due to the fact that one study was conducted in English (a deep orthography) and the other in Hebrew (a shallow orthography) (see Share, 2008; Share & Shalev, 2004, for discussion). Interestingly, neither study supported the self-teaching hypothesis.

It is important to note that in Share and Shalev's (2004) study, the poor readers included dyslexics as well as "garden variety" poor readers. Dyslexics have a large discrepancy between

IQ, (which is typically equivalent with chronological-age matched peers) and reading (which is especially poor when compared to their IQ). Garden variety poor readers show deficits in both IQ and reading compared to their chronological age matched peers. However, garden variety poor readers have a high enough IQ, above 70, that they are not considered ID. Both dyslexics and garden variety poor readers showed the same pattern in Share and Shalev's study, so it is possible that children with ID would show the same pattern as other poor readers (dyslexic or garden variety), at least if they are tested in the same orthography. The present study tested the self-teaching hypothesis in children with ID in the same orthography as those tested by Ehri and Saltmarsh (1995).

Word-Analysis vs. Word-Supply

Although there is little to no research on orthographic learning as a reading skill in children with ID, different error correction procedures have been researched to determine which are more effective in facilitating reading accuracy. Word-supply and word-analysis are two common forms of error correction. Word-supply is simply providing a word that someone cannot read. For example, if reading the sentence, "The dog was having a wonderful day!" a student did not recognize the word "wonderful", the teacher would simply provide the correct pronunciation of the word for the student. Word-analysis involves sounding out the word. In this case, the teacher would instruct the student in sounding out the different phonemes of "wonderful" until the student could put together the whole word.

Singh and Singh (1985) found that, although any error correction is more effective than no correction, word-analysis is significantly more effective than word-supply in increasing accuracy of word reading for children with ID. This suggests that children with ID do benefit from the phonological recoding process in learning to read words (see also Neville & Vandever,

1973; Conners, et al., 2006). However, the effect needs to be replicated in the ID population, as only two of four children in this study showed the effect. Additionally, in error correction studies involving children with learning disabilities, word-analysis has not always been more effective than word-supply (Meyer, 1982; Rose, McEntire, & Dowdy, 1982; Rosenberg, 1986).

Furthermore, because Singh and Singh did not compare children with and without ID, it is not known if the children with ID were more or less efficient in orthographic learning compared to developmental expectations.

Purpose of the current study and hypotheses

The current study tested the self-teaching hypothesis on children with ID by contrasting word-supply and word-analysis techniques and comparing children with ID and TD children of similar verbal age. In a 2 x 2 (Group x Nonword exposure condition) design, children from both groups were exposed to one set of nonwords by word-analysis and a second set of nonwords by word-supply. Approximately three to five days later, children completed tests of orthographic learning.

Previous research has shown that children with ID are weak in semantic processing, or at understanding the meaning of what is read, when compared to TD counterparts (Laing, Hulme, Grant, & Karmiloff-Smith, 2001). To avoid disadvantaging children with ID, the current study decontextualized targets by using list format rather than text-embedded format. Another difference between groups is that the ID group would be older and would have had more experience with print in general. To avoid disadvantaging children with TD, the current study used nonword rather than real word targets.

According to the self-teaching hypothesis, children should show greater orthographic learning when words are learned through word-analysis rather than through word-supply (the

self-teaching effect). Also, if the group with ID is poorer in phonological recoding, this group should show a weaker self-teaching effect than the TD group. Further, the group differences in self-teaching effect should be explained statistically by differences in target-word recoding accuracy.

In addition to testing the self-teaching hypothesis, the proposed study explored three other alternative hypotheses. Similar to the self-teaching hypothesis and consistent with the results of Ehri and Saltmarsh (1995), the dissociation hypothesis predicts that children with ID will show a smaller self-teaching effect than children with TD, meaning that they are less efficient in orthographic learning. However, importantly, group differences in self-teaching effect should remain significant even after controlling for target-word recoding accuracy. The compensation hypothesis predicts a larger self-teaching effect in the ID group than in the TD group. Children with ID might be better at visual types of learning that would help them acquire orthography more efficiently. Finally, the orthographic sensitivity hypothesis predicts that children with ID will show a larger orthographic learning effect that is not attributable to differences in visual skills.

METHODOLOGY

Design

This study was conducted as a mixed two way design. The between-groups independent variable was Group (ID vs. TD) and the within-groups independent variable was Nonword Exposure Condition (word-analysis vs. word supply). There were two dependent variables meant to measure orthographic learning - performance on orthographic choice tasks and performance on spelling tasks.

Participants

Participants included 18 children with ID and 19 children who were TD. Participants were recruited from local schools (for both ID and TD) and organizations for individuals with intellectual and developmental disabilities (for ID). Participants with ID were identified by the school and screened by asking teachers for those students they believed could finish the tasks. Consent forms were then sent to parents, and assent was received from participants before beginning testing.

Criteria for inclusion in the study were (1) a verbal mental age between 6 and 12 years on the Kaufman Brief Intelligence Test, 2nd edition (KBIT-2) and (2) the ability to sound out two nonwords on the Word Attack subtest of the Woodcock Reading Mastery Test – Revised (WRMT-R). The KBIT-2 was also used to get an estimate of participants' IQs and confirm or disconfirm whether participants had ID. Participants received a small, school-appropriate prize for participation in the study.

