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Growth and Decline in Language and Phonological Memory Over Two Years Among Adolescents With Down Syndrome

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Abstract

Forty-two adolescents with Down syndrome (DS) ages 10 to 21 years completed a battery of language and phonological memory measures twice, 2 years apart. Individual differences were highly stable across two years. Receptive vocabulary scores improved, there was no change in receptive or expressive grammar scores, and nonword repetition scores declined. Digit memory and expressive vocabulary scores improved among younger adolescents, but generally held steady among older adolescents. These patterns may reveal key points in development at which interventions may be best applied. Further research is needed to understand specific processes in tasks that appear to be slowing or declining during adolescence. They may be important for understanding early aging and dementia in DS.

Keywords

Down syndrome; language; phonological memory; longitudinal; adolescence

Down syndrome (DS) results from a triplicate of all or part of chromosome 21 and is recognized as having a unique linguistic profile. In particular, expressive language and receptive grammar are specific challenges, whereas receptive vocabulary is consistent with nonverbal mental age (Abbeduto, Warren, & Conners, 2007; Martin, Klusek, Estigarribia, & Roberts, 2009; Næss, Lyster, Hulme, & Melby-Lervåg, 2011). Challenges in language can lead to difficulties not only in everyday communication, but also in school learning and

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social interactions. Phonological memory (memory for speech sound sequences) is also very challenging for those with DS (Jarrold & Baddeley, 2001; Jarrold, Baddeley, & Phillips, 1999; Næss et al., 2011). It is believed to be importantly related to language, potentially because it provides the processing foundation for language learning (e.g., Chapman, Hesketh, & Kistler, 2002; Estigarribia, Martin, & Roberts, 2012; Iacono, Torr, & Wong, 2010; Laws, 2004; Miolo, Chapman, & Sindberg, 2005).

The present study was designed to provide new data on the developmental trajectory of critical aspects of language and phonological memory in DS, particularly in the adolescent age range. In DS, adolescence is a period in which there may be clear differentiation among those skills that are continuing to improve, those that are leveling off, and even possibly those that are beginning to decline (e.g., Chapman et al., 2002). Based on the DS linguistic phenotype and past findings, we expected to see growth in receptive vocabulary and stability or decline in receptive grammar, phonological memory, and possibly expressive vocabulary and expressive grammar (e.g., Byrne, MacDonald, & Buckley, 2002; Chapman et al., 2002; Laws & Gunn, 2004).

Although the basic language profile associated with DS is well established, there is a need for research on the developmental course of language abilities in this population (Abbeduto et al., 2007). Developmental trajectories in DS may be quite different from those of typically developing (TD) children and adolescents. At what point in DS development do specific strengths and weaknesses in language emerge? At what point are there plateaus in development of specific language skills? Are there declines, and if so, at what age do they emerge? Answers to these questions have important implications for the design and implementation of language intervention for individuals with DS, as well as for understanding their ability to meet the changing demands of daily living across the lifespan. Some studies have examined developmental trends cross-sectionally over age (e.g., Alony & Kozulin, 2007; Cooper & Collacott, 1995; Iacono et al., 2010; Kumin, Councill, & Goodman, 1998; Sanoudaki & Varlokosta, 2015; Thordardottir, Chapman, & Wagner, 2002; Zampini & D'Odorico, 2013), but cross-sectional trends only *approximate* actual change over time in the same individuals. What is most needed is longitudinal research in which the same individuals are followed across time.

Language Development

Existing longitudinal studies on language in DS have varied widely in terms of the aspect of language, age range, and time span examined. Considered together, however, they begin to create a view of language development in this population from toddlerhood to adulthood. In the toddler years, there are significant increases in vocabulary. Zampini and D'Odorico (2011) found young children with DS increased their single-word utterances and decreased preverbal communications from ages 2 to 3 years and from ages 3 to 4 years. Children also increased the frequency and length of their word combinations from ages 3 to 4 years. Zampini, Salvi, and D'Odorico (2015) found that toddlers with DS age 2 years seemed to improve in expressive and receptive vocabulary over 6 months when measured by the Italian version of the MacArthur-Bates Communicative Development Inventory (CDI), though the authors did not report a significance test.

In the early school years, expressive and receptive vocabulary continue to improve, as does receptive grammar. For example, Næss, Lervåg, Lyster, and Hulme (2015) found that children with DS improved in these three language skills from age 6 to 8 years, though improvement in receptive grammar was modest. Through the school years and into adolescence, receptive vocabulary continues to grow. Laws and Gunn (2004), for example, reported significant gains over 5 years in participants with DS ranging in age from 5 to 19 years at Time 1, with gains consistent across this wide Time 1 age range. Mackensie and Hulme (1987) reported significant gains in receptive vocabulary over 2 years for youth with DS ages 9 to 16 years, and over 5 years for a subset of the sample. Hick, Botting, and Conti-Ramsden (2005) reported gains in both receptive and expressive vocabulary over 1 year in children ages 8 to 11 years, with the gain occurring in the first half of the year. Martin, Losh, Estigarribia, Sideris, and Roberts (2013) also reported gains in expressive vocabulary over 2 years for children with DS averaging 10 years old at Time 1.

Receptive grammar, on the other hand, grows only modestly through the school years and growth may slow or even decline into adolescence. For example, Byrne et al., (2002) found that among children ages 4 to 12 years there was a significant increase over 1 year followed by a leveling off the following year. Laws and Gunn (2004) found only a 3-month gain in receptive grammar over 5 years in their full sample, ages 5 to 19 years, with little gain at all at the older end of this age range. Chapman et al.'s (2002) hierarchical linear model indicated a decline in receptive grammar in late adolescence and young adulthood, suggesting the loss of skill.

There is less agreement regarding development of expressive grammar during the school years. In contrast to their results for receptive grammar, Chapman and colleagues (2002) found steady growth (and no decline) in expressive grammar over the 6 years of their study of those with DS ages 5 to 20 years (see also Martin et al., 2013, over 2 years). Kay-Raining Bird, Cleave, and McConnell (2000), however, did not find an increase in expressive grammar in the early school years (ages 6–11 years) over 3 years, a finding that was largely replicated by Fowler, Gelman, and Gleitman (1994). One possibly important difference between these two studies and Chapman's is that Chapman elicited the language sample using narrative discourse, whereas the other two studies used conversation samples. Chapman and colleagues (Chapman & Hesketh, 2000; Chapman et al., 2002) have argued that the more formal narrative is more likely to bring out more complex grammatical structures, and is therefore better able to detect improvement with age (see also Thordardottir et al., 2002). In addition, the time frame for Chapman et al.'s (2002) study was longer and the sample was larger.

