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Incidence of Latency as a Measure of Learning in Children with Autism Spectrum Disorders

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Abstract

Autism Spectrum Disorders (ASD) is currently receiving a lot of attention in the scientific community. Along with the increased level of research, studies using children with ASD may not be using the most effective standards to measure learning. Latency, defined as the time it takes to respond to the onset of a stimulus, currently is not often used in autism research even though other studies have shown latency as being an accurate cue for accuracy of an answer. With this in mind a review of the literature was conducted to see if the current studies using discrimination training in children with ASD would benefit from using latency as a measurement of learning. The literature review did indeed reveal that latency would not be difficult to implement in studies and it would be a good measurement to assess learning in children with autism.

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Lastly, I couldn't finish this section without sending a special shout out to coffee. Whether it was 5:00 pm or 5:00 am, coffee was always there to help me finish my thoughts.

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I. Introduction

Human behavior has been something pondered over and studied since humans could first think about their actions. Even today, when we know so much about biology, chemistry, and a plethora of other topics once mysteries to man, human behavior is one thing that still eludes us. So, the question still remains: Why do we do the things we do?

Each area of science has their own way of breaking this question down and theorizing explanations of human behavior. Ask a neuroscientist this question and he/she respond with a complex diagram of biological processes occurring in the brain. Ask a follower of Sigmund Freud and he/she will give you an explanation including sexual repression occurring during childhood. However; if you ask a behavioral psychologist, he/she will give you an explanation for human behavior that can be directly observed by the way that the environment acts upon behavior. Behavioral psychologists are concerned about aspects of behavior that can be visibly seen and therefore manipulated. They would argue that different facets of human behavior occur because of past and present contingencies with these behaviors; if one received praise or a preferred object after a behavior occurred, the likelihood that the behavior will happen again in the future is increased. This has contrasted with the notion that any behavior followed by a punishing factor will have a decreased chance of happening again in the future.

When related to other forms of psychology, applied behavior analysis is somewhat new. The foundations of this form of behavioral psychology can be seen in work done as early the 1910s by Edward Thorndike. Thorndike coined the term "behavior modification" while being a pioneer in research done on learning and modifying behavior (Thorndike, 1911). Thorndike used his observational research on

behavior to describe his law of effect, a precursor and foundation of future behaviorism. In his law of effect Thorndike described two conditions: when a behavior is followed by a positive or satisfying reward, these connections are then strengthened, and behavior followed by unpleasant conditions with therefore be weakened (Thorndike, 1927). This research, which was radical during its time because it was some of the first research to suggest that behavior could be modified by external contingencies, laid the groundwork for future psychologists to build off of.

One of the most prominent psychologists, and influential psychologists in the field of behaviorism who was influenced by Thorndike's work was B.F. Skinner. Skinner founded experimental behavior analysis through his intensive work with the relationship between behavior and its consequences. Throughout years of research Skinner molded behaviorism into what it is today: a look at the contingencies occurring in the environment and their effect on human behavior. Skinner strongly believed that all behavior could be modified by differing relationships with the environment and he discovered the principle of reinforcement (both positive and negative) as the explanation for how nature strengthens behaviors (Skinner, 1953). The theory of reinforcement is arguably the most important contribution to the field of behaviorism, as it is used to almost every psychological study as a mean to keep participants engaged in the tasks being measured. Reinforcement is also an integral component of studies done in the field of applied behavior analysis as it is used to increase the rate of beneficial behaviors.

A pioneer of applied behavior analysis, Ole Ivar Lovaas, took Skinner's experimental work and applied it to autistic children. Lovaas was the first researcher to provide empirical evidence that the behavior of autistic children can be modified through

teaching (Buckmann, 1995). Lovaas initiated the switch from experimental behavior analysis to applied behavior analysis and without his work, the field of applied behavior analysis very well may not be as prominent as it is today. Lovaas took his applied research and then created the Lovaas method of therapy at UCLA. This method of therapy involves discrete trial teaching, breaking down skills to their most basic components, rewarding positive performance with praise and reinforcers, and teaching learners to generalize skills in a more natural setting. When this method was tested against a control group, it was found that 90% of the children using the Lovaas method saw improvements in behavior (Lovaas, 1987). This form of therapy is also the only of its kind to have gotten approval by the U.S. Surgeon General's office in 1999; in which the Surgeon General stated that applied behavior analysis (specifically the techniques developed by Lovaas) was effective in reducing problematic behaviors while simultaneously increasing behaviors dealing with learning and social communication and interaction (Satcher, 1999).

A student of Skinner, Ogden Lindsley founded Precision Teaching; an educational method that directly applies the findings of applied behavior analysis to increase the efficiency of learning. Precision Teaching, unlike typical teaching methods, focuses on rate of behavior change (which is also the key principle of applied behavior analysis). Teachers can then use these quantitative measures to directly evaluate whether or not a skill is being learned or improved upon. Learning could be directly viewed on what Lindlsey coined a "standard celeration chart". This chart allowed students to directly measure their improvement. The most important feature of Precision Teaching is its focus on fluency that is unlike any other teaching method. This new focus on the

correct responses within a given time was unlike any other measurement of learning seen before and completely changed the world of education (White, 1986). Pioneers in the field of fluency, such as Carl Binder and Kent Johnson took Lindsley's work with fluency to new levels. Carl Binder conducted many studies showing the efficacy of fluency in the acquisition of novel behaviors and urges researchers to use fluency as a measurement of learning in their studies (Binder, 1996; Binder & Watkins, 2013). Meanwhile, Kent Johnson applied fluency to his educational program he developed at the Morningside Academy (Johnson & Layng, 1996). The Morningside Academy uses fluency to help learners with intellectual disabilities to decrease their deficits in education and help them to gain reading and math skills.

From the push to teach skills to fluency, the measurement of latency has evolved. Latency is defined as the amount of time, after a stimulus has been presented, it takes for a response to be made (Martin & Pear, 2011). If latency is found to be a valid measurement of learning, then latency should then be used as a measurement of learning in studies done with ASD. This review is a call to use latency as a valid measurement of learning in studies in which children with ASD are taught various skills or behaviors. Using latency as a measurement of learning will help lead to more accurate studies being completed with teaching skills to children with ASD, therefore leading to skills being taught to a higher level of understanding. The type of skill that could be learned using latency could be used most prominently in an academic sense, for example, helping a child with ASD to learn how to read, speak, or solve math problems. This measurement of learning expands to social activities, such as learning how to play sports, learning how to converse in social situations, and learning daily living hygienic tasks.

II. Methods

Literature Review

The literature review was conducted by first looking at various academic journals to find relevant studies and research done in the area of ASD and/or latency. Three main journals given special consideration were, *Journal of Precision Teaching and Celeration, Research in Autism Spectrum Disorders,* and *Journal of Applied Behavior Analysis.* Along with looking through these journals various articles also dealing with ASD and latency were obtained by searching through the OneSearch database located on the University of Nevada, Reno Mathewson-IGT Knowledge Center website. ScienceDirect and Web of Science were two other databases that were imperative in reviewing the literature pertinent to this thesis. Keywords used while searching these databases were: "autism", "autism spectrum disorders", "discrimination training", "latency", and "fluency".

Article Selection

An article was included in this literature review if it met the following standards. Firstly, the article dealt specifically with children diagnosed with ASD. In the review of the literature done with using latency as a measurement of learning, the participants did not have to be diagnosed with ASD, but it was required that the study utilize latency as some form of measurement of behavior. The children involved in the study relating to ASD were between the ages of 2-12 years old. The last criterion was that the article was conducted between 2005-2015.

Interobserver Agreement

An interobserver agreement was obtained between the mentor and mentee of all

the articles used in the literature review. To obtain this, the studies found and analyzed for this literature review was read through and main points were discussed for each article. An agreement about the findings of each study was then made between mentor and mentee to ensure that each study was being analyzed the same way. This agreement was obtained to give more validation to the review and to make sure the articles were being properly analyzed.

III. Autism Spectrum Disorders

Basic Information

Definition

Autism spectrum disorder (ASD) is defined as a developmental disability that has an onset in young children (Autism Speaks, 2015). According to the DSM-5, ASD has a number of defining characteristics which includes persistent deficits in social communication and social interaction across multiple contexts (American Psychiatric Association, 2013). Another defining identifier of ASD is that there is a restricted, repetitive pattern of behavior in at least two of the following categories: stereotyped or repetitive motor movements, insistence on sameness, highly restricted, fixated interests, and hyper or hyporeactivity to sensory input or unusual interest in sensory aspects of the environment. These symptoms must also be present in early childhood and they must cause clinically significant impairment in social, occupational, or other important areas of current functioning (American Psychiatric Association, 2013).

