CLINICAL PSYCHOLOGY & NEUROPSYCHOLOGY | RESEARCH ARTICLE

Visual communication analysis (VCA): Applying self-determination theory and research-based practices to autism

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Abstract: Per the Centers for Disease Control, approximately 31% of children with Autism Spectrum Disorder (ASD) are classified as intellectually disabled and between 25% and 50% of children with ASD do not develop functional verbal communication. This study was conducted to test the effectiveness of Visual Communication Analysis (VCA) as a method to teach communication and reduce maladaptive behaviors in non-verbal children with severe autism. VCA is the application of a well-established theory of motivation-The Self-Determination Theory. Since it is currently impossible to test the IQ of this subset of children with standard measures, changes in the number of letters typed correctly per minute was used to measure progress. An additional measure used was the frequency of maladaptive behaviors at the beginning of the study compared to the frequency at the end of the study. Using both of these measures, individuals utilizing VCA in this study showed statistically significant improvements in communication as well as a decrease in maladaptive behaviors. In addition to demonstrating the efficacy of VCA, these results lead to the questioning of the validity of the original diagnosis of intellectual disability given to this subset of children with ASD. Results also highlight

ABOUT THE AUTHOR

Alternative Teaching Strategy Center (ATSC) is a non-profit organization located in San Diego, California dedicated to providing services to families with children and adults with autism and other cognitive and learning disabilities. ATSC works directly with parents, insurance companies, school districts, and other State agencies, and provides one-on-one treatment services to children and adults from all over the world. ATSC is dedicated to researching treatments and interventions primarily in autism and related disorders with a primary focus on severe autism, due to a sparsely populated research base. The group’s work includes topics related to the effective overall treatment options and methods, the use of technology in treatment, implementation of special education especially in public schools, socialization, and ethical practice, with a goal of improving the quality of life for the aforementioned populations.

PUBLIC INTEREST STATEMENT

According to the Centers for Disease Control, approximately 31% of children with Autism Spectrum Disorder (ASD) are classified as intellectually disabled and between 25% and 50% of children with ASD do not develop functional verbal communication. The subset of nonverbal children in the intersection of these groups are considered “severe” or “low functioning” and are often not included in research studies due to unmeasurable Intellectual Quotient (IQ).

The aim of this study was to test the effectiveness of Visual Communication Analysis (VCA) as a method to teach communication and to reduce maladaptive behaviors in the underserved non-verbal children with severe autism. VCA is the application of a well-established theory of motivation: The Self-Determination Theory. Results indicate statistically significant improvements in communication and the reduction of maladaptive behaviors. This study highlights the need for continued research and application of well-established theories of motivation to the special need population.
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Subjects: Learning; Motivation; Educational Psychology

Keywords: Autism; functional communication; self-determination; maladaptive behaviors; self-injurious behaviors

1. Introduction

According to the most recent edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), Autism Spectrum Disorder (ASD) is identified by a unique set of deficits in social communication and interaction, as well as restricted or repetitive patterns of behavior, interests, or activities (American Psychiatric Association, 2013). Per the DSM-5, ASD affects approximately 1% of the population, with at least 15% of cases associated with an established genetic mutation (American Psychiatric Association, 2013). Prevalence rates and heritability estimates vary across studies. In fact, twin studies estimate phenotype variance due to genetic factors to be as high as 90% (Tick et al., 2016). Additionally, in their most recent biennial update, the Centers for Disease Control (CDC) indicated a 15% increase in the prevalence of ASD in the United States, increasing from 1 in 69 people in 2016 to 1 in 59 people in 2018. (Baio et al., 2018). In the same report, the CDC indicates about 31% of children with ASD were classified as intellectually disabled. Moreover, approximately 25–50% of children with ASD do not develop functional verbal communication (Pattern et al., 2013). This subset of nonverbal children in the intersection of these groups are typically considered “severe” or “low functioning” and tend to display many behaviors associated with sensory issues, and maladaptive behaviors such as biting, hair-pulling, kicking, spitting, etc. (Soke et al., 1971). Studies have found significant correlations between lower levels of expressive and receptive communication with higher rates of aggressive and self-injurious behaviors (Baghdadi et al., 2003; Chiang, 2008; Matson et al., 2009; Murphy et al., 2005; Richards et al., 2012; Weiss, 2003).