Into adulthood, research suggests that receptive vocabulary may continue to improve, depending on environment and opportunity. Burt et al. (1995) found that community-dwelling adults with DS ages 22 to 56 years without Alzheimer's Dementia (AD) showed no significant change in receptive vocabulary over 4.5 years. Similarly, Carr (2000) found that, overall, adults with DS ages 21 to 40 years showed no significant change in receptive vocabulary over 9 years; however, a subgroup that was raised at home and had higher SES did improve over these 9 years. Berry, Groeneweg, Gibson, and Brown (1984) found an increasing trend over 5 years in 41 participants with DS ages 15 to 41 years, with degree of change unrelated to age of participant. Participants in the Berry et al. (1984) study were all in a rehabilitation program; this might have provided them an environment conducive to continued growth in receptive vocabulary.

Expressive vocabulary changes little during the adult years for individuals with DS, as Carr (2000) found no significant improvement over 9 years among adults with DS ages 21 to 40 years, regardless of environment. Burt et al. (1995) found no change over 4.5 years in participants ages 22 to 56 years. However, in older adulthood, among those without AD, crystallized verbal abilities in general tend to decline in DS, in contrast to the general population (Carr, 2005; Couzins, Cuskelly, & Haynes, 2011).

In summary, there is growth in language into adolescence and early adulthood in DS, but it is quite variable across different domains of language, with some domains showing relatively early plateaus. At the same time, there are important gaps in our knowledge. Expressive vocabulary development in DS has been largely neglected beyond the childhood years. Despite evidence of variability across measures of expressive grammar, virtually no studies have included multiple measures of this domain for the same participants. Finally, longitudinal studies to date have focused almost exclusively on describing group changes, leaving individual differences in the trajectory of language largely unexamined.

Phonological Memory Development

In contrast to research on language, longitudinal research on phonological memory has rarely included the toddler age. This may be because current phonological memory measures are not sensitive enough to detect very low levels of ability. The two measures of phonological memory most commonly used in research are (a) digit or word span, in which participants listen to lists of randomly ordered digits or words and repeat them back in the same order; and (b) nonword repetition, in which participants listen to non-words (e.g., *jat; tilgaloon*) and repeat them back exactly. For both types of measures, the tests begin with short lists of digits or short nonwords and progress to longer lists or more complex non-words. Studies focusing on the early to middle school years show that phonological memory increases during this time for children with DS. For example, Naess et al. (2015) found that although 6 year olds with DS scored at the floor on both word span and nonword repetition measures, by age 7 years they were able to score above floor on nonword repetition (though still not on word span) and improved their scores from age 7 to 8 years. Hick et al. (2005) found no improvement in digit or word span over 1 year for children with DS ages 8 to 11 years (see also Cupples & Iacono, 2000); however, Byrne et al. (2002) found modest but significant improvement on digit span over 2 years for children with DS ages 4 to 12 years. Also, Laws and Gunn (2004) found improvement over 5 years in nonword repetition in the younger end of their range, those ages 5 to 13 years (see also Kay-Raining Bird et al., 2000).

In adolescence, however, there may be a leveling off or even decline in phonological memory. For example, Mackensie and Hulme (1987) saw no improvement over 2 years in digit span in their sample ages 9 to 16 years. They did see modest but statistically significant improvement over 5 years, though only 10 of the original 21 participants returned for the 5-year follow-up. Laws and Gunn's (2004) sample spanning from ages 5 to 19 years showed that, whereas there was no improvement in digit span or nonword repetition over 5 years in the sample as a whole (see also Chapman et al., 2002), change scores correlated negatively with chronological age. A close look at nonword repetition revealed that, whereas all eight of the younger participants (ages 5–13 years) improved, 16 of the 22 older participants (ages 14–19 years) *declined*.

Few longitudinal studies have examined phonological memory in DS during adulthood. Devenny et al. (1996) found no change over a period of up to 6 years on the WISC-R Digit Span subtest measure in adults with DS ages 31 to 63 years at Time 1 without AD. Thus, phonological memory may be fairly stable during the adult years. However, longitudinal studies using non-word repetition measures with adults with DS have not yet been conducted.

The Present Study

The present study examined change in a variety of language and phonological memory skills over 2 years in adolescents with DS ages 10 to 21 years. Past research suggests that adolescence may be a unique period when there is growth, slowing, and decline all at the same time, depending on the domain. We were especially interested in replicating three findings: (a) that receptive vocabulary continues to increase through adolescence (Laws & Gunn, 2004); (b) that receptive grammar growth tends to slow, level off, or even regress in adolescence (Byrne et al., 2002; Chapman et al., 2002; Laws & Gunn, 2004), though expressive grammar continues to improve (Chapman et al., 2002); and (c) that phonological memory growth slows or reverses in adolescence (Laws & Gunn, 2004).

We also examined expressive vocabulary, which has not yet been studied longitudinally in adolescents with DS. We used a variety of individually administered standardized language and phonological memory measures as well as narrative language samples.

Although there is a distinct linguistic profile associated with DS, there is substantial variability in the skills and abilities of children and adults with DS. An examination of change over time *groupwise* assumes that individual differences are stable over the time period being examined. That is, those individuals who are strongest in the group at Time 1 for a particular language skill are also assumed to be strongest in the group at Time 2. If individual differences are not stable over time, but instead fluctuate due to different individual rates of growth, then it could be argued that change over time should be characterized in an individual manner as well as in a groupwise manner. What may look like leveling off of growth groupwise may be due to a conglomeration of different individual rates of growth and decline. A few longitudinal studies reviewed in the foregoing sections reported correlations between language measures at Time 1 and Time 2 that reflect high stability of individual differences in DS (Carr, 2000; Devenny et al., 1996; Næss et al., 2015; Zampini & D'Odorico, 2013). However, none of these studies focused on the adolescent age range. It is possible for individual differences to be stable at one point in development, but to become less stable at another point. Thus, the present study examined stability of individual differences as well as change over 2 years in language and phonological memory skills in adolescents with DS.

