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Agenesis of the Corpus Callosum: Developmental Trajectories Through Childhood

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Abstract

Agenesis of the corpus callosum (AgCC) is a congenital brain malformation that affects the area of the brain responsible for interhemispheric transfer of information (Paul, 2011). Individuals with AgCC tend to have specific deficits resulting from reduced interhemispheric transfer for sensory-motor information, cognitive processing speed, and deficits in complex reasoning and novel problem-solving (Brown & Paul, 2019; Mangum, 2018; Miller et al., 2018). There are indications that those with AgCC also struggle with communication skills during early stages of life (Badderudin et al., 2007) and social interactions during adolescence (Paul et al., 2007). The purpose of this study is to discover deficits or delays that may occur in communication, socialization, and daily living skills from early childhood through mid-adolescence. The Vineland-3 Comprehensive Interview Form was utilized with parents of 63 children and adolescents who have a formal diagnosis of AgCC between the ages of 28-195 months. Results of the cross-sectional study showed generalized delays in the development of Communication, Daily Living Skills, and Socialization skills when compared to Vineland 3 norm groups. Although gender alone was not found to effect skills, several interactions between gender and age groups were noted. Children and adolescents with AgCC are more likely to display developmental delays and early intervention is crucial in order to develop compensatory strategies and/or techniques.

Keywords: Agenesis of the corpus callosum, corpus callosum, callosal agenesis development communication, socialization, daily living skills.

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Chapter 1

Dysgenesis of the Corpus Callosum Overview

As human beings, we engage in activities on a daily basis that require communication between the left and right hemispheres of the brain. These activities include simple to complex behaviors and interactions, such as tying one's shoes, understanding the give-and-take of social communication, and "reading" and understanding non-verbal cues. The largest interhemispheric neural pathway in the human brain is the corpus callosum, which is comprised of approximately 190 million axons that connect the left and right hemispheres (Paul, 2011). The corpus callosum is unique to placental mammals and is critical for interhemispheric transfer of sensory, motor, and cognitive information (Paul et al., 2007). Some callosal connections are inhibitory (i.e., allowing functional independence for each hemisphere), but most callosal connections are excitatory and allow integration of information across the hemispheres (Paul, 2011). Dysgenesis of the corpus callosum (DCC) is an umbrella term for developmental malformations of the corpus callosum, including complete absence (agenesis), partial absence (partial agenesis), and hypoplasia (thinning) of the corpus callosum (Schell-Apacik et al., 2008). DCC are anatomic diagnoses that can only be identified in-vivo by visualizing the brain through neuroimaging (ultrasound, CT, or MRI; Vergani et al., 1994). Complete and partial agenesis (AgCC) occur when callosal neurons fail to cross the interhemispheric fissure during the first or second trimester of pregnancy (Paul et al., 2007). In contrast, the developmental mechanisms involved in hypoplasia are varied resulting in greater heterogeneity of this population. To optimize generalization of outcomes for a specific population, the present study restricted participation to children with complete or partial AgCC. Thus, the term agenesis of the corpus callosum was

utilized (AgCC or ACC; the former will be used in this paper). A majority of individuals diagnosed with AgCC have extra-callosal commissures (e.g., the anterior commissure) present (Paul et al., 2007). Even though these extra-callosal pathways are considerably smaller than the corpus callosum they can serve as alternate pathways for transmission of information from one cerebral hemisphere to the other. However, there is substantial evidence that excitatory interhemispheric transfer of information is limited in individuals with AgCC (Paul et al., 2007).

In the typically developing corpus callosum, all callosal fibers are present at birth, and at about 4 months, as myelination begins to occur, functional connectivity via the corpus callosum begins to increase and continues into young adulthood (Paul, 2011). Research conducted with individuals who have undergone a callosotomy (surgical severing of the callosum and other commissures as a treatment for intractable epilepsy) in adolescents and adults results in "disconnection syndrome" characterized by the absence of callosal transfer of sensory information and deficits in bimanual motor coordination (Lassonde et al., 1991). General behavior in adults who underwent callosotomy appeared rather "normal" following the surgery, but upon closer observation, subtle social and emotional processing deficits began to appear, likely as a result of the severing of long-range callosal connections (Paul, 2011). Conversely, individuals with childhood callosotomy and individuals with AgCC exhibit much less impairment of interhemispheric transfer and only mild evidence of disconnection syndrome which provides evidence that neuroplasticity in children may allow alternative neural pathways for specific interhemispheric transfer of information tasks (Paul et al., 2007).

Individuals with AgCC as an isolated condition are often physically healthy and have normal intelligence, but with noteworthy cognitive effects (ACC Network, 2020). Many others

have brain abnormalities or physical or medical conditions that can also affect the health and development of individuals, to varying degrees (ACC Network, 2020).

The causes of partial and complete AgCC are varied and include toxins, infections, vascular problems, and genetic malformations (Paul et al., 2007). Genetic causes of AgCC in humans are variable, and often reflect the complexity of how the corpus callosum develops (Shevell, 2002). A variety of genetic mechanisms including single-gene inherited mutations, single-gene sporadic mutations, as well as complex genetics which include both sporadic and inherited mutations (Shevell, 2002) may play a role in the etiology of AgCC. Cross-sectional cohort studies and retrospective chart reviews have indicated that 30%-45% of AgCC cases have an identifiable cause, 10% have chromosomal anomalies, and the remaining 20%-35% have recognizable genetic syndromes (Paul et al., 2007; Edwards et al., 2014). However, when only considering those with complete AgCC, the percentage of individuals with recognizable syndromes falls to 10%-15% and 75% of cases do not have an identifiable cause (Paul et al., 2007; Edwards et al., 2014).

In addition to the aforementioned factors that contribute to AgCC, it is important to note that environmental factors may contribute to AgCC. A clear example of environmental influences on corpus callosum development include prenatal exposure to alcohol. Clinical and experimental evidence indicates that prenatal alcohol exposure decreases gliogenesis and glial-neuronal interactions which are vital processes for healthy corpus callosum development (Rubert et al., 2006). The incidence of AgCC in Fetal Alcohol syndrome is approximately 6.8% and with a higher incidence of corpus callosum malformations that fall short of a full diagnosis of AgCC (Paul et al., 2007; Lieb & Ahlhelm, 2018). In many Fetal Alcohol Spectrum Disorder cases, hypoplasia of the corpus callosum occurs, and may result from not only the disruption of early

events in the formation of the corpus callosum, but also from later dysregulation of axonal pruning (Paul et al., 2007). Several other environmental factors have been shown to affect development of a corpus callosum including hypothyroidism, musical training, and enrichment or deprivation of experience (Berbel et al., 1994; Alvarez-Dolado et al., 2000; Schlaug et al., 1995; Satoh et al., 2006; Münte et al., 2002).

Long-Term Outcomes in AgCC

Individuals with AgCC tend to have specific developmental deficits including reduced interhemispheric transfer of sensory-motor information, reduced cognitive processing speed, and deficits in complex reasoning and novel problem-solving (Brown & Paul, 2019). Numerous studies have shown that individuals with AgCC are capable of interhemispheric integration of easily encoded visual and tactile information (e.g., Brown et al., 1999; Chiarello, 1980; Jeeves & Ettlinger, 1965; Lassonde et al., 1991; Saul & Sperry, 1968). Conversely, reduced interhemispheric transfer in AgCC was demonstrated in studies that required more complex, and therefore less familiar, information (e.g., Brown et al., 1999; Bryden & Zurif, 1970; Buchanan et al., 1980; Geffen et al., 1985; Jeeves, 1979).

Reduced processing speed and difficulties with complex processing have been demonstrated in individuals with AgCC. Difficulties with processing speed ability has the tendency to affect multiple other cognitive processes and has been demonstrated in cognitive testing (Brown & Paul, 2019). In a sample of 32 adults with complete AgCC, researchers found that WAIS-III processing speed index scores were, on average, significantly lower than perceptual, verbal, and working memory indices (Erickson et al., 2013). Further, deficits in more complex processing including impaired reasoning, concept formation, and novel problem solving has been shown in individuals with AgCC (Brown & Paul, 2019). Deficits in these three

fundamental cognitive processes are likely to have an impact on a wider range of cognitive and psychological functioning (Brown & Paul, 2019). Adults with AgCC were shown to have difficulties encoding verbal and visual memory information as well as spontaneous retrieval of newly learned information (Erickson et al., 2014; Paul et al., 2016), sufficiently understanding non-literal and more involved and complex language (Brown, Paul, et al., 2005; Brown, Symington, et al., 2005; Paul et al., 2003; Rehmel et al., 2016), displaying and applying cognitive inhibition and flexibility (Marco et al., 2012), devising strategies (Brown et al., 2012), and effectually employing imagination and creativity (Paul et al., 2004; Young et al., 2019).

Due to the difficulties with interhemispheric transfer of information and related cognitive changes, social and emotional functioning are also impaired in individuals with AgCC (Paul et al., 2007). Social functioning (i.e., adequately understanding and responding appropriately in social interactions) is a higher-order process that involves multiple cognitive processes and requires a higher level of interhemispheric transfer of information. Deficits in basic semantic language processing, comprehension of second order and non-literal meanings in language, narrative generation, social generation, social behavior, and theory of mind are common developmental challenges for those with AgCC (Paul et al., 2007). Symington et al., (2010) found that individuals with AgCC exhibited significant deficits in social understanding and comprehension that are most evident when stimuli involve real-time processing of social scenarios, multi-sensory perception, and cognitive integration. Adults with AgCC also exhibit difficulties with reasoning abstract emotions in social contexts (Anderson et al., 2017; Paul et al., 2006), interpreting sarcasm as well as understanding the subtleties and nuances of social interactions (Symington et al., 2010) and ability to imagine and infer the mental, emotional, and social functioning of others (Kang et al., 2009; Turk et al., 2009). They also have limited

awareness of their own functional deficits (Kaplan et al., 2012; Mangum, 2018; Miller et al., 2018). Though these deficits may appear to be secondary to reduced interhemispheric transfer of information, decreased processing speed and diminished complex problem-solving abilities may result in significant functional impairments in the adaptive skills needed for everyday life (Mangum, 2018; Miller et al., 2018) as well as deficits in social communication (Paul et al., 2014).