As prevalence rates have continued to increase exponentially, there is an increased need for applicable, evidence-based practices to support this population (Wong et al., 2015). One widely used practice, Applied Behavior Analysis (ABA), has been largely accepted as the standard of care for the treatment of Autism Spectrum Disorder (Vismara & Rogers, 2010). ABA therapy has been viewed as the gold standard for treating children with ASD because various meta-analyses have found it to be efficacious (Eldevik et al., 2009; New York State Department of Health Early Intervention Program, 1999; Virués-Ortega, 2010). However, research has only indicated efficacy with those who have a measurable Intelligence Quotient (IQ), typically at 70 or above (Virués-Ortega, 2010). Many studies use IQ to measure efficacy or as an inclusion criterion, which means that children who are nonverbal, particularly those deemed as “lower functioning” and untestable, are inherently excluded from these studies (Peters-Scheffer et al., 2011). Therefore, nearly all, if not all, research on the efficacy of ABA used on individuals with ASD excludes the severe, nonverbal population; which is the same population displaying self-injurious and maladaptive behaviors due to their inability to communicate.

The lack of efficacious and appropriate treatment for this population may lie in both the absence of an appropriate and scientifically valid measurement tool for non-verbal individuals, as well as in the individual’s inability to communicate (Bishop et al., 2015; Siegel & Minshew, 1996). In fact, communication deficits have been found to have a strong association with maladaptive or self-injurious behaviors (SIB). In clinic-based studies, research suggests that 30% of children with Autism Spectrum Disorder engage in SIB (Giarelli et al., 2016). Research from various fields indicate that lack of communicative skills and/or adaptive skills can be triggers for, and very often directly correlate with SIBs. Researchers have consistently found self-injurious behaviors to be highly associated with lower levels of adaptive and/or speech skills (Baghdadi et al., 2003; Chiang,
2008; Matson et al., 2009; Murphy et al., 2005; Richards et al., 2012; Weiss, 2003). Children who are nonverbal or have lower levels of speech have higher incidences of SIB or problem behavior (Baghdadli et al., 2003; Carr & Durand, 1985; Chiang, 2008; Foxx & Livesay, 1984; Rattaz et al., 2015; Talkington et al., 1971). This research, as well as the lack of supports and appropriate services for non-verbal individuals with ASD, led to the inception of Visual Communication Analysis (VCA).

VCA is an application of Self-Determination Theory (SDT). SDT is a theory of intrinsic motivation that is founded on three main tenets: autonomy, competence, and relatedness (Deci & Ryan, 1985). Researchers Deci and Ryan (1985 & 2000) found conditions that support an individual’s experience of autonomy, competence, and relatedness tend to foster a high quality of motivation and engagement for activities, including enhanced performance, persistence, and creativity. As a result, instead of using an external reward to get a child to perform a task, VCA creates conditions that support the child's experience of autonomy, competence, and relatedness in order for them to be intrinsically motivated to complete tasks. Within the VCA framework, the use of external rewards or punishment is heavily disfavored and never utilized. VCA gives children a variety of choices when learning in order to develop their intrinsic motivation, which is reinforced through presumed competence.

Within the VCA framework, each child receives personalized treatment to ensure that they are provided with tasks at the optimal level of difficulty, which helps to maintain engagement and excitement. Relatedness support includes providing unconditional positive regard, consistent with the Rogerian approach by withholding negative feedback, as well as using technology that provides a method of errorless learning in accordance with SDT principles. Children are met with empathy, their needs are recognized, and instruction is given in a consistently warm and interpersonal environment. The technology used in accordance with VCA therapy incorporates the principles of SDT to further meet the child’s needs for autonomy, competence, and relatedness while enhancing their intrinsic motivation.