Method

Participants

The present analysis is part of a larger study on cognitive predictors of language impairment in DS. Other reports from the same larger study include Channell, Loveall, Conners, Harvey, and Abbeduto (in press); Channell et al., (2015); Loveall, Channell, Phillips, Abbeduto, and Conners (2016); Phillips, Conners, Merrill, and Klinger (2014); and Phillips, Loveall, Channell, and Conners (2014). For the larger study, participants were recruited through many channels at three testing sites in different parts of the United States. Test administration guidelines were documented in detail in a common testing manual used by each site. In the early synchronization of testing activities, site personnel met monthly via videoconference to calibrate test administration procedures.

To be eligible to participate in the study, individuals with DS had to (a) be ages 10 to 21 years; (b) use English speech as their primary mode of communication; and (c) pass screeners for near vision (20/63 or better binocular acuity), hearing (30 db or better at 500–2000 Hz in at least one ear), and autism spectrum disorder (ASD; below 15 on Social Communication Questionnaire screener or below the autism range on clinician-administered Autism Diagnostic Observation Scale, or ADOS). Also, participants had to have a parent/guardian bring them to the testing site, and had to be capable of completing a substantial battery of tests. Further, participants had to (a) complete our nonverbal ability test (Leiter International Performance Test - Revised, Brief Form; Leiter-R Brief Form; Roid & Miller, 1997), (b) score at least one point on our nonword repetition subtest (Comprehensive Test of Phonological Processing; CTOPP; Wagner, Torgesen, & Rashotte, 1999), (c) pass at least one block on our receptive grammar test (Test for Reception of Grammar, 2nd edition; TROG-2; Bishop, 2003), and (d) have the use of their hands for fine-motor manipulation of testing materials. In the present analysis, we included all participants who met these criteria and completed both Time 1 and Time 2 testing 2 years apart. Eight participants who began testing did not meet the criterion for ASD, TROG-2, CTOPP Nonword Repetition, and/or vision. Fourteen participants who were eligible for the study and completed Time 1 did not complete Time 2. Those lost to attrition did not differ significantly from those who completed both sessions in terms of age, $t(54) = 0.24$, $p = .808$; Leiter IQ, $t(52) = 0.78$, $p = .440$; nonverbal ability (Leiter GSV), $t(54) = 0.76$, $p = .451$; or any of the language and phonological memory measures at Time 1 (p's = .11–.82).

The sample for the present study included 42 individuals with DS who were ages 10 to 21 years at Time 1 ($M = 15.07$ $SD = 3.40$). Thirteen of these participants were tested at Site 1 (Time 1 and Time 2), 24 participants were tested at Site 2 (Time 1) and Site 3 (Time 2), and five participants were tested at Site 3 (Time 1 and Time 2). This sample was 73.8% White Non-Hispanic, 14.3% White Hispanic, 7.1% More than One Race and 2.4% Other, with one participant’s race not reported. It was 47.6% male and 52.4% female. Median Leiter-R Brief IQ was 42; range 36–71 (because seven participants scored the lowest possible IQ, we report median and range instead of mean and *SD*); median family income was $79,500 (range $30,000–$200,000, $n = 38$). A large majority of participants were enrolled in speech/language class (78.6%). Most participants’ mothers had graduated from college or completed some college (66.7%), some had completed a graduate degree or some graduate school (31%), and the rest had graduated from high school but did not attend college (2.4%). Four participants were reported by their parent/guardian to have an anxiety disorder diagnosis or to be taking prescription medication for anxiety; one of these also was reported to have a bipolar disorder diagnosis; none of the participants was reported to have a diagnosis of depression or to be taking prescription medication for depression. For all but one participant we had chromosomal analysis or physician's confirmation of DS.

Measures

Receptive vocabulary: Peabody Picture Vocabulary Test, 4th edition (PPVT-4; Dunn & Dunn, 2007)—The PPVT-4 is a standardized test, normed for ages 2.5 years and up. It requires participants to point to the picture that corresponds with a spoken word, from a choice of four options. The test covers 20 content categories and includes nouns, verbs, and adjectives. Split half reliability is .94–.95 (Dunn & Dunn, 2007), and this test is favored for studies of DS because of its low floor, colorful pictures, and nonverbal response requirements. For Time 1 testing, we used Form A for half the sample and Form B for the other half. For Time 2 testing, we used the opposite form than used at Time 1 for each participant. We used growth scale value (GSV) scores in data analysis, which are equal-interval transformed raw scores and are sensitive to change over time.

Receptive grammar: Test for Reception of Grammar, 2nd edition (TROG-2; Bishop, 2003)—The TROG-2 is a standardized test normed on a British sample age 4 to 24 years. It requires participants to point to the picture that corresponds to a spoken phrase or sentence, from four options. Each phrase features a grammatical contrast that must be understood to choose the correct picture. Items are organized into 20 blocks of four items each, and testing discontinues when the participant has failed five consecutive blocks. Internal consistency reliability is .88 (Bishop, 2003). Total items passed (raw score) was used in data analyses.

Expressive grammar: Clinical Evaluation of Language Fundamentals-Preschool, 2nd edition (CELF-P2; Wiig, Secord, & Semel, 2004) Word Structure subtest—The CELF-P2 is a published, standardized, norm-referenced test designed for ages 3 to 6 years that measure expressive mastery of grammatical morphology. It requires participants to complete sentences begun by the tester, who uses pictures to demonstrate (e.g., *This boy is standing; this boy is* _____). To score a point, the participant must use the correct grammatical element. Split half reliability for this subtest ranges from .81–.90 for TD children and .90–.96 for clinical groups (Wiig et al., 2004). Although our sample far exceeded the chronological age range of the test, the performance level was within the test's range. We used the total number of items correct (raw score) in data analyses.

