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Early Intervention for an At-Risk 16-Month Old Using Visual Communication Analysis (VCA) Leads to Gifted Performance

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This research and publication is dedicated to Gary Shkedy.

Abstract

Many developmental screeners focus heavily on receptive and expressive language skills, and the extent to which an infant can maneuver their environment. Research with young children typically involve motor skills, language, and occasionally simple procedural or problem solving tasks. The current study explores skills infants are expected to attain, and other skills that have never been tested in an infant who is considered "at-risk" due to moderate developmental delays.

Researchers collected data via specialized VCA software, video recordings, and the Vineland-3 pre- and post-study. The participant improved in all areas measured by the Vineland-3. Additionally, despite the participant being introduced to novel and progressively more difficult tasks, his average attention span throughout the entirety of the study was significantly longer than previous research suggests for infants. Researchers also implemented the detour box as a gross measure of frontal function. The participant successfully completed the detour task and multi-step problem solving.

Keywords: early intervention, infant development, neurodevelopment, self-determination theory, visual communication analysis

1. Introduction

Current research on infants typically involve motor skills, language, and simple procedural or problem solving tasks. Many developmental screeners focus heavily on how many words an infant might say, how receptive an infant is, and to what extent an infant can maneuver their environment. The assumption is that infants should move passed babbling and the use of gross motor skills within a certain timeframe, largely based on averages that professionals have researched and agreed upon. Infants who do not meet these particular timeframes may be considered "at risk" or "developmentally delayed." The current study is interested in the specific skills infants are expected to attain, as well as other skills that have never been tested. The current study focuses on motor skills, attention, memory and learning, and general executive functioning.

1.1 Motor Skills

Gerber et al. (2010) and the American Academy of Pediatrics describe fine motor skills as those that "relate to the use of the upper extremities to engage and manipulate the environment" (p. 268). Infants are expected to begin to develop fine motor skills at approximately 12 months of age. They should be able to pick up objects with a pincer grasp. Gerber et al. (2010) suggests stacking blocks and releasing objects should be present at 15 months, and by age 2 years toddlers can feed themselves, remove their clothing, grasp a door knob, and draw horizontal and vertical lines (2010). At age 3, toddlers should draw a circle, put on their own shoes, unbutton clothing, and stack 10 or more blocks. In the age of advancing technology and touchscreens, fine motor skills have begun to include other tasks such as scrolling. Bedford et al. (2016), studied toddlers 19-36 months and found that age of touchscreen exposure was associated with fine motor skills (e.g. block stacking), and fine motor milestone achievement (e.g. pincer grasp). The earlier use of scrolling of the screen was associated with earlier fine motor achievement. There are various other studies that have examined the use of touchscreens and fine motor skills but are focused predominantly on preschool-aged children, not infants (e.g. Lin, Cherng, & Chen, 2017; Webster, Martin & Staiano, 2019). Additionally, most studies focus primarily on scrolling, not typing.

1.2 Attention, Memory, and Learning

Attention can be considered the gateway for memory and learning. Failure to attend inhibits the ability to encode information. Without proper encoding, there is no learning (Myers & Dewall, 2019). Consequently, one cannot retrieve information that was not encoded or attended to in the first place. The process of attention is complex and involves several processes and structures (Strauss et al., 2006). Therefore, tests of attention typically measure more than just one attentional process. Attentional processes also change as an individual matures, which is important to consider when working with children, due to the intersection of attention and executive functioning (Strauss at el., 2006). There are few studies and fewer assessments that have been able to assess various forms of attention or executive functioning in very young children and infants. Consequently, measures of sustained focus vary significantly. Some studies suggest an average sustained attention span between 1.5 minutes to 2 minutes in infants aged 13 to 24 months (Bornstein & Tamis-Lemonda, 1997; Choudhury & Gorman, 2000). Suarez-Rivera et al. (2019) measured infant sustained attention (an unbroken gaze) between 500 milliseconds and 31 seconds. Another study found infants had longer sustained attention when interacting with an unfamiliar individual who followed their attentional focus (Miller et al., 2009). The research on attention processes, memory and learning in very young infants is scarce to non-existent.