Participants with ID. Out of 27 participants with ID who were originally recruited for the study, 18 met all criteria, were able to complete the study, and were included in data analysis. Of those 18 participants, the age range was 13.17 – 33.83 years ($M = 19.97$; $SD = 4.99$), and the verbal mental age range was 6.25 – 10.67 years ($M = 8.87$; $SD = 1.30$). Of the participants who did not meet the eligibility criteria of the study and were therefore excluded from analyses, two scored below the lower verbal mental age criterion of 6 years, four could not correctly sound out two nonwords on the Word Attack subtest of the WRMT-R, one did not return to school, where testing took place, after the first testing session, and two had IQ's above 70. The latter two were identified by their teachers for inclusion in the study, but according to their IQ score, appeared not to have an intellectual disability and were not included in data analysis.

TD Participants. Out of 25 TD participants recruited for the study, 19 met criteria, were able to complete the study, and were included in data analysis. Of those ten, the age range was 7.25 – 9.67 years ($M = 8.04$; $SD = .73$), and the verbal mental age range was 6.25 - 12.67 years ($M = 8.72$; $SD = 1.72$). Five TD participants scored outside of the verbal mental age range needed for the study. Specifically, four participants scored below 6 years, one of whom also had a low IQ, and one participant scored above 12 years. In addition to those five participants, one participant was also lost because he was not available to complete the second testing session.

Materials

Kaufman Brief Intelligence Test 2. The Kaufman Brief Intelligence Test, 2nd Edition (K-Bit2) (Kaufman & Kaufman 2005) is a brief measure of verbal and non verbal intelligence. It is individually administered, takes approximately 15-30 minutes, and is standardized for individuals from 4 – 90 years of age. It yields verbal and nonverbal raw scores, verbal and nonverbal standard scores and age equivalents, a composite of verbal and nonverbal standard

scores and an IQ Composite score. The verbal section consists of two subtests, Verbal Knowledge and Riddles. These subtests measure verbal skills by assessing word knowledge, range of general information, verbal concept formation, and reasoning ability.

Verbal Knowledge is the first verbal subtest given. It contains 60 items that measure receptive vocabulary and information about the world. The participant is prompted by the experimenter with a word or question and chooses one illustration or photograph out of six possibilities that best shows the meaning of a word or question. This subtest calls on participants' long-term memory storage, which the participant uses to recognize the illustrations. This is a recognition test and does not require the participant to know or say the exact name of any of the illustrations or photographs.

The second verbal subtest given is Riddles. It contains 48 items meant to measure verbal comprehension, reasoning, and vocabulary knowledge. Investigators ask a riddle and participants are asked to either point to a picture in Items 1-8 or give a single word answer in Items 9-48 that answers the riddle, for example, "What is something round that you put cereal in?" For both subtests, correct answers are awarded a score of 1 and incorrect answers a score of 0. The two verbal subtests each yield a raw score. These are combined to form one total score, which can be converted into a verbal standard score, and/or used to calculate the participants' verbal age equivalences. The verbal standard score is also used to calculate overall IQ. This study used the verbal age equivalence scores to match groups on verbal mental age. IQ was also used to confirm or disconfirm that participants were TD or had an intellectual disability.

The nonverbal subtest is Matrices, and it is given after the verbal knowledge subtest and before the riddles. It contains 46 items in three different sections of increasing complexity. In the first section the participant is shown drawing and is asked to pick the corresponding object

out of five drawing choices. The second section contains analogies. Two side-by-side pairs of objects or designs are shown. An object of one pair is missing, and the participant is to pick the drawing that will complete the analogy. The third and most difficult section shows a square array of drawings. Each row and each column has a pattern, that all of the objects correspond with. The participant is to pick the drawing that completes the matrices. Correct answers are awarded a score of 1 and incorrect answers receive a score of 0. This score serves as the nonverbal score and in the current study as the visual analysis covariate. The present study used the Matrices raw score as a measure of visual analysis skill.

For the participant ages in this study, the KBIT-2 has Spearman Brown split half reliabilities ranging from .90 to .95 for the full test, .86 to .94 for the verbal section, and .81 to .91 for the nonverbal section. The KBIT-2 also correlates with the Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV) at .77 for the full test, .79 for the verbal sections, and .56 for the nonverbal section (Kaufman & Kaufman, 2005).

Woodcock Reading Mastery Tests - Revised, Word Attack Subtest. The Woodcock Reading Mastery Test – Revised (WRMT-R) (Woodcock, 1998) is designed to measure intellectual abilities and academic achievement in populations of individuals from 2 to 90+ years. It consists of six subtests and a two-part supplementary checklist. Different combinations of tests, or clusters, allow the user to focus on specific classes of reading skills. For example, the Basic Skills Cluster is composed of Word Identification and Word Attack. The subtests are used to evaluate fluency in reading and math, as well as general and specific cognitive functioning.