VCA combines SDT principles in combination with visual supports, prompting, and technology-aided instruction and intervention, all evidence-based strategies that are commonly successfully used to support children with Autism (Wong et al., 2015). Technology-aided instruction and intervention are evidenced-based practices shown to support social skills, communication abilities, reduction in behaviors, and school-readiness in students with ASD (Odom et al., 2015). Several studies have found that individuals with ASD preferred the use of technology to teacher-led instruction or pen and paper. Technology usage has been further shown to increase attention and engagement and decrease problem behavior (Sankardas & Rajanahally, 2017; Travers et al., 2011).

The purpose of this study was to examine the efficacy of VCA in teaching nonverbal children with ASD to communicate, as well as VCA’s efficacy in decreasing maladaptive behaviors. The researchers hypothesized that children would learn to type independently (without “facilitation,” “handover-hand,” or any other physical assistance) through the usage of VCA. Researchers also hypothesized a decrease in maladaptive behaviors, particularly in conjunction with increases in functional communication.

2. Method

2.1. Participants
Participants for the study were recruited from new clients at Alternative Teaching Strategy Center (ATSC). Participants were selected to be in the study if they met the following inclusion criteria: (1) had a diagnosis of ASD; (2) had a diagnosis of intellectual disability; (3) had no functional communication ability; and (4) they had never been exposed to independent typing. Participants were recruited over a 16-month window starting in June 2018. There were four males and two females included in the study. Table 1 summarizes the demographics of the study participants. School
Table 1. Summary Demographics of participants

| Participant | M/F | Age at start (years) | Ethnicity       |
|-------------|-----|----------------------|-----------------|
| A           | M   | 6.0                  | Hispanic        |
| B           | M   | 10.5                 | Asian           |
| C           | F   | 9.8                  | Asian           |
| D           | F   | 13.5                 | African American|
| E           | M   | 13.5                 | African American|
| F           | M   | 12.7                 | Caucasian       |

Each participant had a minimum of 45 sessions. Sessions consisted of two hours of individualized instruction, five days per week, for a minimum of nine weeks. The records used in the study included therapy notes, school records, videotapes of sessions, and detailed, computer-recorded timestamped data of participant usage of the VCA software.

2.2. Procedures

Researchers obtained consent for services, data collection, and video recording from legal guardians of each child. All children who participated in the study did so for at least two hours per day, five days per week, for nine weeks. Each child was treated individually in their own room, accompanied by one to three therapists depending on the severity and eventual decrease of the child’s initial maladaptive behaviors. Each room had no decorations and contained a desk, chairs, and whiteboard, along with a video camera used to record the entirety of the session. Every participant was additionally given unconditional access to snacks, water, and breaks as needed or desired. For initial sessions, each participant was also given unconditional access to comfort items such as cuddly toys, music, or YouTube videos.

Each session consisted of the assigned therapist(s) giving the participant a set of tasks to perform, across a variety of domains, using software specifically tailored for VCA, on an iPad. Therapists were rotated across participants to minimize therapist bias and effects. The technology in this study included iPads with application software that is routinely used at ATSC. No external rewards or token systems were used. The software recorded every interaction the child made on the iPad—a more efficient method than the typical data collection process; it additionally removed any perceived negative feedback and pressure that many children feel when therapists manually record data. The data taken by the software were stored on a server and later used for analysis in this study.