1.3 Executive Function

Executive function is used to describe a complex set of processes. Examples of these are higher-order processes such as abstraction, inhibition, problem solving, emotion regulation, organization, etc. (Barkley, 2012). Shallice (1988) emphasized that executive functions are not in maximal use all the time for routine or well-learned behaviors. Instead, these functions are utilized for novel, unfamiliar, and complex circumstances. Executive dysfunctions may manifest as poor planning and organization, poor working memory, inflexibility, perseveration, poor impulse control, etc. (Anderson 1998; Barkley 2012). Executive functions are thought to begin developing in early childhood, and continue to mature into young adulthood (Center on the Developing Child, 2012). This is assumed to be associated with the trajectory of brain development and myelination, but may also be due to the absence of research and standardized procedures to assess areas of executive functioning in very young children. Formal neuropsychological assessment of various aspects of executive functioning are designed for children approximately 7 years of age and older (Strauss et al., 2006). Very few studies have assessed executive functioning in very young children or toddlers. Atkinson et al. (2000) utilized tasks such as "detour box," counterpointing, and "stroop-like" tasks to assess frontal function in children with Williams Syndrome ages 4:8 to 15:4 years. Researchers found a persistent deficit in children with Williams Syndrome when compared to control data from typically developing children ages 4 to 10 years. However, this kind of research in very young children (with or without neurodevelopmental conditions) is rare. There are longitudinal studies focused on toddlers which assess correlations between behaviors or environments and subsequent executive functioning when the toddlers grow older. However, it is difficult to locate studies assessing executive functioning in very young children that are not based solely on parent-report.

1.4 Current Study

The current study aims to assess the above mentioned functions in an infant 16 months of age utilizing Visual Communication Analysis. Visual Communication Analysis is an application of Self-Determination Theory (SDT). SDT is a theory of intrinsic motivation based on three main tenets: autonomy, competence and relatedness. Researchers Deci and Ryan (1985 & 2000) found that conditions that support an individual's experience of these three tenets tend to foster a high quality of motivation and engagement for activities, including enhanced performance, persistence, and creativity. VCA is an efficacious therapy initially developed for children with severe autism. VCA creates conditions that support the child's experience of autonomy, competence and relatedness. Within the VCA framework, the use of external rewards or punishments is heavily disfavored and never utilized. VCA gives each child a variety of choices in order to develop their intrinsic motivation, which is reinforced through presumed competence.

VCA combines SDT principles in combination with visual supports, prompts, and technology-aided instruction. Research on VCA has illustrated significant decreases in maladaptive and self-injurious behaviors, as well as the ability to communicate via typing independently (Shkedy et al., 2020; Shkedy et al., 2021).

The purpose of this study was to assess any benefits of VCA when applied as an early intervention and as an assessment method.

2. Method

2.1 Participant

The participant was a male infant recruited from Alternative Teaching Strategy Center. Parents expressed concern the infant may not meet developmental milestones. The infant has an older brother on the autism spectrum, and was believed to be at-risk. At onset of the study, the participant was 1 year and 4 months old. The participant was exposed to English, Russian, and Hebrew languages in his home. However, he had not begun to verbalize and babbling was uncommon. Additionally, the infant did not respond to his name, did not respond to gestures, did not follow instructions with one action of object, would not attempt to repeat words, did not smile in response to praise, and did not recognize himself in a mirror or photo. The participant could not identify at least three objects, identify images, body parts, and did not verbalize “yes” or “no.” Additionally, the participant could not stack blocks, turn door knobs or handles, or throw a ball with one hand.

2.3 Procedures

Researchers obtained consent for services, data collection, and video recording from legal guardians of the infant. Researchers utilized qualitative data obtained during an interview with the mother, as well as implementation of the Vineland Adaptive Behavior Scales, Third Edition as baseline measures. The interview and the Vineland were conducted at the onset of the study, and then again at 2 years and 2 months of age. Researchers did not incorporate the use of the Daily Living Skills scale on the Vineland, as the items measured by this scale are not typical of most therapies and are most appropriately taught by caregivers at home (e.g. drinks from a cup, feeds with spoon, sucks or chews on finger foods, and cooperates in washing his face).

