**Software-based cognitive therapy intervention targeting core symptoms in
Autism: A single case study**

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ABSTRACT

This study demonstrates the use and effectiveness of an online digital cognitive therapy platform to target core symptoms of Autism. A single case study of a nine-year-old subject is presented who underwent a 15-week cognitive and reading therapy intervention using software-based gameplays. Pre- and Post-intervention assessments show marked improvement in word reading, handwriting, sentence reading fluency and comprehension skills. In addition, the Parent observed positive behavioural changes in social engagement, self-control, improved motor skills, improved tolerance of sensory load, reduction in irritability, hyperactivity and aggressiveness. The study indicates that a short, digital, game-based cognitive therapy and reading training of letter-sound correspondences and word-level reading can boost the reading development of struggling readers in Autism. Such an option is beneficial for effective and meaningful engagement-based remote learning for neurodiverse populations. This case study is the first step in developing a community-based program for engaging parents in providing intervention to their children using simple to using online digital cognitive therapy.

Keywords: Autism Spectrum Disorder, Online Cognitive Therapy, Community Based Intervention, Digital Therapeutics

INTRODUCTION

Autism spectrum disorder (ASD) is a developmental condition characterized by a broad range of challenges in social interactions, repetitive behaviours and communication skills.

Many people across the spectrum present a wide range of learning and reading challenges and require significant support in learning to read and communicate effectively. ASD presents a mounting challenge amongst the many development conditions diagnosed across the globe in young children. With the increasing availability of diagnostic tools, a wider prevalence of autism is being acknowledged. According to the Centers for Disease Control and Prevention (CDC), 1 in 54 children are being diagnosed on being the spectrum in the United States (CDC, 2020).

With increasing numbers, there is an additional burden of personal one-to-one therapy for rehabilitation. Following the exponential growth of internet access throughout the world, internet-based delivery of cognitive therapy can potentially reach far corners of the globe. A digitally accessible healthcare delivery platform can reduce treatment and personnel costs, long wait-lists and alleviate limited access to specialized therapists in remote regions. In a global lockdown scenario that the world witnessed in 2020, such a delivery method could be the perfect solution to home-bound parents and therapists who care for children and teenagers with special needs. Flexible timings help provide for a higher number of sessions.

Internet-based cognitive behavioural therapy literature has multiplied over the years with varying degrees of guidance or support offered to subjects through web-based programs. In recent years, software-based cognitive therapy to remedy learning and communication disabilities is also receiving attention from therapists and users. Amongst many advantages, a software-based therapy, when augmented through state-of-the-art Artificial Intelligence, enables unbiased cognitive training exercises in a gamified environment, where results are tracked and reported automatically. Different subjects receive different difficulty levels, multiple times as and when needed. Therapists can readily deliver such software-based therapies in medical rehabilitation centres, hospitals, special education centres, traditional schools, and homes.

It is known that children with Autism benefit from early intervention, and a community-supported intervention including parents, care providers, medical experts and special education providers help provide effective support. Online delivery of cognitive therapy often does not require sophisticated software and has high usability for children and people with learning difficulties. Here we present a case study of a young child diagnosed with ASD and report substantial improvement in the child's communication and comprehension abilities following artificial intelligence-based cognitive and reading therapy, delivered using software running on a computer.

Case Description: This case study was performed under informed parental consent.

Subject (AT) is a nine-year-old boy diagnosed with Autism Spectrum Disorder (ASD) in accordance with the DSM-V criteria. AT's mother reported he had febrile convulsions as an 18-month toddler. At age four, AT was diagnosed with ADHD and at 6.5 years old when diagnosed with ASD. There were no developmental delays in motor activities (crawling, standing and walking) but showed delayed pronunciation until four years. AT shows atypical social interaction and behaviour, sensory overload, irritability, hyperactivity, and limited motor skills. He shows little verbal communication, has a speech delay and tends to be either silent or repeat in monosyllables. At times, he used certain phrases in a repetitive manner when describing an event or with something irrelevant. He also couldn't sit in one place and was unable to write or grip a pencil at 3.5 years of age. As a result of his limited communication skills, AT can only manage skills at the level of grade 1 and 2, with difficulty, compared to typically developing children of his age with skills at grade 4 school level.