Expressive grammar and vocabulary: Narrative Language task—Participants were shown a wordless picture book from Mercer Mayer's Frog Series. At Time 1 half of the participants were shown *Frog Goes to Dinner* (Mayer, 1974) and the other half were shown *Frog on His Own* (Mayer, 1973); these were then counterbalanced across testing times. First, the examiner slowly flipped through the book, page by page, so the participant could see what happens in the story. Then, the examiner turned back to page one and asked the participant to tell the story, page by page. Following procedures developed by Abbeduto and colleagues (Abbeduto, Benson, Short, & Dolish, 1995; Berry-Kravis et al., 2013; Kover, McDuffie, Abbeduto, & Brown, 2012), the examiner followed a script for administration, which entailed minimal prompting of the participant beyond the first few pages, as well as a standardized script for eliciting the narrative. Each participant's narrative sample was audio recorded and transcribed by trained personnel using Systematic Analysis of Language Transcripts software (SALT; Miller & Iglesias, 2010). Transcribers were trained to reliability and each language sample was transcribed by a primary transcriber, checked by a secondary transcriber, and corrected by the primary transcriber.

Transcribers segmented each transcript into utterances called *C-units* (communication units), defined as an independent clause and its modifiers, which can include dependent clauses (Abbeduto et al., 1995). The C-unit is preferred over utterance as the unit of analysis for individuals beyond the earliest stages of multiword speech. Only fully complete and intelligible C-units were considered in the SALT analysis set. We used mean length of C-units in morphemes (analogous to mean length of utterance, MLU) to reflect expressive grammar in our data analyses and number of different words (total number of different words uttered) to reflect expressive vocabulary. In addition, we used unintelligibility (proportion of total C-units that are partly or fully unintelligible) and talkativeness (number of C-units attempted per minute) as covariates for specific analyses.

Phonological memory: Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999) Memory for Digits and Nonword Repetition subtests—The CTOPP is a standardized test normed for ages 5 to 27 years. In Memory for Digits, participants listen to lists of audio-recorded digits and repeat them back immediately in the same order. The lists start with two digits and increases up to a maximum of eight digits, with three trials at each list length. Testing is discontinued after three missed trials in a row. We used number of trials correct out of a total of 21 in data analyses. Test-retest reliability over 2 weeks is .81 (Wagner et al., 1999).

In Nonword Repetition, participants listen to audio-recorded nonwords and repeat each back after hearing it. The nonwords start short, with a three-phoneme monosyllabic nonword, and increase up to a 15-phoneme 6-syllable nonword. Testing is discontinued after three missed trials in a row. We used number of trials correct out of a total of 18 (raw score) in data analyses. Interscorer reliability is .95–.99 depending on age and test-retest reliability over 2 weeks is .70 (Wagner et al., 1999). For the present study, we counted as acceptable certain common phonological substitutions (e.g., *zh* vs. *j* as final phoneme), certain dialect-related features (e.g., long *i* pronounced as *ah* in southern dialect), and individual participants' own typical phonological substitutions (e.g., using *w* for *r*). Two examiners independently scored participants' responses live in the testing room, and audio recording was used to resolve any scoring discrepancies.

Nonverbal cognitive ability: Leiter International Performance Test-Revised, Brief Form (Roid & Miller, 1997)—The Leiter-R is designed for ages 2 to 21 years and, because it requires no receptive or expressive language skills, it is often used in studies of DS. Four subtests make up the brief IQ battery: Figure Ground, Form Completion, Sequential Order, and Repeated Patterns. These subtests measure visual spatial and inductive reasoning skills typically classified as fluid intelligence. We used the GSV score as a covariate in data analysis, but also computed the brief IQ for sample description. Internal consistency reliability is .88–.90 depending on age, and test-retest reliability is .88–.96 (Roid & Miller, 1997).

Results

Distributions of all language and phonological memory variables were inspected for gross deviations and all were distributed normally. Scores beyond 3.5 *SD* from the mean were considered outliers, and there were two such scores—a high score on narrative syntax at Time 1 and a high score on nonword repetition at Time 2. These two scores were removed from data analysis. Of the 42 participants in the present analysis, one was missing a score on CTOPP Memory for Digits at Time 1 (declined to complete the task), two were missing scores on CELF-P2 Word Structure at Time 1 (tested before this measure was added to the battery), one was missing data from the Time 1 narrative language task, and one was missing data from the Time 2 narrative language task.

Individual Differences Over Two Years

All language and phonological memory measures were significantly correlated from Time 1 to Time 2 (Table 1). There was very strong stability of individual differences in most language measures (receptive vocabulary, receptive grammar, both measures of expressive grammar, and expressive vocabulary), with correlations of Time 1 with Time 2 of $r = .72$–.94. There was also substantial stability of individual differences in phonological memory ($r = .65$–.82). All correlations remained significant (most .77 and over), when controlled for nonverbal cognitive ability through partial correlation (Table 1).

Change Over Two Years

For each of the language and phonological memory measures we compared Time 1 performance with Time 2 performance to determine if there was significant growth or decline in the group as a whole (see Table 1 for means and standard deviations). We also computed a 2-year change score for each participant for each measure and examined the relation of change score to chronological age to determine whether growth or decline was different across the age range of our sample. The fact that our “adolescent” sample extended from just before adolescence (age 10 years) to just after adolescence (age 21 years) allowed us to take a broader look at how change over 2 years might vary from early to late adolescence.

Finally, to take a closer look at individual change, we computed reliable change (RC) index scores for each participant. These scores take into consideration the reliability of the measures and can be used to examine individual change above and beyond measurement error. We used the formula $RC = (X_2 – X_1)/S_{diff,}$ where X_2 is a participant’s score at Time 2, X_1 is that participant’s score at Time 1, and S_{diff} is the standard error of the difference between Time 1 and Time 2 scores (Christenson & Mendoza, 1986; Jacobson & Truax, 1991). Ideally, S_{diff} is computed using the standard error of measurement (SEM) from a standardization sample for the age band of the participant, $S_{\text{diff}} = \sqrt{2(\text{SEM})^2}$. Because we used raw (or GSV) scores and not standard scores, SEMs were not available and we had to estimate them to compute RC. Ideally, in this case, SEM would be estimated from published test-retest reliabilities and standard deviations from a standardization sample in the appropriate age bands for each participant ($\text{SEM} = s_1\sqrt{1 - r_{xx}}$). This was only possible for one measure (receptive vocabulary). For the others we had to compromise in some way—by using internal consistency instead of test-retest reliability, disregarding age band, and/or using reliability or standard deviation from the study data or a related sample. Because of the many compromises in computation of RC, we regard the RCs as exploratory in the present study.

