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Verbal Memory Functioning in Adolescents and Young Adults with Costello Syndrome: Evidence for Relative Preservation in Recognition Memory

David D. Schwartz¹, Jennifer M. Katzenstein², Elisabeth Hopkins³, Deborah L. Stabley⁴, Katia Sol-Church⁴, Karen W. Gripp³, and Marni E. Axelrad¹

¹Section of Psychology, Department of Pediatrics, Baylor College of Medicine/Texas Children's Hospital, Houston, Texas

²Section of Neuropsychology, Department of Neurology, Indiana University School of Medicine, Indianapolis, Indiana

³Division of Medical Genetics, A. I. duPont Hospital for Children, Wilmington, Delaware

⁴Department of Biomedical Research, A. I. duPont Hospital for Children, Wilmington, Delaware

Abstract

Costello syndrome (CS) is a rare genetic disorder caused by germline mutations in the *HRAS* proto-oncogene which belongs to the family of syndromes called rasopathies. *HRAS* plays a key role in synaptic long-term potentiation (LTP) and memory formation. Prior research has found impaired recall memory in CS despite enhancement in LTP that would predict memory preservation. Based on findings in other rasopathies, we hypothesized that the memory deficit in CS would be specific to recall, and that recognition memory would show relative preservation. Memory was tested using word-list learning and story memory tasks with both recall and recognition trials, a design that allowed us to examine these processes separately. Participants were 11 adolescents and young adults with molecularly confirmed CS, all of whom fell in the mild to moderate range of intellectual disability. Results indicated a clear dissociation between verbal recall, which was impaired ($M = 69 \pm 14$), and recognition memory, which was relatively intact ($M = 86 \pm 14$). Story recognition was highly correlated with listening comprehension ($r = .986$), which also fell in the low-average range ($M = 80 \pm 12.9$). Performance on other measures of linguistic ability and academic skills was impaired. The findings suggest relatively preserved recognition memory that also provides some support for verbal comprehension. This is the first report of relatively normal performance in a cognitive domain in CS. Further research is needed to better understand the mechanisms by which altered RAS-MAPK signaling affects neuronal plasticity and memory processes in the brain.

Keywords

Costello syndrome; memory; verbal cognition; academic skills; neuropsychology

INTRODUCTION

Costello syndrome (CS) is a rare genetic disorder that results from germline *HRAS* mutations causing a gain-of-function of the abnormal protein product, which in turn results

* Correspondence to: Psychology Service, Texas Children's Hospital, 6701 Fannin Street, Ste 1630, Houston, TX 77030 Phone: 832 822 1672. Fax: 832 825 4164. ddschwar@bcm.edu.

in dysregulation of the RAS-mitogen activated protein kinase (RAS-MAPK) pathway. CS belongs to the family of neuro-cardio-facial-cutaneous syndromes that includes neurofibromatosis-type 1 (Nf1), Noonan syndrome, Noonan syndrome with multiple lentigines (previously referred to as LEOPARD syndrome), and cardio-facio-cutaneous syndrome (CFCS), among others. All of these conditions are caused by germline mutations affecting RAS pathway proteins, and are collectively referred to as rasopathies [for review see Tartaglia and Gelb, 2010].

There has been increasing interest in learning and memory in the rasopathies following the recognition of the RAS-MAPK pathway's key role in synaptic long-term potentiation (LTP) and memory formation [Mazzucchelli and Brambilla, 2000]. Altered memory functioning has consistently been found to be associated with different rasopathies. Costa et al. [2002] reported deficits in LTP and spatial learning in a mouse-knockout model of Nf1. Alfieiri et al. [2011] examined long-term memory in individuals with Noonan syndrome or Noonan syndrome with multiple lentigines, and found a specific impairment in verbal (word-list) recall but relatively normal recognition memory. They interpreted this finding to suggest that RAS-MAPK pathway dysregulation has a specific effect on the hippocampus, a region that (along with the fornix and mammillary bodies) is strongly involved in recall but has a very limited role in recognition [Eichenbaum et al., 2007; Tsivilis et al., 2008]. However, their findings could also be interpreted as reflecting preservation in visual-spatial memory rather than in recognition per se, as their recognition task was visual-spatial in nature. Their results do not allow these two possibilities to be disentangled.