In addition, AT exhibited sensory processing overload, many symptoms of anxiety, obsessive-compulsive disorder and attention deficit hyperactivity, and limited self-regulation skills with little awareness of the social contexts and norms. AT showed a lack of interaction and teamwork, and his behaviour was like a very animated character (constantly making faces), anger management issues and disproportionate interest in digital gadgets and concepts. He often appeared to be non-engaged and responded inconsistently.

Standardized tests: AT was assessed by a qualified specialist, and his Stanford Binet test scores of IQ were within a normal range (score: 90+/-). He was also examined on the Childhood Autism Rating Scale - High Functioning Version (CARs-2 HF) with a Score 28, which refers to moderate and straightforward behaviours associated with autism. Speech and phonological disorders test (CAAP) showed no major issue with speech production and hearing, except difficulty reciting a sequential story and re-reciting basic details. He was asked to undergo speech and language therapy. He was diagnosed with Autism Spectrum Disorder, with additional observations such as lower mental age than his chronological age. Based on this diagnosis, AT was recommended to undergo behavioural therapy for autism, occupational therapy, assistance with academic skills development program and individual education plan. In addition to the above, AT's Parent decided to use a software-based cognitive therapy intervention. Following informed consent and enrolment procedures, detailed training was provided to the parent to use the software at home. The parent was asked to provide qualitative assessments and complete a survey questionnaire to evaluate the pre and post-intervention changes in the subject.

Intervention: Our proprietary online digital therapy software uses neuroplasticity and psychological principles of engagement to deliver the easy-to-use intervention. Cognitive Therapy (CT) has nine gamified plays backed by our patent-pending algorithms to target various visual and auditory pathways involved in reading and word comprehension. These sessions are one hour each and are administered via a computer. AT did the one-hour gameplay session three times per week for 15 weeks. Reading Therapy (RT) has several reading comprehension passages that target reading speed and comprehension skills. Audio visual feedback (delinked with the subject's performance) during the gameplay facilitated engagement and completion of levels to move to the next. Figure 1 shows the engagement levels of the user with the gameplays during the Cognitive therapy sessions.

Our online therapy software offers cognitive therapy to enhance fluency and comprehension by targeting the visual word recognition mechanisms and auditory pathways involved in symbol-sound mapping. Different gameplays with varying levels of difficulty, targeted the synaptic connections wherein relevant cognitive pathways are strengthened, thereby

boosting phonemic awareness, decoding skills and language structure using predictive analytics.

Figure 1: Engagement levels during the gameplays in the Cognitive Therapy (CT) sessions.

RESULTS

Reading and Writing Skills

A pre-post intervention was designed to engage the parent in assessment and obtaining actionable results to motivate the user. To understand auditory and visual processing and its impact on reading and writing, a test of reading for five minutes, a test of copying text for five minutes and a dictation test for five minutes using a grade-level text was completed. Each of the three tests, the total number of words and errors were counted before and after the intervention. Result serves as an immediately actionable behaviour-modifying incentive to the user. Figure 2 shows the example of changes in handwriting skills of AT before and after the intervention.

Figure 2: (A) Shows AT's handwriting example pre-intervention. (B) shows AT's Handwriting post-intervention. (C) graph showing changes in reading and writing skills pre- and post-intervention.

Behaviour

A survey adapted from Cohen-Mansfield Agitation Inventory (CMAI) was used to assess behavioural symptoms. The mother made all observations over nine months duration. AT showed significant improvements in his communication abilities in comprehending the content and appropriately tailoring his responses. Table 1 and Figure 3 demonstrate improvement observed for each of the parameters.