There is also significant evidence that individuals with AgCC have difficulty in recognizing their own emotional state, regulating emotions, verbally expressing emotion, and verbally identifying emotions expressed by others (e.g., Anderson, et al., 2017; Bridgman et al., 2014; Paul et al., 2006; Paul et al. 2021; Turk et al., 2009; Brown & Paul, 2000; O'Brien, 1994; Symington et al., 2010). Individuals with AgCC were also found to have impairments in recognizing emotions in faces and had decreasing accuracy in judging fear and anger (Bridgman et al., 2014). They found the impairments were directly related to atypical patterns of facial scanning wherein the participant has diminished attention to the eye region (Bridgman et al., 2014). Other studies have shown that people with AgCC used fewer emotion words than matched controls in narrations based on pictures from the Thematic Apperception Test (TAT) (Turk et al., 2009). The individuals with AgCC typically used fewer words related to negative emotions notwithstanding that the TAT is designed to elicit such emotions (Turk et al., 2009). They also report difficulty putting feelings into works (Paul et al., 2021). However, Anderson, et al., (2017) found that adults with AgCC fell within the average range for experiencing and perceiving basic emotions but were unlikely to achieve typical levels of complexity when considering strategies necessary for managing emotions (Anderson et al., 2017).

Development in AgCC

While there is now a fairly robust characterization of long-term behavioral challenges due to AgCC, far less is known about developmental trajectories during childhood. Research found that children with AgCC under the age of 5 years do not always display obvious developmental deficits or impairments, and that social, emotional, and cognitive behavior problems are also not evident prior to the age of 6 years (Andrews, 2012). Children with AgCC were found to have moderate speech problems between the ages of 1 ½ to 5 years on the Persistent Development Problems Scale (Andrews, 2012; Badaruddin et al, 2007).

Badaruddin et al., (2007) found that 61.5% of individuals with AgCC exhibited "emotional non-communicativeness," and 16% presented symptoms of "social indifference." Among the individuals with some expressive language, 86% displayed echolalia and 100% showed language characterized as "meaningless/out of place" (Badaruddin et al., 2007, p. 288). Individuals with AgCC were described as having a "behavioral phenotype of emotional non-communicativeness and a linguistic anomaly in association with lethargy, but in the absence of autism" (O'Brien, 1994, p. 245). It has become increasingly apparent that those with AgCC that present with relatively asymptomatic profiles still display specific cognitive deficits and/or have learning disabilities. Parents reported that their children with AgCC have a tendency to talk in clichés, to have poor social judgment, to have difficulty understanding facial expressions, and they often tend to miss the point of stories and jokes (Badaruddin et al., 2007). Parent reports have indicated that children with AgCC have trouble initiating and maintaining conversation (Mendez-Vigo & Andrews, 2011). Other reported deficits include phonetic discrimination, dichotic listening, and delays in reading skills (Mendez-Vigo & Andrews, 2011).

A small number of studies have shown that children with AgCC who are developing in a seemingly normal manner may exhibit behavioral, social, and cognitive difficulties (Badaruddin et al., 2007; Lau et al., 2013). In one study, parents of children ages 2 to 11 with AgCC reported deficits in social interaction and social communication relative to published norms; children with AgCC showed similar symptom profiles as children who have been diagnosed with autism (Badaruddin et al., 2007). Lau et al., (2013) noted increased rates of autism spectrum disorder (ASD) within the AgCC population. Estimated rates of autism spectrum behavior in adults with a diagnosis of AgCC ranged from 18% to approximately 30% (Lau et al., 2013; Paul et al., 2014). They found children who carry a diagnosis of AgCC and exhibit autism-like behavior exceed the autism-screening cutoff on the child version of the Autism Quotient (Lau et al., 2013; Badaruddin et al., 2007). Badaruddin et al., (2007) found that children between the ages of 6-11 years were rated by family members as showing a substantial rate of problems in social, emotional, and behavioral functioning at both borderline and clinically significant levels. Analysis of an age and IQ matched group of individuals with ASD also found impairment in these areas, but the group with AgCC had significantly less impairment than those diagnosed with ASD without AgCC (Badaruddin et al., 2007).

Due to the small number of studies on children with AgCC, researchers often rely on case studies and anecdotal reports for information about what to expect for “typical” development in AgCC. They found that these children displayed obvious deficits in both receptive and expressive language when compared with a control group (Mendez-Vigo & Andrews, 2011). One case study that followed an individual through their first 23 years of life found that mild delays in expressive language were noted in the first three years of life (Stickles et al., 2002). Expressive language deficits persisted through preschool wherein the child would often repeat

what peers said (echolalia) rather than engage with them, would describe objects rather than label them, and frequently did not respond to vocal inquiries or commands (Stickels et al, 2002). A second case study involving an infant with AgCC found that developmental milestones were reached at a slower pace, as well as delayed emerging expressive language skills by the age of 24 months (Mendez-Vigo & Andrews, 2011). Anecdotal reports found that children piece together sentences with pictures, books, sign language, and verbalization in order to communicate with parents. It is due to this limited research with developmental trajectories in children and adolescents who have callosal agenesis that requires further exploration of the topic. Research examining developmental trajectories in callosal agenesis through adolescence based on gender, age, or an interaction of the two is warranted.

Hypotheses

The current study aims to evaluate development from ages 2 to 16 in children with complete and partial AgCC, through cross-sectional design using scores on the Vineland Adaptive Behavior Scales - Comprehensive Interview Form compared to published norms. I hypothesize that gender and age will uniquely impact scores on the Vineland summary scales (Daily Living Skills, Communication and Socialization) as follows:

Hypothesis 1: Communication

A: For my sample of participants with AgCC, age- and sex-corrected standardized Vineland Communication domain scores will be significantly below the normal distribution.

B: Age will be positively correlated with age- and sex-corrected standardized Vineland Communication domain scores, such that they will be significantly below the normal distribution for younger groups (i.e., 28-45 & 46-55 months), with less impairment in older groups.

C. Boys will be more delayed than girls in communication skills (Mendez-Vigo & Andrews, 2011).

Hypothesis 2: Daily Living Skills

A: For the entire sample of participants with AgCC, age- and sex-corrected standardized Vineland Daily Living Skills domain scores will be significantly below the normal distribution.

B: Age will be negatively correlated with age- and sex-corrected standardized Vineland DLS domain scores, such that they will be significantly below the normal distribution for younger groups (i.e., 28-45 & 46-55 months), but will be significantly lower in older groups (i.e., 130-195 months).

C: Boys and girls will both score similarly to norms for daily living skills.

D: There will be significant interactions between age groups and gender; older girls will have the greatest discrepancy in Daily Living Skills scores.

Hypothesis 3: Socialization

A: For the entire sample of participants with AgCC, age- and sex-corrected standardized Vineland Socialization domain scores will be significantly below the normal distribution.

B: Age will be negatively correlated with age- and sex-corrected standardized Vineland Socialization domain scores, such that younger children's scores (28-45 & 46-55 months) will be similar to the normative average, with impairment emerging as age increases.

C: Girls will more likely score closer to within normal limits in Socialization compared to boys.

Chapter 2

Methods

Participants

Participants included parents of children with dysgenesis of the corpus callosum who were between the ages of 2 years and 16 years at the time of participation. The sample included 32 boys and 31 girls. These individuals are enrolled in a large longitudinal study based at the California Institute of Technology, which includes data collection for the study proposed herein. The children must have received a formal diagnosis of corpus callosal dysgenesis by MRI, CT, or ultrasound prior to being recruited for the study. Parents must complete forms online or in a telephone interview and must be English speaking. This study is international. Participants for the current study were placed into 6 age groupings: 28-45 months, 46-55 months, 56-67 months, 70-85 months, 89-117 months, and 130-195 months, chosen in an attempt to accurately reflect current developmental milestones and developmental time periods (see Table 1).

Table 1

Number of Participants by Gender and Age Range

Age Range	Girls	Boys	Total
(months)		*n*	
28-45	6	2	8
46-55	2	7	9
56-67	5	6	11
70-85	8	8	16
89-117	4	4	8
130-195	6	5	11
Total	31	32	63

Materials

The Vineland Adaptive Behavior Scales Third Edition (Vineland-3) is a standardized assessment tool that utilizes a semi-structured interview to measure adaptive functioning and aids in the diagnosis of intellectual and developmental disabilities, autism, and developmental delays (Hill et al., 2017). Age ranges are from birth to 90 years old and include an interview and parent/caregiver form. The norming sample from the Vineland-3 was stratified according to the United States census on sex, race/ethnicity, individual or parental education level, and geographic region. Further, data were collected on seven clinical samples that coincide with the Individuals with Disabilities Education Act (IDEA) disability categories (Hill et al., 2017) including developmental delay, emotional disturbance, autism, intellectual disability, specific learning disability, speech or language impairment, and all other IDEA disability categories (Hill et al., 2017).

The Vineland-3 is an interview designed to assess three core adaptive behavior domains: daily living skills, communication (including written as well as expressive and receptive language), and socialization (Hill et al., 2017). It has strong psychometric properties. Interrater and inter-interviewer reliability coefficients ranged from 0.70 to 0.81 for the Comprehensive Interview Form (Hill et al., 2017). Internal consistency reliability ranged from 0.90 to 0.98 for the Comprehensive Interview Form (Hill et al., 2017). The validity of the Vineland-3 has been examined based on its content, structure, and relationships with other measures of adaptive behavior, including the Vineland-II and the Adaptive Behavior Assessment System, Third Edition (ABAS-3), as well as measures of developmental functioning, including the Bayley Scales of Infant Development, Third Edition (Hill et al., 2017).

