Mental Imagery Therapy for Autism (MITA) - an early intervention computerized brain training program for children with ASD

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ABSTRACT: There is a broad consensus that early intervention has the greatest chance of positive impact on an individual with ASD. In this paper, we describe the development of an innovative computerized brain-training program for toddlers and preschoolers that has the potential to completely change their developmental trajectory. We describe the design of iPad-based game-like exercises that train a child to notice and respond to multiple cues. This ability is typically impaired in individuals with autism, leading to what is commonly described as stimulus overselectivity, or "tunnel vision". Improving the capacity to discern and to respond to multiple cues has been shown to reduce stimulus overselectivity subsequently leading to vast improvements in general learning. Our hypothesis is **that regular, prolonged practice with such exercises will result not only in a greater ability to attend to multiple cues, but also to vast improvements in transfer tasks measuring visuospatial as well as communicative skills**. We also aim to show that computerized brain-training that is based on evidence based therapies could be used to reduce the gap between the amount of therapy recommended for children with ASD and the amount they actually receive. Finally, we describe early indicators of game engagement and outline planned future work to test the games' efficacy as a therapeutic tool.

Keywords: Autism, ASD, Behavioral Therapy, PRT, Pivotal Response Treatment, Multiple Cue Responding, Stimulus Overselectivity,

INTRODUCTION

The Centers for Disease Control estimates that autism spectrum disorder (ASD) affects 1 in 68 children (1). The failure to provide adequate early intervention services ends up costing society (USA) an estimated $126 billion per year (2). Recently, there has been some incredibly exciting and promising research in the field of early autism screening and treatment. ASD is usually diagnosed no earlier than age 2, though several groups have demonstrated that symptoms of ASD begin to manifest between 6 and 12 months of age (3, 4), allowing for earlier screening. The advantage of earlier screening, of course, is earlier treatment, and some research has shown remarkable success with interventions aimed at infants (5). However, no matter when the diagnosis occurs, there is broad scientific consensus that early and intensive behavioral intervention has the greatest chance of significantly improving outcomes, sometimes even resulting in a complete loss of diagnosis (6, 7, 8).

The American Academy of Pediatrics recommends that individuals with ASD begin to receive no less than 25 hours per week of treatment within 60 days of identification (9). Unfortunately, there are major problems with the availability, quality, and general funding for early intervention programs (10, 11, 12). Families of newly diagnosed children often face lengthy waitlists for therapy, which means children are left without treatment during the most critical, early period of development. Despite the AAP recommendation, two-thirds of US children on the autism spectrum under the age of 8 fail to meet even the minimum recommended treatment (13), and this immense shortage disproportionally affects African American and Latino children (14).

The use of technology in the delivery of much needed therapy promises to be effective for shrinking the gap between the therapy that is recommended for children with ASD and the amount they receive. Recently, there has been a promising trend towards computer-based interventions which capitalize on the often observed preference children with ASD show for flat screen information (15, 16, 17) as well as evidence suggesting that tablets specifically have been a great learning tool for children with autism (18, 19, 20). Given these indications that children with ASD have a proclivity towards tablets as well as video games, and given the broad consensus that children with ASD can benefit greatly from extensive behavioral therapy, we seek to provide a tablet-based therapeutic application as a means of reducing the therapy gap.

Thus, the guiding principle of this project is to design innovative, digital applications that are grounded in established, evidence-based early-intervention therapies made especially for very young children with ASD. These applications have the potential to drastically reduce the gap between the amount of therapy recommended and the amount of therapy actually received by children with ASD as well as to improve the quality of care.

Mental Imagery Therapy for Autism (MITA) is based on Pivotal Response Treatment (PRT), one of the best supported therapies for ASD. PRT is a naturalistic intervention that targets key, or “pivotal,” areas of development that, in turn, affect a wide range of behaviors (1).