The infant participated in the study for approximately 1 hour per day, 5 days a week for 40 weeks. The participant was treated individually in his own room accompanied by one VCA therapist. The room contained a desk, a chair, a booster seat with seat belt, and a video camera used to record the entirety of the session. The participant had access to breaks as needed or desired. No external rewards or token systems were used.

Data was collected throughout each session. Qualitative data was collected by the therapist and recorded outside of the session. Quantitative data was collected and timestamped via VCA software. The software recorded every interaction the participant made on the iPad. This method removed any perceived negative feedback and pressure that many children feel when therapists manually record data. The data taken by the software was stored on a server and later used for analysis in this study. Lastly, therapists were alternated to remove any potential bias.

As described in Shkedy et al. (2020), therapists implementing VCA are vigorously trained in the tenets of self-determination, and person-centered therapy. All tasks presented by the therapists were a combination of matching and typing tasks. Instructions were presented simultaneously both orally and visually. There were at least four types of matching tasks that were utilized. The first was picture-to-picture matching, where five target photos were presented simultaneously on the top and bottom row of the iPad. The infant had to drag the matching photo from the bottom row on the iPad up to the corresponding photo in the top row. On Level 1, all photos lined up in the same order on the top and bottom row. On Level 2, the order of the photos on the bottom row was randomized. On Level 3, the bottom row was changed to the word that corresponded with the picture, but the words were placed in the same order as the pictures on the top row. On Level 4, the words on the bottom row were randomized. The VCA software automatically randomized which photos from the total pool of available photos are presented on each level, based on a preselected list of desired words, so that each subsequent matching task differs from prior tasks, even though some photos may remain the same.

The typing task consisted of presenting the participant with a single photo and having them type the word corresponding to the photo – for instance, the participant was prompted to type “apple” when presented with a photo of an apple. On Level 1, the participant was shown a silhouette of the correct spelling of the word. The next key on the keyboard that needed to be typed would also blink every two seconds. On Level 2, the participant was shown a silhouette of the correct spelling of the word, but the keyboard no longer blinked. On Level 3, the permanent silhouette was removed; the participant was instead provided with a “help” button that would flash the silhouette of the correct spelling of the word for two seconds. All words were initially presented in upper case only and then lower case with the addition of the “shift” key.

In line with Shkedy et al., 2020, in order to maintain engagement and ensure progress, novel tasks (e.g. where the object changed to one the participant had never seen before, the letter case changed in a way the participant had never seen before, etc.) were continually presented. Additionally, as time went on, the tasks presented generally became progressively more complex. This data is presented in Table 1. Table 1 also illustrates the total number of data points captured, giving an indication of the speed at which the participant interacted with the iPad over the same number of sessions.

Researchers also measured letters correct per minute (LCPM) as a measure of learning. During each session, the participant was given the opportunity to type different letters and numbers, and eventually progressed to typing words. The number of different words presented varied by participant and was changed based on the choices of the participant. In order to ensure validity of the data every keystroke made on the iPad was automatically timestamped and stored in a database. Researchers also measured response rate and utilized a detour task similar to Atkinson et al. (2000) to grossly assess frontal function. The detour task was presented utilizing a box in front of the task the participant was to complete. The participant had to deduce that he needed to move the box in order to access and complete the task.

Table 1. Distribution of new tasks

	Average number of new tasks per session	Max number of new tasks per session	Min number of new tasks per session	Total data points captured
Participant	21.8	99	1	86,327

Researchers hypothesize that with daily intervention of VCA, the participant will begin to make progress toward delayed goals or skills. Researchers will also attempt to assess the participant's ability to complete a detour task, engaging higher order processes such as multi-step problem solving. Researchers hypothesize the participant will be able to successfully and consistently solve the detour task by age 22 months.