Behaviour	Pre-Intervention	Post-Intervention
Hitting (including self)	6	2
Kicking	3	2
Grabbing onto people	6	2
Pushing	5	2
Throwing things	6	2
Biting	2	1
Scratching	2	1
Spitting	3	1
Hurt self or others	6	2
Tearing things or destroying property	4	2
Making physical sexual advances	4	2
Paces, aimless wandering	6	2
Inappropriate dress or disrobing	4	2
Trying to get to a different place	1	1
Intentional falling	1	1
Eating/drinking inappropriate substances	1	1
Handling things inappropriately	6	2
Hiding things	1	1

Hoarding things	1	1
Performing repetitious mannerisms	6	2
General restlessness	6	2
Screaming	6	2
Making verbal sexual advances	4	2
Cursing or verbal aggression	6	1
Repetitive sentences or questions	6	2
Strange noises (weird laughter or crying)	6	2
Complaining	6	2
Negativism	2	1
Constant unwarranted request for attention or help	6	2

Table 1: A survey adapted from Cohen-Mansfield Agitation Inventory (CMAI) to document changes in AT before and after digital cognitive therapy.

Figure 3: Graph showing changes in CMAI pre-and post-intervention scores for AT

Core symptoms of Autism

A journal entry method was used to document changes in core symptoms of autism. AT's mother kept a regular diary and maintained a blog to write all the periodic changes observed in AT during the intervention, starting right after the 7th cognitive therapy session. All

observations were characterized under symptomatic measures of irritability, disruptive behaviour, hyperactivity, sensory overload, language, aggression, reading, speaking, writing, eye-hand coordination and grouped as '*core symptoms of autism.*' These measures were ranked by giving scores 5= Most severe (major problem), 4= Severe problem, 3= Moderate problem, 2= Minor problem, 1=least severe (not a problem) (see Figure 4).

Following table 2 is a consolidated summary of observations by the parent during the intervention and four months after.

Measure	Pre-Intervention (please indicate by giving a score 5-1)	Post-Intervention (please indicate by giving a score 5-1)	Remarks
Irritability	5	1	Considerable reduction in irritability, more agreeable personality.
Disruptive behaviour	5	1	<p>Prior to the online software therapy, AT's behaviour was extremely disruptive in class and formal settings as well as informal settings like parks and play areas, often picking up fights with other children. In classroom setting he would finish his work in ten minutes and start disturbing other children not yet finished, or go sit and swivel in teachers chair, and if he did something unpleasant he would say sorry I will never do it again, and next milli second he is doing the exact same thing again, so his teacher complained saying she believes AT does not do things intentionally but it is something he cannot help.</p> <p>Post online software therapy, since AT has better impulse control and self-regulation and able to think before he acts he is much better behaved and disruptive behaviours even in classroom setting is minimal.</p>
Hyperactivity	5	1	Prior to the online software therapy, hyperactivity was severe problem for AT as he was unable to sit still or remain seated in any setting, constantly running through aisles in supermarkets, and corridors in airports, hospitals, clinics, often banging carts into other people's carts in supermarkets, climbing up and