Turning to CS, our group has previously found relatively better nonverbal (visual-spatial) memory compared to nonverbal intellectual functioning, although most individuals still performed in the borderline to mild range of disability on nonverbal memory measures [see Axelrad et al., 2011 for review]. Dileone et al. [2010] investigated verbal memory in five individuals with CS in the context of a study investigating activity-dependent synaptic plasticity. Using a paired-associate stimulation protocol, they found evidence of enhancement in LTP or an LTP-like process in their subjects. Animal studies have shown a strong positive correlation between LTP and learning and memory [Malenka and Bear, 2004], so a similar correlation might have been expected in humans with CS. However, Dileone et al. [2010] found the reverse: their subjects exhibited impaired verbal memory, even with memory scores computed based on participants' mental age. Of note, they used a task requiring word-list recall. In light of the findings of Alfieiri et al. [2011] of a specific recall impairment in Noonan syndrome, it is possible that dysregulation of the RAS-MAPK pathway may likewise have a specific effect on recall in CS, leaving recognition processes more or less intact. The recall task used by Dileone et al. [2010] would not have been sensitive to detecting a potential relative preservation in recognition memory.

In the present study, we sought to examine verbal memory functioning in adolescents and young adults with CS, given prior findings that the development of verbal abilities in CS might accelerate in adolescence/early adulthood [Axelrad et al., 2009]. We hypothesized that CS individuals would show impaired recall but relatively preserved recognition memory, consistent with findings in other rasopathies, and with the enhanced LTP-like activity found by Dileone et al. [2010]. Second, we hypothesized that verbal memory functioning would be associated with language development, academics, and related areas of adaptive behavior (communication and social skills), such that individuals showing preserved memory would also show relative preservation in these areas. This prediction follows from the strong role verbal learning and memory processes are known to play in the development of language and academic skills [Gathercole and Baddeley, 1993; Gathercole et al., 2004].

MATERIALS AND METHODS

Participants

Individuals with CS were asked to participate in this study at the 7th International Costello Syndrome Conference in Chicago, Illinois in July, 2011. Only families speaking English as their primary language were enrolled. Informed consent was obtained from participants and/or their legal guardians/caregivers based on protocols approved by the institutional review boards at Texas Children's Hospital (H-17456) and the A. I. duPont Hospital for Children (#2003-006, #2005-051). When consent was obtained from caregivers, assent was obtained from the youth.

The participants were 11 adolescents and young adults (9 females) with CS confirmed by identification of an *HRAS* mutation [Gripp et al., 2006]. Mean age was 19.7 ± 5.7 yrs (range = 15 – 34 yrs). These participants represent 11 of the 12 individuals 15 years or older in our overall sample; the twelfth was excluded because he did not understand (and thus could not complete) the memory tasks. All nine females had the most common mutation resulting in a predicted amino acid substitution of the glycine residue in position 12 (p.G12S), whereas the two boys had a mutation affecting the glycine residue in position 13, either p.G13C or p.G13D. Nonverbal intellectual functioning was comparable to prior reports, with all 11 participants falling in the mild to moderate range of intellectual impairment based on prior assessment (Leiter-R Brief IQ, $M = 52.7 \pm 12.4$, range = 36 - 67).

MEASURES

Memory Tests

To test for dissociation between verbal recall and recognition memory, we chose memory tasks with both recall and recognition components within the same task. Within-subject and within-task designs have been recommended as a way to distinguish between recall and recognition processes [Cabeza et al., 2002]. Specifically, we used the Verbal Learning and Story Memory subtests from the Wide Range Assessment of Learning and Memory, Second Edition (WRAML-2; Sheslow and Adams, [2003]), a standardized, widely-used battery of tests of memory function in children and adults. Both subtests incorporate three distinct tasks: immediate recall, delayed recall, and delayed recognition.