The present study used the Word Attack subtest, which is specifically meant to measure nonword reading ability. It contains 45 items of nonwords or very low frequency words in the English language. Participants are presented the nonwords on an easel and are asked to

pronounce them (e.g. tat, op, rejune). Scoring is completed during testing based on basal and ceiling levels. Scoring can be done one of two ways. The whole word can be scored as either correct (1 point) or incorrect (0 points), or each phonic or structural component of each nonword can be scored. The present study scores by whole nonword as either correct (1 point) or incorrect (0 points). Raw scores were used as one measure of phonological recoding.

Reliability calculations for each reported grade or age level included all subjects in the norming sample at that level. The WRMT-R Word Attack has Spearman Brown split half reliabilities ranging from .92 to .99 for the full test and from .84-.94 for the Word Attack subtest. WRMT-R's correlation with Woodcock-Johnson reading Tests ranged from .85-.91 for the full test and .64-.90 for the Word Attack subtest (Woodcock, 1998).

Nonword Learning Lists. A pool of 40 pronounceable nonwords (e.g. thomer, blayer, swaner) were used, chosen from lists rated for spelling regularity and phonotactic frequency (Massarro, Taylor, Venezsky, Jastrzemski & Lucas, 1980). The nonwords chosen for the present study were those in the Regular/High frequency. Regularity indicated that the letter strings used in each of the nonwords were phonologically legal and contained common vowel and consonant spellings. High frequency indicated that the position for each letter was common and was determined by summing the position-dependent frequency for each letter in a nonword. See Table 2 for a list of the nonwords used in the present study and their phonetic spellings.

The 40 nonwords were divided randomly into two sets of 20 nonwords, with each set divided into two lists of 10 nonwords. Each set was assigned to a participant. This procedure was repeated until each participant had a unique set of two lists of 10 nonwords. For every participant in the TD group, there was a participant in the ID with matching lists. One list was learned using word-analysis (WA, sounding out) and the second list was learned by word-supply (WS). Lists

were counterbalanced across nonword exposure condition. The result was that all of the nonwords were used in different random combinations across participants and in the same combinations across the two groups. The only deviation from this was that for one participant in the TD group there was no participant in the ID group with a matching list. This was because there was one more participant in the TD group than in the ID group.

Orthographic Choice Task. The orthographic choice task included four nonword choices for each target nonword learned and asked participants to choose the nonword they learned previously (e.g., thomer thowmer thmoer thamer). One nonword was the learned target word (e.g., thomer), one a pseudo-homophone, or phonologically similar nonword, with the same sound (e.g., thowmer), one contained a transposition (e.g., thmoer), and one had a visually-similar, but phonologically different spelling (e.g., thamer). The order of nonwords was randomized. Correct recognition of the previously learned nonword was scored as 1, while incorrect choices received a score of 0. Scores of 1 indicate orthographic learning; scores of 0 did not. Orthographic choice tasks for the word-analysis condition are referred to as WAorth, and orthographic choice tasks for the word-supply conditions are referred to as WSorth.

Spelling Test. The spelling test asked participants to spell each of the learned nonwords, after being presented verbally by an experimenter. The spelling measure developed by Masterson and Apel (in press) was used to score participants' spelling tests. This measure allows partial credit for spellings in which some elements are spelled correctly and others are spelled incorrectly. Each element of a nonword is worth 3 possible points. Participants are awarded 3 points if the element had the correct spelling (e.g., t for t), 2 points if the spelling was legal but incorrect based on the original spelling (e.g., tt for t), 1 point if the spelling was illegal (e.g., b for t), and 0 points if the element was not represented (e.g., nothing where t should be).

Masterson and Apel's (in press) spelling measure yields both an element and a word score for each spelled word, or nonword in the present study. An element score takes the total number of points earned for each nonword and divides it by the total number of elements. An overall element score can also be computed for each spelling test by adding together the element scores across all nonwords and dividing the total element score by the total number of elements.

Masterson and Apel's (in press) measure also yields a word score. Similar to the element score, a word score is provided for each nonword and also for the entire spelling test. If a nonword is spelled correctly it receives a word score of 3 points. If one or more elements of a nonword is spelled incorrectly but legally (i.e. "doormen" for the nonword "dormen"), 2 points are awarded. If a nonword has all elements represented, but one or more elements is incorrect and illegal (i.e. "bormen" for "dormen"), it is awarded a word score of 1 point. If any elements are not represented (i.e. "dormn" for "dormen"), the nonword is given a word score of 0.

Because the overall element score takes into account the element scores for each element and averages them together, it awards partial credit and so is more sensitive than the word score. Therefore, the overall element scores for each spelling test were used for analyses in the present study. Spelling tests for the word-analysis condition are referred to as WAspell and spelling tests for the word-supply conditions are referred to as WSspell. A reliability check revealed that two independent scorers had very strong reliability in coding and scoring a subset of 20 spelling tests, with no reliability under .90.

Procedure

The study involved two to three sessions, one to two sessions for standardized tests and nonword learning and one session for testing. The study lasted approximately one hour for the standardized testing and learning session(s) and approximately 20 minutes for the testing session.