			<p>turning off the freezer lights in the poultry sections in hypermarkets, pressing all red emergency buttons wherever he saw them, running off into the roads impulsively without looking at high speed while chasing cat or bird in the park , jumping off sofas when guests came.</p> <p>Post online software therapy, AT is finally able to sit and remain seated in waiting rooms, walk in the supermarket and not run off, more interested in reading and observing signs than pressing buttons or crashing carts in hypermarket. Much easier to take him out anywhere.</p>
Sensory overload	5	1	<p>Prior to the online software therapy, AT had severe and debilitating form of hyper-sensitivity to loud music, car horns, children shouting in a distance, often dealt with by refusing to come out of the car or stopping the music or swearing at cars that are honking going ballistic. Heightened sensitivity to even some forms of light music as that in a lift or every time the 'Happy Birthday' song is sung at a birthday party, even for his own birthday he would run away as he couldn't stand it.</p> <p>Post online software therapy, I have not seen him put his fingers in his ears again, I can take him outside to even heavily crowded places easily and with less anxiety without any major tantrum and for longer time periods and he happily tolerated the 'Happy Birthday' song being sung for him in his 9th birthday in August 2020 :).</p>
Social interaction	5	2	<p>Prior to the online software therapy, AT had severe interaction issues due to sensory overload, inability to express himself and communicate properly, impulsivity and waiting for his turn, frustration and aggression due to his problems and social anxiety. His school social worker described him as saying "He doesn't even know how to play with kids."</p> <p>Post online software therapy, AT is much better able to interact with teachers and school mates as he can understand and follow instructions, communicate and carry a conversation with others, better self-regulation and impulse control, and though there is still some more improvement that is desired before AT can socialise freely like normal children, he is at least able to remain seated in a group setting and</p>

			participate as opposed to running off and wandering alone . Though he does occasionally say "Hey why are you staring at me!"
Language	5	1	<p>Prior to the online software therapy, AT could speak good English fluently, however, he was often unable to express himself and communicate efficiently, For instance he would only talk about things that interested him non-stop, however, if you asked "How was your day at school?", or even "How are you?" , he could give the appropriate response to any question asked, almost as if he either didn't hear the question or remember it and continue talking about what he was talking. He never had any speech therapy or any problems pronouncing any sounds, he could fluently repeat whatever he heard on tv of interest to him, but totally incapable of carrying a conversation with another person except a one-sided one where only he talks about his favourite toy.</p> <p>Post online software therapy, AT is able to process instructions and questions and give appropriate response to questions asked and carry a conversation with people. It is almost a miracle as before it seemed he lived in a world of his own, but now that he can communicate and interact. It seems as if he has become aware of the real world around him and his becoming verbal a big milestone in overcoming his most serious Autism/ADHD symptoms. Most autistic parents only ever dream of the child becoming verbal and communicating.</p>
Aggression	5	1	<p>Prior to the online software therapy, AT had very poor self-regulation due to inability to control his impulses, or think before he hits or throws something at others for no presumable reason. AT by nature was not aggressive and harmful and tending to hit others or himself, but if he got even slightly irritated due to his sensory, anxiety, inability to express himself issues, or think he's being made fun of, he could act aggressively and often when i took him to park he was get himself into trouble with group of kids often ganging up to hit AT and punch him in parks and McDonald's play areas, though I was never sure what started these major fights. So due to his issues AT did depict violent behaviour in several instances. I often got instantly slapped on my face if I commented on his favourite Transformer characters if he didn't like the comment, and on couple of occasions was almost</p>

			<p>hit by a whiteboard which just missed my eye, and his hitting reaction was so fast and unexpected , there was no time to me to take cover. He would also remember instances where he bore grudges and took revenge later in the day or next day. For instance he slapped (almost boxed) my housemaid very hard on her face on two or three instances when she was busy doing something else, totally unexpected by her.</p> <p>Post online software therapy, AT is able to think before he hits and there is time to reason with him. It is almost as if he now understands the consequences of what he is doing so therefore is less aggressive and more importantly considerably less violent. Though I still hear some complaints of him pushing some kids in the sports period in school, they are as per the school manageable issues and do not happen in classroom setting.</p>
Reading	3	1	<p>Prior to the online software therapy, AT could read well, however, his reading comprehension was extremely poor.</p> <p>Post online software therapy, AT reads much more fluently and confidently, doesn't lose track of where he is reading and reads with understanding and comprehension.</p>
Speaking	4	1	<p>Prior to the online software therapy, AT as explained above in 'Language', he could speak well, however, he could not communicate well (i.e. understand a question and respond appropriately to it.) Most of his speaking was copying or imitation pr repetition and he was completely incapable of a two -way interactive conversation. Being unable to carry normal conversation with AT, he often came across as an immature for his age as he often imitated cartoon characters like Sponge Bob.</p> <p>Post online software therapy, AT seems more mature enough for his age as he seems to understand what is being said to him and respond accordingly, express himself, carry a two way conversation with his teachers and parents and siblings, seems he has come out of his world of cartoons into the real world around him.</p> <p>Thanks to the online software therapy AT is now verbal and it is nothing short of a miracle!</p>