History

ASD has gone through a number of changes in diagnosis throughout the years since it was first catalogued. ASD was first entered into the DSM-3 in 1980 and first carried the name of infantile autism (The National Autistic Society, 2014). The name was then changed to autistic disorder in 1987. In the DSM-4, published in 1994, autism was then split into different categories: Autistic Disorder, Asperger's Disorder, Childhood Disintegrative Disorder, and Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS). These different categories of ASD differed by varying levels of severity of symptoms, and whether or not certain symptoms were present. For example, Asperger's

Disorder is typically distinguished from Classic Autism by having less severe symptoms and an absence of language delays that are typically seen in classic cases of autism (Autism Society). When the DSM-5 was published in 2013, the American Psychiatric Association did away with the separate categories of autism and instead made an umbrella term for all of these disorders known as Autism Spectrum Disorder. ASD is currently viewed as a spectrum of disorders and one can lie on the moderate end of the spectrum if they exhibit only a few symptoms, such as only exhibiting deficits in social interactions. One can lie at the severe end of the spectrum if they exhibit the severe form of multiple symptoms of the disorder, such as displaying stereotypys, deficits in social interaction, and fixated interests.

Causes

The causes of ASD have always been unknown and elusive to researchers, but because of more advanced research techniques leading to a better understanding of the disorder itself, researchers were able to narrow down a list of risk factors of the disorder. There does not seem to be just one factor that causes ASD, instead there is a list of factors which could potentially increase the risk of a child developing ASD.

When the risk factors of ASD were still not known one popular idea was that the MMR vaccine caused bowel inflammation which then led to the onset of regressive developmental disorders, most commonly noted as ASD (Wakefield, 1999). The original study by Andrew Wakefield in 1999 which published this information has since been found to be fraudulent and was retracted from the original journal it was published in. A plethora of studies (DeStefano & Chen, 2001) have tried to replicate the results of this original study but failed to do so. The scientific community has since denied the

existence of a causal relationship between the MMR vaccine and the onset of ASD (Taylor, Miller, Lingam, Andrews, Simmons, & Stowe, 2002).

Genetics seem to play a key role in the cause of ASD. Recently, this area has been getting a lot of attention and research, and it does seem to be that genetics factor into whether or not a child develops ASD (Huguet, Ey, & Bourgeron, 2013). A study comparing monozygotic (identical) twins found that if one twin had ASD there was a 60% chance that the other twin also had ASD, compared to no dizygotic (fraternal) twins in the study both having ASD. 92% of monozygotic twins were both on the spectrum of having cognitive or social abnormalities, compared to only 10% of dizygotic twins (Bailey et. al., 1995). This study leads to the idea that genetics influence the onset of ASD because monozygotic twins share the exact same genotype. With such a high concordance rate, there is some genetic variation in the genotype of these twins which leads to the development of ASD. Also, the dizygotic twins have a much lower concordance rate which is because they do not share an identical genotype. These twins develop from two different eggs, meaning they share about as much genetic material as normal siblings. Because they still do share some genetic material, it is still expected that there is a higher chance of having ASD if one twin has it, however the chances are much lower since both twins may not have inherited the genetic variation. An exact cause of ASD has yet to be established; however genetics seems like the best source at the moment.

Prevalence

As of 2010, it was reported that ASD affects 1 in 68 children in the United States (Centers for Disease Control and Prevention, 2015). This prevalence has been increasing

steadily, with the prevalence in 2000 being 1 child in 150 being affected by ASD. A commonly speculated reason for this large increase in the diagnosis rate of ASD is that the definition for autism has been broadened, as it is now a spectrum of disorders, and more parents are now taking their children to get diagnosed because of better therapy resources that were not available in previous years. There are also better efforts going towards the diagnosis of ASD (Centers for Disease Control and Prevention, 2015).

IV. Applied Behavior Analysis

Definition

Applied behavior analysis is a branch of psychology originating from behaviorism. More and more psychologists are beginning to realize that human behavior can be tested, predicted, and thus altered. While behavioral responses can be variable among individuals, under certain conditions the environment acts upon behavior in such a way that will produce similar behaviors among individuals. Applied behavior analysis works to use a scientific approach to derive the principles of behavior and then uses these principles to improve relevant behaviors to a meaningful degree (Cooper, Heron, & Heward, 1987). A principle of behavior is the functional relationship that a behavior has with the environment and several of the variables that are present in the environment. For instance, the presence of a certain antecedent stimulus or event will prompt a certain behavior to occur, as a result of the behavior being followed, on prior occasions, by a consequence which then strengthens the chance of that behavior occurring after the same antecedent again in the future. Simplified, if the behavior is followed by something favorable, then the behavior is more likely to occur in similar future situations. The techniques used in applied behavior analysis can be used to shape and improve behavior to a meaningful degree (Cooper, Heron, & Heward, 1987). Specifically, applied behavior analysis works to change certain behaviors in people by changing the way that the environment acts on these behaviors. Behavior analysts exclusively study observable behavior, as that is the only aspect of behavior that can be tested and modified. Along with this, a study is only considered behavioral if it can document that the participant's behavior has changed and has produced practical results (Cooper, Heron, & Heward,

1987). A goal after significant behaviors have been functionally modified is to have the participant exhibit generalizability of the relevant behavior. This means that the participant will be able to demonstrate the behavior across a wide variety of settings to help improve daily living. In a clinical setting, behavioral analysts often work to apply interventions, after collecting and analyzing functionally relevant data, to help decrease problem behaviors while also increasing beneficial behaviors.

Precision Teaching

One application of applied behavior analysis is the education of children. One educational practice that has emerged from the basic ideas of early applied behavior analysis is known as Precision Teaching. Precision teaching is the use of behavioral principles to increase the rate of learning in students (Lindsley, 1990). In the 1960s a researcher and student of B.F. Skinner, Ogden Lindsley, came up with the beginnings of Precision Teaching and spent the rest of his career cultivating this practice. Lindsley, since he worked closely with Skinner, originally based precision teaching off of free-operant conditioning (Lindsley, 1990). In this type of environment, students are able to respond at their own pace and do not have restraints placed on them from teachers. The freedom to stop and start learning again is typically supported and is good to allow students to get a better grasp of the material they are attempting to learn (Lindsley, 1996). A large emphasis in precision teaching is put on the student and the student is given a large role in this educational system (Potts, Eshleman, & Cooper, 1993; Lindsley, 1990).

Precision teaching isolated itself from other educational practices with its unique exercises: the development of the standard celeration chart and getting rid of technical jargon are two major themes in precision teaching (Potts, Eshleman, & Cooper, 1993).

The standard celeration chart is an individualized chart for each student which displays frequency in a certain behavior or skill per minute, week, month, or year. This allows students to be given freedom in their education to chart out their own progress and directly see where their skills are exceling and where there skills are lacking. Lindsley, when creating this educational practice, noticed that there seemed to be too much technical jargon polluting the explanations of teaching and learning, which seemed to take away from the ideas themselves. Lindsley then decided to use "plain English" terms to describe his methods of teaching. These techniques were the first ideas that truly separated precision teaching from other types of learning and set things like fluency building on the radar for educational practices.

The goals of precision teaching are directly related to teaching a skill to fluency, which is learning to a high accuracy and a fast rate of response (Binder, 1990). In their article, "Precision Teaching and Direct Instruction: Measurably Superior Instructional Technology in Schools," Binder and Watkins mention that at every level of progress in a student's education, fluency is always a goal (2013). Precision teachers have developed a number of strategies to increase fluency in their lesson plans, such as the use of standard celeration charts. As previously mentioned, precision teaching stresses giving the student freedom to make their responses. In this type of educational environment students are typically able to gain fluency in skills faster (Lindsley, 1996). The self-pacing that precision teaching allows makes it easier for students to achieve higher fluency, as they are not being constrained by time limits or by any lesson plans the teacher makes. The Morningside Academy study in Seattle Washington was one of the first schools to not only emphasize fluency building in their curriculum, but they inevitably also began using

principles found in precision teaching, since fluency and precision teaching are so closely bound (Johnson & Layng, 1992). Time and time again it has been stressed that precision teaching and the fluency building that goes along with it is not hard to combine with various curricula (Lindsley, 1992). Precision teaching is not hard for teachers to incorporate into their lesson plans because it does not require them to radically change their teaching methods. It only requires teachers to discover the most productive learning techniques for their students (Lovitt, Haring, & University of Washington Unit of Child Development and Mental Retardation Center Experimental Education, 1979).

When writing about precision teaching and its goals, Ogden Lindsley gives an example of what a typical precision teaching classroom looks like (Lindsley, 1992). Unlike a normal classroom, Lindlsey states that in precision teaching classrooms the teachers are not lecturing. Instead, Lindsley paints the picture of a noisy, chaotic group of students practicing the skill they are learning as fast as they can. The teacher is merely in the classroom to walk around, supervise the students, and answer any questions the students may have. In a classroom exhibiting precision teaching methods, there is an emphasis put on to teaching skills so that they can be performed rapidly. A key features found in all precision teaching lesson plans is that the students are in charge of their learning and they are learning skills an emphasis on a fluent understanding (Lindsley, 1992).