3. Results

Researchers compared data collected via the Vineland-3 pre and post study. Table 2 presents standard scores and percentile scores for the three domains measured. Table 3 presents subdomains with v-scale scores, percentiles, and a measure of the developmental "gap" in percentages. For example, in the receptive communication subdomain, the participant was 75% behind what was developmentally expected at the onset of the study. At the completion of the study, there was only an 8% gap between his abilities and the developmental expectation for his age. Overall, the participant improved in all areas. At the completion of this study, the participant verbalized single words for requests and also utilized adjectives. He was able to identify various objects and verbalizes or attempts to verbalize them. The participant recognized and labeled members of his family and familiar others. The participant also recognized himself in photos, responded to his name, smiled in response to praise, and responded to facial expressions from others. He copied play of nearby children, showed interest in his surroundings, and tried to interact with others. The participant's gross and fine motor have also significantly improved. He can stack blocks, maneuver stairs, and throw objects with one hand.

Table 2. Vineland Domains Pre- and Post-Study

Domain	Vineland at age 1:4		Vineland at age 2:2	
	Standard Score	**Percentile**	**Standard Score**	**Percentile**
Communication	78	7th	85	16th
Socialization	84	14th	77	6th
Motor Skills	92	30th	110	75th

Table 3. Vineland Subdomains Pre- and Post-Study

Subdomain	Vineland at age 1:4		Vineland at age 2:2	
	v-Scale Score	**Age Equivalent (percent gap)**	**v-Scale Score**	**Age Equivalent (percent gap)**
Communication				
Receptive	9	0:4 (75%)	14	2:0 (8%)
Expressive	10	0:7 (56%)	10	1:3 (42%)
Socialization				
Interpersonal	11	0:5 (69%)	11	1:1 (50%)
Play and Leisure	12	0:7 (56%)	11	1:0 (54%)
Motor Skills				
Gross motor	15	1:4 (0%)	19	4:2 (-92%)
Fine motor	12	0:9 (44%)	14	1:10 (15%)

Researchers also measured level of engagement and response rate. Despite the participant being introduced to novel and progressively more difficult tasks, his average attention span throughout the entirety of the study was approximately 9.9 minutes. The minimum attention span was 1 minute, and the maximum was 50 minutes. Figure 1 displays the moving average attention span. Average response rate was 6.8 seconds. The minimum response rate was 2.5 seconds and the maximum response rate was 36.1 seconds. Figure 2 displays the moving average for response rate.

Figure 1. Moving Average for Attention Span

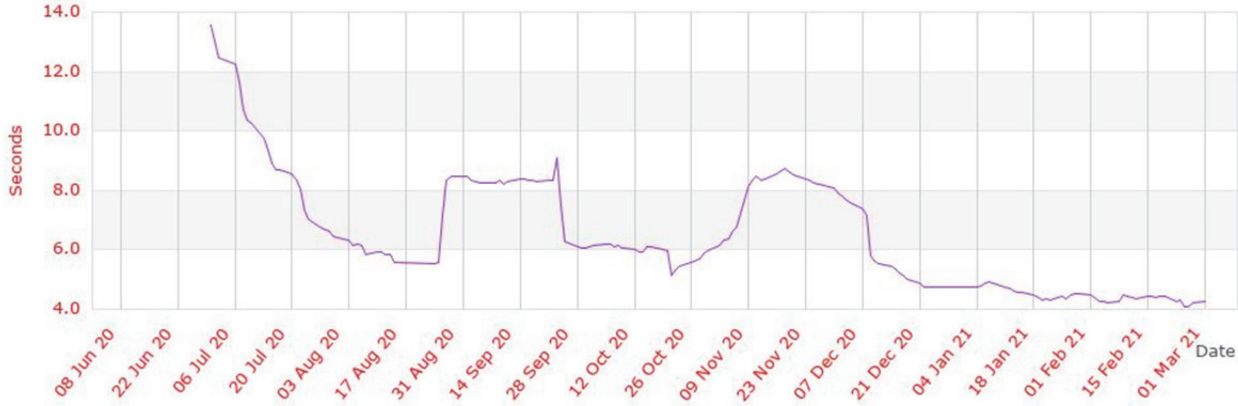

Figure 2. Moving Average Response Rate

Letter correct per minute were measured on three different levels that ranged from visual prompting of keys and words, to no prompting of keys and then only a word prompt. The following charts illustrate an overall upward trend in LCPM. The participant over time developed both the location memory for the keys as well as knowledge identification for letters and numbers. The patient was observed to identify numbers and letters not only when utilizing the VCA software, but he was able to generalize and identify letters and numbers on keypads of office doors, and could type to oral letter dictation on various other note and texting applications. The participant types completely independently without the use of a “facilitator” or any physical contact from an aide.

