

**Comparison of performance on verbal and nonverbal multiple-cue responding tasks in
children with ASD**

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Abstract

In this manuscript, we present data from an ongoing study of a tablet-based therapeutic application designed for newly diagnosed children with autism spectrum disorder (ASD) and modeled on Pivotal Response Treatment (PRT), a technique known to be effective in educating children with ASD. We describe the creation of a variety of analogous tasks that were presented both verbally and nonverbally within the application. This work presents our hypothesis that children with ASD perform better when a command is presented nonverbally. This approach may have important implication for the most effective way of delivering early therapeutic interventions to children with ASD.

Keywords

autism, ASD, behavioral therapy, PRT, pivotal response treatment, multiple-cue responding, stimulus overselectivity, tunnel vision, mental synthesis, cognitive therapy, language therapy, early intervention, ABA

Introduction

The Centers for Disease Control estimates that 1 in 68 (Wingate et al., 2014) children are affected by autism spectrum disorder (ASD), a neurological disorder that disrupts early development in cognition and communication. Approximately two-thirds of children with ASD grow up to have significant cognitive and social impairments, and difficulty in acquiring new adaptive behaviors (Yeargin-Allsopp et al., 2003). There is broad scientific consensus that early and intensive behavioral intervention can result in sizeable gains in cognitive, communicative, social, academic, and adaptive skills, and has the greatest chance of significantly improving outcomes, sometimes even resulting in a complete loss of diagnosis.

Applied Behavioral Analysis (ABA) and Pivotal Response Training (PRT) are some of the best scientifically supported and established, evidence-based therapies for ASD (Wilczynski et al., 2009). One of the four key, or “pivotal,” areas of development targeted by PRT is the ability to notice and respond to multiple-cues presented simultaneously, a skill which affects a wide range of behaviors. To understand this ability, imagine that you are instructed to *pick up a red crayon that is 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 integrate 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 (Lovaas, Schreibman, Koegel, & Rehm, 1971). As a consequence, ASD symptoms often include a phenomenon called stimulus overselectivity, whereby an individual focuses on only one aspect of an object or environment while ignoring others (Lovaas, Koegel,

& Schreibman, 1979; Ploog, 2010; Schreibman, 1988). 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, therefore picking up any available crayon. It is often said that individuals with ASD “can't see the forest for the trees.” They pay too much attention to specific parts, get lost in the details and miss the whole picture (or Gestalt). The consequences of attempting to navigate the world with an impaired ability to respond to multiple cues can be profound and can affect virtually every area of functioning (Lovaas et al., 1971). However, using PRT to develop responsivity to multiple cues has been shown to *reduce* stimulus overselectivity and, most importantly, to lead to improvements in general learning (Burke & Cerniglia, 1990; Wingate et al., 2014).

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. When asking a child to *pick up a red crayon* from a group of objects, the therapist might 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.” This conventional approach to training responsivity to multiple cues has a major setback that often makes it ineffective: it requires a verbal command (*pick up the red crayon*) which may make it inaccessible to those children who have difficulty processing audio stream.

With the aim of finding an additional method for helping children acquire responsivity to multiple cues, we developed a tablet-based therapeutic application for children with ASD called *Mental Imagery Therapy for Autism* (MITA) (Dunn, Elgart, Lokshina, Faisman, Khokhlovich, et al., 2017; Dunn, Elgart, Lokshina, Faisman, Waslick, et al., 2017; Vyshedskiy & Dunn, 2015). MITA includes both verbal and nonverbal activities that train responsivity to multiple cues. The

verbal activity follows the traditional method of using explicit verbal commands (such as “*pick up the red crayon under the table*”) to direct a child to notice multiple cues simultaneously. The nonverbal activity gives the same command in an implicit manner through easily-discernible visual clues. To teach children to follow implicit visual commands that require attending to multiple cues, the MITA program starts with puzzles that require attending to one cue, such as color (Fig. 1A) or shape (Fig. 1B). Once a child shows adequate proficiency in attending to a variety of single cues, MITA activities progress in difficulty by requiring attention to two cues simultaneously, such as both color and shape (Fig. 1C) and eventually to three or more cues, such as color, shape, size and spatial orientation (Fig. 1D).

Are children who struggle to follow an explicit verbal command able to follow an implicit visual command? Can multiple-cue responding be trained outside of the verbal domain? The current study aims to answer these questions and to take a close look at how young kids diagnosed with ASD who are minimally verbal or nonverbal are able to perform analogous verbal and nonverbal tasks.

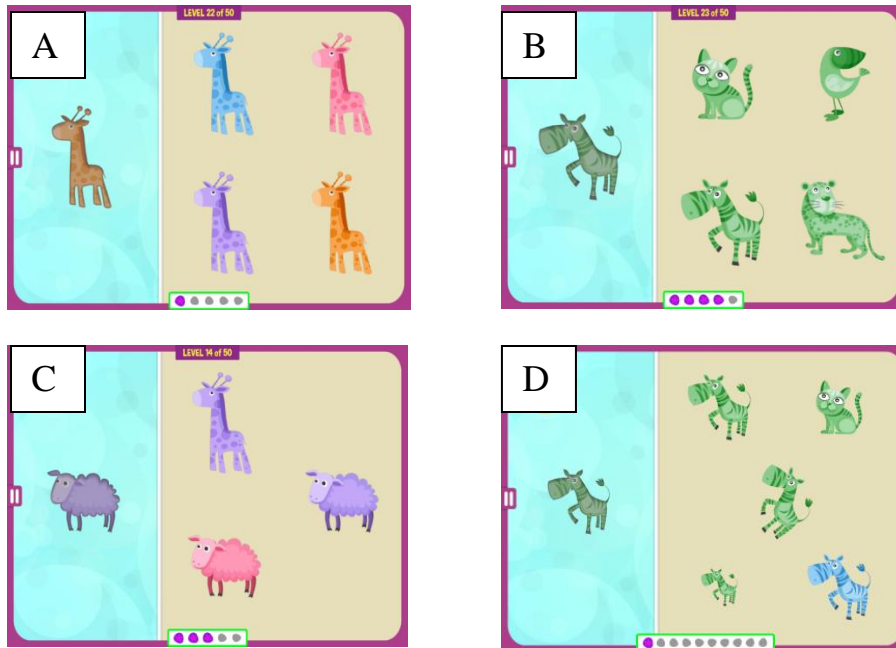


Figure 1. Examples of using implicit visual commands. (a) A child must notice one cue (color) in order to correctly match the animal silhouette on the left side of the screen. (b) A child must notice one cue (shape) in order to correctly match the target animal. (c) A child must notice two cues (color and shape) in order to correctly match the target. (d) A child must notice four cues (color, shape, size, and spatial orientation).