Receptive vocabulary—For receptive vocabulary, there was significant growth over 2 years in the group as a whole, $t(41) = 2.49$, $p = .017$ (see Figure 1). Further, change scores did not correlate with Time 1 chronological age ($r = -.16$, *ns*). Thus, growth magnitude was rather consistent across the adolescent years. However, based on RC analysis, 24% of participants showed statistically reliable growth and 12% showed statistically reliable decline.

Receptive grammar—For receptive grammar, there was no significant growth over 2 years, $t(41) = 0.73$, $p = .470$. On average, participants answered less than one additional item correctly at Time 2 than at Time 1. Further, change scores were not correlated with chronological age ($r = .04$, *ns*), suggesting that the lack of growth in receptive grammar was consistent across the adolescent age range. Based on RC analysis, 2% showed statistically reliable growth and 0% showed statistically reliable decline.

Expressive grammar—Neither the CELF-P2 Word Structure nor MLU from the narrative language task showed significant group-wise change in expressive grammar over two years, $t(39) = 0.25$, $p = .804$ and $t(38) = 0.27$, $p = .788$, respectively. Change in CELF-P2 Word Structure scores did not correlate with chronological age, $r = -.02$, *ns*, though change in MLU trended toward a negative correlation with age, $r = -.28$, $p = .085$. Based on RC analysis, 0% of participants showed statistically reliable growth or decline on the CELF-P2 Word Structure subtest; for MLU, 5% of participants showed statistically reliable growth, and 5% of participants showed statistically reliable decline.

Expressive vocabulary—There was no significant change in expressive vocabulary over 2 years in the full sample, $t(39) = 1.47$, $p = .151$. Our measure of expressive vocabulary was the number of different words used while telling the story of the wordless picture book. Though in general this measure is more ecologically valid than a psycho-metric test, it may be influenced by an individual’s talkativeness. Talkativeness, computed from the narrative language samples, correlated positively with number of different words used at Time 1, $r = .40$, $p = .009$, and also at Time 2, $r = .48$, $p = .002$ (one outlier on talkativeness at Time 2 removed). When the variance in talkativeness was statistically controlled in Time 1 and Time 2 expressive vocabulary measures, there was still no significant change, $t(38) = 1.48$, p

= .147. However, change scores based on the corrected expressive vocabulary scores correlated negatively with age, $r = -.38$, $p = .018$. Visual inspection of the graph (Figure 2) suggests a tendency for younger participants to show improved scores over 2 years, and a tendency for the older participants to show less improved or declining scores. The midpoint of the age range (age 16.115 years) was used to split the sample into a younger and an older group. In the younger group, scores improved significantly from Time 1 to Time 2, $t(22) = 2.85$, $p = .009$. In the older group there was no significant change, though some individuals showed declining scores. Based on RC analysis, 10% showed statistically reliable growth and 0% showed statistically reliable decline.

Phonological memory—For the CTOPP Memory for Digits measure, there was no significant growth over 2 years for the sample as a whole, $t(40) = 0.65$, $p = .517$. After removing one change score that was more than 3.5 SD below the mean, however, change scores correlated negatively with chronological age ($r = -.36$, $p = .024$). Visual inspection of the graph (Figure 3) indicates that many of the younger participants showed improved scores over two years, whereas many of the older participants showed no change or slightly declining scores. Splitting the sample at the midpoint of the age range, scores increased from Time 1 to Time 2 in the younger group, $t(23) = 2.19$, $p = .039$, whereas scores did not change in the older group, $t(15) = 0.76$, $p = .456$. RC analysis indicated that 0% of participants showed statistically reliable growth or decline.

For the CTOPP Nonword Repetition measure, there was a significant decline over 2 years in the group as a whole, $t(40) = 3.99$, $p = .0003$ (see Figure 4). Change scores trended toward a negative correlation with age, $r = -.28$, $p = .08$, raising the possibility that the older participants may have shown larger negative changes. The overall group-wise decline was in spite of improvement in intelligibility from Time 1 to Time 2, $Z = 2.65$, $p = .008$ (Related-Samples Wilcoxon Signed Rank Tests). Also, change in nonword repetition was correlated with change in receptive vocabulary—individuals whose scores declined the least in nonword repetition had scores that improved the most in receptive vocabulary, $r = .36$, $p = .020$. Based on RC analysis, 0% showed statistically reliable growth and 15% showed statistically reliable decline.

Discussion

The purpose of the present study was to determine whether individual differences in language and phonological memory measures are consistent over 2 years in adolescents with DS, and whether these abilities improve, level off, or decline. We found remarkable stability of individual differences in the language measures, which bodes well for their ability to capture growth or decline over 2 years. Further, the present study replicated several previous findings—though not all—and presented new findings relevant to developmental patterns of language and phonological memory across the adolescent years.

Language Development

One replicated finding was that receptive vocabulary continues to improve through the adolescent years in DS. We found increasing scores over 2 years that was consistent across the age range of our study sample. This agrees with the findings of Laws and Gunn (2004), who had an even wider age range (5–19 years) and longer time frame (5 years) than in the present study. It is also consistent with findings on adolescents with Williams syndrome and fragile X syndrome (FXS; Jarrold, Baddeley, Hewes, & Phillips, 2001; Pierpont, Richmond, Abbeduto, Kover, & Brown, 2011), although these syndromes have not been compared directly with DS on receptive vocabulary growth.

