The Effects of Familiarity on Visual Search Performance of Typically Developing Toddlers and Toddlers with Autism Spectrum Disorder

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Abstract

Visual Search is an attention task that measures how efficiently a person is able to find a target among distractors. It has been found before that children diagnosed with ASD can perform better at visual search when compared to age-matched typically developing children (Kaldy et al., 2011, 2013).

Our team conducted a follow-up study with slightly different stimulus parameters (Smith et al., 2015) and two different potential target objects (in this task, an apple vs. a carrot). The results showed that the identity of the target object influenced toddlers' search performance: they were slightly faster at finding the target when it was the apple than the carrot. This study aims to further explore why this phenomenon occurred. We hypothesized that it may be related to either familiarity (apples may be more familiar to toddlers than carrots) or prior knowledge of language measured by a standard cognitive assessment tool (Mullen Scales of Early Learning). We found that toddlers there was a significant difference in performance dependent on the condition, regardless of diagnosis. This results replicated the study done by Smith et al,. (2015). However, when looking to see the relationship between The Mullen Scales of Early Learning scores and overall performance in the visual search tasks no significant relationship was found.

The Effects of Familiarity on Visual Search Performance of Typically Developing Toddlers

In today's society, discussions and mentions of Autism Spectrum Disorder (ASD) have become increasingly prevalent. According to the CDC, 1:68 children have received an ASD diagnosis. This diagnosis occurring more frequently in males (1:42) in comparison to females (1:189) (CDC, 2017). ASD is considered to be a neurodevelopmental disorder which is primarily genetic in its origin that currently can only be diagnosed through psychological and behavioral assessment. In terms of the diagnosis timeline, the earliest time for a child to receive this diagnosis is about two years of age. This is the age of the participants in this current study.

The symptomatology that occurs within the group of people diagnosed with Autism varies greatly. This disorder is referred to as Autism Spectrum Disorder due to the fact that the symptoms can vary form mild to severe on a spectrum. For example, there are people with ASD who are high and low functioning in terms of cognitive capabilities but also vary in sensory, social, and language capacities as well (CDC, 2017). Symptoms develop early on in a child's life, which can lead to an early diagnosis of this disorder and the proper following steps that can best suit the child's growth and overall development both cognitively and socially.

Two distinct diagnostic criteria for Autism Spectrum Disorder that appear in the DSM 5 are (1) deficits in social communication and social interaction and (2) repetitive behaviors and restrictive interests (APA, 2013). Repetitive behaviors can be defined as repetitive movements or repetitive use of objects, such as lining up blocks the same way over and over. Restrictive

Interests can be defined as highly focused and specific interests (for example, in trains, cars, etc.). Children with ASD who demonstrate this behavior do not react well to changes in their environment and may take awhile longer to adapt to those changes. Typically, these children might exhibit a need for routine and preparation. These two clinical symptoms are just a small example on how the world can be processed differently for those with an Autism diagnosis.

In addition to these two core groups of symptoms, there is a growing set of evidence that individuals with ASD also process the visual world differently. There are key perceptual and attentional differences in people with ASD and these differences effect the way they are able to perceive and attend to their environment. People with ASD usually attend to their environment differently than typically developing people. In terms of visual perception, there are differences found in the focus on visual differences among objects (Simmons et al., 2009). These perceptual differences in focus or interest in objects could explain particular interactions people with Autism might have with objects. This could also relate back to restrictive interests or repetitive behaviors diagnostic criteria for Autism if the object has a particularly high perceptual salience or interest.

Then, there are attentional differences that emerge earlier in life that could also potentially lead to the sociocommunicative impairments that are also found in people diagnosed with ASD (Keehn et al., 2013). These early symptoms that relate back to the two main core diagnostic symptoms can effect the way people with Autism continue to develop as a whole through understanding and interacting with their environment, but also on that social level. The attentional differences found in people with ASD can be further explored through differences, and strengths, in visual attention task.

Visual attention is how well a person is able to find and monitor goal-relevant objects in their visual environment. Some of the studies on visual attention in ASD identified an overly narrow focus of attention. This can be related to the restrictive interests common in individuals with ASD. Visual attention can also be understood as the way people are able to process the visual work, and how well they are efficiently able filter through different aspects of their environment. This is an attentional subset that is extremely important to overall functioning since it gauges and relates back to cognitive mechanisms such as memory (Keehn et al., 2013).

One of the classic tasks to study visual attention is the visual search task (Treisman & Gelade,. 1980; Wolfe & Horowitz,. 2004). Visual search is a task used to in psychological based research that measures how successful one is able to find an object among a plot of distractors. A participant is given a target image to look for and then they must find that image when it is mixed with other images that may look similar to the target image in some ways and different in others. Visual search is a way to measure a specific aspect of visual attention (selective attention). In adult studies, participants are presented with displays with or without the target, and their task is to press a button as soon as they can indicate whether the target present or not and their reaction time is measured.