Methods

MITA Activities

MITA consists of nine different developmental activities that follow a systematic approach to train the skill of multiple-cue responding by requiring attention to an object's shape, color, size, quantity, orientation in space, visual details as well as combinations of these features. The choice of these particular stimuli was made to reflect those commonly used by PRT behavioral therapists who 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 (Hiniker, Daniels, & Williamson, 2013). One of the activities, the *Language Game*, provides multiple-cue training within the verbal domain, while the other eight provide the training outside of the verbal domain (Dunn, Elgart, Lokshina, Faisman, Khokhlovich, et al., 2017). All activities start with puzzles that require attending to one cue, such as color, shape or size. Once a child shows adequate proficiency in attending to a variety of single cues, MITA activities adaptively progress in difficulty by requiring attention to two cues simultaneously, such as both color and shape, and eventually to three or more cues.

In this manuscript, we compare children's performance in two of MITA's activities, *Language Game* and *Matching Animals*, which train the skill of multiple-cue responding in the verbal and nonverbal domain, respectively. The reason we have chosen *Matching Animals* out of MITA's eight nonverbal activities is because it correlates most precisely with the verbal tasks in the *Language Game* in terms of task complexity, feature selection and visual layout.

Verbal Activity - Language Game

MITA's *Language Game* trains a child's multiple-cue responding and mental integration skills through a verbal approach. The *Language Game* offers a more conventional approach to facilitating language acquisition, starting with simple vocabulary-building exercises and progressing towards exercises aimed at higher forms of language, such as noun-adjective combinations, spatial prepositions, and syntax.

The *Language Game* exercises are organized into 244 difficulty levels that are adaptively presented to a child over many months. The initial levels introduce the child to ten common nouns (Dog, Cup, Ball, Car, Book, Table, Chair, Couch, Slide and Bed) that are used throughout the rest of the *Language Game*, laying the foundation for all subsequent learning. We have

deliberately limited the exercises to only these ten nouns since the aim is NOT to expand a child's one-word vocabulary, but rather to teach a child to integrate previously-learned words in novel ways. The activity goes on to teach and then integrate adjectives of size (small, large), color (red, blue, green, orange) and number (one, two, three) with all ten previously-learned nouns, Fig. 2A-C.

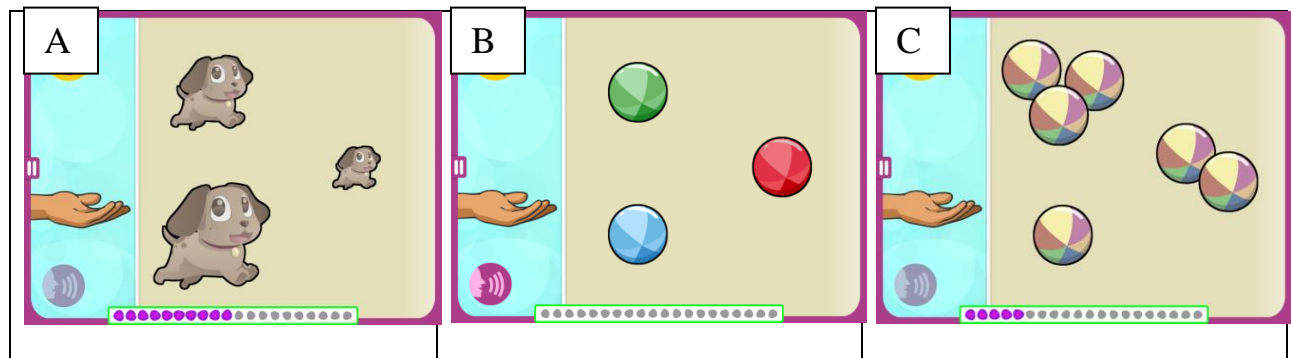


Figure 2. *Language Game* - integration of noun with adjectives for size, color and number. (a) Level 45: “Find the large dog.” (b) Level 67: “Find the red ball.” (c) Level 86: “Find two balls.” The difficulty levels are specified for MITA version 3.2.0.

Once a child learns to integrate adjectives for size, color and quantity with all ten nouns, they are presented with multiple-cue responding tasks in which they must attend to BOTH the adjective and the noun in order to find the correct object. For example, when directed to “find the blue car” (Fig. 3A), a child must attend to BOTH the color (blue) and the object (car). Attending only to the word “car” may result in a wrong answer since there are two cars to choose from. Similarly, attending only to the word “blue” may result in a wrong answer since there are two blue objects to choose from.

Eventually the activity moves on to tasks that combine multiple adjective descriptors. For example, in Level 112 (Fig. 3B), a child must attend to both size and color when asked to “find the small, orange couch,” as there are two small objects and two orange couches to choose from.

By level 156 (Fig. 3C), a child must be able to integrate three adjective descriptors with a single noun, and attend to size, color and number when picking out the correct object.

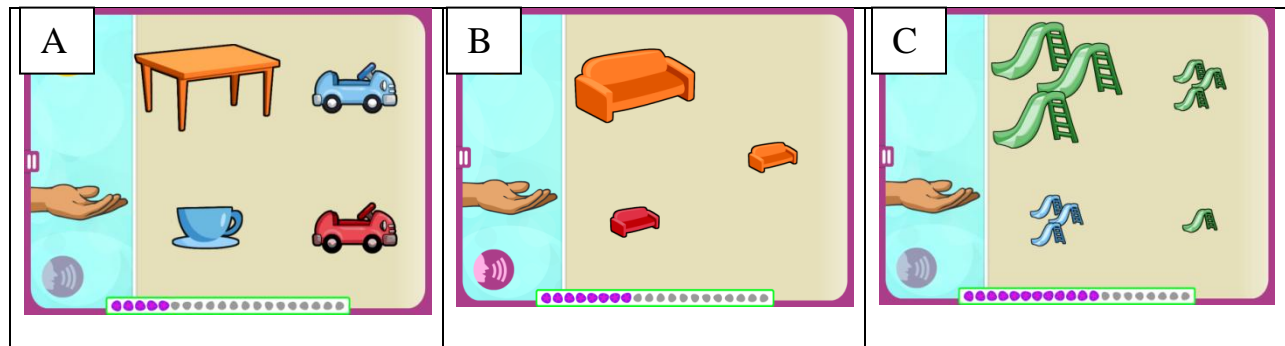


Figure 3. *Language Game* - multiple-cue responding tasks. Each distractor matches the target along a single feature. (A) Level 83: “Find the blue car” with a blue cup and a red car as distractors. (B) Level 112: “Find the small, orange couch” with one other small object and one other orange object as distractors. (C) Level 156: “Find the three, small, green slides” where each of the distractors is similar to the target in two (of three) categories.