When precision teaching is put into action it can be very effective in teaching students with academic problems skills and tasks that they were previously struggling with. For example, a six-year-old boy with academic and behavioral issues was sent to the Experimental Education Unit of Child Development and Mental Retardation Center at

the University of Washington (EEU) to get educational training. The EEU helps children with intellectual disabilities and was created in an effort to reflect the immediate concerns of special education in not only the state of Washington, but also the country (Lovitt & Haring, & University of Washington Unit of Child Development and Mental Retardation Center Experimental Education, 1979). The student was given a lesson plan that emphasized the techniques of precision teaching in three major ways. Firstly, the problem behaviors were pinpointed by using functional analysis procedures so they could be directly worked on. Secondly, the student's performance was measured frequently by observing and recording behavior. The measurements of the student's behavior allowed not only the teacher to see how the student was progressing, but it also allowed the student to see how he was progressing in his learning. Lastly, the lesson plan allowed the student's progress to be recorded and graphed following each session. This works in coordination with the student's behavior being frequently measured, as once the behavior is measured it is able to be graphed on the celeration chart that is typical in lesson plans including precision teaching techniques. After the student spent eight months in the EEU he returned to his classroom in his original school and he understood all the material he previously struggled with. He excelled so much in his learning that math, what had previously been his hardest subject, became his strong point. His social behavior also improved significantly, allowing him to interact and learn more with his peers.

One of the first and largest precision teaching trials was the Great Falls Precision Teaching Project done in the 1970s (Potts, Eshleman, & Cooper, 1993). In 1972, the Special Education Department of Great Falls in Montana allowed public schools to use precision teaching to improve basic skill deficits of elementary and secondary students

with mild deficits in these basic skill areas. Of the 19 precision teaching and control group comparisons, 15 of the precision teaching groups were significantly superior on posttest examinations of the students learning (Potts, Eshleman, & Cooper, 1993). These results are commonly found in studies involving precision teaching. Another study was conducted using 343 moderately and severely handicapped students who were taught to use precision teaching techniques daily. Progress of students was measured before and after individual lesson plans were implemented. Overall, teachers were 2 to 5 times more effective in selecting intervention strategies when precision teaching strategies and procedures were followed and 97% of teachers said that these precision teaching procedures accelerated the student's performance and the teachers would continue to use these techniques.

In his article, "Precision teaching – precision learning", Owen White lists a few more examples of classrooms in which precision teaching has benefitted the student's learning. White mentions a study in which 31 teachers were placed with 343 moderately to severe handicapped students who were then taught to use precision teaching daily. It was found that teachers were 2 to five times more effective in selecting effective intervention strategies when precision teaching rules were followed. On top of this, 97% of the teachers in the study said that the precision teaching procedures enhanced student's performance and they would continue to use these methods (White, 1986). In another study, 48 mildly handicapped students coming from grades 1-3 were split into two groups. The first group allowed teachers to use any type of method they preferred to teach reading, while the other group was told to use precision teaching techniques. Reading skills of these two groups were then compared to the skills of non-handicapped

students. Overall, 92% of the precision teaching students were successfully able to overcome their reading deficits, while only 8% of the non-precision teaching group was able to perform as well. Interestingly, the total daily instruction time for the precision teaching group never exceeded 10 minutes, while the non-precision teaching group never had a session less than 30 minutes (White, 1986). This reaffirms the notion that precision teaching is not only beneficial to the student, but also saves time in the classroom.

While the previous studies do show the merit of precision teaching when applied to a classroom setting, the majority of these studies were conducted at least twenty years ago. While they still hold significance today, there have also been more recent studies which bring precision teaching to the twenty-first century. Psychologists are beginning to realize that early intervention for children with ASD may be the best way to lessen the behavioral symptoms, such as lack of social interaction, from becoming more severe as the child gets older. In 2003, there was a study done applying precision teaching techniques to develop an education program for a child with ASD (Kerr, Smyth, & McDowell, 2003). The child was given math skills to practice and once precision teaching methods were introduced, his accuracy increased to 18 times per minute within four days. To check the retention of these skills, the child was given a period of no practice and then tested again. The child still performed above his goal, showing that the techniques not only worked to give him the skill set, but also worked to help retain the learning.

Fluency

An area within precision teaching which is very prominent in learning is teaching skills to a fluent performance. Fluency can be defined as the accuracy of a task along

with the speed it takes to complete the task (Binder, 1996). More simply put, fluency can be thought of as a description of learning in which a task is completed automatically, like its second nature, or performing a task correctly without hesitation. In his article *Behavioral fluency: Evolution of a new paradigm*, Binder attempts to provide a definition of fluency and he compiles much of the research that has been done on the topic of fluency (Binder, 1996). After analyzing the research, Binder deduces that fluency based education and training programs have produced some of the most dramatic results in terms of significantly improving student's achievement test scores.

In another article Binder goes on to define three types of essential critical learning outcomes that fluency directly contributes to, these being: retention and maintenance, endurance, and application (Binder, Haughton, Bateman, 2002). Retention and maintenance is the ability to execute a task without having practiced the skill recently. Endurance is the ability to maintain a constant level of responding during a time period without getting distracted. In another article he wrote, Binder comments that to build endurance teachers should first implement fluency (Binder, 1990). If fluency is thought to be the speed and accuracy of a task, as both of those variables increase during a child's learning of a certain skill, the endurance of that skill should also increase. Application, the last learning outcome fluency helps to improve, is seen as the child's ability to apply the skill they have learned fluently to new situations, leading to the acquisition of new, more complex skills in the child's repertoire.

When fluency is used as an educational tool it works very effectively. Feedback is imperative in fluency-building exercises (Daly, Martens, Barnett, Witt & Olsen, 2007). When a child is learning a certain skill, the feedback the child receives on how he/she

was performing the skill is vita; whether the feedback be in the form of modeling, prompting, or error correction. At the beginning of a fluency program there are high levels of practice of the desired skill. High levels of practice are used to help the learner gain the necessary skills to complete the task that is being taught (Johnson & Layng, 1996). After the performance has been solidified, practice should then become sparser and spaced out into increasing time intervals. Increasing spacing in learning is known as the spacing effect, and its effectiveness is one of the most dependable phenomena in experimental psychology (Dempster, 1988).

One of the first programs to emphasize fluency and teaching skills to 100% accuracy was at the Morningside Academy in Seattle Washington. The study was made up of 32 male youths and young adults who were aged 16-26 and who had educational skills between second and eighth grade levels. During this study when a fluency program was put into place, students attended the academy Monday through Friday from 1 to 3 p.m. Students were then tested to determine two areas in which they lacked a strong skill set to gain improvement in. Students were given one hour of instruction per skill area per day. There were 32 total students in the study, of which, 29 of them were able to successfully complete the program with skills above the national eighth-grade level literacy standard (Johnson & Layng, 1992). The Morningside Academy offers a money-back guarantee that their students will progress two or more grade levels in one year. The Academy has been running for 33 years and has only refunded less than 1% of the total tuition in that time (The Seattle Foundation).

The excellent results found from the Morningside Academy led way to other programs, specifically different reading and math programs to be aligned with techniques

to teach these skills to a fluent level. A fluency-based reading program was enacted with second and third grade children who were also matched with second and third grade children in a control condition to find the effects of a fluency-based reading program (Martens et al., 2007). It was found that children in the experimental condition of this study, that is the condition using a fluency-based reading program, showed large gains in oral reading fluency on the same day of training, and then had gains that were found to be similar or even larger following a two-day retention period they were given. The control group of children were not found to have any significant gains in oral-reading skills.

An important aspect of fluency, central to my research question, is response latency. Response latency is the amount of time it takes the participant to respond to the stimulus after the stimulus has been presented (Martin & Pear, 2011). Ackerman and Zalmanov (2012) found that latency can often determine accuracy, allowing response latency to be a valid measurement for fluency. The participants in Ackerman and Zalmanov's experiments were engineering college students. In the experiment conducted, math problems were given to these participants and the time it to respond to the problems was measured. The response latency was then compared to the accuracy, and it was found that latency was high in predicting accuracy of the problem. Participants who were more confident in their answers would answer more quickly, have a shorter response latency, than those who were unsure of their answers and required more time to think (Ackerman & Zalmanov, 2012). Latency is a part of fluency which saw its roots in precision teaching. Precision teaching uses fluency as a gold standard to measure learning, and measuring latency is a way to indicate fluent understanding of a skill.

ASD and Applied Behavior Analysis

As mentioned earlier, applied behavior analysis has been used for decades. In terms of specifically helping those with ASD, applied behavior analysis has been useful since the 1960s. In 1961 a study was done using operant methods such as positive reinforcement, extinction, and punishment to help mitigate the symptoms of a child with ASD (Ferster). Once this study showed that techniques from applied behavior analysis could successfully be used with children with ASD, researchers began testing what other treatments could be used. There was a study done demonstrating that language could be taught using these techniques (Risley & Wolf, 1967) and a study done that further showed that these methods could be used to fix behavioral problems of young children with ASD (Wolf, Risley, & Mees, 1963). The latter study was published in one of the first issues of the journal *Behavior Research and Therapy* which was the first applied behavior journal (Matson, Turygin, Beighley, Rieske, Tureck, & Matson, 2012).