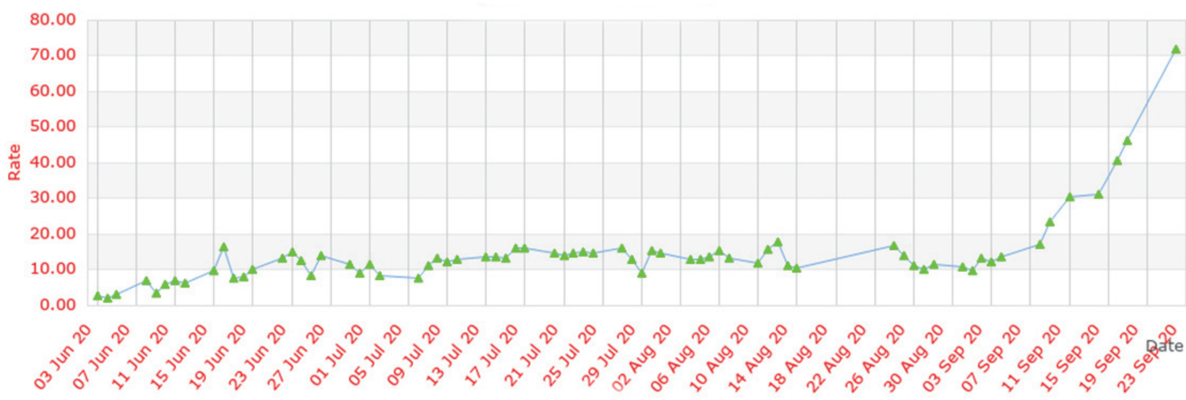

Figure 3. Level 1 Keyboard

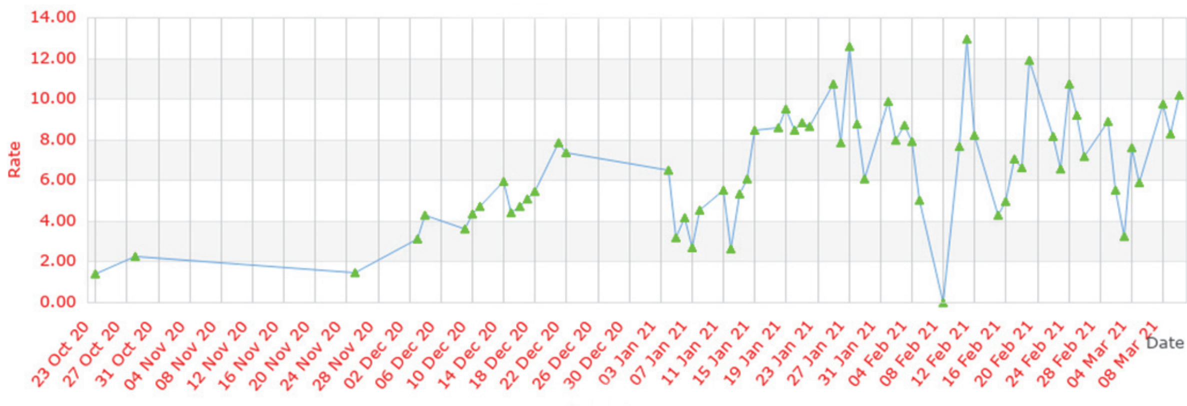

Figure 4. Level 2 Keyboard

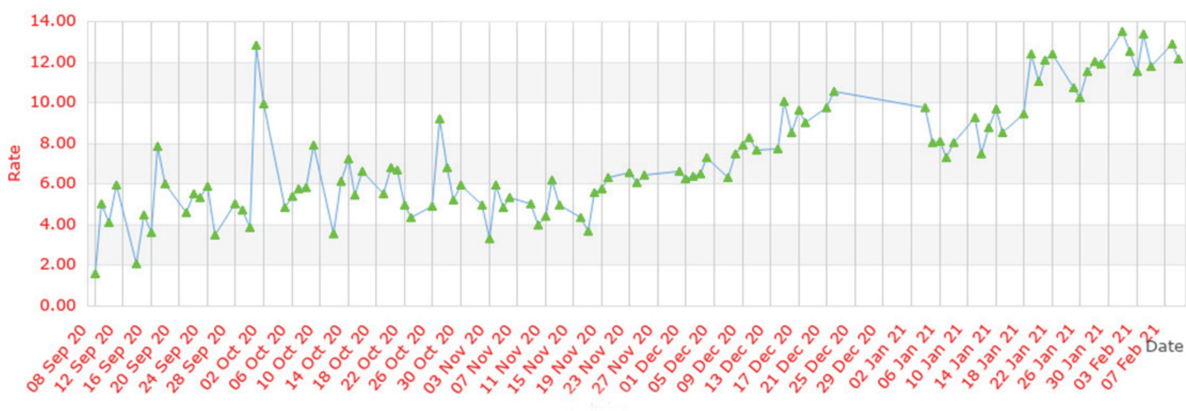

Figure 5. Level 3 Keyboard

Lastly, researchers' implemented the detour box as a gross measure of frontal function. The participant successfully maneuvered the detour box repeatedly. The detour box was presented on different areas of the screen, the box was presented both in solid and transparent forms, and the participant was able to successfully move the detour box and complete the task. The participant achieved this at approximately 19 months of age.

4. Discussion

4.1 Interpretations

Results of this study indicates progress in all domains measured. Of particular note is that expected developmental milestones progress with age, and therefore the participant in the current study had to make up for the delay while also catching up as the goal marker moved farther and farther. By the end of the study, the participant was able to identify letters via matching and typing. He was able to identify his family members and match their appropriate names. The participant was responsive to his name, eye-contact and interaction with his environment significantly improved. As described above in the Results section, the participant began to complete developmentally appropriate tasks and expectations as measured by a standardized assessment. Of particular significance is that the participant began to verbalize words. This is of interest to these researchers because other researchers have suggested that for some children, reading acquisition may develop before language, and teaching whole language may be more effective than isolated phonics instruction (Glezer at al., 2015; Manning & Kamii, 2000). Manning and Kamii (2000) found that children who were taught whole language made more progress in both reading and writing, and with more developmental coherence. Therefore, teaching children in a format that focuses more on whole language instead of phonics instruction may be more effective for some children who struggle with reading, writing and even language development in early childhood. This was the case for the current participant and is particularly important to consider as many children who do not immediately display verbal language are considered delayed and may be vulnerable to receiving inaccurate diagnoses. The current study provides further support for the notion that non-verbal or minimally verbal does not indicate intelligence.