As mentioned above, it has been known for some time that school-age children and adults with an ASD diagnosis perform better in visual search tasks than typically developing children or adults, respectively (Plaisted et al., 1998; O'Riordan, 2004). More recent studies found that even very young children with an ASD diagnosis do just as well or even better in visual search tasks (Kaldy, Kraper, Carter, & Blaser, 2011; Gliga et al,. 2016). In these studies, instead of reaction time and button presses, gaze responses are through an eye tracker.

The success of these studies were also measured through how “successful” participants were at finding the object in an allotted amount of time (Kaldy et al,. 2013). The eye tracker itself is able to track the participants gaze as their eyes follow objects on a screen. When conducting studies with very young children or infants, eye tracking studies are typically done due to them being easier for children to participate in since all they must do is look at what is happening on the screen. In this particular studies, they were looking at a screen that would show a visual search task and they would be expected to find that target object. If they were able to find the target object after a certain period of time (for each trial), then that trail was deemed to be successful.

We hypothesized that better performance in toddlers with ASD was a result of their superior ability to focus their attention on finding the target in the task (Blaser et al, 2014). The question was: were toddlers with ASD focused on the task (finding a target) or on the target itself (finding the red apple). To answer this question, in a recent follow-up study conducted by Smith, Blaser, and Kaldy. (2015), toddlers with an ASD diagnosis were tested on their visual search skills and their ability to switch targets.

The first goal was to replicate earlier findings with different stimuli, the second goal was to test whether participants were able to flexibly update the identity of the target. Here, we will focus on the first goal, and examine a specific hypothesis related to a manipulation that was used. In the Smith et al. study (2015), infants were placed in front of a computer screen and shown a target image. The target image in the first set of trials was either that of an apple or that of a carrot. The same target was displaced amongst distractors of similar shapes or colors (See Figure 1 below).

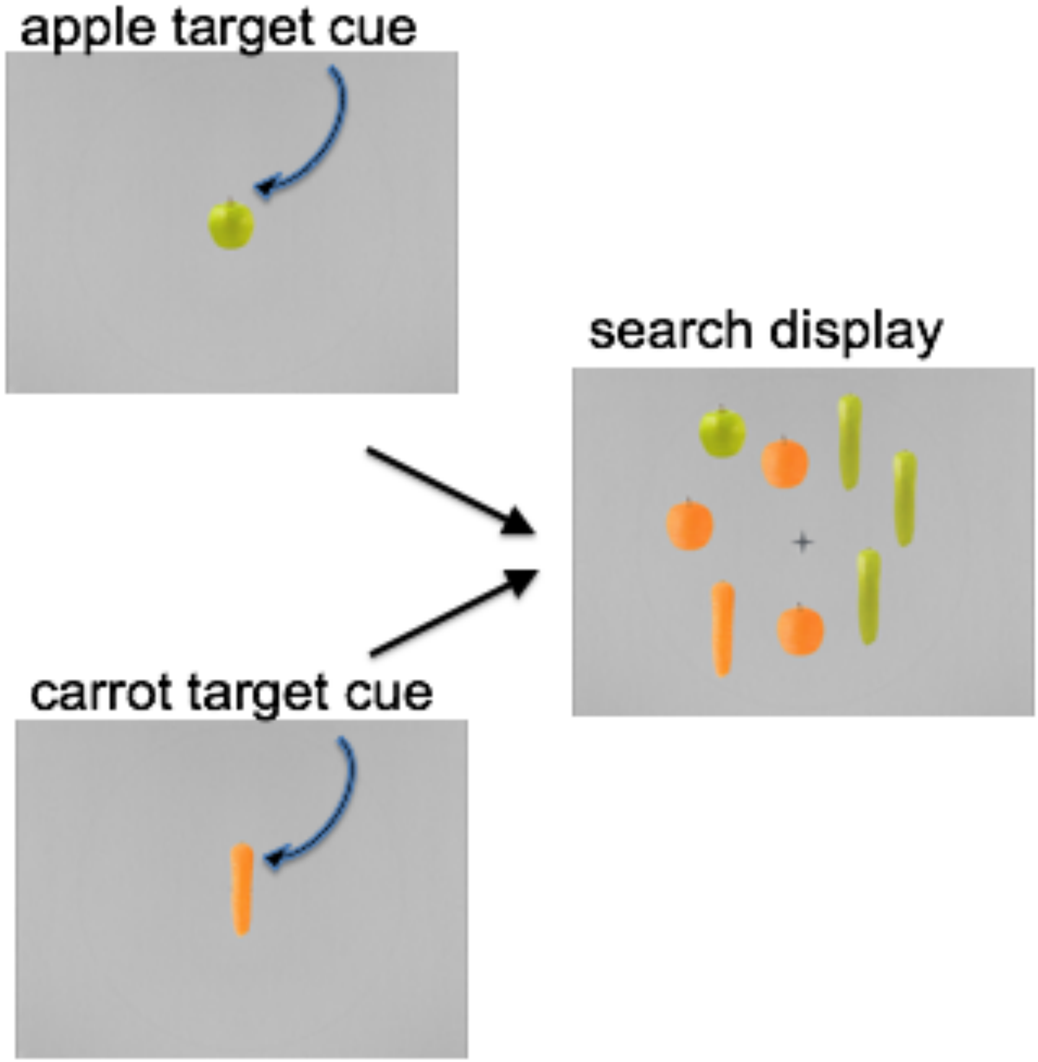


Fig. 1 Visual Search Target Objects and Visual Search Display. Each of the target objects in question were equally salient (visually).