Another replicated finding was that receptive grammar growth slows or levels off in adolescence. We found no significant change in receptive grammar scores across the extended adolescent range of ages 10 to 21 years. Other researchers have also reported slowing down or leveling off of growth in receptive grammar in this age range (Laws & Gunn, 2004; Chapman et al., 2002). Results from Byrne et al. (2002) may suggest that the slowing down of growth could begin in preadolescence, as their children, ages 4 to 12 years, improved in the first year of the study but not in the second. Similarly, Chapman et al. (2002) found that the youngest participants in their sample (averaging 7.5 years) showed greater gains in receptive grammar over 6 years than did their middle group (averaging 12.5 years). Both Laws and Gunn (2004) and Chapman et al. (2002) suggested there might be a decline in receptive grammar beginning at about 17 years of age. The older group in Chapman et al. (averaging 17.5 years) showed a slight but significant decline over 6 years. Laws and Gunn (2004) reported that, of their three participants who declined over 5 years, all were 17 years old or older. In the present study, however, there was no indication at all of negative change scores being more prevalent among older participants. Although our measure (TROG-2) was different from that used by Chapman and colleagues (TACL-R syntax), it was essentially the same as that used by Laws and Gunn (TROG). Perhaps if the present study had been over 4 or 5 years, a decline would become apparent. From our data, however, we conclude that there is neither systematic improvement nor decline in receptive grammar that is detectable in as few as 2 years in adolescents with DS. Our results are consistent with those for adolescent boys with FXS (Pierpont et al., 2011), though adolescent girls with FXS improved in receptive grammar in that study.

The present study did not replicate results from Chapman et al. (2002) regarding expressive grammar. Chapman's participants, ages 5 to 20 years, improved significantly over 6 years regardless of starting age. In contrast, we found no evidence of improvement in either of our two very different measures of expressive grammar. As mentioned in the introduction, Chapman has argued that, when eliciting language samples, it is important to use narrative rather than conversational discourse because narrative discourse brings out more complex grammatical structures (e.g., Chapman & Hesketh, 2000; Chapman, Seung, Schwartz, & Kay-Raining Bird, 1998). Both Fowler et al. (1994) and Kay-Raining Bird et al. (2000) used conversational samples and found no growth in MLU over 4.5 and 3 years, respectively. In the Chapman et al. (2002) study, a combination of conversational and narrative samples was used, with the most formal narrative sampling technique (similar to the one used in the present study) added at the final test time. Adding the formal narrative sampling technique on the final test time could have caused an increase in measured MLU. In contrast, in the present study, we used the same formal narrative sampling technique at Time 1 and at Time 2—a cleaner comparison. Still, it is possible that growth in expressive grammar is so modest in adolescents with DS that it did not become apparent in a span of only 2 years. Further, there was a nonsignificant trend toward a negative correlation of MLU with age in our study, and a larger sample could more clearly reveal smaller effects if they exist. At present, however, our results suggest no growth in expressive grammar over a 2-year period in early adolescence in DS. This flat trend in our sample is in contrast to an increasing trend for adolescents with FXS based on the CASL Syntax Construction Test (Pierpont et al., 2011). Thus, it is possible that our findings are unique to DS, though there is far too little data to make this conclusion.

In addition to receptive vocabulary, receptive grammar, and expressive grammar, we examined expressive vocabulary as measured by the number of different words spoken during the narrative language task. To our knowledge, expressive vocabulary had not yet been examined longitudinally among adolescents with DS. Groupwise, there was no change over 2 years in expressive vocabulary scores. However, change scores correlated negatively with age and, whereas younger participants' scores improved over 2 years, this was not true for older participants. Consistent with our results for younger participants, Pierpont et al. (2011) found that expressive vocabulary improved over 2 years in youth with FXS ages 10 to 16 years. More research directly comparing the two syndromes is needed, however. Adding these findings to those from other studies suggests that in DS gains in expressive vocabulary in the early school years (Hick et al., 2005) may continue into early adolescence, level off in late adolescence, and then maintain into adulthood (Burt et al., 1995; Carr, 2000). However, in our data, a number of the older adolescents had declining scores over 2 years. This warrants longitudinal replication, extending the age range into the young adult years.

Phonological Memory

Growth or decline over 2 years in phonological memory depended on the measure used, and the results were somewhat complex. For memory for digits, there was no change over 2 years for the group as a whole, but younger adolescents showed improved scores, whereas older adolescents did not. For nonword repetition, scores generally declined across the entire sample, with a trend toward greater decline among older participants. It is intriguing that these two measures of phonological memory showed different patterns in adolescents with DS over 2 years.

As in the present study, Mackensie and Hulme (1987) and Laws and Gunn (2004) each reported no overall change in digit memory over their longitudinal period (2 years and 5 years, respectively). However, Mackensie and Hulme's sample (9–16 years) was similar in age range to our younger subgroup (10–16 years), yet we found increases in digit memory scores in this age range. Similar to the present study, Laws and Gunn (2004) reported a negative correlation between change scores and age. However, they did not report whether younger participants showed improvement in their scores and older participants showed little change (as in the present study), or whether a different pattern better characterized the data. The observation that young adolescents with DS may be improving in memory for digits is very encouraging, even though they may stop improving in late adolescence. This suggests that verbal sequential memory, which tends to be highly limited in DS but lays the foundation for important everyday functioning, continues to develop through mid-adolescence. Early adolescence could be a good time for interventions targeting this skill.

It is interesting that our finding of decline in nonword repetition scores during adolescence in DS is consistent with results of Laws and Gunn (2004). Although they found no change groupwise in their sample, they reported that children ages 5 to 13 years all improved whereas most adolescents, ages 14 to 20 years declined. Thus, declining scores over 2 years in our sample, ages 10 to 21 years, is consistent with that in Laws and Gunn's sample over 5 years, ages 14 to 20 years. Although DS is associated with early aging and AD, a decline as specific as this (e.g., in nonword repetition but not in memory for digits) during adolescence is surprising.

The increase in digit memory in early adolescence is consistent with that reported for memory for words in youth with FXS over 2 years from ages 10 to 12 years (Scherr, Hahn, Hooper, Hatton, & Roberts, 2016). However, there are few if any longitudinal data from any other intellectual disability (ID) etiology groups focusing on late adolescence or using a nonword repetition measure.