The final levels of the *Language Game* introduce the spatial prepositions “on,” “under,” “in front of,” and “behind.” A child may hear a request to “put the ball under the bed” and must attend to the correct nouns, prepositions as well as syntax in order to place the objects into the correct configuration. Finally, the *Language Game* culminates with the most difficult levels that incorporate adjectives into the scene, with commands such as “put the small ball in front of the red couch.”

Nonverbal activity - *Matching Animals*

The *Matching Animals* activity trains the skill of multiple-cue responding outside of the verbal domain (Vyshedskiy & Dunn, 2015). The exercises are organized into 50 difficulty levels. In the initial levels, a child is first taught to recognize the shapes of 10 different objects (Elephant, Giraffe, Sheep, Crocodile, Hippo, Zebra, Cat, Leopard, Iguana, and Bird), that are used throughout the rest of the activity. The activity goes on to introduce size (small, large),

color (pink, blue, green, orange and purple) and spatial orientation (facing left, facing right and rotated 45°). In the easier levels, it is enough to notice only one feature of the target animal, such as its shape, color, or size, Fig. 4A-C.



Figure 4. *Matching Animals*. (a) Level 11: Notice the size of the target animal. (b) Level 22: Notice the color of the animal. (c) Level 23: Notice the shape of the animal.

In more advanced levels, *Matching Animals* follows a similar paradigm as the *Language Game* by introducing multiple-cue responding tasks, which require simultaneous attention to two or more features of the target animal by including distractors that match the target along a single feature. For example, in Level 14 (Fig. 5A), a child must notice *both* the color (purple) and the shape (sheep) of the target animal. Noticing only the purple color of the target animal will not be sufficient for finding the correct match because there are two purple animals among the choices. Similarly, noticing only the shape will also not be enough, as there are two sheep to choose from. Similarly, in level 17 (Fig. 5B), a child must notice *both* the shape (hippo) and the size (small) of the target animal. As the levels advance, the activity becomes progressively more challenging by increasing the similarities as well as the number of distractors (Fig. 5C).

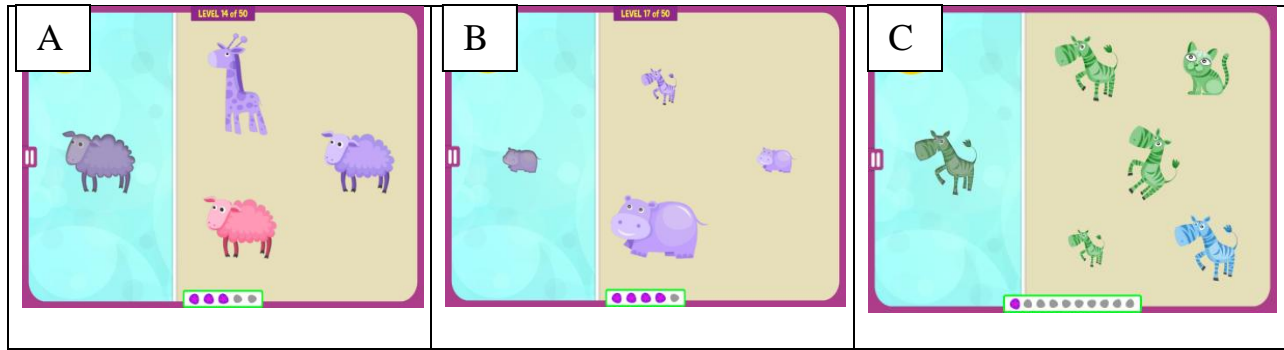


Figure 5. *Matching Animals* - multiple-cue responding tasks. Each distractor matches the target along a single feature. (a) Level 14: Notice the color and shape of the target animal. (b) Level 17: Notice the shape and size of the target animal. (c) Level 49: Notice the color, shape, size and orientation of the target animal.

Analogous Tasks Comparisons

We were interested in studying how children execute analogous tasks when given an explicit verbal command (*Language Game*) versus an implicit visual command (*Matching Animals*) and comparing performance in analogous single cue and multiple-cue tasks. For this analysis, we compared performance in six categories of analogous tasks, three of which require attending to a single cue (object shape, size, or color), two that require attending to two cues (size and shape, color and shape) and one that requires attending to three cues (size, color and shape), Table 1.

Table 1			
<i>Six categories of analogous verbal and nonverbal tasks and examples of corresponding difficulty levels in verbal and nonverbal activities</i>			
Task category	Task type	Verbal Activity corresponding level	Nonverbal Activity corresponding level
1	Attend to OBJECT/ SHAPE	Level 41	Level 23
2	Attend to SIZE	Level 63	Level 11
3	Attend to COLOR	Level 82	Level 22
4	Multiple-cue (Attend to SIZE & SHAPE)	Level 64	Level 17
5	Multiple-cue (Attend to COLOR & SHAPE)	Level 78	Level 14
6	Multi-cue (Attend to COLOR, SHAPE & SIZE)	Level 116	Level 34

Task Category 1: Attend to Object/Shape

In MITA's verbal activity, children are first taught ten objects (Dog, Cup, Ball, Car, Book, Table, Chair, Couch, Slide, and Bed) that are subsequently used throughout the rest of the activity. Once they demonstrate knowledge of these objects, they reach a level that presents four of the objects (picked at random) accompanied by a verbal command to locate one of them and place it on the hand. For example, Figure 6A shows a typical puzzle that is presented along with a verbal instruction: "Give me the ball." A child can hear the verbal command as many times as he or she would like by tapping the speech button in the lower left corner of the screen.

Similarly, in the nonverbal activity, a child is first taught to recognize the shapes of ten different objects (Elephant, Giraffe, Sheep Crocodile, Hippo, Zebra, Cat Leopard, Iguana, and Bird) that are used throughout the rest of the activity. Level 23 tests a child's ability to discern the shapes by presenting four of them (picked at random) and giving a nonverbal command in the form of a silhouette on the left side of the screen. For example, Figure 6B shows a typical puzzle that presents the target object (in this case, zebra) alongside four object choices.