Writing	4	1	<p>Prior to the online software therapy, AT had severe difficulty starting to write, but did so with much efforts from parents, therapists etc, but due to formal education gap , he quickly forgot how to write within lines in small and neat handwriting.</p> <p>Post online software therapy, AT is able to write neatly within lines and small in organised manner with less spelling stakes again.</p>
Eye-hand coordination	4	2	<p>Prior to the online software therapy, AT had great difficulty catching a ball, often fell down, dropped things, great difficulty buttoning and unbuttoning shirts and hooks, wearing shoes independently.</p> <p>Post online software therapy, he able to perform these tasks almost independently with little or no assistance and swiftly.</p>

Table 2: Changes in symptomatic measures reported by the parent. No editing was done to maintain the integrity of parent notes.

Figure 4: **Changes in core symptoms of Autism.**

5= Most severe (major problem), 4= Severe problem, 3= Moderate problem, 2= Minor problem, 1=least severe (not a problem)

DISCUSSION & CONCLUSIONS

The present case study focuses on several modifications used in the treatment of a 9-year-old boy with autism. Continued audio and visual feedback during the gameplay (delinked with the subject's performance) encourage engagement and completion of levels to move to the next. Our online software therapy brought about significant changes in AT's reading and comprehension skills. He learned about phonemic awareness, decoding skills and language structure using predictive analytics engagingly using different gameplays.

In contrast to inferential statistics used in group research, single-subject study relies more on plotting the data and examining the changes and trends. From Figure 2 and Figure 3, it is evident that the online therapy intervention brought about considerable changes in most of the behaviours. A gradual reduction of problematic behaviour is visible in the trend across the conditions. Finally, it is noteworthy that such a trend is visible in the scores within a short period, thereby demonstrating quick changes brought through the intervention. Per Fisch (2001) and Scruggs et al. (2001), the mean and standard deviation in AT's scores for each behaviour is computed and compared, and a t-test is conducted showing significant improvement across all behaviours following the intervention ($t(28)=7.38$, $p<0.001$).

Following the cognitive therapy sessions, AT could carry a Skype conversation with his father for the first time on Skype. This shows a marked improvement in AT's communication skills as he could never have conversations with anyone else except with his mother.

Following the online software therapy intervention, AT could sit through a noisy party environment with loud singing crowds without any sensory discomfort. AT showed better self-regulation in public, has started tuition classes with other children and exhibited a lot less anxiety in groups. He reported sharing his lunch with a new friend at school. AT's mother reported a significant change in his social behaviour that AT shook hands and greeted an acquaintance in a crowded new year hypermarket. It should be noted that AT was still not completely comfortable with people making eye contact with him.

AT was also learning squash and, as an early step, learns to catch a ball. Following the cognitive therapy, AT caught the ball three times in a row, a marked departure from his

inability to catch a moving ball or even simple throws. This shows improved sensorimotor coordination, likely due to improvement in the magnocellular function.

Finding effective solutions to address the core symptoms of autism (such as impairments in social communication and restricted, repetitive behaviours) remains a challenge at the individual, family and community level. As there are different combinations of the core symptoms at varying levels of severity, a combination of approaches such as in-person therapies, pharmacological treatments, community-level interventions, and digital therapeutics are recommended to address the issue.