The educational objective of MITA is to develop one of the four pivotal skills targeted by PRT: a child's ability to notice and to respond to multiple cues presented simultaneously. To understand this ability, imagine that you are asked to *pick up a red crayon that has fallen under the table.* This may seem like a trivial task, but in order to accomplish it successfully, you need to notice three different features, or “cues,” of the object: its color (*red*), its shape (*crayon*) and its location (*under the table*). You must then mentally integrate all three pieces of information into a new mental image, *a red crayon under the table,* in order to take the correct action.

The ability to notice and respond to simultaneous multiple cues is highly developed in individuals not afflicted by ASD well before the age of 6, but it is known to be a common challenge for children on the spectrum (22). Children with ASD often focus on only one cue at a time while ignoring other cues, a characteristic that has been called *stimulus overselectivity* or "tunnel vision" (3, 21). This phenomenon, which was first described in 1971 by Lovaas, Schreibman, Koegel, can have a profound effect on virtually every area of functioning. For example, an individual may have a difficult time differentiating between a fork and a spoon, or between the letters E and F, because of a tendency to hyper-attend to one aspect of the objects, such as the similar color of the utensils or the common vertical line in the two letters, ignoring other salient features.

When asked to *pick up a red crayon under the table*, a child with ASD may hyper-attend to the cue "crayon" and ignore both its location and the fact that it should also be red. The child may therefore pick up any available crayon, failing to attend to the cues of color and location. The consequences of attempting to navigate the world with an impaired ability to respond to multiple cues are profound and can affect virtually every area of functioning (4). Naturally, this impairment extends to the comprehension of the basic elements of language such as spatial prepositions (*the crayon on the table* vs. *the crayon under the table)*, syntax (*the boy chases* *the dog* vs. *the dog chases the boy*) verb tenses (*the boy chased the dog* vs. *the boy was chased by the dog*), adjectives (*the red crayon* vs. *the green crayon*), as well as other elements of language.

Thus, MITA's main educational objective, to develop the ability to respond to multiple cues, was specifically chosen because developing this ability has been shown to decrease stimulus overselectivity and, most importantly, to lead to improvements in general learning (5, 6).

MITA aims to leverage the numerous findings which demonstrate the success of early and intensive behavioral intervention (6, 7, 8) by designing educational exercises in an engaging format specifically intended for early childhood. In a randomized clinical trial of one of the most successful early intervention approaches for ASD, the Early Start Denver Model, therapy was provided for 2-hour sessions, twice per day, 5 days/week, for 2 years (23). Accordingly, MITA, with its large collection of exercises bolstered by an adaptive algorithm that is responsive to the individual abilities of each child, is also designed to be appropriate for daily use over an extended period of time. Our hypothesis, which we intend to test in a longitudinal clinical trial, is that regular, prolonged practice over the course of at least two years with the MITA application will result not only in a greater ability to attend to multiple cues and in a reduction in stimulus overselectivity, but will also lead to vast improvements of transfer tasks measuring visuospatial as well as communicative skills.

RESULTS

MITA Exercises for Training Multiple Cue Responding

MITA's exercises follow a systematic approach for training the skill of multiple cue responding. The most unique feature of the exercises is that they are able to provide the training outside of the verbal domain, which is essential for those kids with ASD who are either nonverbal or minimally verbal. While these children may not be able to follow a verbal command (such as "*pick up the red crayon under the table*"), initial results from our pilot studies (see the "Initial Results" section, below) have demonstrated that they are able to follow a command that is given visually instead of verbally.

To teach children to follow visual commands that require attending to multiple cues, the MITA program starts with exercises that require attending to one cue (such as color, shape or size) and then moves onto two cues (such as both color and shape, or both color and size) and eventually to three or more cues. The choice of these particular stimuli was made to reflect those commonly used by behavioral therapists who practice PRT. A therapist working on multiple cues with a child would intentionally structure the therapeutic environment to include objects of various color, shape and size and then ask the child to find an object based on two (or more) of these features (24).

The MITA program follows a similar systematic approach for developing a child's ability to respond to multiple cues, starting with very simple exercises that require attending to only one cue or characteristic, namely color (Fig. 1A) and size (Fig. 1B).