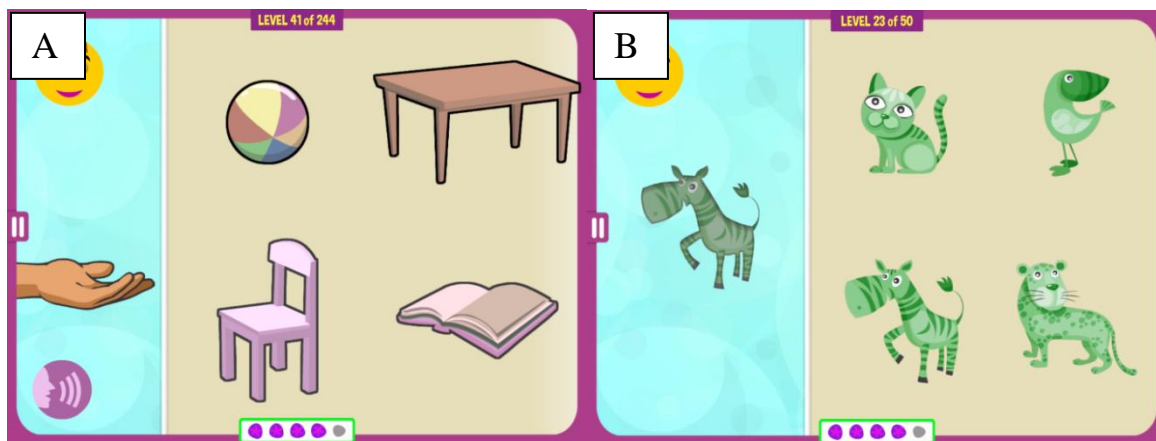


Figure 6: Find the correct object/shape. (a) Level 41: verbal activity – “Find the ball” from among four object choices. (b) Level 23: nonverbal activity – Find the zebra from among four animal choices.

Task Category 2: Attend to Size

Both activities teach children to attend to the size of an object. In the verbal activity, children are first taught the words “small” and “large” and learn to integrate the size descriptors with all ten nouns. Level 43 (Fig. 7A) of the verbal activity requires an ability to recognize and integrate the words “small” and “large” with all ten nouns, by imparting a verbal command such as “find the large (or small) cup” while providing three object sizes (small, medium and large) to choose from. In the nonverbal activity, children similarly learn to discern between the three sizes (small, medium and large) of all ten animals. In Level 11 (Fig. 8B), they must follow the visual command implied by the silhouette on the left by picking the large (or small) animal from among the three size options.

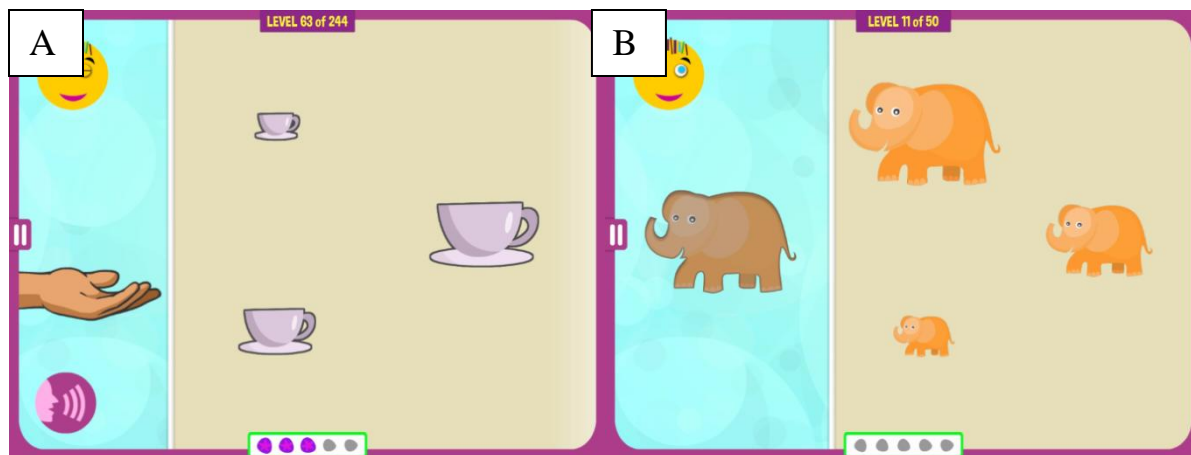


Figure 7: Attend to size. (a) Level 63: verbal activity – “Find the large cup” given three size options. (b) Level 11: nonverbal activity – Find the large elephant given three size options.

Task Category 3: Attend to Color

The verbal activity teaches the words “red,” “blue,” “green” and “orange” and integrates the four colors with all ten objects. Similarly, the nonverbal activity, integrates five colors (pink, blue, green, orange and purple) with all ten animals. Level 82 of the verbal activity (Fig. 8A) and Level 22 of the nonverbal activity (Fig. 8B) both test a child’s ability to integrate color with object in the verbal and nonverbal domain, respectively.

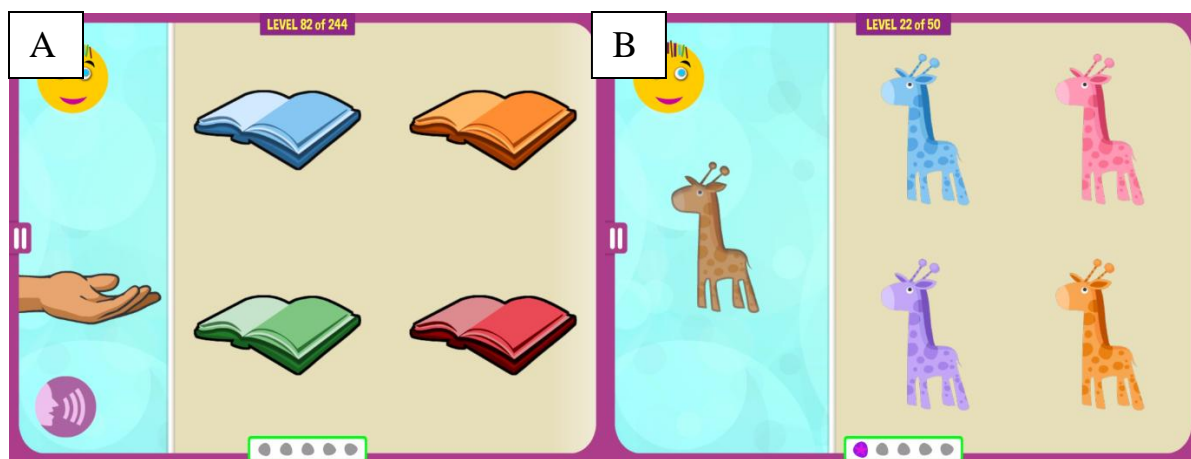


Figure 8: Attend to color. (A) Level 82: verbal activity – “Find the orange book” given four color options. (B) Level 22: nonverbal activity – Find the orange giraffe given four color options.