The current study also attempted to measure cognitive areas that are not typically measured in standardized assessment procedures for very young children. The current study measured attention span. The participant's average attention span was approximately 9.9 minutes, and his maximum attention span was 50 minutes. This data speaks volumes to the potential and capacity for attention and engagement in very young children, when they are intrinsically motivated. Current data suggests children this young can only sustain attention for approximately two minutes (Bornstein & Tamis-Lemonda, 1997; Choudhury & Gorman, 2000).

Researchers also implemented the detour task discussed by Atkinson et al. (2002). The participant was required to maneuver the detour object on the screen first in order to complete a different task. The detour task was presented utilizing a box in front of the task the participant was to complete. The participant determined that he needed to move the box in order to access and complete the task. The detour task was presented to the participant at various locations on the iPad screen, multiple times and on different days. Additionally, the box was sometimes completely solid obscuring the view of the targeted task, and other times the box was transparent so that the participant could see the task at hand. The participant was able to adequately problem solve to complete the task at approximately 19 months of age. McGuigan & Nunez (2006) conducted a similar study with 18–24-month old children. Researchers studied executive functioning by requiring the participants to engage in detour tasks, some with direct causal means-action, and other arbitrary means-action tasks which required multiple steps. Results found that children performed better when they could not see the goal object, perhaps because the children did not need to inhibit the tendency to reach in a straight line (McGuigan & Nunez, 2006). Results also indicated that children were more easily able to shift between two non-arbitrary actions compared to two arbitrary actions. While the current study did not formally test arbitrary versus non-arbitrary actions, the participant was able to infer and move detour with and without seeing the subsequent object task.