Participants were told the purpose of the study was to help researchers learn how different children read. Participants first completed the KBIT-2 and the WRMT-R Word Attack Subtest. Participants then learned two lists of 10 nonwords. Each list corresponded with a “family of creatures”. One family was a family of pretend water creatures and the other a family of pretend space creatures. Participants were shown the families and told that each of the family members had a funny name and that they were going to learn each of the family member’s names. One list was learned using word-analysis (sounding out) and the other list was learned using word-supply (repetition). The order of nonword exposure condition was counterbalanced across participants

In the word-analysis condition, the investigator showed the participant a nonword and said, “This is a family of pretend space creatures. They have funny names. I’m going to show you their names and I want you to try to sound them out slowly.” If the participant correctly pronounced the nonword the first time the investigator said, “That’s correct” repeated the nonword and moved on. If the participant correctly, but slowly, sounded out the word, the investigator then asked the participant to put the sounds together and say the whole nonword. If the participant correctly identified the nonword, the investigator let him/her know that was correct, repeated the nonword and moved on. If the participant incorrectly sounded out the nonword, the investigator went go back to the nonword and asked the participant to sound it out, phoneme by phoneme. If the participant incorrectly sounded out any phoneme, the investigator immediately offered the correct pronunciation. After going through the nonword phoneme by phoneme, the investigator asked the participant to put the sounds together and say the whole nonword. If the participant correctly pronounced the nonword, the investigator said, “That’s right” repeated the nonword and moved on. If the participant incorrectly pronounced the nonword, the investigator said, “That’s not quite right. It’s ‘ _____ ’. Now you say it,” and

then moved on. In this way, for every nonword, both the participant and investigator said the correct pronunciation once, which was also held constant in the word-supply condition.

The word-analysis exposure condition yielded a “sound out score”. Each time a participant attempted to sound out a nonword, he or she could earn up to two possible points. To earn the full two points, the participant had to correctly sound out the nonword on the first attempt without help from the researcher. To earn one point, the participant had to correctly sound out the nonword on the second attempt and/or after receiving help. No points were awarded if the participant did not correctly sound out the nonword on the second attempt. There was a total of 100 points possible: ten nonwords worth two points, each learned five times. Higher scores indicated more accurate phonological recoding of the target nonwords.

In the word-supply condition, the investigator simultaneously showed the participant a nonword and told him/her how to pronounce it. “This is a family of pretend water creatures. They have funny names. I’m going to show you and tell you their names. After I say it I want you to say it too.” The investigator then showed the word and said, “This is ‘thomer’. Now you say it.” Participants went through the lists until they reached 5 trials (Ehri & Saltmarsh, 1995). The order of nonwords in each list was randomized for each participant and for each of the 10 learning trials.

The word-supply exposure condition yielded a “repetition score”. Each time a participant needed a nonword repeated an additional time, an extra point was added to his or her repetition score. Repetitions were a result of inattention, poor hearing and poor articulation. There was no cap on the repetition score. Higher scores indicated more repetitions.

The testing session took place approximately 3-5 days later. Participants were given two spelling tests and two orthographic choice tasks, one for each of the nonword lists they learned

previously. The spelling test was given before its corresponding orthographic choice task for the same list, and the tests were given in the same order as the order that the lists were learned, (e.g. if the word-analysis list was learned first, followed by the word-supply list, then participants were tested on the word-analysis list first and the word-supply list second).

RESULTS

Preliminary Analyses

With all alphas set at .05 and all analyses two-tailed, an independent-samples t-test was conducted to check group comparability on verbal mental age. There was no significant difference between the ID group and the TD group $t(35) = .28, p = .78$ (two tailed). This indicates that groups were appropriately matched on verbal mental age. Box plot analysis was used to examine outliers on the six dependent variables. There was one outlier on the word supply orthographic choice measure. This value was adjusted to fit the boxplot limit. Kolmogorov-Smirnov tests of normality indicated that all six distributions were normal (p 's > .11). There did appear to be one outlier based on number of days between the learning and testing sessions. Analyses were run both with and without that participant's data, and because the outlier did not influence the results, it was included in the analyses. One participant with ID was also notably older than the other participants; however, his age was not a statistical outlier was therefore included in the analyses. There appeared to be no bivariate outliers. See Tables 2 and 3 for descriptives.

As expected, Word-Attack and sound out scores were positively correlated for both the ID group $r = .85, n = 18, p < .001$ and for the TD group $r = .82, n = 19, p < .001$. Both Word-Attack and sound out scores also were positively correlated with the four orthographic measures, with all r 's > .59, p 's < .01.

The four dependent, orthographic measures all intercorrelated as well, all r 's $> .39$, p 's $< .05$, with the exception of word-analysis orthographic choice and word-supply spelling in the TD group, which was marginally significant, $r = .43$, $p < .07$. See Table 3 for correlations.

Surprisingly, there were no differences between groups on Word Attack, $t(35) = 1.11$, $p = .27$, and there were no differences between groups on sound out scores, $t(35) = 1.13$, $p = .27$. There was also no significant differences between groups on visual analysis skill, $t(35) = 1.31$, $p = .20$. However, there was a difference between groups on the repetition scores, $t(23.90) = 3.11$, $p < .05$; partial eta squared = .23.