Each therapist was trained in the tenets of SDT and utilized these to give the participants personalized choices in their learning. One important prediction of SDT is that humans have an innate propensity to perform novel tasks (González-Cutre et al., 2016). As such, therapists were encouraged to combine their provision of choices with presentation of novel tasks as part of those records for each participant indicated that each had never been able to complete any standardized intellectual assessment, resulting in a diagnosis of intellectual disability. While these researchers do not believe IQ tests should be associated with cognition in children with autism, school districts commonly use IQ and achievement tests, limiting researchers’ baseline data. The average age of participants was 11 years old. As such, they each previously had numerous years of attempted intervention. Besides behavioral goals, the school goals for each child no longer included academic goals and only included functional goals. The only exception was Participant A, who had no goals other than behavioral goals, since he was so violent when at school that the school believed that he could not be taught. This, coupled with each child’s diagnosis of intellectual disability, indicated a previous lack of progress in learning any academic material, especially in regards to language abilities such as in recognition of letters.
choices. All of the tasks presented were a combination of matching and typing tasks, where all instructions were presented simultaneously both orally (by the therapist) and visually. There were at least four types of different matching tasks that were utilized depending on the child’s abilities. The first was picture-to-picture matching, where five target photos were presented simultaneously on the top and bottom row of the iPad. The child 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 software used automatically randomizes which photos from the total pool of available photos are presented on each level, based on a preselected list of desired words to teach, 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 child with a single photo and having them type the word corresponding to the photo—for instance, the child was prompted to type “apple” when presented with a photo of an apple. On Level 1, the child 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 child 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 child was instead provided with a “help” button that would flash the silhouette of the correct spelling of the word for two seconds. Every child started typing on Level 1, and depending on performance, progressed to Level 2 or 3.

At the therapist’s discretion, if a task seemed too easy for the child, the child was moved up to the next level and if it was too difficult, they went back down a level. All words were initially presented in upper case only. If the child showed improvement with this method, words were additionally presented in lower case. Finally, if improvement was shown in both, the case was randomly selected by the software each time a new task was loaded. As the child progressed, the answer to the typing question was changed from a single word to a full sentence: for example, “this is an apple” or “this is a green apple” or “the apple is green.” Academic content areas included nouns, calendar, colors, shapes, numbers, counting, life cycles, money identification, following directions, and visual perception. The children were allowed to partake in the selection of a particular content area. The content in many of these applications were customizable to include categories of words that a child tended to prefer working with (such as insects, vehicles, food, etc.), and prompting was individualized to support each child’s level of difficulty and need. Additional choices available to the children were the order of lessons, how long to work on each task, and control of the external environment. Each child was allowed to stand or sit on a chair or on the floor. The lights in the room could be on or off depending on the child’s selected preference.

In order to maintain engagement and ensure progress, novel tasks (e.g., the object changed to one the child had never seen before, the letter case changed in a way the child had never seen before, the answer changed from a word to a sentence in a way the child had never seen before, etc.) were continually presented to the children. Additionally, as time went on, the tasks presented generally became progressively more complex. This data is presented in Table 2. Table 2 also illustrates the total number of data points captured, giving an indication of the speed at which different participants interacted with the iPad over the same number of sessions.

2.3. Dependent variable

The use of correct rates as a dependent variable is well known in research. In Eckert et al.’s (2002) research of reading fluency, researchers used words correct per minute as the dependent variable. Gary et al. (2004), used digits correct per minute as the dependent variable in their study of 2 × 2 digit and 3 × 3 digit multiplication. Rhymer et al. (2002) used problems correct per minute as the...
dependent variable in their study of interventions in increasing math fluency, and McKenna (2011) used digits correct per minute in a study of interventions to teach linear algebra.

Similarly to teaching linear algebra, where the concept is the same but the task presented is different, teaching typing across different domains is a similar concept, but where the tasks presented are different. Therefore, in order to optimally investigate typing fluency, the dependent variable used in this study is letters correct per minute (LCPM). During each session, each participant was given the opportunity to type different words, and each eventually progressed to typing partial and full sentences. 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. The total number of data points for individual letters typed per child is indicated in Table 2. The total number of data points collected for the study was 216,652. Each one of these stored data points was used in the calculation of LCPM.

Digital video recording of the first three and last three sessions of each child’s participation in the study were used to determine behavior counts. Behaviors were outlined in an ethogram and three therapists were assigned to count behaviors. The behaviors that were counted included pinching, pulling hair, grabbing, eloping, hitting, scratching, biting, kicking, and damaging equipment. Each therapist was able to rewind and watch video in slow motion in order to verify behavior counts. The dependent variable for behavior is the average count of behaviors over each of the three sessions.