One integral way applied behavior analysis has increased the behavioral repertoire of children with ASD is with teaching language. Applied behavior analysis breaks down language first into its simplest component: the motor movements necessary to create language. Once this motor repertoire has been learned, simple vocalizations can then be taught through imitation to expand the vocabulary of the child. Once a base vocabulary has been established, these words can then be developed into small phrases and expressive language. Applied behavior analysis is currently the only effective way to help children with ASD develop a vast language skill set (Jackson, Williams, & Biesbrouck, 2006).

While genetics has been the most studied topic dealing with ASD, since there are

many signs pointing in the direction of a heritable component of ASD, applied behavior analysis has been receiving a great deal of attention, and arguably has led to the most promising results in terms of treatment of the symptoms of ASD (Matson et al., 2012). Applied behavior analysis has only recently begun to take the spotlight in research in children with ASD, but studies including these methods are growing as it is being seen how useful they are (Matson, Benavidez, Compton, Paclawskyj, & Baglio, 1996). Behavioral treatments have become more efficient from their humble beginnings in the 1960s which can be seen by the development of various methods used to help further understand the function of behavior. For example, a functional analysis is now an integral part of many behavioral therapy programs, as this method helps determine what type of treatment should be given to a patient. Task analysis is another method developed from applied behavior analysis that can be seen as very useful, especially for children with ASD (Eldevik, Jahr, Eikeseth, Hastings, & Hughes, 2010). These techniques which have been endlessly refined throughout the years are able to target certain problem behaviors one might have, and come up with a treatment to efficiently modify these behaviors.

Currently, applied behavior analysis is considered the standard practice by most professionals in the field of ASD. In a study using low intensity behavioral intervention, it was found that children with ASD who went through this program were able to achieve more gains in adaptive skills and then higher developmental ages than when compared to children in the control group (Peters-Scheffer, Didden, Mulders, & Korzilius, 2010). Essentially this study is showing that even when the ideas of behavior analysis are used in a low intensity format, it is still more helpful than other special education methods. Applied behavior analysis can also be used for a wide variety of behavioral modifications

in children with ASD. An example of these behaviors are: language and socialization, challenging behaviors, such as feeding problems, aggression, and self-injurious behaviors, stereotypies, which are any form of repetitive body movement, rituals, and varying daily life skills. With all of this information in mind, it is no wonder why the techniques in applied behavior analysis are being studied so widely in the world of psychology.

An important area where applied behavior analysis can make a difference in the lives of those with ASD is in everyday activities and behaviors that can be used to make these individuals more independent. Many daily living skills do in fact need to be taught to persons with ASD, on their own they do not have a behavioral repertoire large enough to accomplish many complicated everyday tasks (Domire & Wolfe, 2014). Behavioral techniques have been successful in teaching a wide variety of complex skills such as how to set a table (Goodson, Sigafoos, O'Reilly, Cannella, & Lancioni, 2007), kicking a soccer ball (Luyben, Funk, Morgan, Clark, & Delulio, 1986), and the basic math skills necessary to apply to shopping (Cihak & Grim, 2008). Hygienic skills are also important to teach to children with ASD as these skills are typically lacking and need to be stressed in children with ASD. This kind of adaptive living skill research with those with ASD has been under researched and many researchers believe that there should be a higher emphasis of research on this area (Matson, Hattier, & Belva, 2012).

These daily living skills can us latency as a measurement of learning when they are being modified via behavioral training. Daily living skills involve behaviors which can be observed and therefore quantified. These comprehension of these behaviors can then be quantified using measurements such as latency. The faster and more automatic

the skill is performed, therefore the lower latency it has, the higher degree of learning the child shows for the skill.

Early Intensive Behavioral Intervention

Definition

There is no standard recommended treatment for ASD since the symptoms can vary significantly from one end of the spectrum to the other. Treatments like occupational therapy, speech therapy, and group-based therapy have often been used to reduce the severity of the symptoms of ASD.

Researchers did find that typically, early intensive interventions are the most effective at combating the symptoms of ASD (Peters-Scheffer, Didden, Korzilius, & Sturmey, 2011). From this, a therapy was then developed known as Early Intensive Behavioral Intervention (EIBI). It is now one of the most widely used and arguably most beneficial treatment for children with ASD (Reichow & Wolery, 2009). The techniques found in EIBI are based very much on techniques that were first developed from applied behavior analysis. In fact, along with EIBI it was found that younger children with ASD benefit more from increased hours of applied behavior analysis than older children (Granpeesheh, Dixon, Tarbox, Kaplan, & Wilke, 2009).

This intervention seems to be very effective in reducing the symptoms of ASD and allowing children with ASD to interact more confidently with their environment. Studies which used this intervention typically demonstrated a reduction in symptom severity, large gains in IQ, and adaptive behavior for some, not all, participants (Eldevik, Cross, Jahr, Eikeseth, Hughes, & Hastings, 2009). This increase in behaviors can help children with ASD to better assimilate among their peers.

Features of EIBI

The recommended treatment for component in any program for a child with ASD should address the core deficits of ASD. This in turn means that there should be instruction delivered in structured, predictable settings, a low student-teacher ratio, programming for generalization and maintenance, promoting family involvement, implementing a functional approach to challenging behaviors, and monitoring progress over time. It happens to be that Early Intensive Behavioral Intervention includes all of these parameters (Reichow, Barton, Boyd, & Hume, 2012).

Specifically looking at EIBI, it is best that there is a highly structured teaching approach taken for young children with ASD, typically younger than 5 years of age. Some core elements found within EIBI are: a specific teaching procedure referred to as discrete trial training, the use of 1:1 adult-to-child ratio in the early stages of the treatment, and implementation of the intervention in either a home or school setting for around 20-40 hours a week across 1-4 years of the child's life (Reichow et al., 2012).

EIBI is essentially a more refined treatment using key principles from applied behavior analysis. Without the research done with applied behavior analysis, EIBI would not be able to be where it is today. EIBI takes the techniques of applied behavior analysis and tailors them to specifically work with young children who have ASD. In fact, when EIBI is implemented it typically must happen under the supervision of someone trained in ABA procedures found in different treatment manuals (Reichow et al., 2012). Therefore, any research done within the spectrum of applied behavior analysis and ASD can then be applied to helping EIBI become more effective. Since this is currently the

most widely used and most effective treatment available for young children with ASD, refining the methods used in this treatment could only help these children become more independent and better assimilated into their everyday lives.

V. Current ASD Research

Discrimination Training

While there are obviously many different areas of research involving children diagnosed with ASD, this review specifically takes a closer look at recent studies using discrimination training and teaching children with ASD a skill that was not previously in their repertoire of behaviors. Discrimination training can be defined as teaching a learner to differentiate between different stimuli in varying environmental contingencies. This can be useful in a variety of real world situations ranging from academic knowledge to daily living skills. For example, being able to discriminate between the main behaviors exhibited at a red light and the main behaviors exhibited at a green light is a crucial component of driving a vehicle. Without the ability to discriminate between these stimuli and respond correctly the safety of anyone on the road becomes compromised.

The majority of discrimination training studies involving children with ASD mainly have to do with a skill being taught to these children. A few studies involving discrimination training done with children with ASD will be discussed in depth subsequently. The skills taught in each of these studies directly benefit the child with either the ability to discriminate between pictures and their written and/or spoken counterparts or relationships between items important in daily life.

Current measurements in ASD research, while they are effective, may not be as effective as they could be. One of the most common measurements of learning in research done with children with ASD is the percent of correct answers. While this measurement can determine if a learner has indeed learned whatever task they are practicing, there are other variables that may come into play in which the learner may not

be learning as much as it may seem if the only measurement being made is percent accuracy.

In a study conducted by DeQuinzio and Taylor, four children with ASD were taught to discriminate between reinforced and nonreinforced responses to show implications in observational learning (2015). In this study discrimination training was used to teach participants to respond to certain stimuli with a different behavior dependent upon how an adult in the situation acted. The main dependent measurement in this study was the percentage of correct responses during test sessions. Test sessions were completed either one or ten minutes after each baseline, discrimination training, or generalization training session.

The authors of this study mention that test sessions were originally only supposed to be conducted ten minutes after the baseline, discrimination training, or generalization training sessions; however, because one of the participants did not show an increase in responding during the baseline sessions, the test was then given one minute after discrimination training. This then had to be done with all other participants so the data could be compared. This inability to conduct the test sessions ten minutes after discrimination training was based off of the dependent measure that the authors used: percent accuracy. The authors found that one of the children could not perform high enough based on percent accuracy so the methods of the study then had to be compromised and edited. The child who did not respond high enough may have been taking too long to respond and therefore it seemed like he or she was not learning the task, when in fact the child just may have had a longer latency, making him or her unable to complete as many responses as the other children. Because latency was not measured

in this study, there is no way of knowing if there were any other factors that influenced the child in not having an increased performance.