Domains assessed in the Vineland-3 Adaptive Behavior Scales include Daily Living Skills, Communication, Socialization, and Motor Skills. Daily Living Skills measures a child's performance of everyday tasks of living that are considered appropriate for their age. Daily Living Skills include Personal (ability to be self-sufficient in dressing, eating, washing, hygiene, and health care), Domestic (ability to perform household tasks such as cooking, and chores), and Community (ability to function outside of the home including safety, money, travel, and rights and responsibilities). The Communication domain assesses how well a child exchanges information with others, and how well they appropriately respond to incoming information from others. Communication includes Receptive Language (ability to attend to, understand, and respond appropriately to information from others), Expressive Language (ability to verbally use words and sentences), and Written Language (writing and reading skills). The Socialization domain measures a child's understanding and functioning in social situations. Socialization includes Interpersonal Relationships (relating and responding to others), Play and Leisure

(engaging with others in play and fun activities), and Coping Skills (emotional and behavioral control in different settings involving others). The Vineland-3 also assesses motor skills; however, those were not evaluated for this study due to the age cutoff for the motor domain, which in turn created too small of a sample size.

Procedure

Participants are individuals enrolled in an ongoing longitudinal study conducted at California Institute of Technology (Caltech). Upon initial enrollment, consent to participate was provided using a consent form approved by the Caltech Institutional Review Board. Enrollees received email invitations with a personal survey link at age-specific time-points (ages 6, 12, 18, 24, and 36 months, then one time per year from age 48 months up to age 18 years). With approval from the George Fox University Human Subjects Research Committee and as an investigator on the Caltech protocol for this study, I conducted the Vineland-3 interviews via telephone with participants whose children met inclusion criteria described above and recorded responses in the Caltech Qualtrics account. Following data collection, Caltech provided an encrypted file containing de-identified raw data from the Vineland-3, as well as background demographic data. The Vineland-3 was scored through Q-local software from Pearson, providing age- and gender-corrected standard scores for analysis.

Analyses

Independent variables include age (grouped as follows; 28-45 months, 46-55 months, 56-67 months, 70-85 months, 89-117 months, and 130-195 months) and sex at birth (boys and girls). Dependent variables include summary scores from the VABS-3: daily living skills, communication/language development and socialization/emotional functioning.

Using 1000 bootstrapped samples drawn from the entire sample and from each age range, age- and sex-corrected standardized scores on the Vineland domains (M = 100, SD = 15) were compared with a normal distribution. Significant findings were followed by post-hoc comparison of bootstrapped subdomain scores (M = 15, SD = 3) to a normal distribution, as well as post-hoc comparisons to normal distribution for bootstrapped samples of age- and sex-at-birth-stratified domain scores. Modified Bonferroni correction was applied to these analyses.

Frequency of participants with clinically significant impairment (i.e., 1.5+ standard deviations below the mean) was tested using Fisher's Exact Test. In a sample of 63 participants, 12 or more individuals with a standard score of less than or equal to 77 (or scaled score of 10.5) would constitute a statistically significant proportion for the three domain measures using Bonferroni correction (X^2 = 6.13, p = .0133). For post-hoc analysis of frequency of clinically significant subdomain scores, 10 out of 63 participants constitutes a statistically significant proportion (X^2 = 4.20, p = .0404).

Chapter 3

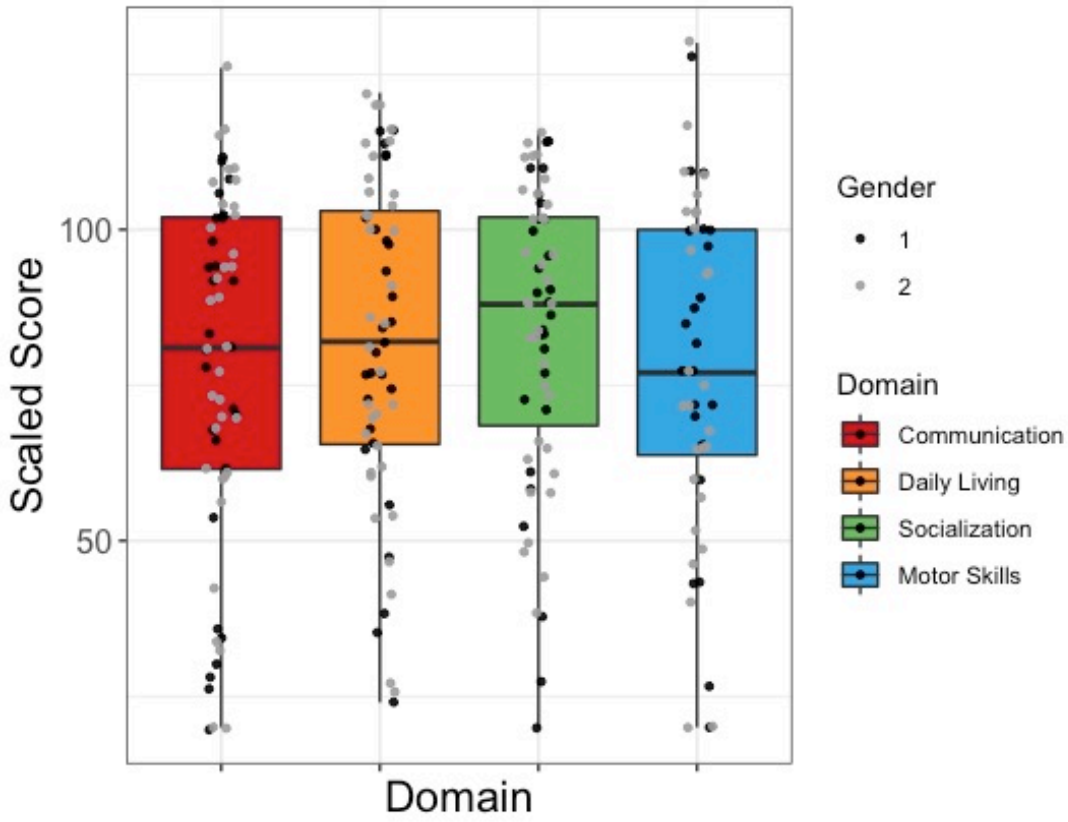
Results

Comparison of Entire Sample to Vineland Norms

Analysis of 1000 bootstrapped samples drawn from the entire sample revealed significant impairment for all three domains for standard scores compared to the normal distribution (with Bonferroni correction) and significantly greater than expected number of participants scoring 1.5 standard deviations below the mean (see Figure 1 and Table 2).

Figure 1

Vineland-3 Domain Scores with Gender Data Overlays



Note. 1 = Girl; 2 = Boy. Quartiles are shown with boxes demonstrating the 2nd and 3rd quartiles divided by the sample mean.

Table 2

Descriptive and t*-test Statistics for Vineland Scores from All Participants and Bootstrapped Comparison to a Normal Distribution*

Domain	Mean (*SD*)	Range	*t*-value	*p*	*d*	95% CI	% < = *1.5SD (n)*
Communication*	77.75 (28.25)	20-126	-6.254	< 0.001	28.3	-29.37, -15.14	*44% (28)
Receptive+	11.08 (4.89)	1-21	-6.155	< 0.001	4.9	-5.19, -2.64	+38% (24)

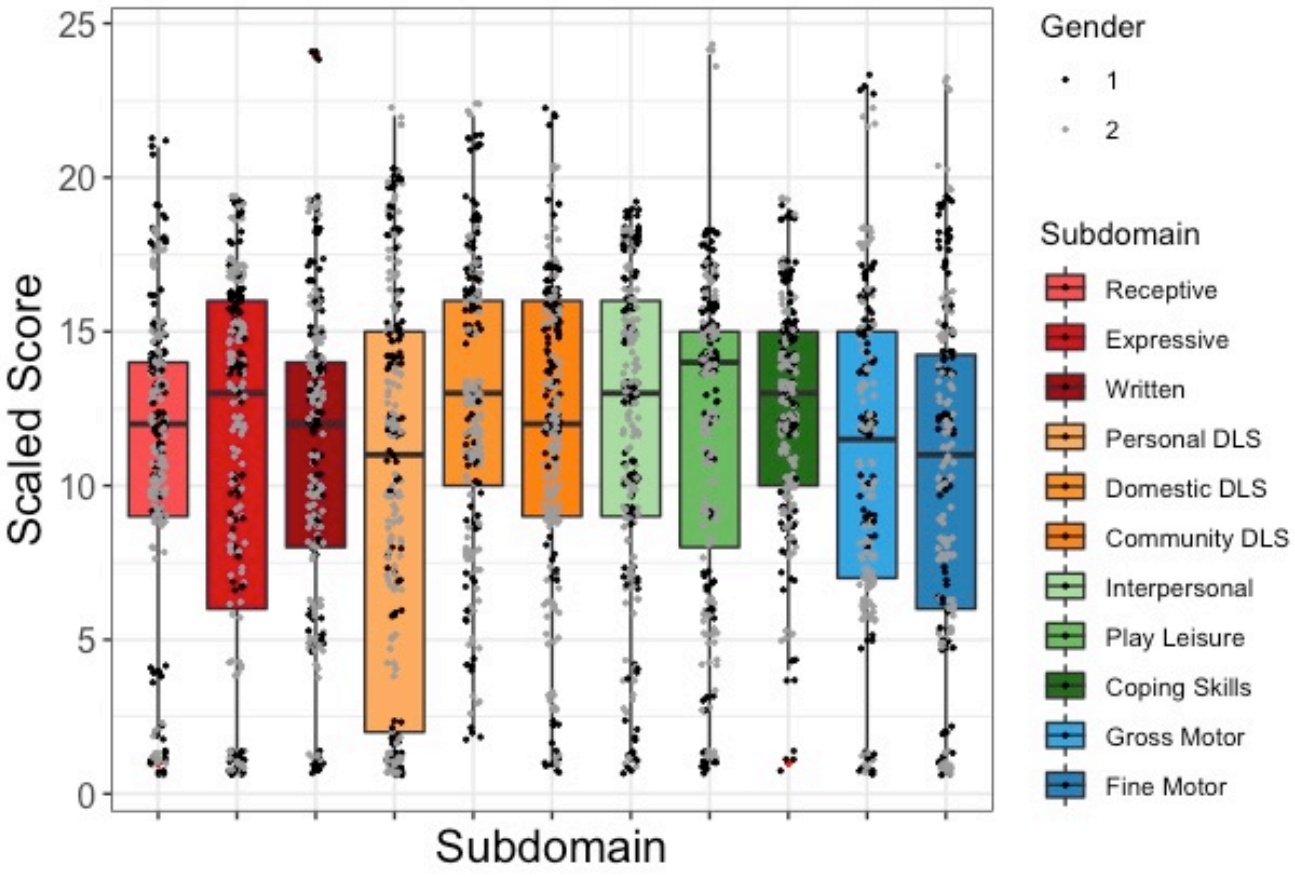
Domain	Mean (*SD*)	Range	*t*-value	*p*	*d*	95% CI	% < = *1.5SD (n)*
Expressive+	10.81 (5.99)	1-19	-5.371	< 0.001	6.0	-5.75, -2.63	+41% (26)
Written+	11.24 (5.05)	1-24	-5.724	< 0.001	5.1	-5.08, -2.45	+40% (25)
Daily Living*	82.10 (26.14)	24-122	-5.436	< 0.001	26.1	-24.49, -11.32	*44% (28)
Personal+	9.93 (6.48)	1-22	-6.012	<0.001	6.5	-6.76, -3.38	49% (31)
Domestic+	12.71 (4.58)	2-22	-3.838	<0.001	4.6	-3.48, -1.09	25% (16)
Community+	11.69 (4.88)	1-22	-5.204	<0.001	4.9	-4.58, -2.03	32% (20)
Socialization*	83.79 (23.56)	20-116	-5.459	< 0.001	26.6	-22.14, -10.27	*33% (21)
Interpersonal+	11.95 (4.81)	1-19	-4.870	<0.001	4.8	-4.30, -1.80	35% (22)
Play & Leisure+	11.56 (5.29)	1-24	-4.994	<0.001	5.3	-4.82, -2.06	33% (21)
Coping Skills+	12.56 (3.63)	1-19	-5.164	<0.001	3.6	-3.39, -1.49	27% (17)