Because there was a significant difference between groups on the repetition score, independent samples t-tests were conducted to compare groups on both word-supply dependent variables. On spelling there was a marginally significant difference in scores between the TD group ($M = 2.53$, $SD = .24$) and the ID group $M = 2.31$, $SD = .44$; $t(26.02) = 1.95$, $p = .06$; partial eta squared = .10. On orthographic choice there was no significant difference in scores between the TD group ($M = 5.63$, $SD = 2.01$) and the ID group $M = 6.17$, $SD = 2.85$; $t(35) = .66$, $p = .5$; partial eta squared = .01.

Independent samples t-tests were also conducted to compare groups on both word-analysis dependent variables. On spelling there was a significant difference in scores between the TD group ($M = 2.67$, $SD = .19$) and the ID group $M = 2.43$, $SD = .41$; $t(23.73) = 2.23$, $p < .05$; partial eta squared = .12. On orthographic choice there was a marginally significant difference in scores between the TD group ($M = 6.21$, $SD = 2.15$) and the ID group $M = 7.50$, $SD = 2.09$; $t(35) = 1.85$, $p = .07$; partial eta squared = .09.

Main Analyses

A 2 (Group) X 2 (Nonword Exposure Condition) mixed multivariate analysis of variance was performed to investigate orthographic learning, with the dependent variables spelling and orthographic choice. Preliminary tests showed no serious violations of the assumptions of normality, linearity, homogeneity of variance-covariance matrices, or multicollinearity, and there were no univariate or multivariate outliers. Order effect of condition was entered into the equation, but did not have a significant impact and was therefore not included in the rest of the analyses, $F(2, 33) = .341, p = .71$; Wilks' Lambda = .980.

There was a statistically significant effect of group on the combined dependent variables $F(2, 34) = 9.41, p < .05$; Wilks' Lambda = .64; partial eta squared = .36. Within-group analyses revealed a significant effect of nonword exposure condition $F(2, 34) = 12.11, p < .001$; Wilks' Lambda = .58; partial eta squared = .42. There was no group by nonword exposure condition interaction $F(2, 34) = .88, p = .43$.

Between-groups univariate analyses revealed a significant difference between groups on spelling, with the TD group performing significantly better than the ID group $F(1, 35) = 4.78, p < .05$; partial eta squared = .12. There was no significant group difference, however, on orthographic choice $F(1, 35) = 1.78, p = .19$; partial eta squared = .12.

Within-group univariate analyses supported the self-teaching hypothesis by revealing a significant difference between nonword exposure conditions, with performance better in the word-analysis condition than in the word-supply condition. This was true both for spelling, $F(1, 35) = 22.95, p < .001$; partial eta squared = .40 and for orthographic choice, $F(1, 35) = 9.06, p < .05$; partial eta squared = .21.

Paired-samples t-tests were conducted to evaluate whether each group individually showed self-teaching on spelling and orthographic choice. For spelling, the ID group performed significantly better in the word-analysis condition than in the word-supply condition, $t(17) = 3.17, p < .05$; partial eta squared = .37. The ID group also showed self-teaching on the orthographic choice measure, performing significantly better in the word-analysis condition than in the word-supply condition, $t(17) = 2.52, p < .05$; partial eta squared = .27.

The TD Group also showed the self-teaching effect on the spelling measure, performing significantly better in the word-analysis condition than in the word-supply condition, $t(18) = 3.62, p < .05$, partial eta squared = .42. However, on the orthographic choice tasks, while the TD group did perform slightly better in the word-analysis condition than in the word-supply condition, the difference was not significant, $t(18) = 1.60, p = .13$.

Because the groups were not significantly different in phonological recoding ability, measured by Word Attack and sound out scores, and were not significantly different on visual analysis skill, these were not used as covariates in the analyses.

DISCUSSION

Self-teaching Hypothesis

The present study was designed to test the application of Jorm and Share's (1983) self-teaching hypothesis to individuals with ID and verbal mental age-matched controls. This hypothesis suggests that by sounding out words, individuals incidentally pick up on the orthographic structure of those words, acquiring word-specific orthographic representations for the phonologically recoded words. In the present study, self-teaching was indicated by participants performing better in the word-analysis condition than in the word-supply condition.

By including a word-supply condition to contrast with the word-analysis condition, the present study used a more stringent test of the self-teaching hypothesis for TD participants than has been used in many previous self-teaching studies (Cunningham, 2002; Share, 1999; Share, 2004). While other studies often had participants sound out nonword targets and then tested whether participants chose those nonword targets more often than other foils in a multiple choice format, spelled them more accurately than other pseudohomophones, and named them faster than other nonwords, it is unclear whether or not participants had actually been exposed to the alternate foils they were to name and spell. The present study controlled for learning by exposure by including a word-supply condition, in which participants were exposed to other nonword targets, yet were not to sound them out.

Results showed a main effect of condition, with both groups performing significantly better in word-analysis conditions than word-supply conditions. Results also indicated a main effect of group, with the TD group performing significantly better than the ID group on spelling measures. There was no significant group by condition interaction.