The study showed that three out of the four children increased their correct responding to 100% during test sessions conducted one minute and ten minutes after discrimination training (comparable to a correct response rate of 60% or below after baseline sessions), while one child was able to have a correct response rate of 100% during test sessions conducted one minute after discrimination training, but was only able to achieve a correct response rate of 80% after the test sessions occurring ten minutes after discrimination training.

Taking these results at face value implies that all of these children have learned the skill of observationally learning whether or not to discriminate between stimuli. However; an aspect the authors never approach is whether or not the children became fluent in this skill. Fluency has been defined as the combination of accuracy and speed, gives a learner an almost automatic performance at a certain task (Binder, 1996). With this in mind, it would be interesting to understand the fluency level of the children participating in this study. Even though the correct responses may have illustrated some sense of understanding, the measure of latency could give an even better clue into how well the children grasped the task. If the children took a long time to respond after the stimuli was presented and the adult made their response, then the response behavior may not strongly controlled by the stimulus.

The next study aimed to produce coin equivalence in children diagnosed with ASD (Keintz, Miguel, Kao, & Finn, 2011). Two boys diagnosed with ASD were the participants in this study and conditional discrimination training was used to teach the

relationship between a physical coin and its printed price along with other visual-visual and auditory-visual matching to sample tasks. The main dependent measure in this study was also the percentage of correct responses which was calculated by dividing the total number of correct responses by the total possible number of responses per block.

The results of this study showed that the conditional relations between coins and their dictated names, coins and their printed prices, and printed prices and dictated coin names were able to be successfully taught. It was also found that the two participants were able to learn other conditional relations that were not explicitly taught to them.

Like in the study mentioned before this, only the number of correct responses was measured. Also, the criterion for the relationship to be considered evident was getting 89% of the trials correct. This is directly conflicts with fluency research which demonstrates that skills should be learned to 100% accuracy (Johnson & Layng, 1992). Fluency research argues that it isn't until 100% accuracy that the participant can begin to perform the behavior as if it is second nature, without any thought whatsoever. This lack of training to fluency may lead to the acquired skill to develop a lower rate of retention, eventually leading to the skill

After the search of the literature was completed it was found that there was a study done comparing various simple and complex conditional discriminations (Rosales, Maderitz, & Garcia, 2014). This study used three children, two diagnosed with ASD and one child who was seen as typically developing. The study either taught children to: conditionally relate pictures and their corresponding dictated names, respond to a dictated word and corresponding printed word, or match a dictated name and picture to a corresponding printed word. The dependent measure of this study was the number of

correct responses, in which the child not only had to provide a correct response, but they had to do so within 10 seconds after the presentation of the item. The child moved onto the next training session when the mastery of the skill was 100%.

While this study does not specifically report that it uses fluency building procedures, the procedures are present in the study. The fact that mastery of a skill was seen to be 100% is a key characteristic in fluency building procedures and is not present in a lot of the discrimination training literature. Latency was used in this study since a response was only seen as correct if it was observed to occur within ten seconds of the stimulus being presented. While this does not directly measure latency since the only thing being measured is whether or not a response was indicated within ten seconds, it is a step in the right direction. By defining a response as incorrect if it takes longer than ten seconds to respond, the authors are implying that learning is not occurring if the response takes too long. This idea agrees with current fluency building research which implicates the same thing. Fluency building literature includes the rate of responding in its measurement of accuracy therefore the latency is always important in fluency building procedures.

The last study used actually dealt with fluency outcomes in the acquisition of responding to images (Kelly & Holloway, 2015). This study described learning of three children who were diagnosed with ASD and presented them with index cards with pictures on them and asked the children to tact the picture. The dependent variables of this study were measures related to fluency, and included: acquisition, retention, endurance, stability, and application. Notably, latency was unfortunately not included in the dependent variables. Acquisition was defined as the total correct and incorrect

responses at the end of each session, a dependent measure found in almost all of the studies done with learning on children with ASD. Retention was defined as maintaining a high level of correct responding after four weeks with no practice, endurance was measured by testing the children after they had reached the fluency criterion to determine if the child could engage in the learned skill for an increased period of time. Application was defined as seeing if the skill could be generalized, or applied to untrained stimuli.

Results from this study showed that the children were successful in reaching their fluency acquisition aims. However, one child experienced difficulty and her responding ended up plateauing. This demonstrates how important individualized fluency aims are for children with ASD instead of having the same goal for all the children involved even though they may learn differently. An idea of precision teaching, which commonly has fluency building procedures as a component, is that the children control their learning, which this study did follow. The children in this study were taught to pick up the cards with the images on them, to tact the picture, and then place the card down on the table. This allows the child to be the one in control of how fast or how slowly they are learning to tact the pictures.

Once again, this study is lacking any sort of measurement of latency. Even though fluency is a vital component of this study, the authors fail to use latency as any sort of indication of learning. Since one child plateaued in her learning of tacting the pictures it would have been interesting to note if she had also exhibited a plateau in latency. If she had shown a decrease it latency but was unable to tact more pictures it might be noted that she was getting frustrated with the task and perhaps began to respond more frequently as a mechanism of frustration. If this had been the case then the results that

were seen from this child could only be taken with a grain of salt and no real conclusions should be made with her data.

Lack of Latency as a Measurement of Learning

After a literature review was conducted of current research done with various forms of discrimination training, it was found that latency is not recorded in any of these studies. It is imperative for the measurement of latency to be recorded in relation to learning, and it is not something that researchers up to this point have recorded. Learning is directly related to the length of time it takes to perform a certain skill and latency is the only valid measurement of this amount of time.

According to fluency-based research, the rate of response is invaluable. One can't have fluent performance in a certain skill without taking the rate of responses into account. Because fluency has been found to be a good standard for learning, it only stands that latency should also be a good measurement for learning. If a child is found to accurately perform a skill 100% of the time, but the latency is extremely high, then has the child *really* mastered the skill? If a child with ASD still exhibits a longer latency then they will still find problem in their daily lives as it make take them too long to perform these newly acquired skills for them to be useful. Taking one of the aforementioned studies as an example; if a child does learn to discriminate between a physical coin and its monetary value, it will do the child no good to learn this skill if the time it takes the child to associate the coin with its value is too long. If the child were to go into a grocery store and try to pay for something, a long latency will cause problems with the cashier and any other customers waiting in line. The child is not effectively learning the skill to a significant and meaningful degree and therefore cannot exhibit this skill to a functional

understanding in the natural environment. Because of problems like this it is essential that the latency of response also be measured in learning studies done with children with ASD, and it is important that these skills be taught to have lower latencies as well as high accuracy rates.

VI. Latency in Current Research

While latency is not often seen being used in studies of learning involving children with ASD that does not mean that it is not used in other scientific studies. In fact, latency has been frequently used in other studies, specifically as a measurement of accuracy or a measurement of confidence of an answer choice. These studies have found that latency is a valid predictor of accuracy, or believed accuracy depending on what the specific question of the study.

Latency as a Cue of Accuracy

Latency has been popularized in many studies by using it as an indicator of accuracy. It has been experimentally found that shorter response latencies often correlate to more correct answers than answers given after longer response latencies (Ackerman & Koriat, 2011). Latency is useful for measuring accuracy of an answer because it is an objective measurement that can be used regardless of the child's subjective feelings on whatever task is being learned. Latency is an objective way to see if the child has started learning correctly and effectively.

In a study conducted by Ackerman & Koriat children were given a series of pictures with a short description of what happened in the picture (2011). Children were then given a filler task and during the test phase the child was presented with a description of the event from the picture and had to identify, from two pictures, which picture was related to the event. The study found that every increased second in latency reduced the likelihood that the answer would be correct by 12%. This statistic gives the measurement of latency a great deal of power in predicting the accuracy of a given answer.

The relationship between latency and confidence values was also measured in this study by also asking the participants to rate how confident they felt in their answer. It was then found that latency produced a more reliable prediction of accuracy over the prediction of confidence values in the participants. In this way response latency was able to reliably discriminate between correct and false memory reports that the children may have had when trying to recall the image associated with the short description they were given.

The authors of this study mentioned that one of the key benefits of using latency as a measurement of accuracy is that latency can be easily measured. It does not take a lot of material or time to measure latency. If a computer program is being utilized for a study then the program itself can record latency. If no computer is being used it still is not difficult to calculate latency. A stopwatch can be used which can either be operated by the experimenter themselves or a bystander to the experiment can record latency using a stopwatch.

Another study that utilizes latency as a measurement of accuracy presented children with forced-choice general knowledge questions and asked them to choose the correct answer and the confidence in their answer (Koriat & Ackerman, 2010). It was found through this study, like in the previous study, that a faster answer, an answer with a lower latency, is more likely to be correct. With this in mind the authors came to the conclusion that latency could be used as a diagnostic cue to accuracy.