* Significant at Bonferroni adjusted alpha of $p < .017$; + $p < .05$.

Post-hoc analyses found that all subdomain scores were also significantly below the normal distribution (see Figure 2 and Table 2).

Figure 2

Subdomain Means Compared to Vineland Norms



Note. 1 = Girl, 2 = Boy. Boxes represent the 2nd and 3rd quartiles divided by the Medium. All subdomain scores are significantly lower than the norm.

Descriptives were calculated for each of the Vineland-3 domains and subdomains for each of the age groups (see Table 3).

Table 3

Descriptive and t*-test Statistics for Vineland Scores from Age-Restricted Bootstrapped Samples Compared to a Normal Distribution*

Domain	Mean (*SD*)	Range	*t*-value	*p*	*d*	95% CI
Communication						
28-45 months (n = w)	91.88 (30.39)	32-116	-.76	.474	30.39	-.97, .448

Domain	Mean (*SD*)	Range	*t*-value	*p*	*d*	95% CI
46-55 months (n = w)	94.78 (12.74)	71-111	-1.23	.254	12.74	-1.081, 284
56-67 months (n = w)*	79.00 (30.07)	28-108	-3.05	.012	27.21	-1.62, -191
70-85 months (n = w)*	71.00 (34.26)	20-126	-3.75	.002	30.50	-1.52, -334
89-117 months (n = w)*	71.25 (33.07)	20-106	-2.46	.044	33.17	-1.67 -.024
130-195 months (n = w)*	70.18 (26.08)	20-108	-3.79	.004	26.08	-1.89, -357
Daily Living Skills						
28-45 months (n = w)	92.38 (30.41)	26-116	-.71	.500	30.41	-.95, .463
46-55 months (n = w)	94.67 (17.71)	77-122	-.90	.393	17.71	-.962, .377
56-67 months (n = w)*	77.36 (24.21)	41-114	-3.10	.011	24.21	-1.63, -203
70-85 months (n = w)*	80.31 (23.90)	54-120	-3.30	.005	23.90	-1.38, -243
89-117 months (n = w)	80.75 (34.00)	27-116	-1.60	.153	34.00	-1.30, .202
130-195 months (n = w)*	72.64 (27.04)	24-114	-3.36	.007	27.04	-1.73, -261
Socialization						
28-45 months (n = w)	94.25 (22.26)	58-116	-.73	.490	22.26	-.96, .456
46-55 months (n = w)	98.44 (12.77)	81-114	-.37	.724	12.77	-.774, .538
56-67 months (n = w)	86.80 (29.35)	38-112	-2.04	.070	23.56	-1.25, .047
70-85 months (n = w)*	80.62 (21.50)	48-112	-3.61	.003	21.50	-1.47 -.306
89-117 months (n = w)*	76.50 (25.31)	38-104	-2.63	.034	25.31	-1.75, -066
130-195 months (n = w)*	72.36 (27.96)	20-106	-3.28	.008	27.96	-1.70, -243

* $p < .05$.

Comparisons of Vineland-3 Scores by Sex at Birth and Age Groups Within the Sample

A *Multivariate Analysis of Variance (*MANOVA) was utilized to evaluate the first hypothesis of whether age and/or gender influences a parent's rating of their child's development across the domains of the Vineland-3. I began by looking at the grand scheme. I hypothesized that I would find a main effect for age at birth as well as interactions between age and sex on the domains of Communication, Daily Living Skills, and Socialization. In order to use age as a factor, age groups were developed based upon the frequency distribution of the sample and developmental stages (see Table 4).

Table 4

MANOVA of Vineland Domain Standard Scores by Age Groups and Gender

	df	*F*	*p*	η_p^2
Age Groups				
Communication	5	1.680	.156	.141
Daily Living Skills	5	1.473	.215	.126
Socialization	5	2.196	.069	.177
Gender				
Communication	1	.263	.610	.005
Daily Living Skills	1	.566	.455	.011
Socialization	1	1.240	.271	.024
Age x Gender				
Communication	5	.467	.799	.044
Daily Living Skills	5	1.539	.194	.131
Socialization	5	.792	.561	.072

Note. MANOVA = multivariate analysis of variance.

Vineland-3 domain scores by sex at birth were completed (see Table 5).

Table 5

Vineland 3 Domain Scores by Sex at Birth

Domain	Boys		Girls	
	Mean (*SD*)	Range	Mean (*SD*)	Range
Communication*	79.81 (25.68)	26-112	75.61 (30.95)	20-126
Receptive+	11.45 (4.373)	1-19	10.68 (5.45)	1-21
Expressive+	10.94 (5.955)	1-19	10.68 (6.13)	1-19
Written+	11.32 (4.636)	1-19	11.14 (5.56)	1-24
Daily Living*	85.00 (21.17)	35-116	79.10 (30.51)	24-122
Personal	10.1 (5.827)	1-20	9.75 (7.23)	1-22
Domestic	13.23 (3.972)	4-21	12.14 (5.18)	2-22
Community	12.26 (4.366)	2-22	11.07 (5.402)	1-19
Socialization*	87.41 (19.70)	38-114	80.06 (26.79)	20-116
Interpersonal	12.65 (4.054)	2-19	11.18 (5.505)	1-18
Play & Leisure	12.26 (4.449)	1-18	10.79 (6.082)	1-24
Coping Skills	12.68 (3.145)	5-19	12.43 (4.16)	1-19

* Significant at Bonferroni adjusted alpha of $p < .017$; + $p < .05$.

Communication Domain and Subdomain Analyses

My first hypothesis addressed the differences anticipated in the Vineland 3 scores due to gender and age progression. There was no main effect for gender in the Communication Domain, $F(1, 51) = .263$, $p = .610$ $\eta_p^2 = .005$). There was no main effect for age groups but the effect size was large; $F(5, 51) = 1.680$, $\eta_p^2 = .141$ (using the cutoffs of Sullivan & Feinn, 2012; see Figure 1 for means). Post hoc analysis indicated a trend toward a significant difference in the Communication Domain between children in the 70-85 months group from those in the 46-55 months age group (LSD $p = .055$). There was no significant interaction between age groups and gender for the Communication Domain, $F(5, 51) = .467$, $p = .799$, $\eta_p^2 = .044$.

The three subdomains for Communication were also evaluated: Receptive Language, Expressive Language, and Written Communication. There were no main effects for gender for any of the subdomains (see Table 6).

Table 6

Communication Subdomains

Subdomain	Statistical Sentence	Sample Means (SD)	
		Girls	Boys
Receptive Language	$F(1, 47) = .349$, $p = .558$ $\eta_p^2 = .007$	10.68 (5.45)	11.45 (4.373)
Expressive Language	$F(1,47) = .003$, $p = .957$, $\eta_p^2 = .000$	10.68 (6.129	10.94 (5.955)
Written Expression	$F(1,47) = .003$, $p = .957$, $\eta_p^2 = .000$	11.14 (5.556)	11.32 (4.636)

Note. No differences in scores between boys and girls.

There is no main effect for age groups for the Communication subdomains but there are large effect sizes for Receptive and Expressive language subdomains (see Table 7).

Table 7

Communication Subdomain Means by Age Groups

Subdomains	Statistical Sentence	Age Groups (months)	Means (*SD*)
Expressive Language	$F(5,47) = 1.757$, $p = .140$, $\eta_p^2 = .158$.	28-45	16.5 (2.082)
		46-55	14.44 (3.941)
		56-67	10.09 (6.204)
		70-85	9.13 (6.407)
		89-117	9.63 (5.854)
		130-195	9.82 (6.161)
Receptive Language	$F(5,47) = 2.039$, $p = .090$, $\eta_p^2 = .178$.	28-45	16.75 (3.403)
		46-55	13.89 (2.571)

Subdomains	Statistical Sentence	Age Groups (months)	Means (*SD*)
		56-67	10.55 (4.947)
		70-85	9.81 (5.023)
		89-117	10.13 (5.384)
		130-195	9.82 (4.665)
Written Language	$F(5, 47) = .887$, $p = .498$, $\eta_p^2 = .086$	28-45	13.75 (1.708)
		46-55	14 (2.693)
		56-67	11.09 (4.182)
		70-85	10.69 (6.074)
		89-117	10.13 (6.749)
		130-195	9.82 (4.834)

There is no significant interaction between gender and age groups for Receptive Language, Expressive Language, or Written Language (see Table 8).