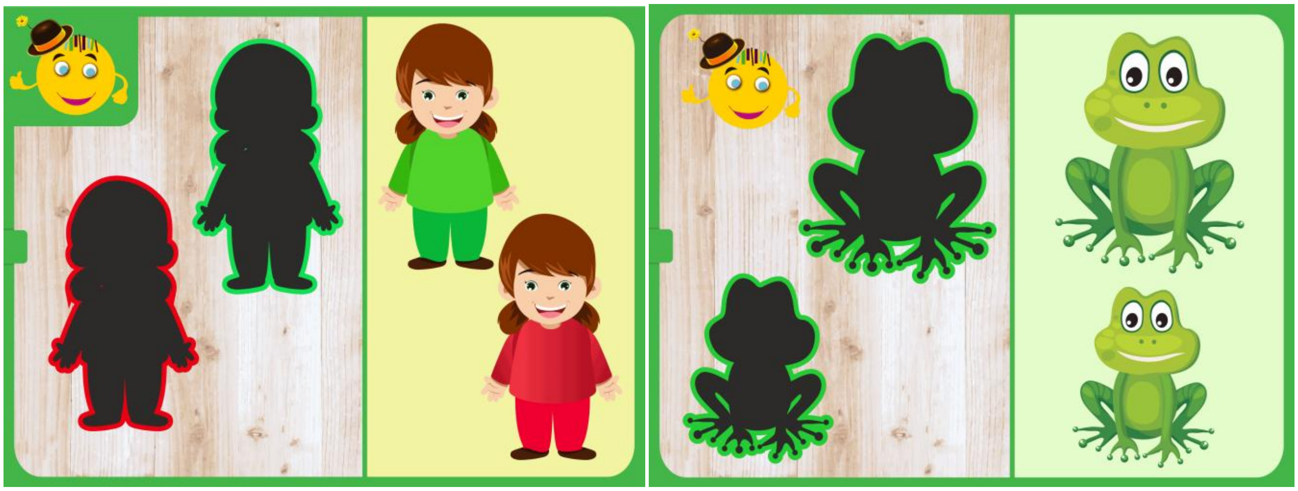


Figure 1. Examples of exercises that require attending to only one cue. A: color; B: size. To solve a puzzle, a child needs to drag all movable pieces shown on the right side of each screenshot into their correct positions on the left side of the screen.

Once a child shows competence at attending to one cue, the program presents the child with exercises that require the child to attend to two cues simultaneously. Figure 2 shows exercises in which a child needs to simultaneously attend to two cues in order to match each object with its proper location: color and shape (Fig. 2A) and color and size (Fig. 2B). For example, in Figure 2A, when determining where to place the red helicopter, only noticing its shape would be insufficient since there are two helicopter silhouettes; only noticing its color would be equally insufficient since there are two red silhouettes. The child must learn how to hold two pieces of information in the mind ("red" and "helicopter") and make a decision based on both cues.