Latency as a Measurement of Confidence

Not only has latency been found to be a reliable predictor of the validity of an answer, but it is an accurate measure participant's confidence of the correctness of their

answer. Showing confidence in one's answer is another important aspect of learning because if one is confident in the answer, there is a higher likelihood that the answer is in fact correct (Ackerman & Koriat, 2011). In social contexts, the judged truth of an answer is typically measured with the speed at which the answer is given, and when given a general knowledge question, most participants use the speed at which the answer is given as a cue to the correctness of the answer (Topolinski & Reber, 2010).

A study took temporal contiguity, which is defined as the interval of time in which two stimuli are presented, and measured its relatedness to the measurement of correctness of a given answer (Topolinski & Reber, 2010). In this manner, temporal contiguity is able to be related to latency in that they both measure the length of time it takes for a response to be made after a stimulus has been presented. This study took anagrams of unfamiliar words and presented them to participants. After the word was presented a blank screen appeared for varying amounts of time in which the correct version of the word was presented. Incorrect anagrams that were made by replacing one consonant with another one not originally included in the word. By varying the temporal contiguity, with which the answer was presented to participants, the authors found that the shorter the temporal contiguity was, the more likely participants were to mark the answer as the correct word coming from the previously viewed anagram. This directly correlates back to the idea that the less delay there is between a stimuli and the response from it, the more likely the answer is to be viewed as correct. Giving a longer delay between the stimulus and the presentation of the answer gives more time for the participant to change their behavior and act differently than how they may have originally acted without such a long temporal contiguity.

The two studies mentioned in the previous section, discussing latency as a measurement of accuracy also included latency as a measurement of confidence in their studies (Ackerman & Koriat, 2011; Koriat & Ackerman, 2010). In the first study, response latency was measured and compared to the confidence rating participants gave each of their answers. Results showed that the response latency very accurately acted as a cue to the confidence level of the participant in their given answer. Latency was seen to have an inverse relationship with confidence judgements (Ackerman & Koriat, 2011). This means that the longer the recorded latency, the less confident the participant was in their answer. Similarly, the second study mentioned measured confidence of the general knowledge question asked and compared the accuracy of that question to the latency recorded. This study also found that as latency increased, the judgement of confidence from participants decreased (Koriat & Ackerman, 2010).

The relationship between latency and the confidence of participants' answers is a measurement not typically applied to learning, but the argument can be made that it should be applied to this field. While learning itself seems very objective; learners are taught rules to follow and then how to generalize these rules to various different stimuli and situations, the argument can still be made that learning is very subjective as well. Learning is very much dependent on the mindset of the learner and their willingness to learn. If latency can be used to increase perceived confidence in answers, then the willingness at which a learner may performance could see an increase. With increased self-esteem in the learner's abilities, the rate of responding may increase. Since latency was also found to be an accurate indicator of the correctness of a response, not only will the learner be perceiving a more correct answer, but they may also be performing with a

higher validity.

VII. Research Studies in ASD with Latency

Studies Involving Latency as a Measurement of Learning

When going through the literature on learning in children with ASD over the past ten years, there have not been a lot of research studies utilizing latency as a measurement of learning. The few studies which did include latency as a measurement of learning in studies done with children with ASD are described below.

The first study listed used latency as a measurement of learning to reduce problem behaviors (O'Connor, Prieto, Hoffmann, DeQuinzio, & Taylor, 2011). The participant used in this study was a child diagnosed with ASD who involved in motor and vocal stereotypy, repetitive behaviors, so often that it affected his daily living activities, such as reading books. The study then used discrimination training to teach the participant that when a red index card was presented the participant was not allowed to participant in stereotypy, whereas if a green index card was indicated the child was allowed to engage in any behavior. When baseline sessions were conducted, and the participant was allowed to engage in any behavior, the mean latency was 15.7 seconds. Latency in regards to this specific study was defined as the amount of time it took the child to participate in a stereotypy. After discrimination training and invention procedures were conducted, the child had a latency of 4 minutes and 15 seconds, a large improvement to his baseline conditions. Before the intervention the child was unable to visit a library or read a book in his classroom because of the abundance of stereotypy that occurred in the presence of books. This study helped the child to gain the incredibly important skill of being able to sit in the classroom and read a book or go to the library and check out and read a book.

The child now has a plethora of new behaviors he can learn thanks to his reduction in stereotypy in the presence of books.

Had the authors of this study used a different method to measure learning in the child, this experiment may not have been as effective. Using latency to determine how long from the presentation of the stimulus, a book, it took the child to engage in stereotypy effectively allowed the authors to measure the problem behavior and work to decrease the frequency of stereotypy.

Another study involving the use of latency as a measurement of learning in children diagnosed with ASD was done to teach participants a wide variety of daily living skills (Weiss, Fabrizio, & Bamond, 2008). In this study different skills were taught to different programs; some programs taught skills to a high frequency, some used low duration as the dimension of interest, a the last group of skills were taught by using latency as the dimension of interest. Skills such as various components of manners, requesting behaviors, and responding to greeting were taught with latency as the main measurement of learning. The skills were evaluated on retention tests that were performed at various times after learning had occurred (Table 1).

Table 1. Results of the study conducted by Weiss et. al (2008). Skills taught to frequency, latency or low duration were given retention tests at various times after intervention sessions were completed and the percent of skills that passed these retention exams is recorded.

	Frequency Building	**Latency**	**Low Duration**
1 Month	98.7%	100%	100%
2 Months	98.9%	100%	100%
3 Months	96.2%	100%	100%
4 Months	95.7%	97.8%	100%

As can be seen by Table 1, when latency lowering procedures were used to teach

skills to participants, the retention of these skills was in fact higher than frequency building procedures, procedures that are typically seen in studies teaching skills to learners with ASD. Frequency building procedures targeted higher frequencies of correct responding in the skills that it is targeted towards. Because the authors did not use fluency techniques when teaching these skills to a higher frequency, the participants may not have truly mastered these skills. This can then be seen by the larger amount of skills that did not pass retention tests, whereas latency lowering procedures had more skills passing retention checks. This again back up the claim that teaching skills to fluency building standards allows the learner to become more proficient in the skill and master the skill in a way they would not if they were taught merely on the increase of correct responses.

Fluency Building Procedures and Latency

Fluency building procedures are a departure from the standard measurement of learning characterized by learning that is evaluated by the percentage of correct responses. Latency is added into the picture in fluency building procedures, something that is not taken into account when looking at the percent of correct responses. Discrete trial instruction (DTI) and discrimination training are currently the main way skills are being taught to children with ASD, and the measurement of learning in these methods are percent of correct responses. While DTI has been found to be effective for leaners with ASD, this method overlooks latencies in response time, therefore missing a key piece in the learning process.

Because of the lack of teaching skills to fluency and a lack of regard for the

latency of response, learners can develop fluency problems with a lot of the skills they are being taught (Weiss, Pearson, Foley, & Pahl, 2010). These fluency problems become apparent in laborious responses and longer latencies in learning. As previously discussed, latency is used as a valid cue for accuracy (Ackerman & Koriat, 2011), implying that the longer latency for these learners can be detrimental as they may no longer be responding correctly. A longer response time also affects the interaction level a learner has with his or her group. If a learner has a slower response time, he or she may miss opportunities to participate in group learning or participate in group social activities.

Learners with ASD also tend to have short attention spans; therefore, many skills have low endurance rates because the learners cannot partake in the skill for an extended period of time (Weiss, et al., 2010). It has been found that if teachers wish to increase endurance skills with learners with ASD, fluency building skills such as high levels of practice should be used (Binder, et al., 1990). Improving the endurance of a skill could also in turn increase the learner's fluency in that skill. Since the learner practices the skill for longer periods of time he or she becomes more fluent and the skill will come more naturally to the learner. It is not only the accuracy of the skill that decides the learner's ability to integrate the skill into the broader environment; the speed of response also affects this generalization. If the skill being taught is academic, merely learning the skill to a high percent accuracy is not enough to make sure the learner will be able to participate in group learning involving the particular skill. If the learner still has a high latency with the particular skill, they may fall behind or respond too slowly to properly get involved with his or her classmates on a discussion involving the particular skill. Latency is therefore a crucial measurement to determine whether or not a child with ASD

has thoroughly learned a skill. With this measurement being made and a decrease of latency in response to a certain skill being obtained, teachers can confidently determine that their learner has learned the skill fluently and will then be able to use the skill in ways that will improve his or her daily living.

VIII. Conclusion

Call for the Use of Latency

With Autism Spectrum Disorders (ASD) becoming more prevalent (Centers for Disease Control and Prevention, 2015), studies involving children with ASD should be using the most accurate measurements to get the most accurate results. By using latency as a measure of learning, studies involving children with autism could be more accurate than they currently are. Many research studies are not using the measurement of latency as an indicator of learning in participants. The fluency and precision teaching literature has shown that latency matters in the acquisition and maintenance of skills learned by children with ASD (Ackerman & Zalmanov, 2012), (Binder & Watkins, 2013). Latency has been shown to be a valid indicator of accuracy of responses (Ackerman & Koriat, 2011). With this in mind, if skills are taught to a certain level of latency there is a better chance that the learner will also be performing the skill more accurately than if just percent of correct responses was the measurement to which learning occurred.