Task Category 4: Multiple-cue: Attend to Size & Object/Shape

The verbal activity and nonverbal activity have analogous levels that require attending to multiple cues simultaneously. Level 64 in the verbal activity and Level 17 in the nonverbal activity require attending to both size and object because the answer choices always include distractors that match the target in one of the two features. For example, in the verbal activity (Fig. 9A), a child may be asked to “find the small book” with a large book (distractor for object) and small chair (distractor for size) as distractors. In the nonverbal activity (Fig. 9B) a child may be asked to locate the small hippo with a large hippo and small zebra as distractors.



Figure 9: Multiple-cue – attend to size and object/shape. (a) Level 64: verbal activity – “Find the small book” with two distractors. (b) Level 17: nonverbal activity – Find the small hippo with two distractors.

Task Category 5: Multi-cue: Attend to Color & Object/Shape

The two activities also have analogous levels that require attending to both color and shape. In level 78 of the verbal activity (Fig. 10A), a child may be asked to “find the blue ball” with a blue chair and red ball as object and color distractors, respectively. In level 14 of the nonverbal activity (Fig. 10B) a child may be asked to locate the purple sheep with a purple giraffe and pink sheep as distractors.

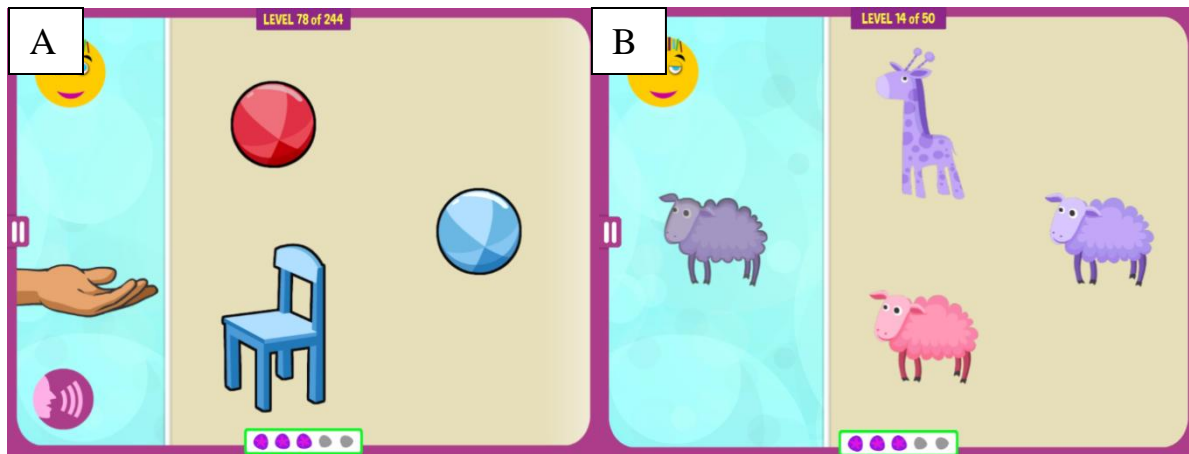


Figure 10: Multiple-cue – attend to color and object/shape. (a) Level 64: verbal activity – “Find the blue ball” with two distractors. (b) Level 17: nonverbal activity – Find the purple sheep with two distractors.

Task Category 6: Multi-cue: Attend to Size, Color & Object/Shape

Finally, we compared the performance in two analogous levels that require attending to three cues simultaneously: size, color and shape. In level 116 of the verbal activity (Fig. 11A), a child may be asked to “find the large, red couch” where each of the distractors is similar to the target in two (of three) categories. In level 34 of the nonverbal activity (Fig. 11B), a child may need to locate the large, green iguana with three green objects, three large objects and three iguanas to choose from.

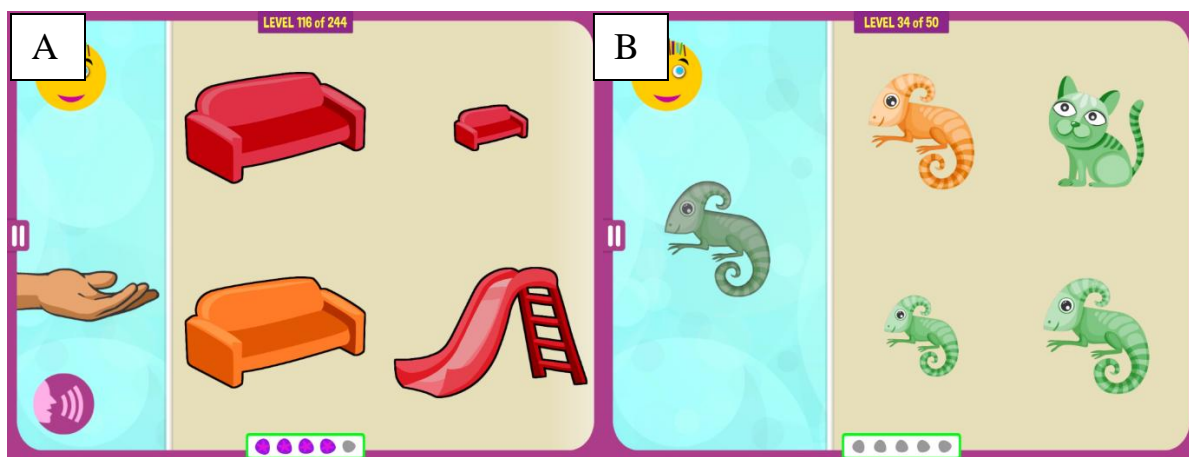


Figure 11: Multiple-cue – attend to size, color and object/shape. (a) Level 116: verbal activity – “Find the large, red couch” with three distractors. (b) Level 34: nonverbal activity – Find the large, green iguana with three distractors.

Application development

MITA was developed by ImagiRation from 2013 to 2016 and made available for free at all major app stores in February of 2016. In the first year, MITA was downloaded 70,325 times, indicating a significant interest in supplemental therapy for ASD. Once MITA was downloaded, the user was asked to register and provide demographic details, including the child’s diagnosis as well as month and year of birth. During twelve months (from February of 2016 to February of 2017) MITA was registered 41,690 times (59% of downloads).