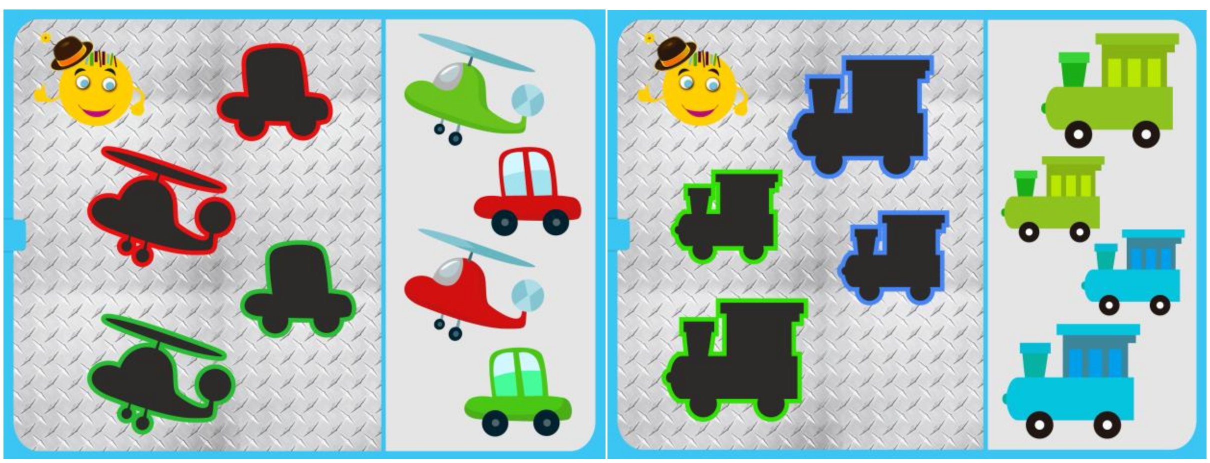


Figure 2. Examples of more difficult exercises that require attending to two cues simultaneously. A: color and shape, B: color and size.

Over time, the exercises increase in difficulty, requiring the child to attend to a greater number of cues. Figure 3 shows an exercise in which a child must attend to an object's color, shape, and size.

Figure 3. Example of an exercise that requires attending to three cues: color, shape and size.

The most complex exercises require a child to attend to a whole variety of visual cues simultaneously.

For example, consider the "missing patch" puzzles shown in Figure 4. Can you find the patch that completes the image?

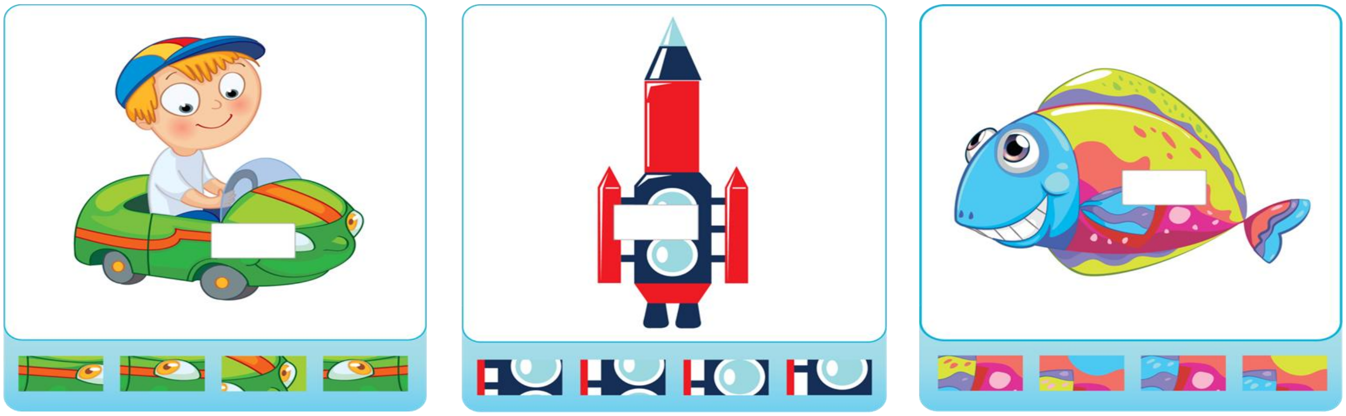


Figure 4. Examples of complex exercises that require attending to a whole variety of visual cues simultaneously.

The success in solving these and similar puzzles depends on a child's ability to simultaneously take into account a whole variety of visual cues, including multiple colors and various shapes. As a child progresses through MITA's systematic exercises, he or she is developing the ability to simultaneously notice and integrate a greater number of visual cues.

Visual approach to PRT

Currently, training a child to overcome stimulus overselectivity is provided by a behavioral therapist who deliberately structures the natural environment in such a way that a child must notice multiple cues simultaneously. For example, when asking a child to "*pick up the red crayon*" from a group of objects, the therapist would intentionally include a red Lego, a green Lego and a green crayon in the group of objects, therefore forcing the child to attend to both cues "red" and "crayon" (Fig. 5, insert in the top left corner).