Latency should not, however, be the only measurement used when evaluating learning in children with ASD. Percent of correct responses is still a fairly useful measurement of learning, and latency can be measured in addition to it. In fact, if both measurements of accuracy and latency are used to measure the learning of a skill, then the learner is said to become fluent in the skill, since fluency is defined as the combination of accuracy and the speed of response (Binder, 1996). When these two measurements are taken together they can lead to a more accurate grasp of a certain skill. Fluency training has also been found to be very effective in terms of teaching skills specifically to children with ASD (Weiss et. al., 2010). Becoming fluent in a skill directly

addresses some of the specific troubles children with ASD struggle with, such as having response durations being too slow to keep up with group learning or group socialization. If fluency then helps to decrease this latency in responding, the child will not only be able to respond more often in class, but the classroom will run more smoothly as all the students will be responding on a similar level. A regiment including fluency training helps to specifically address these issues and enables the child to effectively interact with his or her environment, peers, and educational learning.

In terms of applied behavior analysis (ABA), it makes complete sense to begin using latency as a measurement of learning. ABA looks strictly at outward, observable behavior. Therefore, any measurement made in studies should therefore be quantifiable and observable. Latency has both of these measurements. Latency can be quantified as the number of seconds (or minutes, hours, etc.) it takes to respond to a stimulus after its presentation. Latency is observable in that the behavior can be directly observed when it happens. Latency can then be empirically measured in studies involving learning.

Future Directions

There are numerous future directions that this knowledge can lead research in. Most importantly, future research studies involving discrimination training and learning in children with ASD can begin using latency as a standard measurement of learning of these tasks. As previously stated, this would not take a lot of effort to do and is a very simple measurement to take. While latency is so simple to measure, it could have an invaluable effect on the learning ability and skill acquisition of a child taking part in a research study. Latency does not need to become the only indicator of learning, it would just facilitate more accurate results if it were *also* used to measure learning, in addition to

the current methods being used to measure leaning in children with ASD.

Using latency as a measurement of learning in children with ASD could also be important with Early Intensive Behavioral Intervention (EIBI). While this method of treatment has already been found to be very effective at mitigating the symptoms of ASD (Reichow & Wolery, 2009), using latency as another measurement for treatment could only help this therapy become more effective as a treatment option for young children diagnosed with ASD. In this manner, teachers using EIBI would be able to use latency in their teaching plans to help their students more completely understand skills and become fluent in them.

Latency is not only important as a measurement of learning in academic skills. While its full potential and applicability is first seen in academic skills, it can be generalized to skills covering all aspects of a child with ASD's life. Because ASD is a developmentally developing disorder it typically does not only affect one aspect of the child's life, but multiple aspects. There are various daily living skills that children with ASD struggle with, especially hygienic skills (Luyben, et. al., 1986). Using latency as an indicator of learning could help improve the acquisition and retention of these skills.

If latency is used as a measurement of learning in studies teaching meaningful skills to children with ASD, the accuracy and effectiveness of these studies will be increased. Learners with ASD will also be receiving the most efficient form of treatment and learning that they can receive which in the end will benefit their quality of living. With a better grasp of the skills they are being taught, children with ASD will also be able to attain more independence than they previously had. The quality lives of those around these children (parents, siblings, friends, etc.), will also be increased because of

the increased independence and therefore most likely increased happiness of the child with ASD. Latency does not take a lot of effort to measure and calculate, and the benefits in produces will help children diagnosed with ASD to gain a more independent life with a better comprehension of new behaviors that they are being taught. In this way, latency is a very beneficial measurement of learning in studies using children with ASD.

IX. References

Ackerman, R., & Koriat, A. (2011). Response latency as a predictor of the accuracy of children's reports. *Journal of Experimental Psychology-Applied, 17*(4), 406-417. doi: 10.1037/a0025129

Ackerman, R., & Zalmanov, H. (2012). The persistence of the fluency–confidence association in problem solving. *Psychonomic Bulletin & Review, 19*(6), 1187-1192.

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders: DSM-5. Washington, D.C: American Psychiatric Association.

Autism Society. *Asperger's Syndrome.* Retrieved from: http://www.autism-society.org/what-is/aspergers-syndrome/

Autism Speaks. (2015). *What is Autism?* Retrieved from: https://www.autismspeaks.org/what-autism

Bailey, A., Le Couteur, A., Gottesman, I., Bolton, P., Simonoff, E., Yuzda, E., & Rutter, M. (1995). Autism as a strongly genetic disorder: evidence from a British twin study. *Psychological medicine, 25*(1), 63-77. doi: 10.1017/S0033291700028099

Binder, C. (1990). Increasing Endurance by Building Fluency: Precision Teaching Attention Span. *Teaching Exceptional Children, 22*(3), 24-27.

Binder, C. (1996). Behavioral fluency: Evolution of a new paradigm. *Behavior Analyst, 19*(2), 163-197.

Binder, C., Haughton, E., & Bateman, B. (2002). Fluency: Achieving true mastery in the learning process. *Professional Papers in Special Education,* 1-20.

Binder, C., & Watkins, C.L. (2013). Precision teaching and direct instruction: measurably superior instructional technology in schools. *Performance Improvement Quarterly, 26*(2), 73-115. doi: 10.1002/piq.21145

Buckman, S. (1995). Lovaas revisited: Should we have ever left? *Indiana Resource Center for Autism Newsletter, 8*(3), 1-5,7.

Centers for Disease Control and Prevention. (2015). *Autism Spectrum Disorder (ASD): Data & Statistics.* Retrieved from: http://www.cdc.gov/ncbddd/autism/data.html

Cihak, D.F., & Grim, J. (2008). Teaching students with autism spectrum disorder and moderate intellectual disabilities to use counting-on strategies to enhance independent purchasing skills. *Research in Autism Spectrum Disorders, 2*(4), 716-727. doi: 10.1016/j.rasd.2008.02.006

Cooper, J. O., Heron, T. E., Heward, W. L. (1987). *Applied Behavior Analysis.* New York: Macmillan Publishing Company.

Daly, E.J., Martens, B.K., Barnett, D., Witt, J.C., & Olson, S.C. (2007). Varying intervention delivery in response to intervention: Confronting and resolving challenges with measurement, instruction, and intensity. *School Psychology Review, 36*(4), 562-581.

Dempster, F.N. (1988). The spacing effect – A case-study in the failure to apply the results of psychological-research. *American Psychologist, 43*(8), 627-634. doi: 10.1037//0003-066x.43.8.627

DeQuinzio, J.A., & Taylor, B.A. (2015). Teaching children with autism to discriminate the reinforced and nonreinforced responses of others: Implications for

observational learning. *Journal of Applied Behavior Analysis, 48*(1), 38-51. doi: 10.1002/jaba.192

DeStefano, F., Chen, R.T. (2001). Autism and measles-mumps-rubella vaccination: controversy laid to rest? *CNS Drugs, 15*(11), 831. doi: 10.2165/00023210-200115110-00002

Domire, S.C., & Wolfe, P. (2014). Effects of video prompting techniques on teaching daily living skills to children with autism spectrum disorders: A review. *Research and Practice for Persons with Severe Disabilities, 39*(3), 211-226. doi: 10.1177/1540796914555578

Eldevik, S., Cross, S., Jahr, E., Eikeseth, S., Hughes, J., Hastings, R. (2009). Meta-analysis of early intensive behavioral intervention for children with autism. *Journal of Clinical Child & Adolescent Psychology, 38*(3), 439-450. doi: 10.1080/15374410902851739

Eldevik, S., Jahr, E., Eikeseth, S., Hastings, R.P., & Hughes, C.J. (2010). Cognitive and adaptive behavior outcomes of behavioral intervention for young children with intellectual disability. *Behavior Modification, 34*(1), 16-34.

Ferster, C.B. (1961). Positive reinforcement and behavioral deficits of autistic children. *Child Development, 32*(3), 437-456. doi: 10.2307/1126210

Goodson, J., Sigafoos, J., O'Reilly, M., Cannella, H., & Lancioni, G.E. (2007). Evaluation of a video-based error correction procedure for teaching a domestic skill to individuals with developmental disabilities. *Research in Developmental Disabilities, 28*(5), 458-467. doi: 10.1016/j.ridd.2006.06.002

Granpeesheh, D., Dixon, D.R., Tarbox, J., Kaplan, A.M., & Wilke, A. E. (2009). The effects of age and treatment intensity on behavioral intervention outcomes for children with autism spectrum disorders. *Research in Autism Spectrum Disorders, 3*(4), 1014-1022. doi: 10.1016/j.rasd.2009.06.007

Huguet, G., Ey, E., & Bourgeron, T. (2013). The genetic landscapes of autism spectrum disorders. *Annual Review of Genomics and Human Genetics, 14*, 191-213. doi: 10.1146/annurev-genom-091212-153431

Jackson, M., Williams, L. W., Biesbrouck, J. (2006). Equivalence relations, the assessment of basic learning abilities and language: A synthesis of behavioral research and its implications for children with autism. *Journal of Speech and Language Pathology – Applied Behavior Analysis, 1*(1), 27-42. doi: 10.1037/h0100185

Johnson, K.R., & Layng, T.J. (1992). Breaking the structuralist barrier: Literacy and numeracy with fluency. *American Psychologist, 47*(11), 1475-1490.