Based on previous studies' findings (see Conners, 2003 for a review), the ID group was expected to perform worse than the TD group on measures of phonological recoding. However, preliminary data analyses revealed that this was not the case. There were no group differences on two separate measures of phonological recoding, Word Attack and sound out score. Further, the groups were equivalent in verbal mental age, and there was no significant group difference on visual analysis skill. This may have been because this study required participants to successfully sound out two nonwords on the Word Attack to be eligible for the study. Any participants who could not do so were not included in the study.

There were, however, significant differences between groups on the repetition score. In the word-supply condition participants in the ID group needed more repetition of the nonword targets than participants in the TD group to correctly pronounce the nonwords. This appeared to be due to poorer articulation on the part of the participants with ID. Nevertheless, the ID participants could have had an advantage over the TD participants in the word-supply condition due to more exposure to the nonwords. However, there were no significant group differences on either spelling or orthographic choice in the word supply condition. This could indicate that repetition did not affect performance on the orthographic tasks. However, it is possible that if the two groups had been limited to the same number of repetitions, the TD group would have performed significantly better on word-supply measures. This, in turn could have resulted in a smaller self-teaching effect in the TD group than in the ID group.

The present results do not support the compensatory processing hypothesis. This hypothesis states that participants with ID have some kind of strength associated with orthographic learning, such as a basic processing advantage in the visual domain or an acquired processing style, to compensate for poor phonological recoding ability. For the present study, this hypothesis predicted that participants with ID would perform worse than TD participants on Word Attack and sound out score, but would compensate with a strength in orthographic learning and perform equivalently or even better than the TD group on all the measures of orthographic learning. Further, this strength in orthographic learning might be linked to visual analysis. However, results of the study indicated that the groups were not significantly different on phonological recoding measures, nor were they significantly different in visual analysis skill. Because the groups were matched on phonological recoding, the revised compensatory processing hypothesis would suggest that the ID group should perform even better on orthographic learning measures. However, the ID group did not show significantly better performance on orthographic measures. In fact, they performed significantly worse than the TD group on spelling measures. Finally, the self-teaching effect was not significantly larger in the ID group than in the TD group.

While previous research by Ehri and Saltmarsh (1995) seemed consistent with the dissociation hypothesis, the present results do not support this hypothesis. The dissociation hypothesis suggests that ID participants have a weakened link between phonological recoding and orthographic learning. For the present study, this hypothesis predicted little difference between word-supply and word-analysis conditions for participants with ID. It also suggested that participants with ID could not acquire the same self-teaching effect as TD participants without additional learning trials. However, the ID group performed significantly better in word-

analysis conditions than in word-supply conditions. Also, the number of trials was similar for both groups in the word-analysis condition, and both groups showed orthographic learning.

The orthographic sensitivity hypothesis was also not supported by the present results. This hypothesis suggests that after a critical volume of print experience, participants with ID develop sensitivity to the orthography of words, leading to an acquired print-specific processing skill. This hypothesis predicts that despite poor phonological recoding skills, participants with ID have an advantage in orthographic processing. For the present study it predicted that participants with ID would perform better than TD participants on both word-analysis and word-supply orthographic learning measures. Although there was a trend in this direction for the orthographic choice measure, this difference was nonsignificant and there was a significant difference in the opposite direction for the spelling measure.

The self-teaching hypothesis was best supported by the present study's data. This hypothesis suggests that phonological recoding leads to orthographic learning. The self-teaching hypothesis predicted that, if participants with ID were poorer in phonological recoding ability, they would be at a disadvantage in orthographic learning and therefore would show a smaller difference between word-supply and word-analysis conditions. However, based on equivalent phonological recoding abilities, the self-teaching hypothesis would predict that both groups would show the same self-teaching effect, similarly performing better in word-analysis conditions than in word-supply conditions. The results supported this hypothesis, with both groups performing better in word-analysis than in word-supply conditions.

In addition to the self-teaching finding, multivariate analyses revealed an overall group difference. Specifically, the TD group performed significantly better on spelling, but there were no differences between groups on orthographic choice measures. The difference was primarily

carried by spelling in the word-analysis condition. This difference could have been the result of the different cognitive loads that each task required. Orthographic choice was a recognition task, while spelling involved recall and production. The spelling task, as a recall test, could have been more taxing on working memory than the recognition-based orthographic choice task. The spelling test required participants to listen to the word being repeated by the experimenter, hold those sounds in memory, recall the nonword they learned previously, manipulate letters and phonemes in their mind and write them all down.

Limitations and future directions

While the self-teaching hypothesis has previously been empirically tested for TD individuals, this was the first demonstration of the self-teaching hypothesis in individuals with ID. Now that self-teaching has emerged for list-learning, it would be an obvious and interesting extension to see if it applies to paragraph reading. For the purposes of this study it made sense to use nonwords in isolation, but it would be interesting to see how participants with ID would perform if the nonwords had been embedded in paragraphs, as many self-teaching studies have previously done (Bowey & Miller, 2007; Bowey & Muller, 2005; Cunningham, 2006; de Jong & Share, 2007; Share, 1999; 2004; Share & Shalev, 2004).