Verbal Learning

(VL) is a list-learning task that requires the participant to listen to a string of 16 unrelated words, and to repeat back as many words as he or she can recall. This cycle of learning and recall occurs for four consecutive trials, which are totaled (VL Recall). A fifth (delayed) recall trial occurs after approximately 10 minutes of interpolated tasks (VL Delay). This is followed after another 10 minutes by a recognition task, in which the participant responds “yes” or “no” to a list of words, some of which were on the original (learned) word list, and some of which are new (VL Recognition). The *Story Memory* (SM) subtest requires the participant to listen to two stories and, after each, to recall as many story details as possible (SM Recall). A delayed recall trial is administered after approximately 15 minutes, when the participant is again asked to recall each story (SM Delay). Following delayed recall, the recognition trial is administered, in which the participant must answer a series of orally-presented multiple-choice questions about each story (SM Recognition). Each subtask results in a scaled score with $M = 10$ and $SD = 3$. The scaled scores for the VL and SM immediate recall trials are then combined to derive the *Verbal Memory Index* (VMI), while the VL and SM recognition trials are used to derive the *Verbal Recognition Index* (VRI). Both index scores are standard scores with $M = 100$ and $SD = 15$. The VMI and VRI have strong internal consistency (Cronbach's $\alpha = .92$ and $.85$ respectively) and test-retest

reliability ($r = .82$ and $.63$, respectively), and moderately high external and convergent validity in terms of correlation ($.53$ to $.66$) with the comparable indices of the Wechsler Memory Scales-III [Psychological Corporation, 1997; Sheslow and Adams, 2003].

Language Tests

Language skills were assessed with the *Recalling Sentences* and *Formulated Sentences* subtests of the Comprehensive Evaluation of Language Fundamentals, Fourth Edition (CELF-4)[Semel et al., 2003], the *Comprehension of Instructions* subtest from the NEPSY-II [Korkman et al., 2007], and the *Pragmatic Judgment* subtest from the Comprehensive Assessment of Spoken Language (CASL)[Carrow-Woolfolk, 1999].

Recalling Sentences has the participant listen to and repeat back sentences of increasing length and syntactic complexity. The task measures expressive language, specifically with regards to linguistic knowledge and phonological working memory. *Formulated Sentences* has the participant orally compose sentences about a picture using a supplied word, and provides a second measure of expressive language skill. Both subtests have good internal consistency in individuals with intellectual disability (Cronbach's $\alpha = .95$ and $.94$, respectively), test-retest reliability ($r = .86$ and $.86$), and validity based on factor analysis. *Comprehension of Instructions* is a measure of receptive language that has the participant listen and respond to increasingly complex spoken directions for pointing to different stimuli. It has demonstrated reliability (Cronbach's $\alpha = .64$; test-retest stability coefficient = $.75$) and validity based on factor analysis. On the *Pragmatic Judgment* subtest, the participant listens to a series of social vignettes and either judges their appropriateness or answers questions about them. It measures the knowledge, understanding, and use of language in a social context. The measure has good internal reliability ($.77 - .82$) and test-retest reliability ($.65$), and correlates highly with other language measures.

Academic Tests

We used the Wechsler Individual Achievement Test - Third Edition (WIAT-III)[Wechsler, 2009] battery to assess academic skills development. The WIAT-III provides a comprehensive assessment of academic skills, with well-documented reliability and validity [Wechsler, 2009]. The following subtests were administered: *Listening Comprehension* (listening to and answering questions about brief spoken passages), *Word Reading* (reading aloud a list of increasingly difficult word), *Pseudoword Decoding* (reading aloud a list of nonwords), *Numerical Operations* (solving a series of increasingly difficult written math problems), and *Spelling* (correctly writing words spoken by the examiner). In addition, we attempted to administer the *Reading Comprehension* and *Math Problem Solving* subtests to all subjects, but only one participant was able to understand and complete these tasks.

Adaptive Behavior

The Vineland-II Adaptive Behavior Scales Survey Interview Form (VABS-II)[Sparrow et al., 2005] is a semi-structured interview completed with the patient's caregiver/guardian. It was used to assess participants' daily adaptive skills in the domains of *Communication* (receptive, expressive, and written language skills), *Daily Living Skills* (personal, domestic, and community skills), and *Socialization* (interpersonal relations, play, and coping skills). The VABS-II has good internal reliability (Cronbach's $\alpha = .84 - .86$ across domains in the age range tested) and test-retest reliability ($.74 - .93$), and has demonstrated validity based on factor analysis and correlation with other measures of adaptive functioning.