2.4. Independent variable

The independent variable for the study on correct letters per minute was the instruction time each child received. Since the software automatically timestamped and stored every interaction with the iPad, the time elapsed between interactions can be calculated. An interaction is any touch on the screen of the iPad. If the time elapsed is small enough, then the child is paying attention. If the time elapsed is large, then the child is no longer paying attention and is therefore not receiving instruction. The choice of the bound for this calculation is similar to the choice of a step size in numerical integration, i.e., the smaller the value, the smaller the approximation error. However, unlike numerical integration, if the bound gets too small, the error increases since the child may be thinking and still paying attention but not interacting with the iPad.

For this study, the bound was set to 60 seconds or 0.00069 days, so if the elapsed time between two interactions on the iPad is less than 60 seconds, then the child has attended for that period of time. For comparative purposes, the average elapsed time between interactions was calculated for each child and the minimum was 5.3 seconds and the maximum was 31.9 seconds. The average break time was also calculated for each child. The minimum break time was 208 seconds and the

| Table 2. Distribution of new tasks per participant |
|-----------------------------------------------|
| **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** |
| A | 4.69 | 17 | 1 | 9,426 |
| B | 49.84 | 97 | 18 | 42,369 |
| C | 17.32 | 68 | 1 | 15,548 |
| D | 85.44 | 161 | 18 | 61,101 |
| E | 62.70 | 135 | 3 | 64,739 |
| F | 40.37 | 89 | 10 | 23,469 |
| **Average** | **43.39** | **94.5** | **8.5** | **36,108** |
maximum was 447 seconds. It is interesting to note that, in general, the children with the minimum average interaction time were the children with the greatest average break time.

Therefore, a bound of 60 seconds is more than accurate for this study. Thus, the independent variable for each day was set to the sum of elapsed time changes up to that day, i.e., the cumulative instruction time up to that point.

2.5. Study design
A multiple-baseline across subjects design was used in this study since learning to type is an irreversible condition and therefore not suitable for an A-B-A type design. Further complicating the design is the fact that during intervention a stable terminal state can never be reached as the tasks presented are constantly being modified in order to maintain engagement, and so there will always be fluctuations in the child’s ability to type. As a result, visual analysis of the study data is inappropriate, and thus statistical tests were employed to test results.

Since learning to type is irreversible and each child was selected with no previous experience typing, the baseline for each child was verified using school records. Since it is not possible to test typing skill without teaching them to type, any attempt to measure the baseline would influence future measurements and contaminate the willingness of the children to participate in the study. Therefore, the stable baseline measured over a period of years for each child was that they were unable to type.

Since the LCPM in this study is auto correlated due to the connection between day-to-day typing abilities, a time series was used to analyze the data. The model used was a variant of ARMAX, which is regression on an exogenous variable with autoregressive moving average (ARMA) errors. The reader is referred to Mills (1990) and Hyndman (2010) for a more comprehensive explanation of the ARMAX statistical method. Since learning is not a smooth process, the series, LC, was set equal to the 5-day moving average of the LCPM that was calculated every day. This series was then regressed against the cumulative instruction time for all tasks received to that day (Equation (1)) and the intercept was set to zero to reflect the baseline of each participant. The errors were then modeled as an ARMA(1,0) process (Equation (2)) where LC is the 5-day moving average of LCPM on day i, Ii is the cumulative instruction time in days as measured on the iPad, ui is the regression error term at day i, ϕ is the autocorrelation coefficient, and εi is a normal error term. Using a model of this form allows for the determination of given that the process is auto correlated.

\[
LC_i = \beta \cdot I_i + u_i
\]  
\[
u_i = \phi \cdot u_{i-1} + \epsilon_i
\]

The advantage of this model is that it allows for the usual interpretation of the regression coefficients, meaning that we can statistically determine the relationship between the dependent and independent variables.