The discrepant longitudinal patterns for memory for digits versus nonword repetition in participants with DS strongly suggest that these are not two measures of the exact same construct. These two measures must tap some distinct processes. The processes tapped by memory for digits improve during early adolescence in DS. The processes tapped uniquely by nonword repetition seem to decline throughout adolescence. One difference between the two tasks is that the to-be-remembered information is familiar in the case of memory for digits, and unfamiliar in the case of nonword repetition. This means that there is less semantic support in nonword repetition, and so the actual speech sound sequence is more important to task performance. Also, the units to be processed and recalled are larger and spaced out temporally in memory for digits, but small and very quickly presented in nonword repetition. Laws (1998; Laws & Gunn, 2004) found that nonword repetition and digit span did not always relate to language measures the same way in youth with DS. Archibald and Gathercole (2006) found that children with specific language impairment showed more severe impairments on nonword repetition tasks than digit/word span tasks. In a subsequent paper, they suggested that, more so than digit/word span tasks, nonword repetition taps (1) the use of co-articulation and prosody cues, (2) speech motor planning and execution, and (3) processing of rapid and sustained stimuli (Archibald & Gathercole, 2007). In future research, these processes could be examined to determine if one or more of them is critical in the timing of improvement and/or decline in phonological memory in adolescents with DS.

Limitations of the Present Study

The present study is limited in that it measured change over only 2 years, using a sample that is relatively modest in size. Because of these two factors, the study may not have been able to detect small gradual changes or subtle changes that are not linear. With more years and a larger sample, it would be possible to look for subgroups with different developmental trajectories during adolescence. For example, there could be subgroups of "late bloomers," "steady-goers," and "early decliners." Also, eligibility criteria restricted the degree to which the sample is truly representative of the population of individuals with DS. For example, all participants were verbal, had no more than a moderate hearing loss, and did not have ASD.

Another limitation of the present study is that we were not able to include a comparison group of same-age participants with ID other than DS. Thus, we are not able to say whether the results of the present study are specific to DS, or characteristic of ID in general.

Finally, the present study included only limited information to examine the potential impact of psychiatric and other health-related factors on growth or decline in language and phonological memory measures (e.g., psychiatric comorbidities, sleep issues, heart defects). Psychiatric comorbidities such as depression, for example, may increase during adolescence in DS (see Dykens, Shah, Sagun, Beck, & King, 2002; Dykens et al., 2015) and could contribute to declines on performance measures. In the present study, no participants were reported by their parent to have a depression diagnosis or to be taking medication for depression. The four participants whose parents reported a diagnosis of and/or medication for anxiety and/or bipolar disorder, however, scored within the range of scores of the larger group at Time 1 and Time 2 and in terms of difference between Time 1 and Time 2. There was nothing in their data that would suggest that their psychiatric conditions influenced the results in the present study. Still, these were parent-reported diagnoses and we had no information on sleep issues or heart defects.

Conclusion

The results of the present study indicate that, in DS, receptive and expressive grammar remain stable over 2 years during much of adolescence. However, receptive vocabulary improves over 2 years in adolescence, and expressive vocabulary improves in early adolescence, but holds steady in late adolescence. Relative strength in receptive vocabulary plus continued growth during adolescence suggest that this skill could be capitalized on in interventions for reading and other academic subjects. Further, if expressive vocabulary is increasing in early adolescence as our data suggest, this may be an especially productive time for speech-language therapists to work on this language domain. It is unclear from the present study whether expressive vocabulary actually begins to decline toward the end of adolescence and into early adulthood, but this is an important avenue for future research.

Phonological memory, a relative weakness in the cognitive-linguistic profile of DS, is also changing during adolescence. Memory for digits seems to increase in early adolescence and then level off. In contrast, nonword repetition seems to decline throughout adolescence. An analysis of the processes that are similar and different across these two tasks may lead to recommendations for targeted intervention in aspects of phonological memory that could enhance language, reading, and following oral directions. Such an analysis may also be helpful in identifying very specific cognitive processes that begin to decline as early as the adolescent period in DS. These could be candidate markers for early cognitive aging in DS; thus, more research is warranted.

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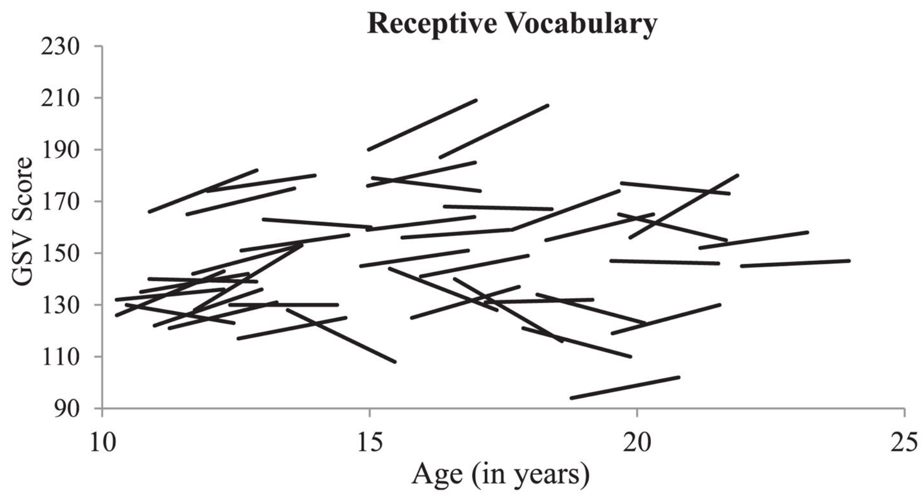

Figure 1.

Change over two years in receptive vocabulary scores. Individual Time 1 vs Time 2 scores plotted by participant's age. Groupwise, receptive vocabulary scores improved significantly over the two years. Age did not correlate with change scores. GSV = Growth Scale Value.