Instead of verbal instructions, the special status of the target was highlighted by making honking noises and spinning. These cues helped to keep the toddlers interest and focus on the object in question. The rationale behind not giving specific verbal instructions is because at this age not all children are verbal. Also, making the target object special in some regard, could potentially increase the interest in the target. These noises and spinning of the shapes substituted any potential verbal instructions. Then, in the second set of trials the target item would switch to a carrot if the original was an apple and vise versa. This design allowed Smith et al. (2015) to measure target switching performance. This was an eye tracking study, so the toddlers' gaze was measured and the duration of time spent on an object was measured. In this study, it was noted that there was a difference in performance for the two potential targets. It seemed that overall the toddlers in the study, both with an Autism diagnosis and those typically developing, did not perform as well when the target was the carrot. Therefore, it seemed as though there was something about the carrot specifically, since both groups preformed less successfully when in the carrot condition.

This is where the first hypothesis for our current analysis stems from. One potential explanation for this phenomena could be language development. The words Apple and Carrot have different developmental trajectories, and are used and understood at different points during a toddler's life, as shown in figure 2 (Frank et al., 2016).

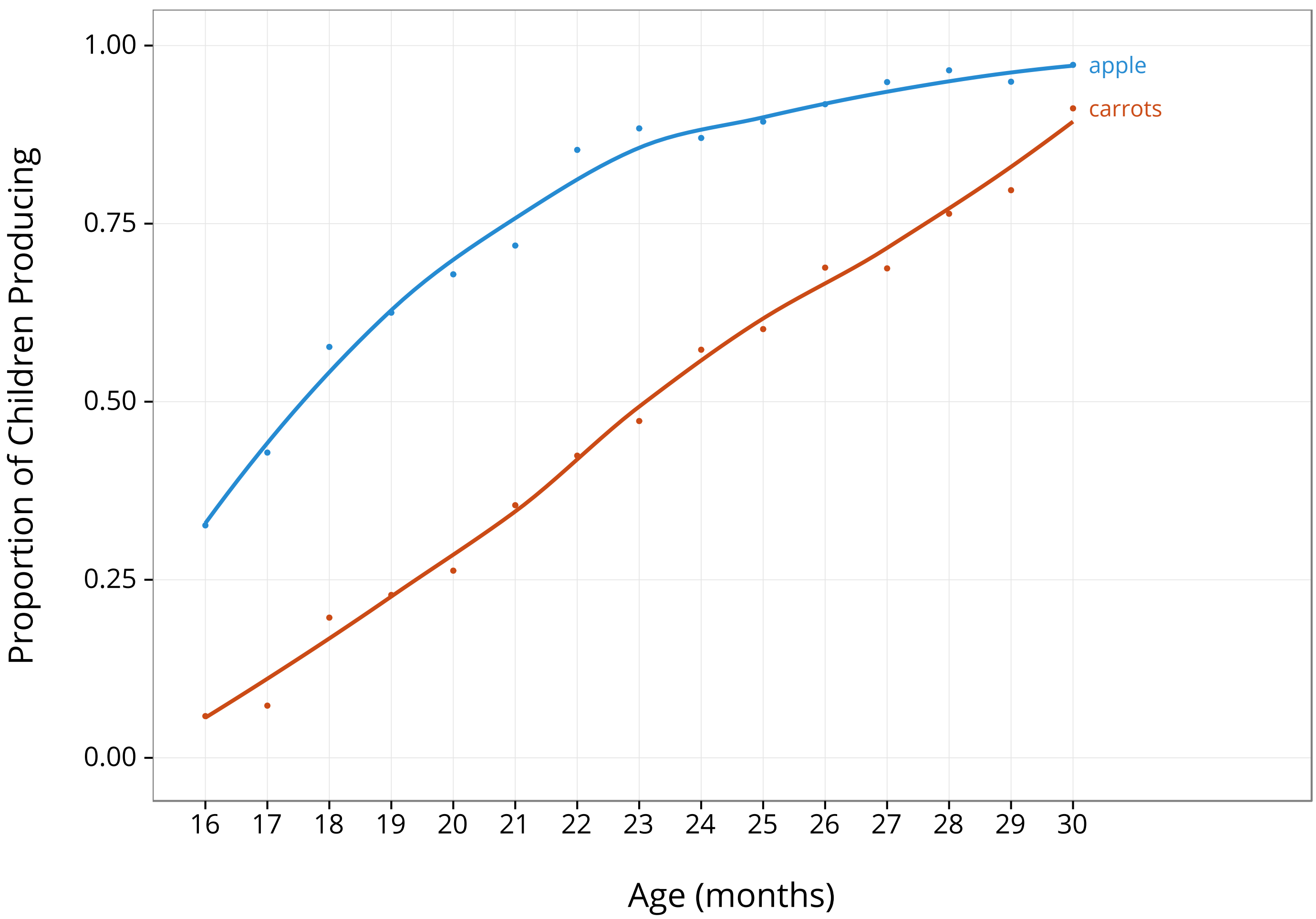


Figure 2. production of the words Apple and Carrot when compared to age. The producing of words is measured both linguistically but also by making gestures.