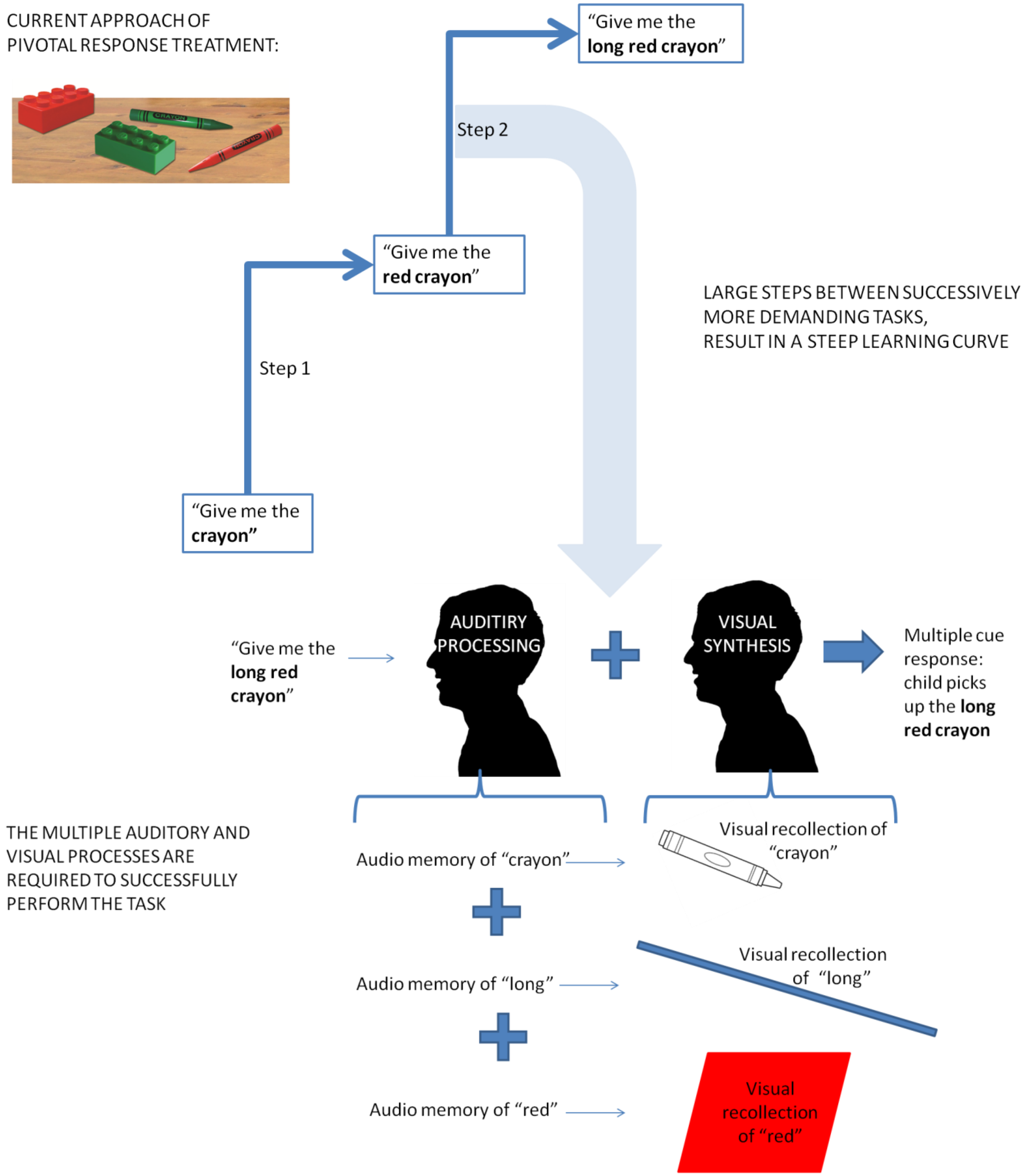


Figure 5. In a typical verbal approach to training multiple cue responsivity, the steps between successively more demanding tasks are large, resulting in a steep learning curve. If the child cannot make the leap between recognizing a stick and recognizing a long stick, then the child will be stuck without being able to make progress. It could be this reason, that PRT is not effective in a large number of children with ASD. Furthermore, many of these kids with ASD are nonverbal, and they will simply not follow verbal instruction, though they often can do a task that is presented to them outside the language domain.