At the conclusion of the analysis of the multiple-baseline across subjects, a random effects meta-analysis on correlation was used to aggregate the results of the individual studies to determine the overall effects of the combined study.

3. Results
By design, the results of each participant were analyzed separately. The data were extracted from the database and an ARMAX analysis was performed on the data for each participant. The first step was to ensure that the time series was stationary for each participant. This was accomplished by examining the absolute values of the complex roots of the resulting AR(1) equation and verifying that it was greater than 1.00. As long as the absolute value of the roots of the equation are greater than 1.00, i.e., outside the unit circle, the process is stationary. The results of each of
the ARMAX analysis summary statistics are shown in Table 3. As can be seen in these tables, each of the studies was stationary and statistically significant.

Table 4 shows the solution coefficients for the regression equation (Equation (1) above) and the coefficients for the ARMA(1,0) process (Equation (2) above) in separate rows for each participant. In addition to the value, the standard error, calculated t-test and statistical significance for each parameter is listed on the same row.

Each of the above studies can be considered as investigation of the typing efficiency of each participant when presented with a random task measured against the amount of instruction they have received. A random effects meta-analysis on correlation was performed using Hedge’s methods (Hedges & Vevea, 1998). Using the correlations for each study listed in Table 3, the between study variance is calculated to be 0.40 and using Fisher’s r-Z transformation, the mean effect size is 1.089. The standard error of the mean effect size is 0.267. Therefore, a 95% confidence interval [0.45, 0.91] of correlation indicates a consistent positive effect of VCA-based instruction on typing efficiency.

Three therapists determined behavior counts. Interrater reliability for the therapists’ counts was determined by using the video recordings of a session of three different children. The recordings were divided into 30-second intervals and the behavior identification for each therapist was recorded per interval. Reliability was measured using Gwet’s AC2 instead of kappa; since it does not require independence between observations and accounts for observations where there is at least one rater, resulting is a better statistical measure. Including the intervals with no behaviors observed, the Gwet’s AC2 was 0.856 with a 95% confidence band of (0.833, 0.879). Removing intervals with no behaviors observed, the Gwet’s AC2 was 0.860 with a 95% confidence band of (0.761, 0.959).

Table 5 describes the average behavior count (including self-injurious behaviors) taken over three sessions at the beginning and three sessions at end of the study. It should be noted that the observed baseline behavior counts for each of the participants were lower than those reported on their Individualized Education Plans.

A paired-samples t-test was conducted to compare the average count in behaviors before and after treatment. There was a significant difference in the scores for baseline behaviors (M = 8.1, SD = 9.46) and the post-treatment behaviors (M = 0.4, SD = 0.49). T(5) = 2.08 and the p-value is 0.046. The result of the t-test suggests that, at a 95% confidence level, the use of VCA does have an effect on the reduction of maladaptive behaviors.

Table 3. ARMAX analysis summary statistics

| Participant | Statistic | p       | R²   | Correlation | Characteristic Root |
|-------------|-----------|---------|------|-------------|---------------------|
| A           | F(1,40) = 1610.0 | < 0.0001 | 97.5% | 0.861       | 1.50                |
| B           | F(1,40) = 157.4   | < 0.0001 | 79.7% | 0.066       | 1.01                |
| C           | F(1,40) = 319.8   | < 0.0001 | 88.9% | 0.891       | 1.03                |
| D           | F(1,40) = 313.6   | < 0.0001 | 88.7% | 0.708       | 1.02                |
| E           | F(1,40) = 286.0   | < 0.0001 | 87.7% | 0.475       | 1.01                |
| F           | F(1,40) = 866.3   | < 0.0001 | 95.6% | 0.953       | 1.09                |
4. Conclusions

4.1. Interpretations

Researchers hypothesized that with the use of Visual Communication Analysis-based instruction, participants would learn to type independently. As reported above, the coefficient of regression for instruction time was positive and statistically significant for each participant, even though there was one participant who in the short study time did not progress beyond the first level of typing. Using a multiple-baseline design, and given that each of these studies occurred at different points in time with different therapists, the hypothesis of learned independent typing was supported by the data. In addition, the random effects meta-analysis confirm that there is a positive effect of VCA-based instruction on typing efficiency. The rotation of therapists was also significant as it helped to eliminate bias and addressed various threats to validity which could have affected the results and produced a Type I error.