The decrease in performance when toddlers are exposed to the Carrot as the target object could be explained by the knowledge of the words "Apple" and "Carrot". It can be hypothesized that since the word apple is understood or produced more at a younger age then they might be more knowledgeable of apples and therefore more interested in them. For example, if a child saw apples frequently in their home and then watched how the apple behaved on the visual search trail in our lab they might be more focused on it because it is an object they are familiar with that might be acting in unfamiliar ways.

Familiarity is a key point when learning about objects. The more exposure one has to an object that more familiar they may be with it and the less novel the object is. It has been demonstrated in previous research that infants will spend more time investigating and looking at novel objects than objects they may already be accustomed to seeing. Apples and carrots may be objects that a toddler is familiar with, but one might be far less novel than the other. The role of familiarity when choosing a stimulus might be one to look further into, for this type of variable could affect the studies outcomes in a way not predicted or affected by the visual search task or diagnosis.

During the Smith et al. (2015) study the participants also took a Mullen Scales of Early Learning (Mullen, 1995) test. This is a standardized assessment that evaluates the cognitive functioning of infants and toddlers. Two portions of the MSEL were measuring receptive and expressive language. These two components could give an idea of a child’s understanding and use of language. Items on the receptive language scale look at how well children can understand a set of words, while items on the expressive scale look at how well they would be able to repeat or correctly identify an object using the words. Not only does the MSEL measure overall cognitive functioning, one assessment that can be used during an ASD diagnostic process, but it can give supporting data for the idea of familiarity of objects. How well a child might do on the MSEL could be connected to how many objects they understand or know, and that information can be brought into question when thinking about how familiar or novel the items in the study are to the participants.

What this present study looks into is the relationship of visual search and familiarity. The previous study conducted by Smith et al. (2015) showed that children both typically developing and with ASD are both able to complete visual search tasks, but the depending on the target, different results were found. The stimulus present, an apple or carrot, may have different levels of familiarity depending on the exposure the child may have to that object. For example, according to the Word Bank from Stanford University, (2016) it is clear that from an earlier age children understand the world 'apple' versus 'carrot'; the understanding of the word carrot comes later (see fig. 2).

It has also been shown that a child's knowledge of the word associated with an object, or a label, could potentially increase their focus or attention for that object (Vales & Smith,. 2015). Therefore, exposure to the names of these objects could influence the focus on the participant or it could just make the object more interesting to look at during the visual search task. In general, vocabulary size is highly variable at this age (in both toddlers with and without ASD). Also, children who have an ASD diagnosis have a different trajectory when it comes to language development (American Psychological Association, 2017). Although Smith et al., (2015) did not find a difference between group performance but only condition performance the language development may not be relevant but should still be noted.

In order to measure language development or understanding in this analysis, we looked at the MSEL language scores for both receptive and expressive language. These scores give us better insight into what might be expected for language understanding or knowledge. Therefore, this study aims to further analysis the data previously collected in Smith et al. (2015) to see if there is a link that could further explain the difference in performance for children in the apple vs.

carrot conditions. This may also be related to the aspect of familiarity mentioned above and how items like apples might be more familiar or less novel to toddlers of this age range.

To quantify the success of visual search in this task we analyzed a measure that we defined as Target Priority Score. In each display, there are 8 potential objects that the participant can look at (target, non-target, and six distractors). This is a ranking system of 1-8, 1 being the first object a child set their gaze on and 8 being the last object their gaze was fixed upon. The ranking was gathered for both the target and the non-target stimulus. This is what will be used to measure success over the speed to which each item is found.

The main two hypotheses' in this study is to see if there is in fact a difference between performance in trials where the target was the apple or the carrot in the first visual search phase and if there is a difference in performance between the two groups. The group difference mentioned would be any difference found between the typically developing children or the children with an ASD diagnosis. Finally, we will further examine if the Target Priority Score depends on the language measures of Receptive and Expressive Language scores taken from the MSEL test.

Methods

Participants

In the current study, 18-36 months old toddlers were recruited from the local Boston area. The toddlers recruited from this method were typically developing. Participants with an ASD diagnosis were gathered through local early intervention facilities. The toddlers who were diagnosed with ASD took various assessments such as the ADOS-2 (Autism Diagnostic and Assessment Scale, 2012) and the MSEL; they were also assessed by a clinical psychologist trained to diagnose toddlers with this disorder (Dr. Alice Carter and her clinical assessment team members). Demographic and language information was also assessed during the visit to the lab for the study. Many toddlers in this study were both raised in a monolingual household, where either English or another language such as Spanish was spoken prominently, or bilingual households. Data for two parent-based surveys was available for a subset of our participants. There were also several other parent based assessments given such as the BITSEA (Brief Infant Toddler Social and Emotional Assessment, 2005) and the POSI (Parent Observations of Social Interaction, 2013).