Johnson, K.R., & Layng, T.V.J. (1996). On terms and procedures: Fluency. *Behavior Analyst, 19*(2), 281-288.

Keintz, K.S., Miguel, C.F., Kao, B., & Finn, H.E. (2011). Using conditional discrimination training to produce emergent relations between coins and their values in children with autism. *Journal of applied behavior analysis, 44*(4), 909-913. doi: 10.1901/jaba.2011.44-909

Kelly, L., & Holloway, J. (2015). An investigation of the effectiveness of behavioral momentum on the acquisition and fluency outcomes of tacts in three children

with autism spectrum disorder. *Research in Autism Spectrum Disorders, 9*, 182-192. doi: http://dx.doi.org/10.1016/j.rasd.2014.10.007

Kerr, K., Smyth, P., & McDowell, C. (2003). Precision teaching children with autism: helping design effective programmes. *Early Child Development and Care, 173*(4), 399-410. doi: 10.1080/0300443032000079087

Koriat, A., & Ackerman, R. (2010). Choice latency as a cue for children's subjective confidence in the correctness of their answers. *Developmental Science, 13*(3), 441-453. doi: 10.1111/j.1467-7687.2009.00907.x

Lindsley, O.R. (1990). Precision teaching: By teachers for children. *Teaching Exceptional Children, 22*(3), 10-15.

Lindsley, O.R. (1992). Precision teaching – Discoveries and effects. *Journal of Applied Behavior Analysis, 25*(1), 51-57. doi: 10.1901/jaba.1992.25-51

Lindsley, O.R. (1996). The four free-operant freedoms. *The Behavior Analyst, 19*(2), 199-210.

Lovitt, T.C., Haring, N.G., & University of Washington Unit of Child Development and Mental Retardation Center Experimental Education. (1979). *Classroom application of precision teaching*. Seattle: Special Child Publications.

Lovaas, I. O. (1987). Behavioral treatment and normal educational and intellectual functioning in young autistic children. *Journal of Consulting and Clinical Psychology, 55*(1), 3-9. doi: 10.1037/0022-006X.55.1.3

Luyben, P.D., Funk, D.M., Morgan, J.K., Clark, K.A., & Delulio, D.W. (1986). Team sports for the severely retarded: training a side-of-the-foot soccer pass using a

maximum-to-minimum prompt reduction strategy. *Journal of Applied Behavior Analysis, 19*(4), 431-436. doi: 10.1901/jaba.1986.19-431

Martens, B.K., Eckert, T.L., Begeny, J.C., Lewandowski, L.J., DiGennaro, F.D., Montarello, S.A., & Fiese, B.H. (2007). Effects of a fluency-building program on the reading performance of low-achieving second and third grade students. *Journal of Behavioral Education, 16*(1), 39-54.

Martin G., Pear J. (2011). Behavior modification: What it is and how to do it. (9th ed.) NJ: Simon & Schuster.

Matson, J.L., Hattier, M.A., Belva, B. (2012). Treating adaptive living skills of persons with autism using applied behavior analysis: A review. *Research in Autism Spectrum Disorders, 6*(1), 271-276. doi: 10.1016/j.rasd.2011.05.008

Matson, J.L., Benavidez, D.A., Compton, L. S., Paclawskyj, T., & Baglio, C. (1996). Behavioral treatment of autistic persons: A review of research from 1980 to the present. *Research in Developmental Disabilities, 17*(6), 433-465. doi: 10.1016/S0891-4222(96)00030-3

Matson, J.L., Turygin, N.C., Beighley, J., Rieske, R., Tureck, K., & Matson, M.L. (2012). Applied behavior analysis in autism spectrum disorders: Recent developments, strengths, and pitfalls. *Research in Autism Spectrum Disorders, 6*(1), 144-150. doi: http://dx.doi.org/10.1016/j.rasd.2011.03.014

The National Autistic Society. (2014). *Q&A: DSM-5*. Retrieved from: http://www.autism.org.uk/about-autism/all-about-diagnosis/changes-to-autism-and-as-diagnostic-criteria/qanda-dsm-5.aspx

O'Connor, A.S., Prieto, J., Hoffmann, B., DeQuinzio, J.A., & Taylor, B.A. (2011). A stimulus control procedure to decrease motor and vocal stereotypy. *Behavioral Interventions, 26*(3), 231-242. doi: 10.1002/bin.335

Peters-Scheffer, N., Didden, R., Korzilius, H., & Sturmey, P. (2011). A meta-analytic study on the effectiveness of comprehensive ABA-based early intervention programs for children with autism spectrum disorders. *Research in Autism Spectrum Disorders, 5*(1), 60-69. doi: 10.1016/j.rasd.2010.03.011

Peters-Scheffer, N., Didden, R., Mulders, M., & Korzilius, H. (2010). Low intensity behavioral treatment supplementing preschool services for young children with autism spectrum disorders and severe to mild intellectual disability. *Research in Developmental Disabilities, 31*(6), 1678-1684. doi: 10.1016/j.ridd.2010.04.008

Potts, L., Eshleman, J.W., & Cooper, J.O. (1993). Ogden R. Lindsley and the historical development of precision teaching. *The Behavior Analyst, 16*(2), 177-189.

Reichow, B., Barton, E.E., Boyd, B.A., & Hume, K. (2012). Early intensive behavioral intervention (EIBI) for young children with autism spectrum disorders (ASD). *Cochrane Database of Systematic Reviews, 10*(10), CD009260. doi: 10.1002/14651858.CD009260.pub2

Reichow, B., & Wolery, M. (2009). Comprehensive synthesis of early intensive behavioral interventions for young children with autism based on the UCLA young autism project model. *Journal of Autism and Developmental Disorders, 39*(1), 23-41. doi: 10.1007/s10803-008-0596-0

Risley, T., & Wolf, M. (1967). Establishing functional speech in echolalic children. *Behaviour Research and Therapy, 5*(2), 73-88. doi: http://dx.doi.org/10.1016/0005-7967(67)90001-0

Rosales, R., Maderitz, C., & Garcia, Y. A. (2014). Comparison of simple and complex auditory-visual conditional discrimination training. *Journal of Applied Behavior Analysis, 47*(2), 437-442. doi: 10.1002/jaba.121

Satcher, D. (1999). Mental health: A report of the surgeon general. *Department of Health and Human Services.* United States.

The Seattle Foundation. *Morningside Academy.* Retrieved from: http://www.seattlefoundation.org/npos/Pages/MorningsideAcademy.aspx.

Skinner, B. F. (1953). *Science and Human Behavior.* New York: The MacMillan Company.

Taylor, B., Miller, E., Lingam, R., Andrews, N., Simmons, A., & Stowe, J. (2002). Measles, mumps, and rubella vaccination and bowel problems or developmental regression in children with autism: population study. *BMJ: British Medical Journal, 324*(7334), 393-396. doi: 10.1136/bmj.324.7334.393

Thorndike, E. L. (1911). Provisional laws of acquired behavior or learning. *Animal Intelligence*, New York: The McMillian Company.

Thorndike, E. L. (1927). The law of effect. *The American Journal of Psychology*, *39*(1), 212-222.

Topolinski, S., & Reber, R. (2010). Immediate truth – Temporal contiguity between a cognitive problem and its solution determines experienced veracity of the

solution. *Cognition, 114*(1), 117-122. doi: http://dx.doi.org/10.1016/j.cognition.2009.09.009

Wakefield, A.J., Murch, S.H., Anthony, A., Linnell, M.B., Casson, D.M., Malik, M., Berelowitz., Dhillon, A.P., Thomson, M.A., Harvey, P., Valentine, A., Davies, S.E., & Walker-Smith, J.A. (1998). Retracted: Ileal-lymphoid-nodular hyperplasia, non-specific colitis, and pervasive developmental disorder in children. *The Lancet, 351*(9103), 637-641.

Weiss, M.J., Fabrizio, M., & Bamond, M. (2008). Skill maintenance and frequency building: archival data from individuals with autism spectrum disorders. *Journal of Precision Teaching and Celeration, 24*, 28-37.

Weiss, M.J., Pearson, N., Foley, K., & Pahl, S. (2010). The importance of fluency outcomes in learners with autism. *The Behavior Analyst Today*, *11*(4), 245-252. doi: 10.1037/h0100704

White, O.R. (1986). Precision teaching--precision learning. *Exceptional children, 52*(6), 522-534.

Wolf, M., Risley, T., & Mees, H. (1963). Application of operant conditioning procedures to the behaviour problems of an autistic child. *Behaviour Research and Therapy*, *1*(2), 305-312. doi: 10.1016/0005-7967(63)90045-7