Subjects

From the pool of potential study subjects, we selected subjects based on the following criteria:

1. The subject must have worked for a month and completed over 100 puzzles. Since our application was available for free to the general public, we expected a large volume of downloads by people of widely-ranging commitment. We needed a benchmark to discern those who had serious intentions in working with a therapeutic application and those who did not. Subjects who invested the time to work with the application for at least a month and who completed over 100 puzzles demonstrated such minimal commitment. As of February 2017, out of the 41,690 registered users, 7,323 (or 18% of all potential subjects) had met this benchmark.

2. The subject's parent must have self-reported the diagnosis as ASD. Since our primary interest is early intervention for ASD, only data from ASD subjects were analyzed for this report. Out of the 7,323 subjects who worked with MITA for at least a month and who completed over 100 puzzles, 3,763 (40%) self-reported their child's diagnosis as ASD. Other subjects reported diagnoses of various other neurodevelopmental disorders or that they were not yet diagnosed. Some subjects chose not to report a diagnosis since this was not a required field.

3. The subject must have been 12 years of age or younger at the time of registration. Since we are interested in the effects of early intervention, we decided to limit our analysis to subjects who were 12 years of age or younger at the time of the first questionnaire. Therefore, we excluded another 820 subjects because of age. Thus, the total number of subjects included for analysis was reduced to 2,943 (7% of all registered users).

4. The subject must have completed the analogous levels in both the Language Game and the Matching Animals activities. Both the *Language Game* and the *Matching Animals*

activity are automatically selected as being part of a daily session, but parents can override this initial setting. Since we were interested in comparing the performance in specific levels of these two activities, we had to limit our subjects to kids who had played comparable levels in both activities. At the higher levels in the two activities, the subject pool naturally decreases as fewer kids have reached these higher levels in both activities.

Table 2	
<i>The number of subjects for each task category.</i>	
Task category	Number of subjects who completed both the verbal and nonverbal tasks in the category*
1	330
2	208
3	151
4	162
5	144
6	49

*out of the 2,943 eligible subjects

Performance Measurements

Performance is assessed after the completion of every puzzle by normalizing the number of errors by the number of answer choices. For example, in a puzzle with one task (e.g. find the matching animal) and three answer choices (one correct and two decoys), the performance score could be 100% (subject found the correct answer on the first try), 50% (subject found the correct answer on the second try) or 0% (subject found the correct answer only after exhausting all possible options). Making more than three errors in a puzzle with only three answer choices corresponds to a performance score of 0%. Accidental drags and drops did not count as incorrect answers because we did not want to penalize subjects for poor fine motor skills. The performance scores for all the puzzles solved in a task category were averaged into the Average Performance score.

Statistical Analysis

The data was expressed as mean \pm standard deviation. Comparisons of the data were undertaken with paired Student's t-tests. A two-sided $p < 0.05$ was regarded as statistically significant.

Results and Discussion

In this manuscript, we present data from an ongoing study of a tablet-based therapeutic application for children with autism spectrum disorders (ASD). We compared children's performance in six analogous tasks that were presented both verbally and nonverbally within the application. We measured and analyzed the performance of children under the age of 12 with ASD who have been working with the *Mental Imagery Therapy for Autism* (MITA) application for one to twelve months, between February of 2016 and February of 2017.

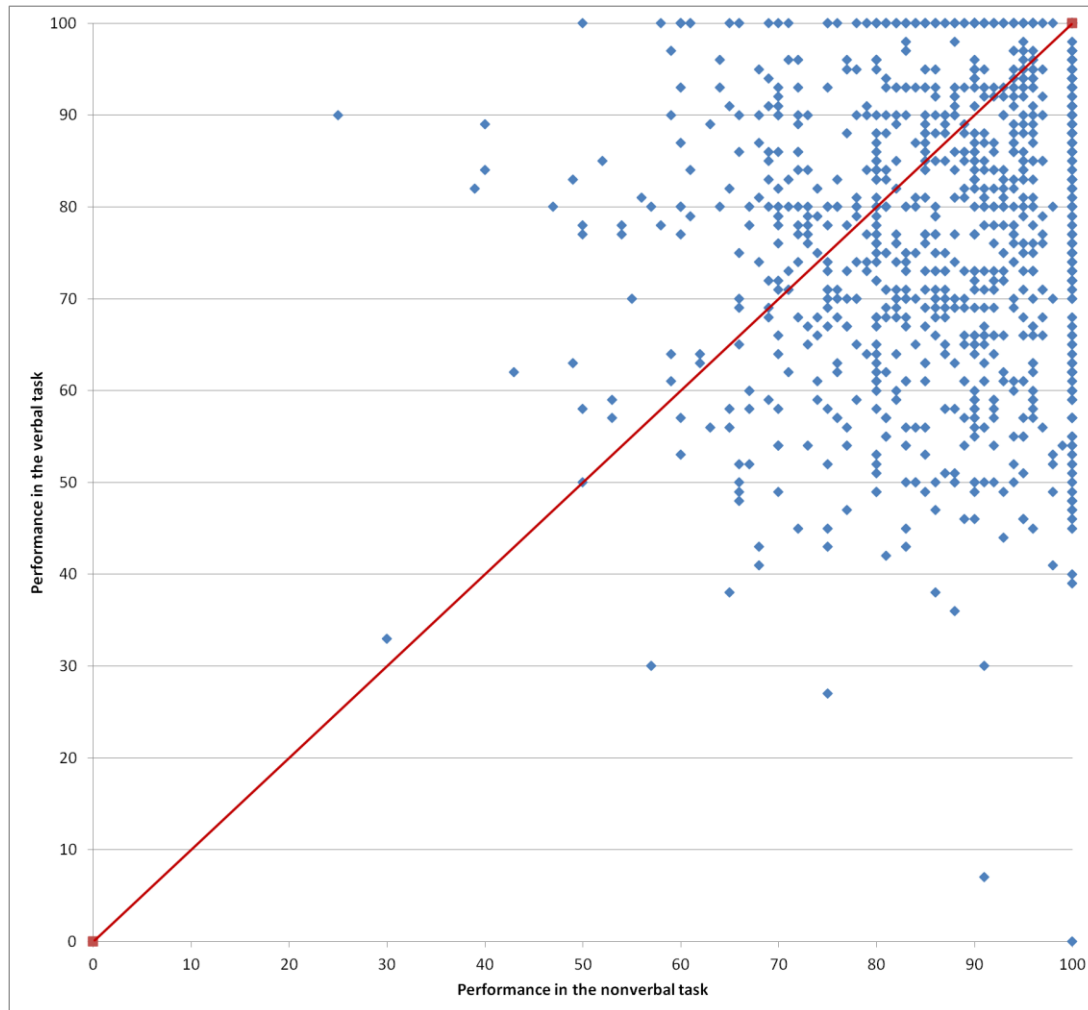


Figure 12. The performance of subjects in the verbal task as a function of performance in the nonverbal task. Each marker represents an individual who completed both the verbal and nonverbal level in any one of the six categories.