The final sample used for this study and analysis consisted 38 toddlers diagnosed with ASD (mean age: 27.7 months, 2 females) and 45 typically developing toddlers (mean age: 28.1 months, 22 females).

Procedure

Participants' gaze was monitored by a Tobii T120 Eye Tracker. The eye tracker had an attached screen where the visual search task would be displayed. With this type of eye tracker, the child does not have to wear any sort of headgear in order for the device to track their gaze.

An infrared light is emitted by diodes in the eye tracker and its reflection from the participant's cornea allows the calculation of the eye gaze direction. There is no harm in this method and the participant is unable to feel the light at all.

The toddlers in this study would be placed either in a high chair or on their guardian's lap. The guardian would then wear either glasses or a visor to prevent their eye gaze from being tracked.

The visual search task in the present study involved two different types of target images that were dependent on the condition. In one condition, the target object was an orange carrot and in the other condition the target object was a green apple. The target object would then be shown on the screen alone for and then would spin and make a honking sound. Then the visual search screen would appear for 4 seconds followed by the target image spinning and making another interesting noise among the distractors surrounding it for another second. This would then repeat for 5 trials (Please see Figure 1). This part is called phase one

. Phase two would then be a target switching task where the target object would switch to the non-target. For example, if your target object was the green apple in phase one then the non-target would be the orange carrot, and in phase two the target object would be that orange carrot. The same procedure would follow for phase two, where the new target image would be shown on a screen alone and then among the visual search tasks for 5 trials. Phase three would then start, which would be the target image switching back to its original target image. The same steps would apply.

However, in the present study and for the following analysis we only looked at the first phase and ignored the task switching. Our research question was not concerned with the task switching component but only with the performance according to condition, or being exposed to the apple as the target image versus being exposed to the carrot as the target image.

Once finishing the visual search task, the parents were given the other assessments such as the ADOS-2, BITSEA, and POSI as needed. The MSEL was also given to assess the child participant. The ADOS-2, BITSEA, and POSI were all different autism diagnostic assessments that looked into things like social interaction and behaviors related and not related to emotion.

In terms of measuring success in the visual search task, we used Target Priority Score. Target Priority Score is a ranking system, for example if there were a total of 8 items on the screen and you looked at two distractor items before the target object your Target Priority Score would be a 3. A Target Priority Score would be taken for both the target object and the non-target object. The target object and non-target object in question would depend on the condition that the participant was in.

To get the final Target Priority Score we took the difference between both of the target priority score of the target object and the non-target object. For example, if the ranking for the target image is 3 and the non-target image's rank is 2 the target priority score would be 1. This is how we measured the how successful a participant was in the visual search task. This measure is different from what was used in earlier studies in our lab (Kaldy et al, 2011; Smith et al, 2015). In those studies, since there was only one target, we used hit rate which is the number of times the target was fixated during the search period. Here, given that there were two potential targets, we used Target Priority Scoring.

Results:

The following analyses were done regarding phase one of the visual search task. The target priority score for each participant was run through a univariate test in SPSS to see if condition, group (ie: diagnosis), or any of the MSEL language scores showed a significant relationship connected with their target priority score. A significant difference was found in Target Priority Score between the two conditions (apple or carrot) ; p=0.038. This finding replicated the previous study conducted by Smith et al., 2015 which also found a significance difference in performance in the two target conditions. It was found that participants found the apple more successfully than they found the carrot. This finding was regardless of diagnostic group, for group itself was also not significant, (p=0.210, f= 3.145, df=1)