Table 8

Communication Subdomains Gender and Age Group Interactions

Subdomain	Statistical Sentence	Age (months)	Mean (*SD*)	
			Girls	Boys
Receptive Language	$F(5, 47) = .497$, $p > .05$, $\eta_p^2 = .050$	28-45	16.33 (4.041)	18 (0)
		46-55	15.5 (2.121)	13.43 (2.637)
		56-67	10 (5.745)	11 (4.69)
		70-85	10.5 (5.071)	9.13 (5.222)
		89-117	8.75 (5.188)	11.5 (5.972)
		130-195	8.33 (5.989)	11.6 (1.517)
Expressive Language	$F(5, 47) = .416$, $p > .05$, $\eta_p^2 = .042$	28-45	15.67 (1.528)	19 (0)
		46-55	16.5 (.707)	13.86 (4.337)
		56-67	12 (6.205)	8.5 (6.285)

Subdomain	Statistical Sentence	Age (months)	Mean (*SD*)	
		70-85	8.38 (6.865)	9.88 (6.289)
		89-117	9.75 (6.185)	9.5 (6.455)
		130-195	8.83 (6.210)	11 (6.595)
Written Language	$F(5, 47) = .160, p > .05, \eta_p^2 = .017$	28-45	14 (2)	13 (0)
		46-55	16 (1.414)	13.43 (2.76)
		56-67	11.8 (4.438)	10.5 (4.278)
		70-85	10.38 (7.708)	11 (4.408)
		89-117	10.25 (6.449	10 (8.042)
		130-195	17 (4.446)	10.6 (5.683)

Daily Living Skills Domain and Subdomain Analyses

I hypothesized that there would be no significant difference between the sample and the Vineland 3 Manual normative sample means. There would be no main effect for gender. 1 also hypothesized was that there will be a main effect for age groups; younger children with AgCC would be similar to the normative average, with impairment emerging as age increases. Finally, I hypothesized there would be significant interactions between age groups and gender with older girls having the greatest discrepancy in Daily Living Skills scores.

No main effect for gender was found for Daily Living Skills Domain, $F(1, 51) = .566$, $p = .455$ $\eta_p^2 = 0.011$. No main effect for age groups was found for Daily Living Skills but there was a moderate effect size, $F(5, 51) = 1.473$, $p = 0.215$, $\eta_p^2 = 0.126$. There is no significant interaction between gender and age groups for Daily Living Skills, but there is a moderate effect size. $F(5, 51) = 1.539$, $p = .194$ $\eta_p^2 = .131$.

There is no main effect for gender in any of the three subdomains for Daily Living Skills (see Table 9).

Table 9

Daily Living Skills Subdomains Means

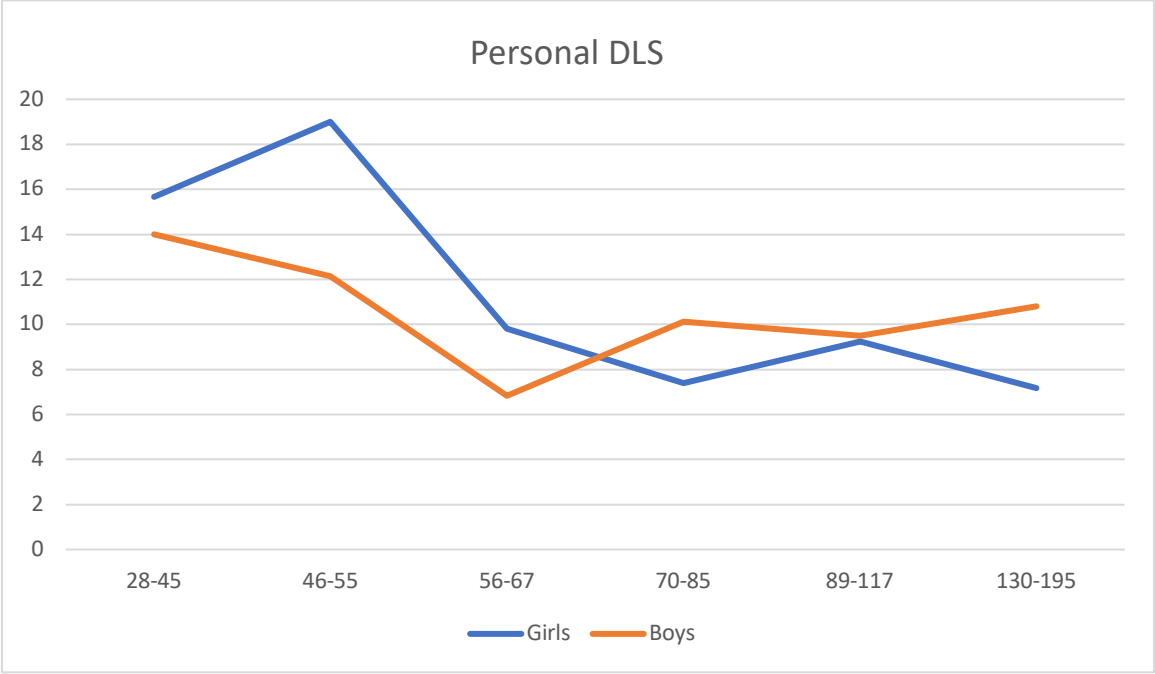
Subdomain	Statistical Sentence	Means (*SD*)	
Daily Living Skills		Girls	Boys
Personal	$F(1, 47) = .164$, $p = .687$, $\eta_p^2 = .003$	9.75 (7.23)	10.1 (5.827)
Domestic	$F(1,47) = .598$, $p = .443$, $\eta_p^2 = .013$	12.14 (5.183)	13.23 (3.972)
Community	$F(1, 47) = .412$, $p = .524$, $\eta_p^2 = .009$	11.07 (5.402)	12.26 (4.366)

Note. No differences.

Interactions between gender and age groups for Personal Daily Living Skills subtests were completed (see Figure 3).

Figure 3

Significant Interaction between gender and age groups for Personal Subtest



Note. Girls show a steeper decline in personal daily skills across the age groups than boys.

Socialization Domain and Subdomain Analyses

I hypothesized that younger children's scores (28-45 & 46-55 months) Vineland-3 will be more similar to the normative average, with impairment emerging as age increases. Also hypothesized was that girls will be more likely to score closer to within normal limits compared to boys.

There was no main effect for gender with Socialization domain, $F(5, 51) = 1.240$, $p > .271$, $\eta_p^2 = .024$. Although there is not a main effect for age groups with socialization, there is a large effect size. $F(5, 51) = 2.196$, $p > .069$, $\eta_p^2 = .177$. There is no significant interaction between gender and age groups for Socialization, but there is a moderate effect size. $F(5, 51) = .792$, $p > .05$, $\eta_p^2 = .072$.

There is no main effect for gender with any of the subdomains (Interpersonal Relationships, Play and Leisure, Coping Skills; see Table 9). There is a main effect for age with Play and Leisure and a large effect (see Table 10).

Table 10

Socialization Subdomain Analyses with Gender

Subdomain	Statistical Sentence	Means (*SD*)	
Socialization		Girls	Boys
Interpersonal Relationships	$F(1, 51) = 1.482$, $p = .229$ $\eta_p^2 = .028$	11.13 (5.505)	12.81 (4.054)
Play and Leisure	$F(1, 51) = .942$, $p = .336$, $\eta_p^2 = .018$	10.77 (6.082)	12.44 (4.449)
Coping Skills	$F(1, 51) = .464$, $p = .499$, $\eta_p^2 = .009$	12.32 (4.158)	12.78 (3.145)

Note. No differences.

There is no main effect for age groups with Interpersonal Relationships subdomain, but there is a moderate effect. For Coping Skills and age groups, there is not a main effect but there is a moderate effect size (see Table 11).

Table 11

Socialization Subdomains with Age Groups Means and Effect Sizes

Subdomain	Statistical Sentence	Age Group (months)	Means (*SD*)
Interpersonal	$F(5, 53) = 1.442, p = .226, \eta_p^2 = .124$	28-45	15.5 (2.082)
		46-55	14.33 (3.162)
		56-67	12.55 (5.087)
		70-85	11.06 (4.494)
		89-117	10.75 (5.751)
		130-195	10.27 (5.442)
Coping Skills	$F(5, 53) = 1.490, p = .185, \eta_p^2 = .127$	28-45	14 (3.109)
		46-55	14.11 (2.315)
		56-67	12.64 (3.501)
		70-85	12.56 (3.054)
		89-117	11.75 (2.659)
		130-195	10.73 (5.312)
Play & Leisure	$F(5, 53) = 2.69, p = .031, \eta_p^2 = .202$	28-45	15.75 (2.062)
		46-55	15.67 (3.536)
		56-67	11.91 (4.908)
		70-85	10.5 (5.292)
		89-117	9.63 (6.186)

Correlations with age and Vineland-3 domains were completed (see Table 12).

Table 12

Correlations with Age and Vineland Domains

	Age	Communication	Daily Living Skills	Socialization
Age	1	-.269*	-.246*	-.343**
Communication		1	.884**	.905**
Daily Living Skills			1	.865**
Socialization				1

Note. *$p < .05$, **$p < .01$, ***$p < .001$.

A Pearson Correlation was also run with age in months and all the subdomains in order to observe the movement of the variables (see Table 13).

Table 13

Correlations with Age in Months and Subdomains

	Age	RL	EL	WL	PDLS	DDLS	CDLS	IP	PL	CS
Age		-.266*	-.204	-.276*	-.209	-.238	-.213	-.259*	-.367**	-.313*
RL			.834**	.757**	.779**	.709**	.796**	.839**	.859**	.750**
EL				.746**	.817**	.754**	.779**	.849**	.840**	.760**
WL					.776**	.653**	.734**	.710**	.713**	.650**
PDLS						.717**	.756**	.766**	.761**	.663**
DDLS							.880**	.819**	.787**	.674**
CDLS								.821**	.835**	.736**
IP									.876**	.784**
PL										.734**
CS										

Note. *$p < .05$, **$p < .01$, ***$p < .001$; RL = Receptive Language; EL = Expressive Language; WL = Written Language; PDLS = Personal Daily Living Skills; DDLS = Domestic Daily Living Skills; CDLS = Community Daily Living Skills; IP = Interpersonal; PL = Play & Leisure; CS = Coping Skills.