PROCEDURE

All participants were administered the study measures at the biannual Costello Syndrome Family Network Conference. Each subject was tested individually by one of the authors, a licensed psychologist (JMK). Participants were told that they did not have to complete the measures if they did not wish to. All measures were attempted with each participant, but some tasks had to be discontinued secondary to the individual's inability to understand task instructions or complete the task. Caregivers were administered the VABS-II interview individually in a private location by a second author, also a licensed psychologist (MEA). Scoring was verified by a trained technician before entry into the SPSS database. All scores were derived using normative data based on participants' chronological age. Means are reported ± 1 SD. Two subjects had missing data. One stopped participating before completing the verbal learning test; the other was unable to complete any verbal measure due to a severe speech impairment. These subjects were therefore not included in the analyses. All analyses were conducted using the IBM SPSS Statistics 20 software package with alpha levels set at .05.

RESULTS

Verbal Memory

On the WRAML-2 indices, individuals with CS showed significantly better recognition (VRI $M = 86 \pm 14$) than recall (VMI $M = 69 \pm 14$), $t(8) = 5.391$, $p = .001$. As can be seen in Table I, neither index score was driven by outliers. On the VRI (recognition), the majority of participants fell in the low-average to average range, with more than half showing average performance relative to same age peers. In contrast, on the VMI (recall), 7/9 participants fell in the impaired to borderline range. Memory performance was significantly higher than nonverbal IQ, both for recall, $t(7) = 2.792$, $p = .027$ and recognition, $t(7) = 5.974$, $p = .001$, while neither recall nor recognition was significantly associated with nonverbal IQ ($p = .49$ and $.42$, respectively).

A discrepancy between recall and recognition was also evident within each memory subtest (see Table I), indicating that the effect was not task-specific. On the VL subtest, recognition was significantly higher than immediate recall, $t(8) = 4.5$, $p = .002$, and delayed recall, $t(8) = 3.953$, $p = .004$. Likewise, SM recognition was significantly higher than immediate recall, $t(9) = 5.250$, $p < .001$, and delayed recall, $t(9) = 5.225$, $p = .001$. There was no difference between the immediate and delayed recall trials on either subtest. There was also no difference between the comparable tasks (Immediate Recall, Delayed Recall, or Recognition) across subtests (VL and SM). The VMI is based on immediate recall, so it is possible that the VMI/VRI difference was due to a difference between immediate and delayed memory rather than between recall and recognition. To rule out this possibility, we created a delayed recall composite by averaging the delayed recall trials of the VL and SM tasks (the WRAML-2 does not have a delayed recall index). A similar composite index was created with the recognition trials. Consistent with our hypothesis, the delayed recognition composite ($M = 7.7 \pm 2.5$) was significantly higher than the delayed recall composite ($M = 4.5 \pm 2.9$), $t(8) = 5.543$, $p = .001$.

Language Functioning

Mean performance on the measures of receptive language, expressive language, and language pragmatics fell in the impaired range (Table II). One subject performed in the low-average range on the two CELF-4 expressive language subtests; this individual, who has a p.G13C mutation, has consistently performed above the CS mean in multiple domains, as

reported previously [Axelrad et al., 2009; 2011]. All other participants fell in the impaired range on all four language measures.

Academic Skills

Group performance in Listening Comprehension fell in the low-average range overall ($M = 80 \pm 12.9$). One participant performed in the average range ($SS = 102$), three performed in the borderline to low-average range ($SS = 77-81$), and one was impaired ($SS = 59$). There was an almost perfect correlation between listening comprehension and recall (see Figure 1), indicating that these skills are highly related. Listening comprehension was also significantly correlated with story recognition ($r = .897$, $p < .05$) but not with verbal learning recognition ($r = .0482$, $p = .939$) or with nonverbal IQ ($r = .340$, $p = .575$). However, the participants who were able to complete the listening comprehension test ($n = 5$) did have higher nonverbal IQ than the four who were not, a difference that approached significance ($M = 59.6$ versus 44), $t(7) = 2.357$, $p = .051$.

With the exception of listening comprehension, academic skills fell in the impaired range for the majority of subjects (see Table III), commensurate with their intellectual functioning. Once again, the participant with p.G13C was a significant outlier. We compared his academic performance to the CS group mean using a modified independent samples t-test developed by Sokal and Rohlf (1995; discussed in Crawford and Howell, 1998) for comparing an individual's score to a small sample. He showed significantly better listening comprehension ($M = 102$ vs. 74), $t(3) = 2.41$, $p < .05$, Word Reading (88 vs. 55), $t(9) = 2.43$, $p < .02$, pseudoword decoding (93 vs. 50), $t(9) = 4.00$, $p = .002$, and Spelling (84 vs. 53), $t(6) = 2.16$, $p < .04$, and marginally better numerical operations (i.e., math calculation skills, 74 vs. 51), $t(9) = 1.79$, $p = .053$ (all one-tailed) than the CS group. However, even when this participant was taken out of the analyses, the group continued to show a relative strength in listening comprehension ($M = 74$) compared to word reading ($M = 56$), pseudoword decoding ($M = 51$), spelling ($M = 59$), and numerical operations ($M = 58$). The participant with p.G13D, in contrast, did not differ from the group mean on any subtest.