Another interesting extension of this study would be to find out if orthographic learning can aid in phonological recoding. The self-teaching hypothesis is direction specific, in that it predicts that phonological recoding allows for orthographic learning. It would be interesting to see if the direction could be reversed, and if orthographic processing could aid in phonological learning. If, as the present study suggests, orthographic processing is a relative strength in ID, and if orthographic processing could aid in phonological recoding, then it might help improve overall reading abilities for children with ID.

For this first study, the mental age match design was used. Although this is a traditional matching paradigm it has been criticized on several grounds. In future research a developmental trajectory analysis (Thomas, Annaz, Ansari, Scerif, Jarrold, & Karmiloff-Smith, 2009) could help explain how orthographic and phonological recoding skills compare over age between individuals with ID and individuals with TD. Developmental trajectory analysis provides a developmental perspective, detects atypical versus slow development, and helps avoid matching issues, such as whether to match on chronological and/or mental age. It avoids the assumption that the dependent variable develops at the same rate as the matching variable. Further, while the traditional mental age match requires other variables to differ (e.g. chronological age), the developmental trajectory allows for multiple matches. For example, in the present study the ID group was significantly older than the TD group, had more years in school, and more print exposure. A developmental trajectory study that accounted for experience could be very informative.

Further, it would be beneficial to take into account the types of reading instruction and spelling tests that different classrooms use, to see if there are differences between groups that could be attributed to different learning environments. It would also be interesting to see if a larger sample size would produce a significant interaction.

The self-teaching hypothesis suggests that phonological recoding may have a double benefit: participants are able to sound out and gain orthographic processing at the same time. If orthographic processing is in fact a relative strength in ID, one way to capitalize on this strength would be to work on phonological recoding. According to the present study, increased phonics instruction for participants with ID would aid in both orthographic learning and overall reading skills.

Table 1: List of all nonword targets used in the present study and their phonetic spellings

begrid - bəgrɪd	primet – prɪmɪt
blayer - bleə	ramine – rəmin
bodule – bɑdʒʊl	rapley - ræpli
cainot – kenat	sarone – səron
caleng – kælɪŋ	sarted - sartɪd
chager – tʃegə	sartil - sartɪl
dormen – dɔrmɪn	shread – ʃrɛd
drunet – drunɛt	siftlet - sɪftlɪt
fering – fɛrɪŋ	snigel - snɪgəl
foamus – foməs	surtel - sɜːtəl
goblen – gəblɪn	swaner - swenə
hyrald – haɪrəld	tasmer - tæzmə
lareny – lɛrɪni	thaber - θebə
logren – lagrɪn	thager - θegə
manely – menli	thomer - θomə
mauton – matɪn	frames - tremz
nagred – nəgrɪd	triwen - traɪwɪn
petory – pɛtɔri	vartle - vartəl
pimsel – pɪmsəl	weraly - wɛrəli
prased – prezd	yulper - jʌlpə

Table 2: Sample Descriptives

	Typically Developing (N=19)			Intellectual Disability (N=18)		
	Mean	SD	Range	Mean	SD	Range
IQ	105.47	11.15	83-122	60.44	9.86	40-79
VMA	8.72	1.72	6.25-12.67	8.87	1.30	6.25-10.67
VAS	25.21	6.21	15-35	22.72	5.30	16-34
WA	24.37	9.02	10-40	20.72	10.90	6-40

Note. VMA = verbal mental age. VAS = visual analysis skill. WA = Word Attack.

Table 3: Dependent Variable Descriptives

	Typically Developing (N=19)			Intellectual Disability (N=18)		
	Mean	SD	Range	Mean	SD	Range
SOS	73.84	14.76	43-95	67.33	20.14	26-97
REP	1.37	1.21	0-4	3.44	2.57	0-8
WAorth	6.21	2.15	2-10	7.50	2.09	3-10
WSorth	5.63	2.01	2-9	6.17	2.85	1-10
WAspell	2.67	.19	2.28-2.96	2.43	.41	1.65-3.00
WSpell	2.53	.24	2.02-2.91	2.31	.44	1.45-2.96

Note. SOS = sound out score. REP = repetition score. WAorth = word-analysis orthographic choice task. WSorth = word-supply orthographic choice task. WAspell = word-analysis spelling test. WSpell = word-supply spelling test.

Figure 1: Mean orthographic choice tasks by group for word-analysis and word-supply conditions