Chapter 4

Discussion

The importance of understanding potential developmental trajectories for children and adolescents with AgCC is imperative in order to better inform parents, caretakers, and health providers. My results indicate that children and adolescents who have complete AgCC are lower than expected in development, across several domains as noted in the Vineland-3.

Communication

I hypothesized that Communication domain scores from the Vineland 3 would be impaired in younger children who have AgCC, however, would become more typical as age increases. This hypothesis was not supported. Looking at gender by itself did not make a difference in communication scores. Age groups were found to be different suggesting that as the child with AgCC ages and communication skills become more challenging, their ability does not mature at the same rate when compared to their age-equivalent peers. The two younger age groups were not significantly different from their age-equivalent peers. Beginning at 56 months, significant differences in communication skills emerge and continue into adolescence. As children mature, the communication skill gap between their age-equivalent peers grows for children who have AgCC. They are not able to develop the skills at the same pace as their age-equivalent groups. This difficulty in the ability to communicate can open up several additional challenges including skills in socialization.

Looking at the subdomains for communication, gender again does not make a difference, however, the effects of age negatively affect communication skills. Receptive and Expressive Language skills were shown to have the same pattern of decline across the age groups. As children age, they fall farther behind their age group comparisons. Difficulties in Written

Language skills were most apparent as complexity increases with the largest differences noted in the oldest age group (130-195 months).

For the Communication domain, gender and age groups show an interaction. The pattern of scores for Receptive Language shows that girls have more difficulty and fall behind their peers at different points in their development relative to boys. It appears that the youngest girls are seen by their parents as more delayed that are younger boys (age group 28-56 months). We see the skill delay again as children are in early elementary years, 56-67 months, and again in middle school years, 89-117 months. There is only one point during which boys were more impaired than girls (70-85 months). Receptive language skills are focused on the ability to understand what is being heard, the messages from others. It is possible that more understanding is expected from girls than boys and thus they are rated differently. When children are lacking in understanding of language, they will respond with withdrawing behavior or acting out. It is possible that there are different expectations about behaviors that stem from a lack of understanding of language.

For the Expressive Language subdomain, I found differences in ability between girls and boys at two age groups. The results indicated that boys are significantly more impaired than girls in the 46-55 months range and girls are significantly more impaired than boys in the 70-85 months range. Expressive language skills allow the children to communicate their ideas, needs, and wants with others. These results indicate that girls are struggling with expressing themselves during preschool years while boys show more challenges at the start of formal educations.

Communication, particularly the acquisition of language, is complex and the backbone of human social relationships. As we have evolved, our social connections have played an immense role in communication development, and in brain development overall (Dunbar, 2003).

Evolutionally, this led to a hierarchy in social groups and led to different roles that females and males assumed (Joseph, 2000). Often, females took on roles that were more likely to require the acquisition of communication skills including language such as food gathering, domestic tool construction, and child raising, whereas male primates were those that hunt and kill (Joseph, 2000). It may be possible, due to the social deficits that typically accompany AgCC and what have been demonstrated in this study (discussed in detail below), that girls are more susceptible to communication delays due to their accompanied AgCC social deficits. As previously discussed, outside of having AgCC and as seen in typical development, girls are often faster in picking up language skills and have better language acquisition skills than boys (Lindsay & Strand, 2016; Zubrick et al., 2007; Scheiber, et al., 2015). Typical communication development relies on our social connections to foster strong skills. The lack of social skills that accompanies AgCC may account for the current results which demonstrate that girls have more impairment overall. As previously mentioned, reduced interhemispheric transfer of information may have a secondary impact on deficits seen in AgCC including decreased processing speed as well as diminished complex problem-solving abilities. These deficits may result in significant functional impairments in the adaptive skills needed for everyday life (Mangum, 2018; Miller et al., 2018) as well as deficits in social communication (Paul et al., 2014). The foundation for acquiring communication skills in individuals with AgCC may be unstable at the onset, leading to impairments in many areas, including the domains that were assessed in this study. Furthermore, other factors such as education and cultural expectations may account for some of the delays that are seen.

Daily Living Skills

As hypothesized, Daily Living Skills scores in younger children with AgCC were more similar to the normative average and as they age, impairment increases. Subdomain analyses indicate that there are no differences in gender in any of the three subdomains for Daily Living Skills (i.e., Personal, Domestic, Community). Age and gender interaction difference trends occur especially between the ages of 46-55 months, and 130-195 months. From 56 months to 195 months, the children are below their peers with the greatest gap from their peers noted in the oldest group. The largest variance of the subdomains was in Personal Daily Living Skills. In Personal Daily Living Skills, girls show the most impairment beginning in 70-85 months, and have better scores in late middle to high school. For Domestic Daily Living Skills, no real gap was seen for boys and girls, except for girls in the 130–195-month range. For Community Daily Living Skills, the 130–195-month group is below the average for the norms for girls.

There are many factors that contribute to completing daily living skills. Different cognitive skills and components play a large role in the ability to execute these demands. As we know, children with AgCC typically have an average IQ but can display difficulties in certain cognitive domains (i.e., processing speed; Brown et al., 2012). If there is a deficit in one or more cognitive domain, it can have large effect on other cognitive domains and areas of functioning. Additionally, perhaps these children may be less able to learn and/or maintain the skills necessary to execute daily living skills at different time points in their lives. The varying social, cultural, educational, and familial expectations on boys and girls widely differ. As is sometimes seen, boys and girls are not given the same expectations and the demands from family and society are also different between boys and girls. In some areas, like the skills that are required to carry out domestic daily living skills, girls are more likely to hold the burden and majority of

those demands, and therefore may be assessed differently. The results for the Daily Living Skills domain pose a need to examine and gain a better understanding of our training and education between boys and girls including socialization differences and brain development differences. For various reasons, boy's subdomain are able to recover from previously demonstrated deficits in Daily Living Skills whereas girls are not, and perhaps a larger examination into social, educational, cultural, physiological, and gender differences is warranted to gain a better understanding of said differences.

Socialization

I hypothesized that Socialization domain scores in younger children with AgCC will be similar to the normative average, with impairment emerging as age increases. Different ratings in the Socialization domain were not found for gender and age alone. Once again, a large effect size for age groups and a moderate effect size for the interaction between gender and age were noted. When looking at scores, the children show a slight decline in socialization skills as they age lagging behind their age-equivalent peers.

Socialization delays may occur due to the deficits noted in other domains (e.g., Communication & Daily Living Skills). Girls struggle more than boys in socialization; however, both boys and girls are struggling more than their age-equivalent peers. The two youngest age groups did not display impairment in socialization. This may be due to lower expectations with young children for social skills. There may be some reporting bias and parents' struggle to recognize their children's social deficits. Socializing skills are complex. The necessity for understanding nuanced cues becomes more important as children age in order to comprehend what is meant behind certain words and phrases. Being able to read body language becomes more important with age. Without the ability to integrate verbal and visual information

effectively, due to the lack of the corpus callosum, children will struggle to understand socialization norms and struggle to make appropriate or expected responses in real time.

It appears that the underlying functionality of children with AgCC may have a large impact on the skills required for many aspects of development, including Socialization, Communication, and Daily Living Skills. Their reduced interhemispheric transfer of information likely has a secondary impact on deficits seen in AgCC, which in turn may result in significant functional impairments in the adaptive skills needed for everyday life. For example, Brown and Paul, 2019 have demonstrated reduced processing speed in AgCC individuals. Due to this reduced processing speed, other cognitive processes are likely affected including the ability to easily understand and process incoming information. This likely has impacted language and communication abilities (the acquisition and understanding of language may be compromised and delayed due to reduced processing speed), daily living skill abilities (i.e., taking longer to understand and complete tasks), and socialization skills (i.e., Symington et al., (2010) found that individuals with AgCC displayed substantial deficits in social understanding and comprehension that are most apparent when stimuli involve real-time processing of social scenarios, multi-sensory perception, and cognitive integration). The underlying reduced processing speed that is seen in AgCC has tremendous global cognitive impacts.

Results of this study demonstrate that children and adolescents with AgCC are falling behind their peers in all three of the major domains assessed (Communication, Daily Living Skills, Socialization). As is well known, early intervention is critical when faced with limitations and difficulties, and many parents of AgCC children have sought out resources to assist in intervention (i.e., physical therapy, occupational therapy, speech therapy, etc.). Results from this study demonstrate the need for continued emphasis on early intervention for individuals with

AgCC . This in turn may lead to different supports being implemented, or perhaps these results provide a better understanding of how AgCC children will likely develop. Parents and caregivers can therefore be better prepared for what to expect and what supports are necessary to achieve optimal functioning for their children.

Limitations

Limitations of the study include a small sample size and cross-sectional, rather than longitudinal design. Many factors can affect cross-sectional design, one major one is the design only provides a snapshot of functioning without acknowledging the many factors that affect development and/or functioning. A longitudinal study would more likely account for other developmental factors and confounding variables Due to the small sample size, the results may not be strong enough to be extrapolated to the larger population of individuals with AgCC, although with bootstrapping, we are able to have more confidence in our ability to extrapolate to the population. In the future, a larger sample size is more likely to avoid these points of limitation.

Further, anytime that a parent is requested to rate their children, there will always be a margin of error. Although we can standardize our inventories, parents may often have a different understanding of the statements they are being asked to rate. An example is parents needing to think through whether their child is able to read or understand materials from a specific grade-level or whether they are able to carry out a specific activity. Parents often have different interpretations of what may be expected of their children at specific developmental timepoints or may have a different interpretation of what is involved in different activities, and therefore answers may vary based on subjective ratings.

Future Directions

One direction would be to increase the sample size and conduct a repeat longitudinal study, where children who are diagnosed with AgCC are assessed at various developmental timeframes and other factors that can affect development can also be assessed and taken into consideration (i.e., other health diagnoses, environmental factors, access to care and support, etc.). The domains in the Vineland-3 are so intertwined, it is important to ask if there a way to understand one domain more objectively (i.e., does a language delay impact socialization, or vice-versa, or is it all domains) in order to recognize where we need to assist and help these children learn to manage the larger deficits. The three domains have a number of far-reaching impacts and interactions that must be studied.