Adaptive Functioning

Consistent with prior findings [Axelrad et al., 2007; 2009; 2010], adaptive function was in the impaired range overall (Adaptive Behavior Composite $M = 65 \pm 7$), with a mild relative strength in social skills (Socialization Composite, $M = 71 \pm 8$). Looking at subscales, the group showed a relative strength in receptive language and coping skills, both of which fell in the low average range ($z = \times 1$). All other subscales fell in the impaired to borderline range ($z = \times 2$ to $\times 3$).

Adaptive functioning was highly correlated with memory, although recall and recognition showed different patterns of association. Recall (as indexed by the VMI) was significantly associated with the Communication Domain ($r = .840$, $p = .003$) and the Socialization Domain ($r = .841$, $p = .005$), whereas recognition (as indexed by the VRI) was associated with Daily Living Skills ($r = .896$, $p = .003$), although this seemed primarily to reflect Story Memory Recognition.

DISCUSSION

Individuals with CS showed relative preservation in verbal recognition memory, which was generally in the low-average to average range compared to normative data from same-age peers. This is the first report of largely normal function in a cognitive domain in individuals with CS. In contrast, recall performance with the same test stimuli was generally impaired. This dissociation between recall and recognition is consistent with the memory pattern

reported in individuals with Noonan syndrome and Noonan syndrome with multiple lentigines [Alfieiri et al., 2011], and thus provides evidence for a more general preservation of recognition memory in the rasopathies.

Recognition memory is widely viewed as being comprised of two separate components: *familiarity*, or a sense that the stimulus has been encountered before, and *recollection*, which involves remembering the context in which the stimulus event occurred [Eichenbaum et al., 2007; Squire et al., 2007]. Recall is thought to be contingent on recollection processes, whereas recollection and familiarity both contribute to recognition. Moreover, it is commonly held that recognition memory performance can in many circumstances be maintained by familiarity alone. Thus, when recognition is preserved while recall is impaired, the underlying deficit is presumed to be in recollection, with familiarity largely intact.

We therefore interpret our findings as most likely indicating relatively preserved familiarity-based recognition in CS, coupled with impaired recall/recollection. This account is consistent with Alfieri et al.'s [2011] hypothesis that hippocampal dysfunction is a primary outcome of HRAS dysregulation, given converging data from neuroimaging, lesion, and animal studies suggesting that recall processes depend primarily on the hippocampus [Eichenbaum et al., 2007]. However, other explanations for our subjects' recall deficit are also plausible. For example, it is possible that the cerebellar overgrowth and resultant posterior fossa crowding in CS [Gripp et al., 2010] disrupts cerebello-frontal and cortico-cerebellar tracts involved in recall [de Ribaupierre et al., 2008]. The present data do not allow us to distinguish between these possibilities.

In contrast to recall/recollection, familiarity appears to depend on the integrity of perirhinal cortex (PRC) [Brown and Aggleton, 2001], which lies adjacent to the hippocampus. For example, Bowles et al. [2007] reported data from a patient who underwent resection of a large portion of PRC with sparing of the hippocampus, and who showed impairment in familiarity across multiple tasks, with intact recollection [see also Peters et al., 2009]. Our findings of relatively preserved familiarity-based recognition therefore suggest that PRC may be relatively unaffected in CS. Another (not mutually exclusive) possibility is that enhancement in LTP processes, as reported by Dileone et al. [2010], may result in enhanced familiarity, perhaps by strengthening item representations in PRC (Eichenbaum et al., [2007]). Further research on the precise mechanisms underlying preservation in recognition memory in CS and other rasopathies could help elucidate the relation between RAS-MAPK signaling, neuronal differentiation, and plasticity in different brain areas.