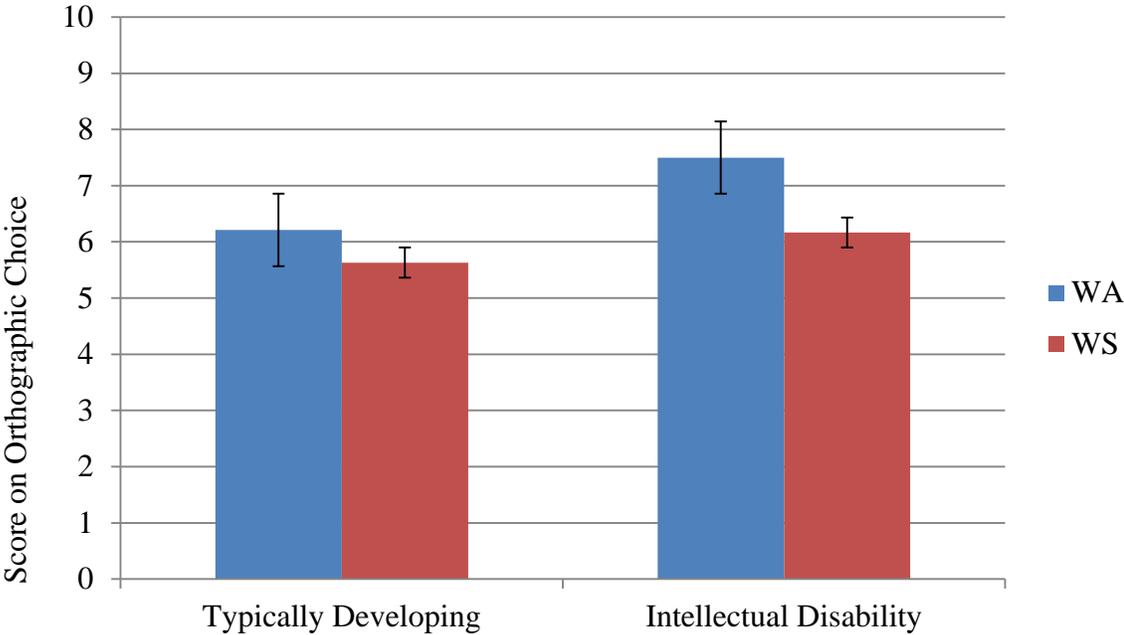


Figure 2: Mean spelling tests by group for word-analysis and word-supply conditions

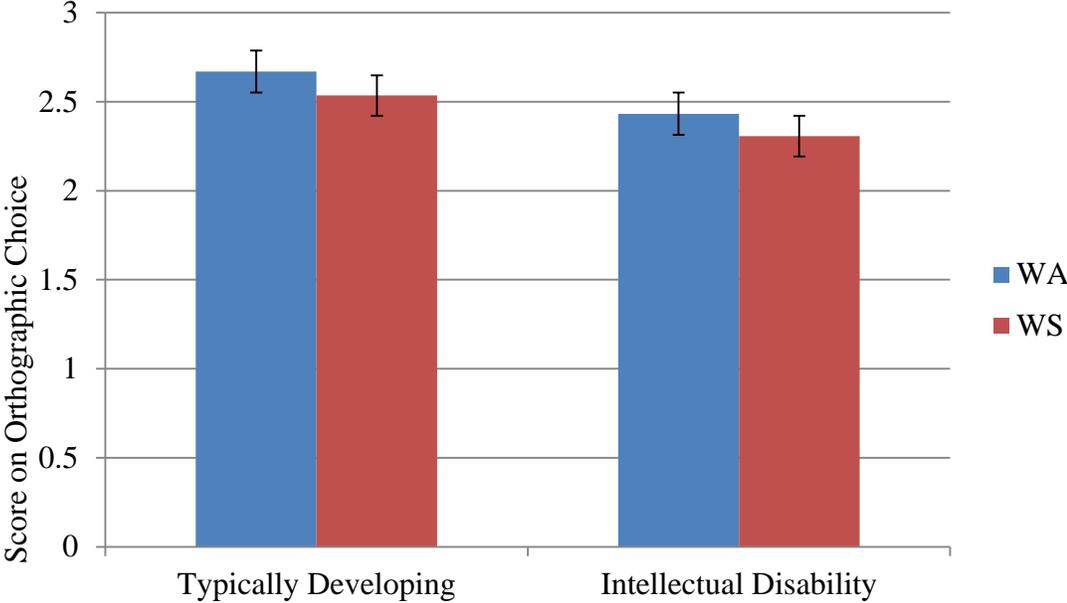


Table 4: Correlations among key variables (TD group above the diagonal; ID group below the diagonal)

	1	2	3	4	5	6	7	8	9	10
1. IQ	---	.73**	.87**	.48*	.20	-.27	.20	.38	.11	.51*
2. VMA	.60**	---	.50*	.67**	.47*	-.60**	.44	.52*	.36	.63**
3. VSA	.75**	.30	---	.49*	.29	-.11	.19	.40	.28	.63**
4. WA	.02	.00	-.29	---	.82**	-.51*	.61**	.77**	.72**	.85**
5. SOS	-.02	-.11	-.37	.85**	---	-.50*	.58**	.87**	.76**	.80**
6. REP	-.09	-.14	.21	-.84**	-.82**	---	-.46*	-.44	-.28	-.52*
7. WAorth	.32	.12	.09	.62**	.59*	-.54**	---	.72**	.49*	.43
8. WSorth	.30	.27	.11	.75**	.63**	-.76**	.63**	---	.55*	.68**
9. WAspell	.12	.03	-.22	.78**	.77**	-.61**	.66**	.62**	---	.74*
10. WSspell	.12	-.02	-.28	.82**	.87**	-.72**	.63**	.69**	.92**	---

Note. VMA = verbal mental age. VAS = visual analysis skill. WA = Word Attack. SOS = sound out score. REP = repetition score. WAorth = word-analysis orthographic choice task. WSorth = word-supply orthographic choice task. WAspell = word-analysis spelling test. WSspell = word-supply spelling test.

** $p < .01$, * $p < .05$, 2-tailed

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