Results of the present study have demonstrated and supported previous research that indicates significant impairments across several areas and domains for individuals with AgCC. As previously mentioned, Brown and Paul, (2019) demonstrated that these individuals have deficits that include reduced processing speed, complex reasoning, and problem-solving skills, among others, which in turn influences other aspects of cognition and development. Results the current study indicate there are impairments in the domains of communication, daily living skills, and socialization, and this information will hopefully assist several fields (e.g., psychology, pediatrics, primary medicine, etc.) in supporting these individuals with early intervention and future directions of research in the field.

Conclusion

Results of this present study indicate that there are generalized delays in the development of children and adolescents with AgCC, with the Daily Living Skills and Communication domains seeming to be the most affected. The age gap between the typical norms becomes

greater with girls having the most impairment in Daily Living Skills. Children and adolescents with AgCC are more likely to display developmental delays and early intervention is critical in order to develop compensatory strategies and/or techniques.

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Curriculum Vitae

Kristin M. Eddy, MA
Curriculum Vitae

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EDUCATION

Doctor of Clinical Psychology (PsyD), George Fox University; Newberg, Oregon
August 2022

Dissertation: *Agenesis of the Corpus Callosum: Developmental Trajectories Through Childhood*
Emphasis: Lifespan Neuropsychology

Committee: Glena Andrews, PhD (chair), Lynn K. Paul, PhD, Elizabeth Hamilton, PhD

Master of Arts, George Fox University; Newberg, Oregon; May 2019
Concentration: Clinical Psychology

Advisor: Glena Andrews, PhD

Bachelor of Science, Portland State University; Portland, Oregon; August 2017
Concentration: Psychology (graduated *magna cum laude*)

Advisors: Ellen Skinner, PhD and Bill Griesar, PhD

SUPERVISED CLINICAL EXPERIENCE

Postdoctoral Fellowship in Clinical Neuropsychology, Wake Forest University, Wake Forest Baptist Hospital, Winston Salem, NC.

September 2022 – Present

- Provide neuropsychological evaluations for a variety of presentations including movement disorders, neurodevelopmental disorders, neurodegenerative disorders, Parkinson's disease/DBS surgery evaluations, epilepsy & pre-surgical epilepsy evaluations, stroke, post-acute sequelae of COVID-19, and demyelinating disorders. Involved in interview, assessment, scoring, diagnosis, and written reports. Provide supervision to doctoral practicum students regarding neuropsychological assessment, case conceptualization, and written reports.
- Participate in a variety of didactic and grand rounds seminars, including neuropsychological assessment, report writing, case conceptualization, neuroanatomy, and review of relevant journal articles.
- Provide relevant supervision to practicum students and psychology interns.
- Supervisor: Laura Flashman, PhD

APA Accredited Internship: Clinical Psychology Doctoral Intern, Neuropsychology and Geropsychology, Central Regional Hospital, Geriatric Services Unit, Butner, NC & University of North Carolina, Physical Medicine and Rehabilitation, Chapel Hill, NC.

September 2021 – August 2022

- Provide psychological and neuropsychological services to adults and older adults in a manner consistent with APA Ethical Standards through the adherence of the Scientist-Practitioner training model.
- Rotation 1 – Central Regional Hospital, Geriatric Services Unit. Provide psychotherapy, neuropsychological, and psychological assessment services for individuals housed in the geriatric services unit. Provide group therapy as well as long-term and short-term psychotherapy services. Involved in interview, assessment, scoring, and written reports/evaluations/assessments.
- Rotation 2 – University of North Carolina Chapel Hill, Physical Medicine and Rehabilitation. Provide neuropsychological evaluations for a variety of presentations including movement disorders, neurodevelopmental disorders, neurodegenerative disorders, Parkinson's disease/DBS surgery evaluations, epilepsy & pre-surgical epilepsy evaluations, stroke, post-acute sequelae of COVID-19, and demyelinating disorders. Involved in interview, assessment, scoring, diagnosis, and written reports. Provide supervision to doctoral practicum students regarding neuropsychological assessment, case conceptualization, and written reports.
- Participate in a variety of didactic and grand rounds seminars, including neuropsychological assessment, report writing, case conceptualization, neuroanatomy, and review of relevant journal articles.
- Supervisors: Laura M. Clark, PhD; Matthew Harris, PhD; Karla Thompson, PhD

Psychology Pre-Intern Practicum Student, Assessment Clinic at the Behavioral Health Center,

George Fox University, Newberg, OR
August 2020 – July 2021

- Held position as a Co-Assistant Director of the Assessment Clinic.
- Patients seen across the lifespan and are referred for a wide variety of concerns including ADHD/LD, TBI, dementia, autism, and other medical conditions.
- Provided comprehensive outpatient neuropsychological evaluations for a community mental health center.
- Interviewed patients, administered assessments, completed scoring, provided conceptualization, wrote reports, and provided peer supervision.
- Provided administrative services consisting of triaging cases to appropriate clinicians, conducting peer supervision, and called and maintained own schedule.
- Participated in and led group supervision exercises consisting of fact-finding, case presentations, weekly didactics, and journal club.
- Supervisors: Glena Andrews, PhD & Kenneth Logan, PsyD

Psychology Practicum II Student, Samaritan Neuropsychology; Albany, Oregon August 2019 – August 2020

- Provided comprehensive neuropsychological evaluations in outpatient and primary care settings.
- Patients come from a wide variety of backgrounds (e.g., age, SES, educational level) and ages across the lifespan, ranging from young adult to geriatric.
- Duties: Reviewed charts, interviewed patients, administered assessments, completed scoring, provided conceptualizations, and wrote reports on the same day.
- Participated in group supervision consisting of journal club, psychometric presentations, factfinding, case presentations, and didactics.
- Provided comprehensive neuropsychological testing for baseline concussion data for athletes at Oregon State University. Observed structured interviews, as well as screened athletes for ADHD/LD, and psychiatric conditions. Scored protocols and entered data into a research repository.
- Supervisors: Robert R. Fallows, PsyD & Ashley K. Smith-Watts, PhD

Psychology Practicum I Student, Willamette Valley Medical Center; McMinnville, Oregon July 2018 – July 2019

Setting: Senior Behavioral Health Unit (Inpatient Psychiatric Unit)

- Population includes geriatric patients with a variety of referrals including psychiatric illness, suicidal ideation, homicidal ideation, degenerative conditions.
- Duties: Administered older adult neuropsychological assessments, conducted interviews, gathered history, wrote neuropsychological reports and made recommendations to patients and their families. Findings were reported to the unit's psychiatrist.
- Provided individual and group psychotherapy.
- Attended group specialist meetings to provide neuropsychological and psychological insight into patients' condition(s).

- Supervisor: Luann Foster, PsyD

Setting: McMinnville Surgical Associates (Outpatient Bariatric Consult)

- Population includes young adults to geriatrics.
- Conducted psychological evaluation and psychodiagnostics assessment in order to determine candidacy for bariatric surgery.
- Provided individual therapy to assist patients in overcoming psychological barriers for weight loss and behavioral change.
- Provided group therapy designed to diminish and discourage harmful eating habits and behaviors.
- Provided support throughout the weight loss surgery (i.e., pre- and post-surgery).
- Wrote integrative reports and made recommendations to clients.
- Collaborated with an interdisciplinary team to coordinate patient treatment plans.
- Supervisor: Luann Foster, PsyD

Setting: McMinnville Internal Medicine (Primary Care Unit)

- Population includes young adults to geriatrics in a primary care setting. Referrals included a wide variety of concerns ranging from anxiety, grief, depression, to managing symptoms of psychiatric illnesses.
- Provided individual therapy aimed at assisting patients to overcome their distressing symptoms and provided support along the way.
- Collaborated with patients' primary care physician to update patient progress, coordinate treatment plans, and discuss recommendations.
- Supervisor: Luann Foster, PsyD

Pre-Practicum Therapist, George Fox University Graduate School of Clinical Psychology; Newberg, Oregon

January 2018 – April 2018

- Provided 10 outpatient individual therapy sessions to volunteer young adult undergraduate students in a university counseling setting.
- Conducted intake interviews, prepared treatment plans, and maintained proper documentation.
- Wrote reports and presented case conceptualizations.
- Recorded all sessions, reviewed and analyzed them in individual and group supervision.
- Supervisors: Glena Andrews, PhD, and Nicole Ford, MA

CONSULTATIONS & REVIEWS

Consultant, Topic: Evaluation of George Fox University's Multicultural Committee

- Supervisors: Marie Christine Goodworth, PhD, Mary Peterson, PhD, Winston Seegobin, PsyD.
- In consultation with George Fox University's Graduate School of Clinical Psychology Multicultural Committee to gather a greater understanding of its function within the program and its perception within the student body.

- Developed a mixed methods survey.
- Coordinated with the Committee and professors to distribute to the student body.
- Analyzed and interpreted data.
- Offered feedback to the Committee and overseeing professors in order to bolster diversity and inclusion with the Graduate School of Clinical Psychology program.

TEACHING & ACADEMIC APPOINTMENTS

Teaching Assistant, Fall 2020, PSYD 527 Neuropsychological Assessment Foundations
Professor, Glena Andrews, PhD

Duties: Aid in the teaching of administration and scoring of child, adolescent, adult, and older adult neuropsychological assessments. Demonstrate fixed, flexible, and process battery approaches in a weekly practice lab. Test students in competency of administration and scoring. Assist in preparation and administration of sheep brain clinical exam.

Teaching Assistant, Summer 2020, PSYD 585 Geriatric Neuropsychological Assessment

Professor: Glena Andrews, PhD, Kristin Eddy, MA

Duties: Teach students administration and scoring of neuropsychological assessments appropriate for evaluating geriatric patients in inpatient and primary care settings. Co-taught course in tandem with the professor.

Teaching Assistant, Spring 2020, PSYD 510 Psychopharmacology
Professor: Glena Andrews, PhD

Duties: Assist professor with classroom instruction, exams, and record keeping; Tutor and mentor students; Prepare and deliver lectures.

Student Editor and Writing Coach, Fall 2019 – Present, George Fox University, Newberg, Oregon

Duties: Facilitated weekly meetings with students to review, edit, and amend reports and essays. Supported first-year students through weekly mentorship.