These numbers not only represent learning and accuracy, but also the participants’ success with novel tasks. As displayed in Table 2 above, each participant engaged in new tasks and progressively more difficult tasks, during each session, while maintaining a relatively reasonable LCPM. This data challenges traditional approaches to testing and teaching children with ASD. All six of the participants from the current study were diagnosed with Autism Spectrum Disorder and were also

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Table 4. ARMAX analysis summary for variables predicting letters correct per minute

| Participant | Instruction Time | Coefficient | Std. Error | t-statistic |
|-------------|------------------|-------------|------------|-------------|
| A           | 2.25 ***         | 0.056       | 40.13      |
|             | Φ 0.67 ***       | 0.113       | 5.93       |
| B           | 7.08 ***         | 0.564       | 12.546     |
|             | Φ 0.99 ***       | 0.026       | 38.319     |
| C           | 5.08 ***         | 0.284       | 17.884     |
|             | Φ 0.97 ***       | 0.055       | 17.638     |
| D           | 20.20 ***        | 1.141       | 17.708     |
|             | Φ 0.98 ***       | 0.030       | 32.397     |
| E           | 12.54 ***        | 0.742       | 16.910     |
|             | Φ 0.99 ***       | 0.025       | 39.151     |
| F           | 4.85 ***         | 0.165       | 29.433     |
|             | Φ 0.91 ***       | 0.056       | 16.291     |

***p < 0.0001.

Table 5. Behavior counts

| Participant | Baseline Behavior Count | Final Behavior Count | Percent Decrease |
|-------------|-------------------------|----------------------|------------------|
| A           | 15.3                    | 1.3                  | 91.5%            |
| B           | 12.7                    | 0.7                  | 94.5%            |
| C           | 0.3                     | 0                    | 100.0%           |
| D           | 4.3                     | 0.3                  | 93.0%            |
| E           | 0.3                     | 0                    | 100.0%           |
| F           | 3.7                     | 0.3                  | 91.9%            |
| Mean        | 6.1                     | 0.4                  | 95.2%            |
| Std. Dev    | 6.39                    | 0.49                 | 0.04             |
diagnosed with Intellectual Disability. These participants attended different schools, and were diagnosed by different professionals in different fields. However, with the use of VCA, and with a maximum span of 45 sessions, all children showed an affirmatively positive ability to learn and to succeed despite being presented with progressively more difficult and complex tasks. This data is great news for parents, professionals, and educators alike, as it can inform the child's actual cognitive abilities, treatment plans and Individualized Education Plans (IEP), and most importantly, give each child a means to communicate through typing.

The researchers attribute the children’s willingness to progress through VCA with relatively minimal issue to the application of the Self-Determination Theory, which was embedded in all aspects of the applied therapy used in this study. The inability to communicate, such as through typing, may be a major source of frustration and can foster a sense of helplessness in many individuals with ASD, especially those who are non-verbal or minimally verbal. However, through the use of VCA, researchers hypothesize that the participants were able to feel a sense of autonomy, competence, and relatedness that produced the intrinsic motivation to continue to progress with the increasingly difficult sessions. The current study supports the continued need and use of applying well-established theories of motivation to the special needs population.

The use of technology in the current study is also noteworthy. Odom et al. (2015) conducted a meta-analysis of research regarding technology-aided interventions and instruction for adolescents with ASD, and found that only one focused on improving communication. With the increasing rise of technology aimed at supporting learners with ASD, educators, families, and clinicians should consider the use of technology within their current approach to interacting with children with ASD. Furthermore, unlike other attempts at teaching communication, the participants in the current study do not rely on a facilitator, letter board, or any kind of physical aid in order to type (and did not at any point during before, or after the study), making this therapy one-of-a-kind in terms of giving children complete autonomy and control.