Familiarity effects can be conceptualized as resulting from activation within the semantic memory network [Anderson, 1983; Collins and Loftus, 1975; Nelson et al., 1998; Steyvers and Tenenbaum, 2005], at least part of which is thought to be instantiated in PRC [Davies, Graham, Xuereb, Williams, and Hodges, 2004]. Preservation in familiarity-based recognition memory in CS would therefore predict more general preservation in semantic memory (i.e., stored knowledge about objects, words, and concepts). Consistent with this, we previously found evidence of a relative strength in semantic knowledge in CS [Axelrad et al., 2007], as indexed by performance on a test of single-word receptive vocabulary knowledge [PPVT-4; Dunn and Dunn, 2007]. However, in prior studies [Axelrad et al., 2007] we have also found impaired performance on other tasks that rely on semantic memory, including expressive (naming) vocabulary [EOWPVT-3; Brownell, 2000], and answering questions about everyday social situations (WISC-IV Comprehension) [Vargha-Khadem et al., 1997]). The present findings of a recall-recognition dissociation in CS help resolve this apparent contradiction. The PPVT-IV – which involves pointing to pictures named by the examiner – can essentially be considered a recognition task, whereas naming

pictures or answering questions about the world place substantial demands on recall processes.

Contrary to predictions, the CS preservation in memory was not associated with language and academic skills, with the notable exception of the strong relationship identified between story recognition and listening comprehension. Familiarity-based recognition by itself likely provides little support for language and academic development, which appear to be much more strongly associated with other aspects of memory, in particular working memory [Bors and MacLeod, 1996; Gathercole and Baddeley, 1993; Gathercole et al., 2004]; and recent research has shown that working memory is related to recollection but has little to no relationship to familiarity-based recognition [Öztekin and McElree, 2010]. While we did not directly assess working memory in our participants, we strongly suspect that their performance on working memory tasks would be impaired.

Our subjects' relative strength in story memory was unexpected. The story recognition items were embedded in sentences that needed to be understood in the context of the presented story, and could not be answered based on whether the item was heard earlier, as (in most cases) all three choices had been taken from the story. Thus, some degree of comprehension was necessary. We therefore believe the evidence points to narrative comprehension as a second area of relative preservation in CS. Other research has demonstrated that individuals with mild intellectual impairment show normal sensitivity to the effects of story structure, which is essential to the comprehension of narrative, and that this ability is largely independent of other language skills [Kim et al., 2008; Wolman et al., 1997]. Narrative memory may be particularly robust in the face of neurodevelopmental disorders, given its likely adaptive utility as a social commodity [Barsalou, 1999].

Further evidence that our subjects' story recognition performance reflected a strength in narrative comprehension as well as in recognition comes from its strong relation with the listening comprehension task ($R^2 = .97$). However, it should be noted that our subjects have not performed uniformly well on different types of comprehension task administered over the course of this ongoing longitudinal study. They have done best when answering multiple-choice questions about recently presented information (WRAML-2 Story Memory); they did less well when answering more open-ended questions about recently presented information (WIAT-III Listening Comprehension); and they did poorly when answering open-ended questions in the absence of any recently presented information (WISC-IV Comprehension) [Axelrad et al., 2011]. Thus, they did best when the presented information (and the questions used to probe for it) was recent, explicit, and more highly structured, factors that minimize demands placed on recall and facilitate use of recognition-based processes. This suggests that our subjects' strength in recognition memory provided support for their comprehension, at least under conditions of high informational constraint.

LIMITATIONS

Interpretation of the results of this study must be tempered by recognition of a number of limitations. First, sample size was small, and not all tasks could be completed by all subjects. This means that the data are somewhat skewed in favor of the more capable subjects, particularly on the listening comprehension subtest. Second, the sample was also skewed by gender toward females, although it should be noted that the proportion of females to males was similar to the overall sample (which was 75% female). In addition, both males had a p.G13 amino acid change, while all the females had a p.G12 change, further limiting generalizability of the results, as there are recognizable differences in the associated phenotypes [Gripp et al., 2011]. It should be noted that there were four other males at the CS conference in the appropriate age-range for this study, but we did not attempt to enroll them

given their apparent level of impairment. All of these males had a p.G12 change. This raises the intriguing possibility that level of cognitive impairment related to changes on p.G12 may be moderated by gender, consistent with the hypothesis that males are ontogenetically more fragile than females [Kraemer, 2000]. However, without actual data on these individuals' levels of functioning, this supposition must remain speculative for the present. All biases noted above are unavoidable consequences of the small overall sample size, which itself reflects the extreme rarity of CS, which has an estimated prevalence of about 1 in 300,000 [Gripp & Lin, 2012] to 1 in 1,290,000 [Abe et al., 2012].