Teaching Assistant, Fall 2019, PSYD 502 Psychopathology
Professors: Elizabeth Hamilton, PhD and Amber Nelson, PsyD

Duties: Assist professor with classroom instruction, exams, case conceptualizations, and record keeping; Tutor and mentor students; Prepare and deliver lectures.

Teaching Assistant, Spring 2019, PSYD 510 Psychopharmacology
Professor: Glena Andrews, PhD

Duties: Assist professor with classroom instruction, exams, and record keeping; Tutor and mentor students; Prepare and deliver lectures.

Teaching Assistant, Fall 2018, PSYD 502 Psychopathology
Professor: Elizabeth Hamilton, PhD

Duties: Assist professor with classroom instruction, exams, case conceptualizations, and record keeping; Tutor and mentor students; Prepare and deliver lectures.

RESEARCH EXPERIENCE & PARTICIPATION

Research Vertical Team Member, Graduate School of Clinical Psychology, George Fox University, Newberg, Oregon. August 2017 – July 2022
Chair: Glena Andrews, PhD
Research: Meet bi-monthly to discuss and evaluate progress, methodology, and design of group and individual research projects including dissertation.

Secondary Researcher for Serial Neuropsychological Assessment Towards a Reliable Concussion Protocol, George Fox University, Newberg, Oregon. May 2019 – May 2021
Collaborated with Dr. Glena Andrews, PhD. and Daniel Soden, MA to gather information for a dissertation on creating a reliable neuropsychological assessment battery for athletes who experience a concussion. Recruited and scheduled undergraduate participants and administered a neuropsychological battery of 8 assessments.

Researcher at National Organization for Disorders of the Corpus Callosum, George Fox University, San Jose, California. July 2018
Administered the Bayley Scales of Infant and Toddler Development to Children (1 month – 3.5 years of age) with partial or complete agenesis of the corpus callosum. Attended

psychoeducational workshops and presentations. Provided reports to parents regarding the developmental trajectory of their child.

Compiled data and presented research findings at the 2019 National Academy of Neuropsychology conference in San Diego, CA.

Research Assistant for Science in Learning Gardens with Middle-School Aged Children, Applied Developmental Psychology Department, Portland State University, Portland, Oregon. June 2016 – October 2016

Organized and managed datasets, performed various administrative tasks such as copying forms, preparing consent form packets, organization of files and supplies, compiled and entered data using Microsoft Excel and Microsoft Access. Supervisor: Ellen Skinner, Ph.D.

RESEARCH PRESENTATIONS

Andrews, G.L. & **Eddy, K.,** (2022). *Agenesis of the corpus callosum: Developmental trajectories through adolescence.* Presented at International Neuropsychological Society Convention, Barcelona, Spain.

Andrews, G.L. & **Eddy, K** (2022). *Development across childhood: An update*. Presented at International Researchers Consortium Scientific Meeting, Frisco, TX.

Eddy, K., Gibson, A., & Andrews, G. (2019). *Assessing global delays in corpus callosum agenesis: Infants and toddlers.* Poster presented at the National Academy of Neuropsychology Annual Convention, San Diego, CA, November 2019.

Soden, D., Andrews, G., Chakara, F., Seitz, D., **Eddy, K.,** Rich-Wimmer, N., Gibson, A. (In Preparation). *Serial Neuropsychological Testing toward a Reliable Concussion Protocol*.

PROFESSIONAL PRESENTATIONS & TRAININGS ATTENDED

Forster, C. (2019, October 15). *Intercultural prerequisites for effective diversity work.* Colloquium Presentation at George Fox University, Newberg, OR.

Worthington, E. (2019, September 25) *Promoting forgiveness.*

Colloquium Presentation at George Fox University, Newberg, OR.

Andrews, G. (2019, June-July). *Neuroanatomy*

[Graduate Certificate Course]. George Fox University, Newberg, OR

Ribeiro, M. (2019, June 28, June 29, June 30). *Principles of Group Psychotherapy* [Graduate Certificate Course]. George Fox University, Newberg, OR.

Marlow, D. (2019, March 20) *Marital therapy and the Gottman standard.*
Grand Rounds Presentation at George Fox University, Newberg, OR.

Diomaris, S., & Millkey, A. (2019, February 13) *Opportunities in forensic psychology.* Colloquium Presentation at George Fox University, Newberg, OR.

Pengelly, S. (2018, October 10). *Old pain in new brains.*

Grand Rounds presentation at George Fox University, Newberg, OR

McMinn, M., Graham McMinn, L. (2018, September 26). *Spiritual formation and the life of a psychologist: Looking closer at soul-care.*
Colloquium Presentation at George Fox University, Newberg, OR.

Barsness, R. (2018, May 5). *Core Competencies of Relational Psychoanalysis: A Workshop with Dr. Roy Barsness*. Seminar Workshop Presentation, Vancouver, WA.

Vogle, M. (2018, March 14). *Integration and ekklesia.*

Colloquium Presentation at George Fox University, Newberg, OR.

Taloyo, C. (2018, February 14). *The history and application of interpersonal psychotherapy*.
Grand Rounds presentation at George Fox University, Newberg, OR.

Sordahl, J. (2017, November 8). *Telehealth*.

Colloquium presentation at George Fox University, Newberg, OR.

Safi, D., & Millkey, A. (2019, February 13) *Opportunities in forensic psychology.*

Colloquium Presentation at George Fox University, Newberg, OR

Gil-Kashiwabara, E. (2017, October 11). *Using community based participatory research to promote mental health in American Indian/Alaska Native children, youth and families*. Presentation at George Fox University Grand Rounds, Newberg, OR.

ACADEMIC AWARDS AND HONORS

Dean's List, Portland State University, 2013-2017
Psi Chi, The International Honor Society in Psychology, 2018 – Present

PROFESSIONAL AFFILIATIONS

American Psychological Association, 2017 – Present (graduate student affiliate)
Division 40, Society for Clinical Neuropsychology, 2018 – Present (student affiliate)
Psi Chi, Psychology Honors Society, 2018 – Present (member)

ASSESSMENT COMPETENCY, EXPERIENCE, & EXPOSURE

16 Personality Factors (16PF)

A Developmental Neuropsychological Assessment – Second Edition (NEPSY-II)

ACS Word Choice

Adaptive Behavior Assessment System – Third Edition (ABAS-3)

Bayley Scales of Infant and Toddler Development – II (BAYLEY-II)

Behavior Assessment System for Children – 3rd Edition (BASC-3)

Beck Anxiety Inventory

Beck Depression Inventory

Behavior Rating Inventory of Executive Function – Second Edition (BRIEF 2)

Behavior Rating Inventory of Executive Function for Adults

Benton's Judgment of Line Orientation

Brief Visuospatial Memory Test – Revised (BVMT-R)

Boston Diagnostic Aphasia Examination (BDAE)

Boston Naming Test, 2nd Edition

Booklet Category Test, 2nd Edition

California Verbal Learning Test, 2nd Edition, Adult Version (CVLT-II)

California Verbal Learning Test – Children's (CVLT-C)

Category Fluency Task – Animals

Child Behavior Checklist (CBCL)

Columbia Suicide Severity Rating Scale (C-SSRS)

Comprehensive Test of Nonverbal Intelligence – Second Edition (C-TONI)

Controlled Oral Word Association Test

Conners – Third Edition

Conners Adult ADHD Rating Scales (CAARS)

CLOX: An Executive Clock Drawing Test

Delis-Kaplan Executive Function System (D-KEFS)

Dementia Rating Scale – 2 (DRS-2)

Epworth Sleepiness Scale

Executive Function Inventory (EXIT)

FAS Test of Phonemic Fluency

Generalized Anxiety Disorder 7-Item Scale (GAD-7)

Geriatric Depression Scale – short form (GDS-SF)

Green's Word Memory Test (WMT)

Grooved Pegboard

Hare Psychopathy Checklist – Revised

Independent Living Scales (ILS)

Hopkins Verbal Learning Test – Revised (HVLT-R)

Millon Clinical Multiaxial Inventory, 3rd Edition (MCMI-III)

Millon Clinical Multiaxial Inventory, 4th Edition (MCMI-IV)

Minnesota Multiphasic Personality Inventory, 2cd Edition (MMPI-2)

Minnesota Multiphasic Personality Inventory, 2cd Edition, Revised Form (MMPI-2-RF)

Mini Mental Status Exam (MMSE)

Montreal Cognitive Assessment (MoCA)

Modified Wisconsin Card Sort (M-WCST)

Neuropsychological Assessment Battery (NAB)

Neuropsychiatric Inventory Questionnaire (NPI-Q)

Patient Health Questionnaire – 9 (PHQ-9)

Personality Assessment Inventory (PAI)

Pittsburg Sleep Quality Index (PSQI)

Repeatable Battery for the Assessment of Neuropsychological Status (RBANS)

Roberts Apperception Test for Children: 2

Rey-Osterrieth Complex Figure Test and Recognition (RCFT)

Ruff 2&7 Selective Attention Test

Saint Louis University Mental Status (SLUMS)

Stroop Color and Word Test

Symbol Digit Modalities Test (SDMT)

Tactual Performance Test

Test of Memory Malingering (TOMM)

Test of Practical Judgment (TOP-J)

Test of Premorbid Functioning (TOPF)

Texas Functional Living Scales (TFLS)

The Dot Counting Test

The Pillbox Test

Trail Making Test (A&B)

Vineland Adaptive Behavior Scales – 3rd Edition (Vineland-3)

Wechsler Abbreviated Scale of Intelligence (WASI)

Wechsler Adult Intelligence Scale, 4th Edition (WAIS-IV)

Wechsler Adult Intelligence Scale, 4th Edition, iOS Version

Wechsler Individual Achievement Test, 3rd Edition (WIAT-III)

Wechsler Intelligence Scale for Children, 4th Edition (WISC-IV)

Wechsler Memory Scale, 4th Edition (WMS-IV)

Wechsler Nonverbal Scale of Ability (WNV)

Wender Utah Rating Scale (WURS)

Wide Range Achievement Test – 4th Edition (WRAT-4)

Wisconsin Card Sort Test (WCST)

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PROFESSIONAL REFERENCES

References available upon request. Please email me at keddy17@georgefox.edu to request professional, academic, or personal references.