The performance of subjects in all six categories of analogous tasks is represented in the graph in Figure 12. Each marker represents an individual who completed both the verbal and nonverbal level in any one of the six categories. The horizontal axis shows the individual's performance (on a scale from 0 to 100) in the nonverbal task while the vertical axis shows performance in the verbal task. A marker that falls on the red line represents an individual with the same performance score in both the verbal and nonverbal activity. Anyone to the left of the red line did better in the verbal paradigm and anyone to the right did better in the visual

paradigm. If there was no difference in performance between the verbal and nonverbal tasks, we would see roughly the same number of individuals to the left and to the right of the line.

However, the higher density of markers to the right of the red line indicates better performance in the visually presented tasks, with 60.5% of all individuals doing better in the nonverbal paradigm compared with 30.8% of individuals who performed better in the verbal paradigm.

Let's take a closer look at the verbal and nonverbal performance in all six categories.

Task category 1: Attending to a single cue – Shape. The nonverbal task in this category requires attending to shape by demonstrating visual recognition of 10 distinct objects, while the verbal task requires knowing the names for all ten objects. It is reasonable to assume that children who already knew the names of the objects, or who were able to learn them quickly would do better on this level than kids who generally struggle with language. The data show that the average nonverbal performance score (87.6) was 14.4% higher than the average verbal score (76.5), and 64.1% of kids who completed both the verbal and nonverbal category 1 task performed better on the nonverbal task compared to 26.1% who performed better on the verbal task ($P < 0.001$). Developmentally speaking, these results should not be surprising because differentiating between shapes of objects is easier for most individuals than learning the names associated with those objects. It is important to note that this explanation becomes moot for all subsequent task categories since it is impossible for kids to progress in the nonverbal activity without performing well on these initial levels. Only kids who demonstrated adequate knowledge of the vocabulary were able to advance to the subsequent levels.

Task category 2: Attending to a single cue – Size. Both the verbal and nonverbal tasks of category 2 require attending to size. The data show that the average nonverbal performance score (83.3) was 7.7% higher than the average verbal score (77.3), with 60.9% of children performing

better on the nonverbal task compared to 31.4% doing better on the verbal task ($P < 0.001$). While the difference in category 2 performance scores is not as large as that of category 1, it is nevertheless statistically significant, and indicates that it was easier for kids to detect large and small objects when directed to do so nonverbally instead of verbally. It is important to reiterate that only children who demonstrated a fluency with all ten nouns as well as knowledge of the words “large” and “small” could access the verbal levels of this category, so the difference in performance could not be attributed to a lack of necessary vocabulary.

Task category 3: Attending to a single cue – Color. Interestingly, the only task which had no significant difference between performance scores in verbal and nonverbal tasks is category 3, which requires attending to color. The average performance score for both the verbal and the nonverbal task was 85.5% with 46% of individuals doing better on the nonverbal task compared to 45.3% who did better on the verbal task ($P = 0.95$).

The anomaly stems from the surprisingly high average performance score in the verbal tasks of this category. Once kids had learned the words “red,” “blue,” “green,” and “orange,” they were better able to integrate the four color words with all ten objects (average performance score of 85.5 on such tasks) than they were at integrating the two words for size (average performance score of 77.3). These findings are exactly the opposite of what we would expect to see since the verbal color tasks (category 3) require the knowledge and integration of more word choices than the verbal size tasks: kids were expected to know four words for colors (“red,” “blue,” “green,” and “orange”) but only two words for size (“large” and “small”). It is unclear why verbally attending to color seems to be easier than verbally attending to size or to shape, and we will continue to monitor this phenomenon to see if this anomaly disappears as the sample size increases.

Task category 4: Attending to multiple cues – Size & Shape. Besides category 1, the two categories of tasks with the most gaping difference in performance between the verbal and nonverbal tasks are two of the multiple-cue responding tasks: category 4 and 6. For category 4, the average performance on the nonverbal tasks was 13.1% higher than average verbal scores, and 62.1% of the individuals performed better on the nonverbal task compared to 29.8% who performed better on the verbal task ($P < 0.001$). Overall, when directed visually instead of verbally, kids were better able to simultaneously notice both the size and the shape of an object (category 4) than to notice size or shape individually (category 2 and 1, respectively).

Task category 5: Attending to multiple cues – Color & Shape. For category 5 tasks which require simultaneous attention to color and shape, the average performance on the nonverbal tasks was 7.9% higher than average verbal scores, and 60.8% of the individuals performed better on the nonverbal task compared to 30.1% who performed better on the verbal task ($P < 0.001$). While these numbers are not as high as the ones for the other multi-cue tasks, they are nevertheless significant, especially when considering that attending to color on its own (category 3) had virtually no difference among verbal and nonverbal performance.

Task category 6: Attending to multiple cues – Size, Color & Shape. For category 6, the average performance on the nonverbal tasks was 15% higher than average verbal scores, and 72.9% of the individuals performed better on the nonverbal task compared to 20.8 who performed better in the verbal task ($P < 0.001$). Overall, when directed visually instead of verbally, kids were better able to simultaneously notice both the color, size and shape of an object (category 6) than to notice color, size or shape individually (category 3, 2 and 1, respectively).