Many pharmacological interventions in place have side effects and limited success (Farmer, Thurm & Grant, 2013). There is increasing recognition and demand for digital cognitive therapies to support people with ASD and ADHD. Accessibility is the top perceived benefit around using digital therapies, and our online cognitive and reading therapy software offers a suitable solution to address symptoms of ASD and ADHD. Engagement in the form of games that are fun to play, cost savings to therapists or caregivers by reducing dependence on in-person therapies and effectiveness due to regular use to improve symptoms are other advantages.

Cognitive therapy delivered through an online system on a computer serves the needs of busy parents and children in terms of ready availability as well as cost-effective intervention. There is a growing body of research evidence showing efficacy in remediation of learning and reading disabilities using the software as a service delivery platform (Ronismus et al. 2019). In a non-pharmacological intervention measure, we offer online cognitive therapy software that addresses most of the core symptoms of autism effectively and engaged.

The dual route cascade model of reading postulates that beginner readers use cognitive strategies differently from skilled readers. When learning to read, beginners use individual word identification and decoding as opposed to skilled readers that have automatized the word recognition to meaning as a rapid, effortless process. Much of the working memory in a beginner reader is overloaded with lower-order skills and is thus slower and can't transition to an automatized process. Based on neuroplasticity principles, our cognitive therapy training

targets the cognitive pathways that underlay reading and learning difficulties. Through the various gameplays, our training software targets the mechanisms underlying reading and comprehension, particularly the visual word recognition mechanisms and auditory pathways involved in symbol-sound mapping, working memory, and executive functioning.

Different gameplays target saccadic eye movements, tracking and attentional allocation at foveal and peripheral locations. Rotating octagons in the first gameplay targets visual perception composure, visual closure and ocular vestibular activation critical for reading. Targeting the auditory and visual cues help in attentional retraining, visual search training in different contrasts and cognitive flexibility to enhance working memory. In addition, visual placement and discrimination skills are improved. Delayed timing in some gameplays helps retain items in visual memory and in decoding skills. Elongated words provide an opportunity to process individual components of a word and then close the sounds to formulate complete words, thereby enhancing phonemic awareness and decoding skills.

One of the biggest perceived challenges around using digital therapies to address symptoms of ASD and ADHD include usability due to physical/cognitive limitations of persons with disabilities and Training/Education efforts required to learn how to use a digital therapy program effectively. It is estimated that a combination of therapist-guided and regular at-home use of digital cognitive therapies would be the most effective method to overcome the perceived challenges. It is likely that special schools mainly condition or modify the resultant behaviours rather than actively targeting the cognitive and neural pathways underlying the developmental conditions. A 2019 study demonstrated the benefits of behavioural therapy in autism at subsequent changes to the neural (white matter) tracts after 12 months (Saaybi et al. 2019).

As a community-based intervention, AT was supported by a specialist in an outpatient mental health setting. His mother, who is his primary caregiver, was keen on a structured teaching approach to building positive behaviours (such as social communication) and reduce unwanted behaviours (such as tantrums, aggression, and self-injury). Our online software therapy, targeting the cognitive and behavioural pathways, helped achieve significant improvements in AT. While research on this topic is relatively new, there is considerable

interest in community-based early interventions using digital therapeutics for neurodiverse populations across the globe.

From a community intervention point of view, data presented here from the parent-driven assessment is critical. In this case, the parent being the observer of the change in the child's behaviour, their satisfaction with the behavioural improvements, ease of use and the subject's engagement with the gamified therapy stands out as an essential tool. Parents are generally not trained to address autism-related behavioural issues; online software provides an opportunity for parents to engage in the therapy process.

At times when during when in-person therapy is unavailable, like in the ongoing covid-19 related lockdown measures, parents can provide much needed cognitive therapy at home without time and space restrictions. Digitalization of therapy also offers the opportunity to develop an online community of parents to participate collaboratively. In times of pandemic when in-person therapy is restricted, AI-based online therapy software can help reduce the disparities in addressing the needs of diverse students. This single case study provides an early account of success with software-based online cognitive therapy to address core symptoms of autism. A larger cohort of subjects could be studied in future studies to obtain more evidence in these directions.

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