Lastly, the participant was able to identify all letters of the alphabet. He also began to type to oral dictation without any kind of visual of physical prompt. This is especially noteworthy as research suggests children learn approximately half of the alphabet by age 3 and the whole alphabet by age 4. Research studying letter identification found that at age 3 children could name 4.03 uppercase letters and 2.74 lower case letters correctly (Worden & Boettcher, 1990). Studies typically focus on preschool aged children when researching emergent literacy skills (Piasta & Wagner, 2010; Puranik, Lonigan, & Kim, 2011). However, the current study suggests literacy and communication may be acquired much sooner despite the absence of verbal language. The participant can recognize and identify all capital letters of the alphabet and some lowercase letters ahead of his cohort. He is also able to maneuver any keyboard and generalized to various applications and devices. This is important as the participant now has the potential for freedom and autonomy to communicate without a specialized device or another person attempting to facilitate or speak for him. In sum, the participant who was considered "at-risk" at the beginning of the current study, may now be arguably considered "gifted." The participant displays an attention span significantly greater than research has suggested for his age. The participant can also identify letters and type to oral dictation which is a skill far ahead of his peers. He can maneuver various devices to identify numbers and letters he requires to engage in communication. These researchers hypothesize that with continued VCA intervention he will be able to express complete sentences via typing ahead of his cohort. However, despite the participant's great strides in progress and visible areas of superiority compared to his cohort, these areas would never be objectively assessed or even subjectively reported utilizing the current methods of assessment for development. This information should be considered by the various professionals who use developmental screeners and assessment tools for diagnostic purposes as they are very limited and do not account for intelligence or any true cognitive functions.

4.2 Limitations

A notable limitation to the current study is that while the standardized procedure utilized is a validated and widely used measure of adaptive functioning, the procedure requires parent-report. Self-report measures are inherently prone bias. Researchers attempted to help mitigate this by recording qualitative and electronic data in addition to this procedures for comparative purposes. However, these researchers cannot affect any potential bias in the responses given by the parents while completing the Vineland. Limitations are inherent in the design of a single case study. This study will require replication in order to determine generalizability.

4.3 Areas for Future Study

It is noteworthy that the participant only received VCA services for 1 hour a day, 5 days a week for 40 weeks. This is very little compared to other early interventions and behavioral therapies. Many organizations and some researchers suggest 25 intervention hours per week is appropriate for very young children (Downs & Downs, 2010). Children receiving Applied Behavior Analysis-based early intervention, for instance, receive up to 40 hours per week of therapy. However, more recent studies have suggested that receiving fewer hours of therapy on a weekly basis do not make a significant difference. In fact, a multisite study conducted by UC Davis found that there was no significant or clinical benefit between 15 and 25 hours of early intensive behavioral intervention (Rogers et al., 2020). The current study suggests that VCA can be at least 3 times more effective, with only 5 intervention hours a week. The rate of acquisition and learning is much faster. Other research has found this to be true for older children however, replication of this study can determine if this is also true for very young children as was found in this case study (Shkedy et al., 2020; Shkedy et al., 2021).

Lastly, the participant in the current study was considered delayed and "at-risk." He was nonverbal, did not respond to his name, could not identify or label objects, he did not show any interest in others or in his surroundings, etc. The participant was also delayed in milestones as measured by the Vineland. However, at the close of the current study, the patient displayed superior skills in certain areas when compared to his peers. This participant may have very likely been diagnosed with a number of developmental issues based on traditional developmental assessments that do not account for any real cognitive abilities. Future research should focus on the specifics used to evaluate and diagnosis children as they may be inaccurate and/or lacking a comprehensive approach to development. Future research should also assess other "at-risk" or delayed children to determine if they could be in fact be "gifted" in certain areas despite the slower than average emergence of verbal language.

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