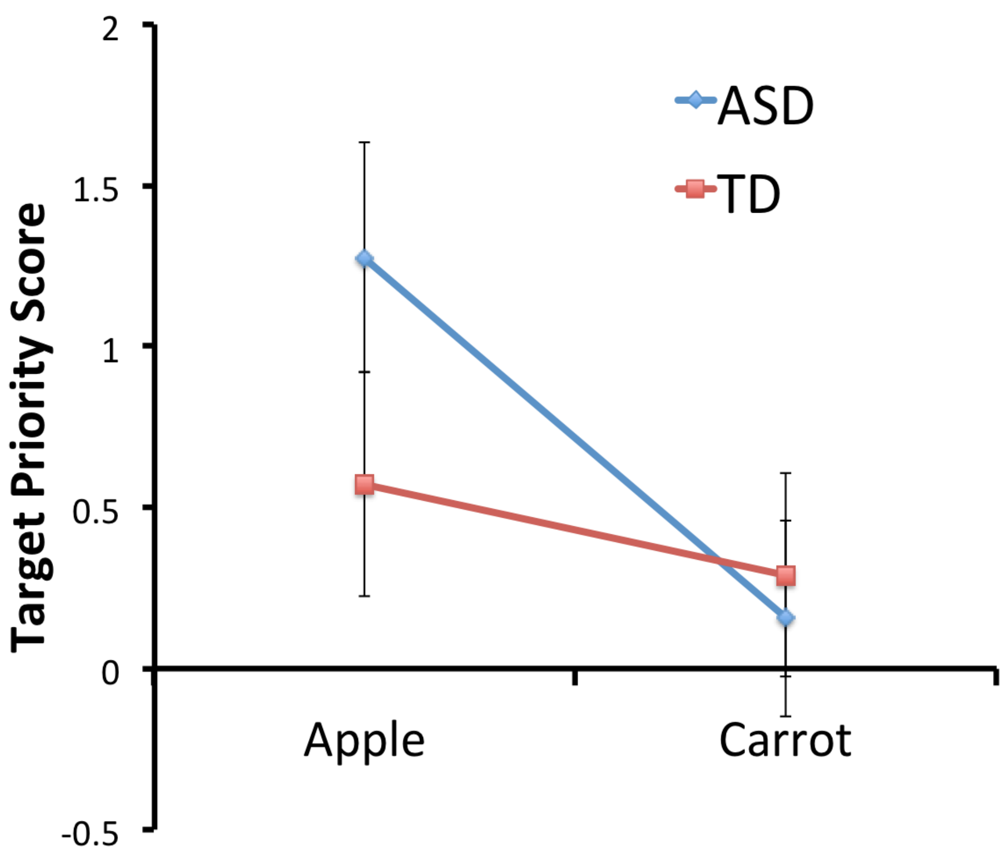


Figure 3. The Effect of Condition on Target Priority Score in the two groups (ASD/TD)

To look into our hypothesis regarding why the phenomenon occurred, we looked into the subscales of the MSEL. The main two priority scores in question were the Receptive Language Score and the Expressive Language Score. These two measures were the only subscales in the MSEL representative of language knowledge or understanding. After further analysis it was found that neither of these scales were significant when looking the relationship between them and the target priority score, receptive language (p.=0.646, r=0.0612) and expressive language (p=.850, r=0.096).