This conventional verbal approach to training responsivity to multiple cues has two major setbacks that often make it ineffective. The first setback is that it requires a verbal command ("*pick up the red crayon*") which makes it inaccessible to those children who have difficulty processing audio stream. We have deliberately designed our puzzles to train responsivity to multiple cues without the need of a verbal command or verbal instructions. This modification allows us to deliver successful therapy even to kids who are completely non-verbal.

The second setback of conventional PRT is that the verbal nature of the commands creates large steps between successively more demanding tasks, resulting in a steep learning curve. A therapist would start with tasks that require a child to attend to only one cue ("give me the crayon"), and practice until a child becomes proficient. Then the therapist would logically move on to the more demanding task requiring a child to attend to two cues ("give me a red crayon"). There is a steep learning curve between these two tasks, and if a child is unable to attend to two simultaneous cues, he or she will not be able to recognize the "red crayon." The visual nature of MITA puzzles allows the steps between successively more demanding tasks to be much smaller, resulting in a more gradual learning curve (Fig. 6). Such a fine gradient between successively more demanding tasks is only possible in the visual domain, since the necessary objects would require an overabundance of words to describe.

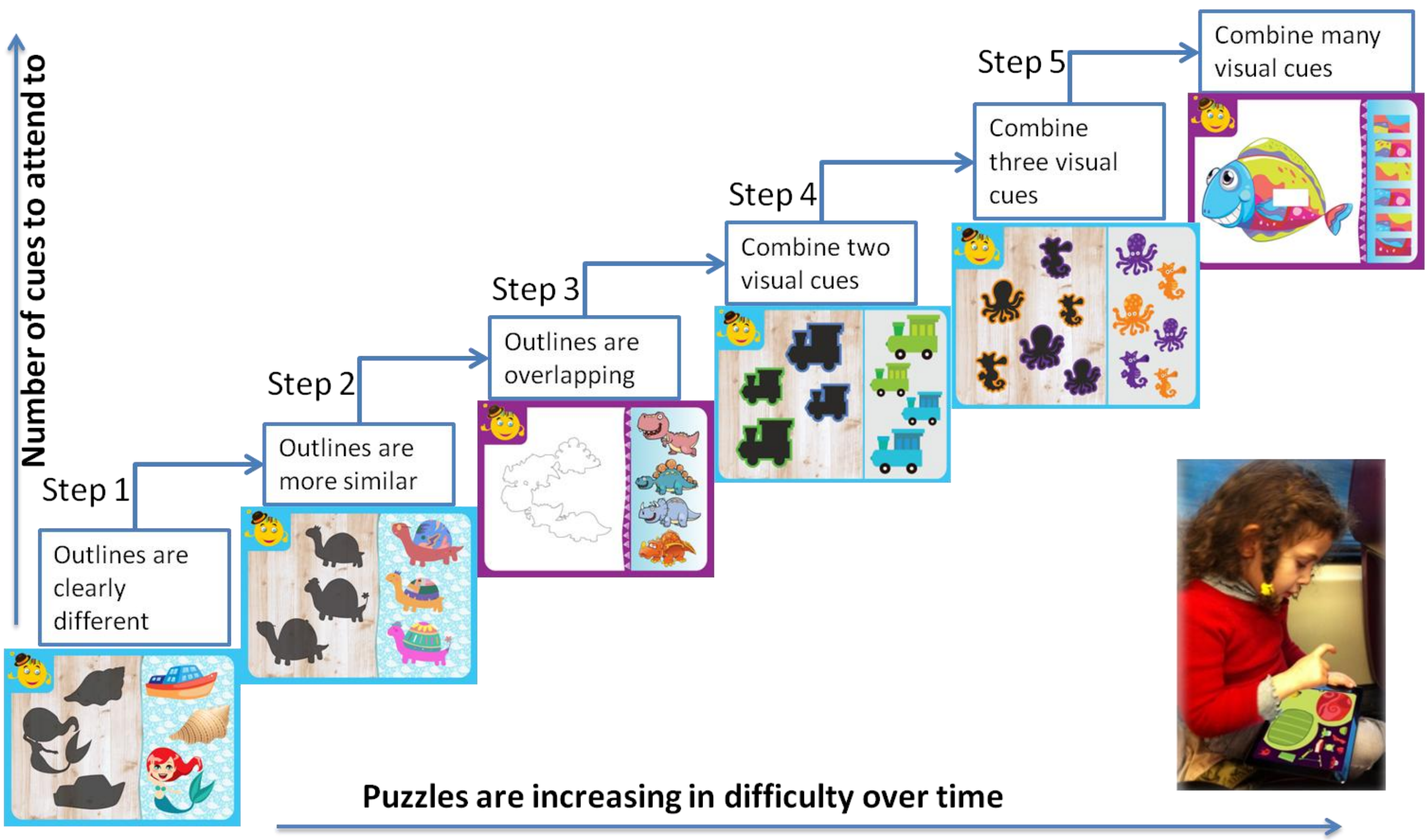


Figure 6. **MITA puzzles are ideal for effectively training responsivity to multiple cues**. The visual nature of MITA puzzles allows the steps between successively more demanding tasks to be much smaller and more gradual. This completely visual approach to PRT is especially appropriate for kids with a language delay.

Since the software is designed to require minimal instruction and explanation, it works more as a facilitator. Kids work independently to figure out the solution without verbal instruction, an approach that is ideal for the development of other "pivotal" skills: motivation and self-initiation. MITA, therefore, creates a non-verbal way for kids to develop responsivity to multiple cues in an environment that encourages self-motivated and self-initiated progress. These critical skills are acquired in a fun-filled, game-like environment with kids being unaware that they are self-administering Pivotal Response Treatment.

MITA exercises are feasible for early childhood