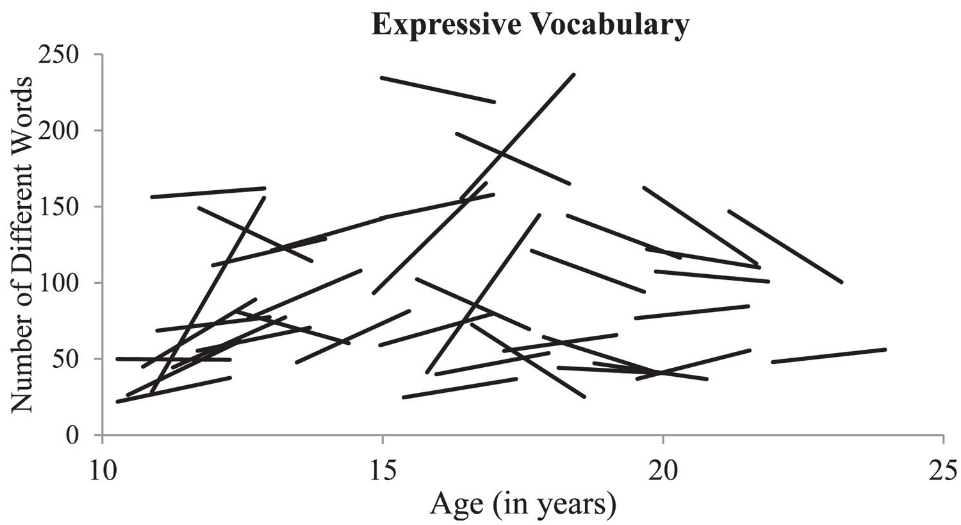

Figure 2.
Change over two years in expressive vocabulary scores. Individual Time 1 vs Time 2 scores plotted by participant's age. Age correlated negatively with change. Also, when the sample was split at the midpoint of the age range, younger participants' scores increased from Time 1 to Time 2 whereas older participants' scores did not change.

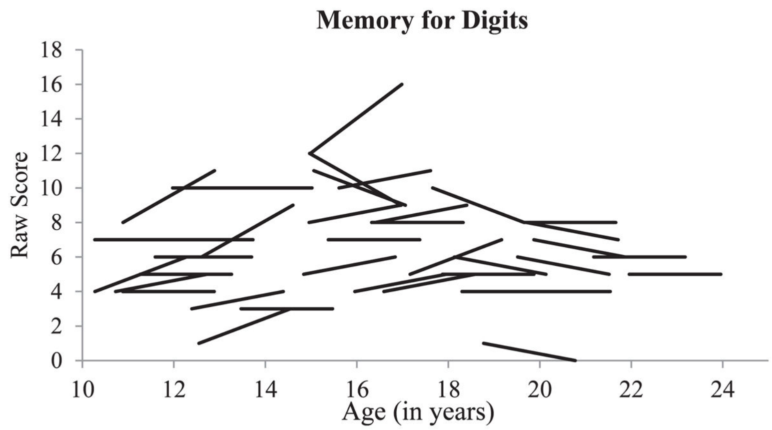

Figure 3.

Change over two years in memory for digits scores. Individual Time 1 vs Time 2 scores plotted by participant's age. Age correlated negatively with change. Also, when the sample was split at the midpoint of the age range, younger participants' scores increased from Time 1 to Time 2 whereas older participants' scores did not change.

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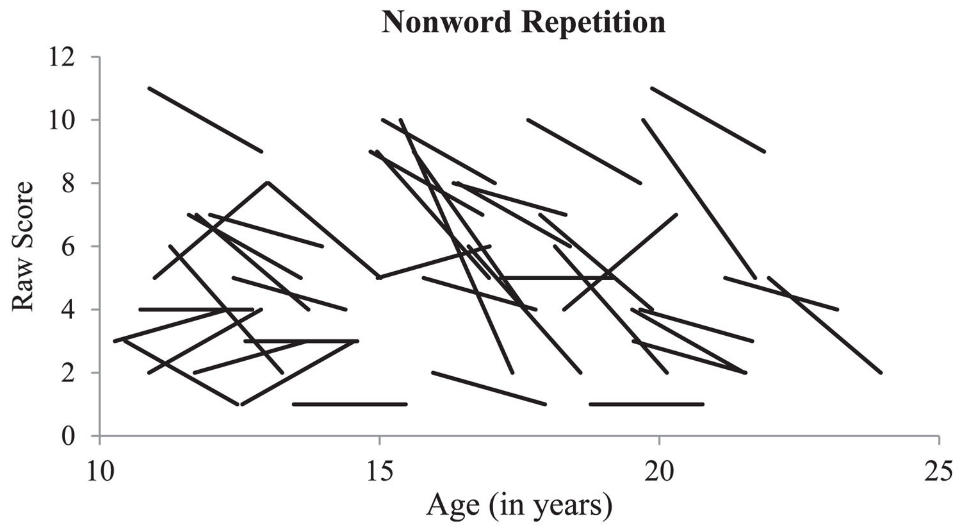

Figure 4.
Change over two years in nonword repetition scores. Individual Time 1 vs Time 2 scores plotted by participant's age. Groupwise, nonword repetition scores declined significantly. Age did not correlate with change scores.

Table 1

Language and Phonological Memory Measures at Time 1 Versus Time 2

		Time 1		Time 2				
	N	**Mean**	***SD***	**Mean**	***SD***	***p***	***r***	**Partial *r*[a]**
Receptive Vocabulary (PPVT-4 GSV score)	42	146.07	21.43	150.33	25.10	.017	.898	.813
Receptive Grammar (TROG-2 raw score)	42	29.26	13.77	29.98	15.12	.470	.908	.852
Expressive Grammar (CELF-P2 Word Structure raw score)	40	10.95	6.92	11.05	7.46	.804	.941	.916
Expressive Grammar (MLU from Narrative Language task)	39	5.22	2.62	5.28	2.19	.788	.823	.788
Expressive Vocabulary	40[b]	86.25	56.85	96.18	57.23	.151	.718	.669
(# Different Words; Narrative Lang task)	39[c]	87.68	52.65	96.94	50.75	.147	.716	.584
Phonological Memory (CTOPP Memory for Digits raw score)	41	6.49	2.77	6.66	2.78	.517	.818	.770
Phonological Memory (CTOPP Nonword Repetition raw score)	41	5.71	2.93	4.29	2.27	.0003	.647	.564

Note. All correlations are significant at $p < .005$ or lower. PPVT-4 =Peabody Picture Vocabulary Test, Fourth Edition; GSV = Growth Scale Value; TROG-2 = Test for Reception of Grammar, Second Edition; CELF-P2 = Clinical Evaluation of Language Fundamentals, Preschool Second Edition; MLU =Mean Length of Utterance; CTOPP =Comprehensive Test of Phonological Processing.

[a] After correcting for Time 1 Leiter GSV.

[b] Before correcting for talkativeness.

[c] After correcting for talkativeness.