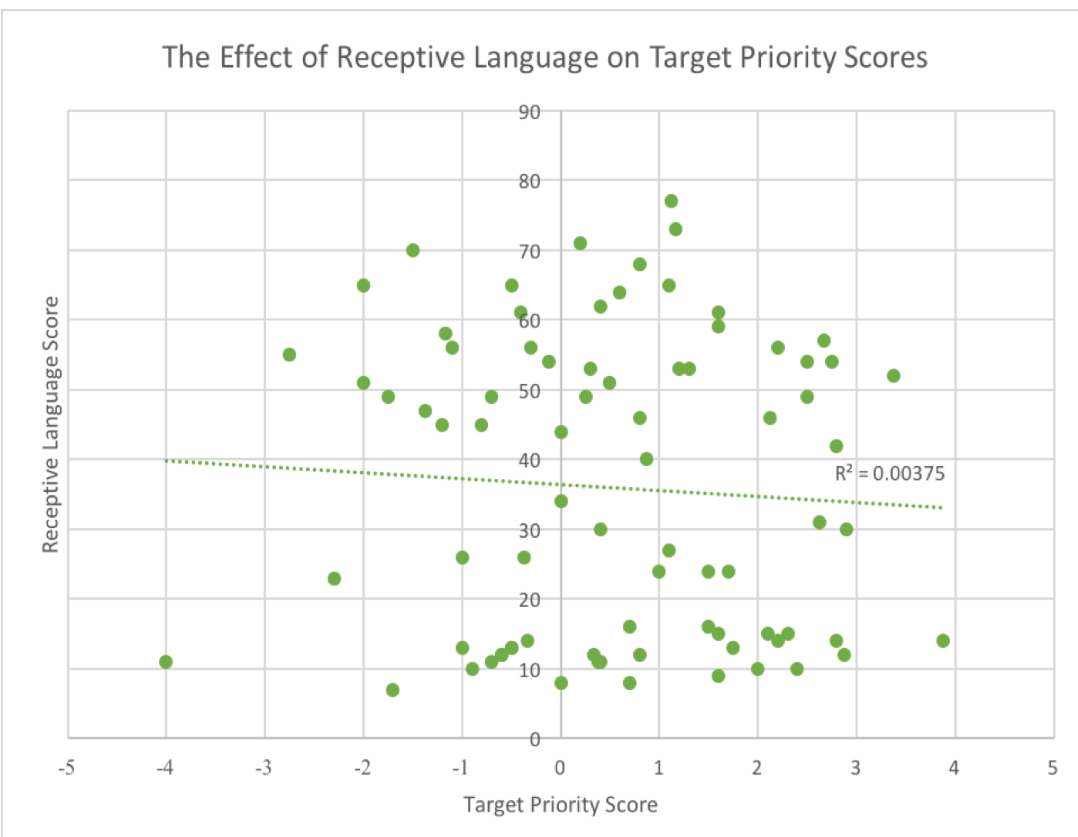


Fig. 4 Target Priority Score and Receptive Language MSEL Score

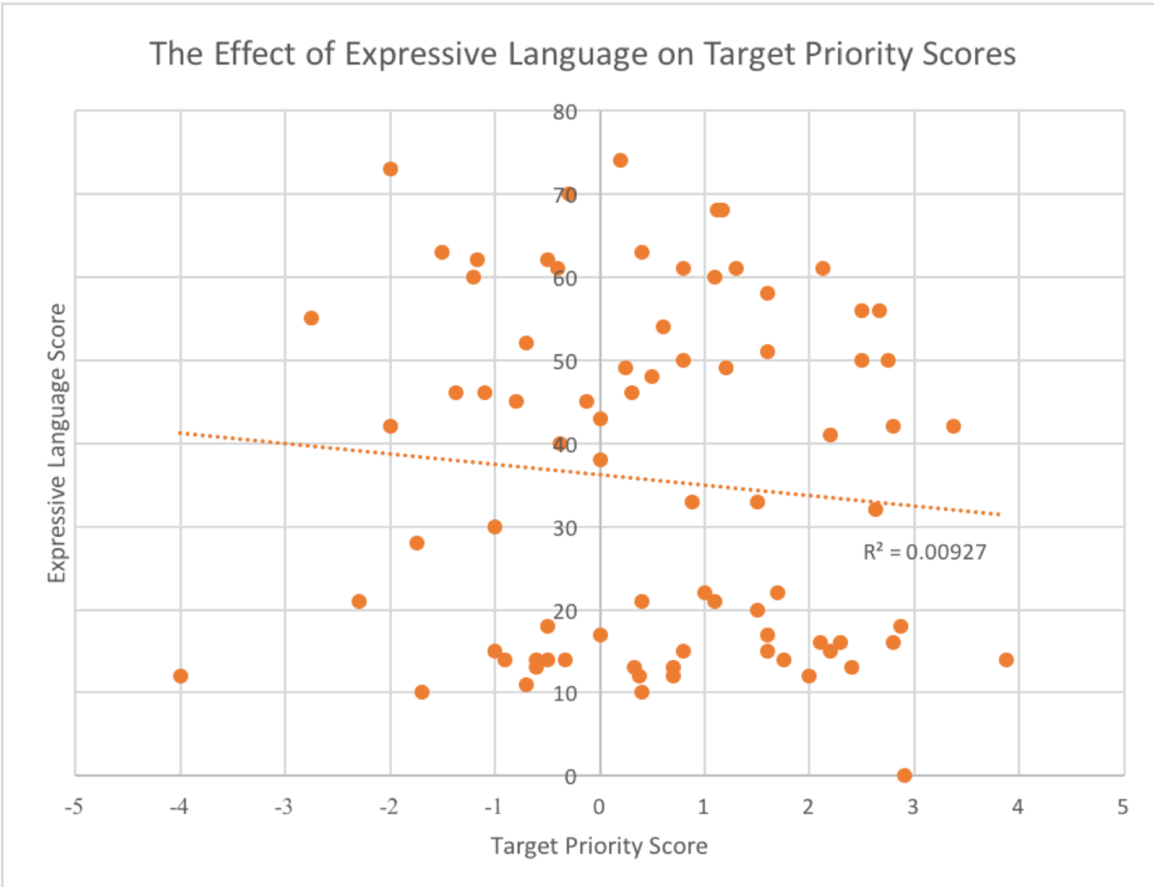


Fig 5. Target Priority Score and Expressive Language MSEL Score

The MSEL consists of five subscales in total: Receptive Language, Expressive Language, Fine Motor, Visual Perception, and Gross Motor. For the current study, the Gross Motor subscale was not used because it was not relevant to our focus. Although the only two subscales that were hypothesized to be significant were the language subscales, for completeness we analyzed the relationship between Target Priority Scores and the remaining MSEL subscales:

Visual Perception and Fine Motor. There was no significance found in these analysis as well, visual reception ($p=0.905$, $r=0.01$) and Fine Motor ($p=0.186$, $r=0.10$).