While there is a myriad of autism applications currently available on the market, there is a dearth of applications designed and intended for *early* childhood, a time period that has been shown to be the most critical for development. Therefore, our first goal was to create a therapeutic application that would be suitable for children as young as two years of age, and thus could be used as soon as a diagnosis is made. To accomplish this goal we focused on developing three major accommodations:

(1) MITA puzzles were designed to be accessible to users with minimal fine-motor skills: (a) the puzzles use large, easy-to-drag images; (b) once a child touches an image, that image is slightly expanded in order to provide the child with clear visual feedback that he or she is actually holding the image; (c) for children who repeatedly experience motor difficulties, optional settings, such as tap-to-solve instead of drag-to-solve, were developed to simplify actions within a puzzle; (d) the adaptive algorithm was specifically designed not to penalize for minor motor mistakes.

(2) MITA puzzles were developed to maximize attention on the given task and to minimize all distractors. Once a child starts working on a solution, there are no elements within the puzzle that move.

(3) MITA puzzles utilize a variety of prompts: an image of a hand pointing to the correct object, the correct object highlighted/flashing on the screen, an auditory command, etc. In addition, the program adheres to common ABA prompt-fading strategies that follow the most-to-least (used when a student is first learning a skill) and least-to-most (used when a child has previously demonstrated success with a task) hierarchy.

These optimizations were developed as a result of feedback from therapists who used the software in their practice over the course of 9 months. Thanks to their generous feedback and our own user-testing, MITA has evolved into a robust system of exercises suitable for very young children.

Initial Results

In two pilot studies conducted over nine months, MITA software was used by two therapists as a reward at the end of a regular speech therapy session. Of the fourteen children in the two studies, all of whom were between the ages of 3 and 5, eight of the children were ranked by the therapists as showing "high engagement" with the software, four as showing "moderate engagement" and two as showing "low engagement." The twelve children who showed either moderate or high level of engagement with the software, performed, on average, 27 tasks before becoming unengaged, with an average session length of 10 minutes. In addition, 2 children showed a tendency for using trial-and-error to solve puzzles as opposed to active mental simulation. Both therapists noted a significant improvement in fine motor skills for all participants at the conclusion of the nine month study.