Lastly, researchers also hypothesized a decrease in maladaptive behaviors over time, which was also supported by this data. This is particularly important since as of yet, there has been no formal, efficacious treatment that is effective for treating maladaptive behaviors in populations of children with ASD and co-occurring conditions of intellectual disability, as well as those with limited or non-verbal communication. Results from this study also support various other studies that have found a correlation between the lack of functional or adaptive language and the presence of maladaptive behaviors (Baghdadli et al., 2003; Chiang, 2008; Matson et al., 2009; Murphy et al., 2005; Richards et al., 2012; Weiss, 2003). Previous research has noted a decline in maladaptive behaviors and self-injurious behaviors when children are equipped with functional communication skills (Baghdadli et al., 2003; Carr & Durand, 1985; Chiang, 2008; Foxx & Livesay, 1984; Rattaz et al., 2015; Talkington et al., 1971). The current study found results consistent with other research, which highlights the importance of teaching this population to communicate on their own. One other surprising result was that 50% of the participants either started verbalizing or using language.

4.2. Limitations
One limitation of the current study is the small sample size. While the sample size is limited to six participants, the effect size is statistically significant. Additionally, these six participants in particular had tried various therapies and interventions in the past, all unsuccessful and all consistent with an intellectual disability diagnosis which essentially predicts a plateau in their ability to progress. Therefore, while researchers cautiously draw conclusions from the current study, the data is promising.

Another limitation of this study is that researchers are unable to accurately assess any influence from past therapies. All participants with ASD had received two or more different types of therapies and treatments from various other service providers prior to the study. Given the baselines of both behaviors and LCPM, researchers do not believe there was any significant and possibly not even any negligible influence from these past therapies. This is because these prior therapies had not aided any
of the participants in making any significantly relevant progress, as all participants started near a bottom baseline of learning. However, researchers have no means of measuring such a construct.

Similarly, the median age of participants is 11 years of age. Therefore, researchers are not able to account for differences in age, and were unable to test the efficacy of VCA in very young children within the parameters of this study. Other unpublished evidence suggests VCA may be efficacious in preschool-aged children, since VCA was piloted at a public preschool for children with autism and other special needs. However, this data was not included in the current study.

Lastly, it is important to note that the current study only assessed the first 45 sessions. Therefore, while results indicated positive results in terms of reducing maladaptive behaviors and improving communication via typing, the data cannot assess for long-term effects. These 45 sessions were only the beginning of these participants having exposure to VCA. As such, future progress or even potential regression cannot be noted at this time. Furthermore, while throughout the current study, participants were taught to begin to generalize the skill of typing to other devices and applications (e.g., cell phones, notes, text messages), this was not formally measured and therefore cannot be assessed at this time.

4.3. Future directions
This research proves to be very promising not only for the Autism community but for various other populations as well. The use of VCA may be able to serve those with various other neurodevelopmental disorders or learning disorders, and even English as Second Language (ESL) students. VCA has applied research on brain function and coupled it with Self-Determination Theory in technology as well as in the delivery of services. This innovative therapy could be expanded for use in various regional centers, special education classes, jump-start classrooms, etc. Future studies can attempt to recruit younger children with Autism Spectrum Disorder in order to assess efficacy within this age group. A future study can also attempt to discover the reasons for the increase in verbalizations and use of spoken language that were observed with the use of VCA.

Funding
The authors received no direct funding for this research.

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Disclosure statement
On behalf of all authors, the corresponding author states that there is no conflict of interest. Authors received no direct funding for this research.

Citation information
Cite this article as: Visual communication analysis (VCA): Applying self-determination theory and research-based practices to autism, Gary Shkedy, Dalia Shkedy, Aileen H. Sandoval-Norton & Grace Fantaroni, Cogent Psychology (2020), 7: 1803581.

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