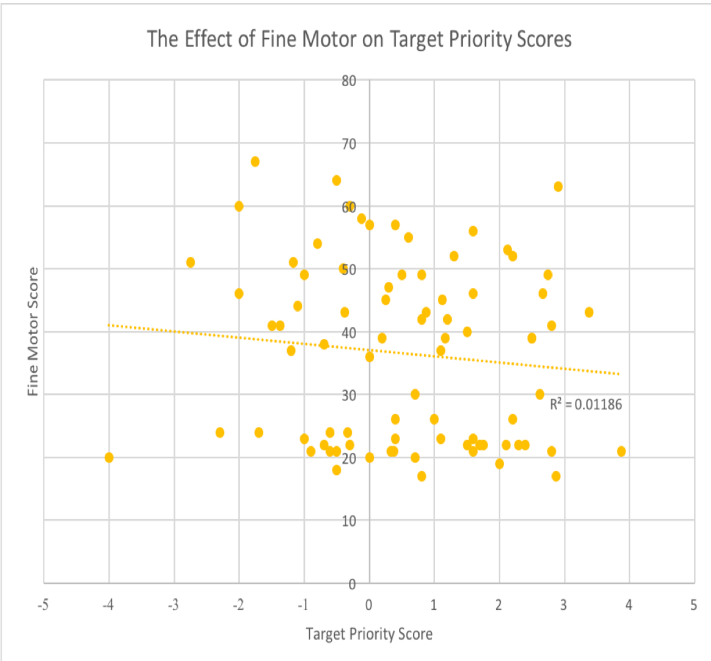
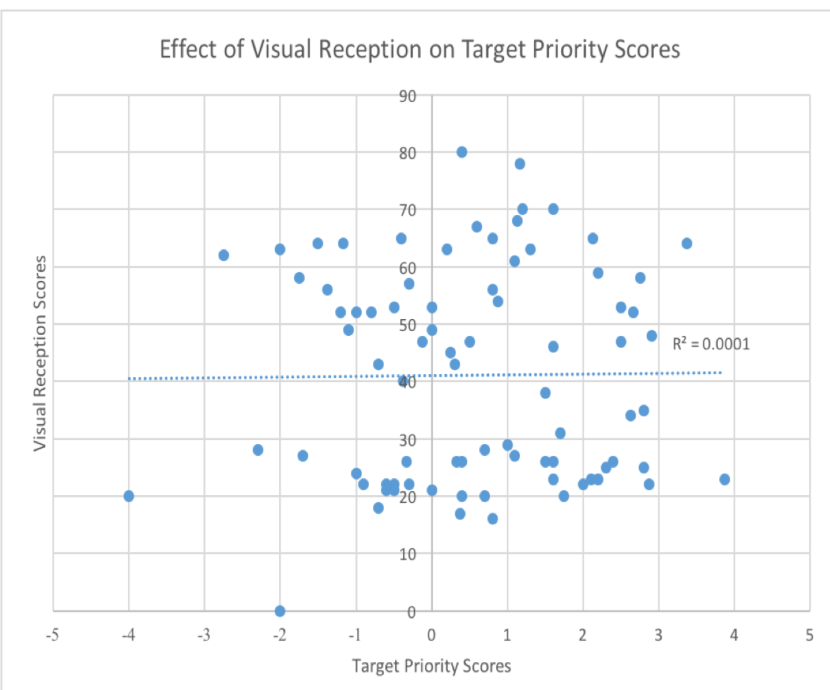


Fig 6. Target Priority Score and Fine Motor Score

Fig 7. Target Priority Score and Visual Reception



Score

We also analyzed the effect of the age of the participants on Target Priority Score, no significance can be reported here.

Fig 8. Target Priority Score and Age

None of the MSEL subscales or age can predict Target Priority Scoring or success in the visual search tasks. The condition is the only thing we can report with significance.

Discussion

The present study sought to explore why the performance differed in the conditions regardless of group. We hypothesized that the language knowledge of the stimulus in question, or the level or familiarity with that object a participant may have with the object in question could explain this phenomenon. However, we were not able to explain the difference in terms of MULLEN MSEL scores, we are only able to say that there is indeed a statistically significant difference in performance.

According Frank et al., (2016) the word carrot becomes more frequently used and is "understood" at a later age in development than apple is. Apple is more frequently used and understood at a younger age, see figure one. The use of some of these words when in a teaching or home setting may directly affect not only a child's knowledge of the word but also familiarity. This was the theory behind the basis of our hypothesis as to why this phenomenon occurred and even though our results did not find any relationship there is a chance that our measures did not measure this world knowledge accurately.

The Mullen Scales of Early Learning assess both Expressive Language and Receptive Language, but it does not have any direct measure of word knowledge regarding the words 'apple' and 'carrot'. Therefore, this scale may be too indirect to draw this type of conclusion from. In the future, an assessment measuring linguistic knowledge specifically regarding the target objects' names could potentially yield more significant or conclusive results.

Regardless of results, this phenomenon regarding the effect of condition can bring about many important questions regarding stimulus selection. The effect of the stimulus itself seems to be able to affect results and ways that might have not been able to be predicted prior. At this age, toddlers are paying attention special attention to their environment and what is in their general surroundings. They may also be in an importance stage of language development, objects that they are familiar with or unfamiliar with may prompt different responses.

The novelty or familiarity of an object may affect not only the child's interest but also their attention, which in theory could affect visual search performance if the stimulus is more familiar to a child versus a stimulus that is different than anything they have interacted with previously.

Alternatively, it is possible that there was some sort of perceptual salience difference between the two objects. Rather than being due to a conceptual difference regarding knowledge, the findings of this study could potentially be explained by how interested the toddlers were in the objects themselves. Toddlers might have preferred the shape or color of the apple rather than that of the carrot. Therefore, toddlers would be more successful in the trials where they were exposed to the apple due to some type of perceptual salience.

Since this difference in performance was found regardless of diagnostic group, something general about the carrot condition makes it difficult for toddlers to find the carrot as successfully as the apple; for both groups found this more challenging. Follow up studies can be conducted to further analysis this finding, and further questions can be asked about the effects of familiarity and linguistic knowledge. Specific measures may be used in the future to determine more precise findings.

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