Furthermore, in the two months since its release to the general public, MITA software has been downloaded by over 500 users. We have little user information for those individuals who have downloaded MITA through the Apple app store, due to Apple policy. However, amongst the individuals who downloaded and tried MITA on Android devices, 59 self-reported as being parents of children with ASD. Over half of these parents have consistently administered the therapy at least twice a week since downloading. Children younger than 4 account for 42% of the subjects (25 children). Fifteen of these children (60%) have used MITA consistently at least twice a week. These data are consistent with the hypothesis that MITA exercises are feasible for early childhood.

Algorithmic design

When designing exercises intended for daily use over many years, it is vital not only to create a vast collection of puzzles but, more importantly, to create a collection that is appropriate for a wide range of ages and abilities. Thus, our second goal was to develop a methodology that will automatically determine the difficulty of a particular puzzle. The level of difficulty in a matching-scheme puzzle is determined by: (a) the similarity of the options (a feature we call "span") and (b) the number of options.

The "span" is the count of the number of features that differ between two items. For example, the two ice cream combinations shown in Figure 9 differ in four categories and therefore have a span of 4.

In a task where the goal is to choose the option that matches the target, an easier puzzle (Fig. 7) requires a player to attend to either one of the differing features in order to choose correctly. In this case there are only 2 features that separate the options (sauce and topping), so the puzzle has a span of 2.

TARGET:	OPTIONS:
	

Figure 7:
easier matching puzzle with 2 options, and span of 2

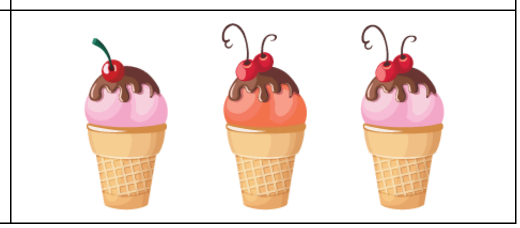
TARGET:	OPTIONS:
	

Figure 8:
more difficult matching puzzle with 3 options and span of 1

As the span decreases, and the number of options increases, the matching task becomes more difficult and requires the player to pay closer attention. For example, adding a third option (Fig. 8) with only one feature separating each one of the three options from the target (span of 1), necessitates that the player attend to two cues simultaneously (both the color of the ice cream and the topping) A system that tracks both the span as well as the number of options presented to the player can precisely calibrate the difficulty level of each task resulting in tasks appropriate for a wide range of abilities.

DISCUSSION

We believe that systematic, computerized training is the best way to train a child's ability to respond to multiple cues, an ability that has been shown to lead to vast improvements in general learning (5). Our hypothesis is that regular practice with the MITA application will result not only in a greater ability to attend to multiple cues, but also in vast improvements of transfer tasks measuring visuo-spatial as well as communicative skills.

Furthermore, we hope to show that MITA, coupled with an effective vocabulary training program, can lead to improvements in the realm of language comprehension. We predict that children who begin training at an early age, and who make consistent progress over the course of training, will see drastic improvements in their language function. Since many kids diagnosed with ASD are already receiving ample vocabulary training, what's missing is the skill to attend to various combinations of learned words, which is the backbone of true language comprehension. For example, a child who has learned the words "red" and "crayon" but who cannot attend to both cues, will struggle to pick out a "red crayon" from an array of objects, while a similar child who has learned to respond to multiple cues will likely be successful with the task. Combining the ability to respond to multiple cues with vocabulary knowledge, will result in an understanding of a full syntactic language, which will eventually lead to a significant reduction of the severity of the ASD diagnosis and ultimately to a more productive and independent life.

We intend to test these hypotheses in a longitudinal clinical trial set to begin in early 2016. We plan to measure multiple cue responding, receptive and expressive language, nonverbal IQ as well as autism severity at regular intervals throughout the trial in order to gauge the efficacy of the MITA therapy.

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