CLINICAL IMPLICATIONS & CONCLUSION

When working with individuals with mild to moderate degrees of cognitive impairment, it is especially important to identify and build upon strengths. The overall cognitive phenotype in CS is characterized by deficits across most domains of function [Axelrad et al., 2011]; it is therefore of utmost importance clinically when strengths can be identified. In the present study, we found relatively preserved verbal recognition memory in a majority of adolescents and young adults with CS. Recognition is a highly robust, sensitive, and reliable mechanism for deriving and retaining important information about the world [Pachur et al., 2011]. It can be used as a simple but very effective heuristic for making inferences [Goldstein and Gigerenzer, 2002], and may in fact often be the first basis for decision-making, given the speed and automaticity with which information about item familiarity becomes available [Pachur et al., 2011]. It is therefore a strongly adaptive ability. In this study, recognition likely also provided support for our subjects' comprehension of brief story passages.

Narrative comprehension was a second strength identified in our subjects. Humans seem to be especially primed to process narrative information, perhaps because of its adaptive importance for social understanding and interaction. Stories also provide a ready-made organizational structure that can support learning and memory even when other cognitive abilities are less well developed. Intriguingly, story recognition was strongly associated with daily living skills, further suggesting that narrative may provide a useful scaffold for helping individuals with CS organize tasks and fostering adaptive behavior. Narrative approaches may therefore provide an especially fruitful strategy for working with and teaching individuals with CS [Clark and Rossiter, 2008].

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Figure 1. Comparison of Verbal Recall to Listening Comprehension. Axis labels represent standard scores with $M = 100$ and $SD = 15$. $R^2 = 0.972$.

Table I

Verbal Memory Performance by Subject

Subj #	<u>Memory Indices</u>			<u>Verbal Learning</u>			<u>Story Memory</u>		
	BIQ	VMI	VRI	Immed	Delay	Recog	Immed	Delay	Recog
01	67	94	99	7	9	7	11	11	13
02	48	85	93	7	7	9	8	8	9
03	42	77	99	6	4	9	6	7	11
04	67	72	96	6	6	8	4	4	11
05	68	67	93	5	4	7	3	5	11
06	*	57	88	1	3	7	3	4	9
07	*	*	*	*	*	*	2	1	7
08	40	57	68	2	1	4	2	1	5
09	54	55	74	1	2	7	1	1	4
10	36	*	*	*	*	*	1	1	*
11	52	55	62	1	2	5	1	2	2
<i>M</i>	52.7	68.8	85.8	4.0	4.2	7.0	3.8	4.1	8.2
<i>SD</i>	12.4	14.3	14.1	2.7	2.6	1.7	3.3	3.4	3.6

Note. BIQ = Leiter-R Brief IQ; VMI = WRAML-2 Verbal Memory Index; VRI = WRAML-2 Verbal Recognition Index. The BIQ, VMI, and VRI are standard scores with $M = 100$ and $SD = 15$. Subtests scores are all scaled scores with $M = 10$ and $SD = 3$. Scores marked with an asterisk were not able to be completed by the individual subject.

Table II

Group Performance on Language Measures

Measure	<i>n</i>	<i>M</i>	<i>SD</i>	Range
CELF-4 Formulated Sentences	8	1.8	1.8	1-6
CELF-4 Recalling Sentences	11	2.3	2.5	1-8
NEPSY-2 Comprehension of Instructions	9	1.8	1.3	1-4
CASL Pragmatic Judgment	4	52.0	14.4	40-69

Note. The CELF-4 and NEPSY-2 subtests scores are scaled scores with $M = 10$ and $SD = 3$.

The Pragmatic Judgment score is a standard score with $M = 100$ and $SD = 10$.

Table III

Group Performance on Academic Measures

Measure	<i>n</i>	<i>M</i>	<i>SD</i>	Range
Listening Comprehension	5	80	15	59-102
Word Reading	11	57	16	40-88
Pseudoword Decoding	11	53	16	40-93
Spelling	8	57	16	40-84
Numerical Operations	11	40	13	40-74

Note. All scores are standard scores with $M = 100$ and $SD = 15$.