Task category	Task type	Verbal Average Performance Score	Nonverbal Average Performance Score	Relative difference in Verbal and Nonverbal scores in percent of verbal score	P-value
1	Attend to OBJECT/SHAPE	76.5 \pm 18.2	87.6 \pm 12.4	14.4	<0.001
2	Attend to SIZE	77.3 \pm 16.4	83.3 \pm 13.4	7.7	<0.001
3	Attend to COLOR	85.5 \pm 13.1	85.5 \pm 12.9	0.1	0.95
4	Multiple-cue SIZE & OBJECT/SHAPE	79.7 \pm 17.0	90.2 \pm 9.8	13.1	<0.001
5	Multiple-cue COLOR & OBJECT/SHAPE	83.1 \pm 14.4	89.7 \pm 10.0	7.9	<0.001
6	Multi-cue SIZE, COLOR & OBJECT/SHAPE	81.3 \pm 14.3	93.4 \pm 7.8	15.0	<0.001

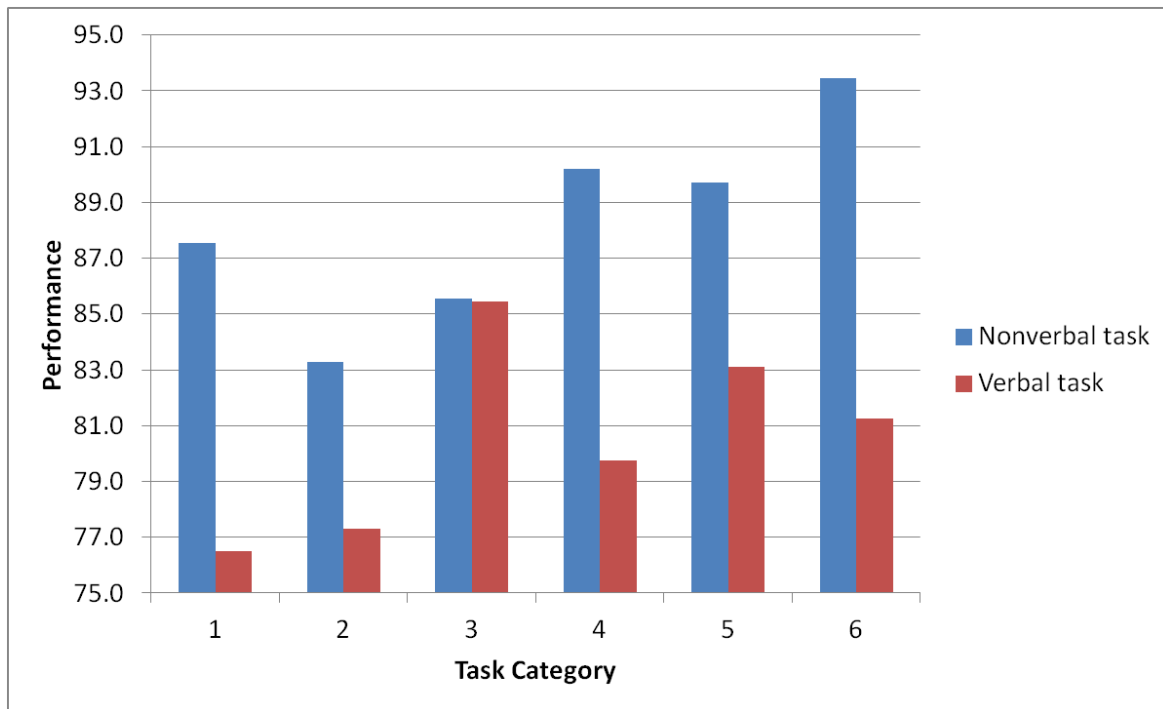


Figure 13. Pair-wise comparison between the verbal and nonverbal average performance scores in all six task categories. See Table 3 for P-value and standard deviations.

Table 3 shows a summary of verbal and nonverbal performance scores in all six task categories, as well as the percent difference between the two scores (see also Figure 13). The average performance scores in the nonverbal task were higher than the average performance in the analogous verbal task in all six task categories. In fact, the percent of individuals who performed better on the nonverbal task is greater than the percent of individuals who performed better on the verbal task for all task categories, Table 4.

Table 4			
<i>Percent of individuals who performed better on the nonverbal task compared to percent of individuals who performed better on the verbal task</i>			
Task category	Task	% with better performance in Nonverbal activity	% with better performance in Verbal activity
1	Attend to OBJECT/ SHAPE	64.1%	26.1%
2	Attend to SIZE	60.9%	31.4%
3	Attend to COLOR	46%	45.3%
4	Multiple-cue (SIZE & SHAPE)	62.1%	29.8%
5	Multiple-cue (COLOR & SHAPE)	60.8%	30.1%
6	Multi-cue (COLOR & SIZE & SHAPE)	72.9%	20.8%

Conclusions

In this manuscript we compare performance on a variety of analogous tasks that were presented both verbally and nonverbally to children with ASD. Many parents and therapists who use MITA have indicated that a child who fails to respond to hardly any form of verbal communication can succeed and even thrive with the puzzle-like nonverbal tasks in the majority of MITA's activities. In other words, a child who may be completely unresponsive to a verbal command such as "find the red crayon" may have no problem finding a red crayon when directed to do so nonverbally. The findings presented in this manuscript support the anecdotal evidence gathered from many MITA users: the average performance was better in nonverbal tasks and

more children had better performance in nonverbal tasks compared to analogous verbal tasks. These findings may have important implications for best practices in ASD therapy. Therapists should keep in mind that their young patients who are undergoing PRT therapy and are struggling to understand or perform verbally-delivered multiple-cue tasks may very well be able to do the tasks if they are presented nonverbally.

Limitations

It is important to note the relatively small sample size. As our study continues and as more and more individuals work with MITA, our sample size will naturally increase. We will continue to monitor performance in the analogous verbal/nonverbal categories to see how increased data size affects the results. It is also important to keep in mind some natural limitation of our data. Since MITA is primarily administered at home by parents, we have no control and very limited knowledge in how it is delivered. For example, some of the inferior performance in verbal MITA tasks may be a result of volume settings that are not properly adjusted during some therapy sessions.

Compliance with Ethical Standards:

This is observational study is exempted from IRB and informed consent according to Code of Federal Regulations, TITLE 45, PUBLIC WELFARE, DEPARTMENT OF HEALTH AND HUMAN SERVICES, PART 46, PROTECTION OF HUMAN SUBJECTS, Subpart A, Basic HHS Policy for Protection of Human Research Subjects, §46.101 (b) (1): “Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii)

research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.”

Competing Interests

Rita Dunn, Jonah Elgart, Lisa Lokshina, Alexander Faisman, Edward Khokhlovich, Yuriy Gankin, and Andrey Vyshedskiy have financial interests in ImagiRation LLC, the developer of the Mental Imagery Therapy for Autism (MITA) application for children with ASD. ImagiRation has been supported by developers donating their time as well as small monetary donations from MITA users. Otherwise, there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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