A Behavior Analytic Approach to Analyzing the Phenomenon of Emulation

Tricia R. Clement

A Dissertation Submitted to the Faculty of

The Chicago School of Professional Psychology

In Partial Fulfillment of the Requirements

For the Degree of Doctor of Philosophy in Applied Behavior Analysis

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Abstract

Emulation has been presented in several ways within animal cognition and developmental psychology literature to explain a range of social learning processes or within a larger taxonomy of imitation. However, a clear, concise behavioral definition of emulation is still lacking. Building upon the unpublished dissertations of Rothstein (2009) and Philp (2016), this study analyzed the role of emulation with possible corequisite verbal developmental cusps and determined if an emulative repertoire can be established in children diagnosed with developmental disabilities. Results of the initial tests were analyzed using a correlational analysis of imitation and emulation tasks and demonstrated a statistical significance to the listener literacy cusp. Results of this further analysis demonstrated that trial-and-error teaching was successful in establishing an emulative repertoire. Additional theoretical and socially significant findings related to the induction of emulation in children with ASD or developmental delays are highlighted.

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Chapter 1

With the rise in children and young adults diagnosed with autism spectrum disorder (ASD; Center for Disease Control and Prevention, 2019) comes the need to find effective instructional methods. If one were to view many of the traditional special education programs across the United States, one would initially note some consistent findings for those providing instruction to students with ASD or developmental delays, including the use of prompting strategies to promote learning, direct teaching methods, schedules, visuals, clear directions, and the addition of support such as paraprofessionals. Howard, Stanislaw, Green, Sparkman, and Cohen (2014) discussed this notion when they noted that many individuals diagnosed with ASD or developmental delays typically require specific and intensive teaching and interventions to elevate the deficits often associated with ASD. What these typical recommendations have in common is their alignment with adult-direct approaches to teaching whereas most skills are directly taught.

In opposition to the intensive and individualized educational and treatment plans for individuals diagnosed with ASD are the standard teaching procedures implemented with typically developing children. The use of direct teaching as well as indirect instruction or instruction that is mainly student-centered are observed in a traditional classroom setting (Rüütmann & Kipper, 2011). With indirect instruction, teachers seek a high level of student involvement in the learning process while encouraging students to generate alternatives to a given task or solutions to problems. The role of the teacher in indirect instruction shifts from the director of learning to that of the facilitator. Thus, the teacher arranges the learning environment to promote opportunities for student involvement while providing feedback to facilitate acquisition of problem solving and untaught skills (Mesquita et al., 2015).

In traditional education settings within the United States, typically developing children seemingly develop basic skills incidentally or without the need for intensive educational interventions. The use of incidental teaching and thus incidental learning opportunities for such students usually results in typically developing children developing more skills than what was seemingly taught. The acquisition of such untaught skills is commonly referred to as emergent or untaught behavior and has been accounted for across several behavior analytic accounts, including naming, stimulus equivalence, relational frame theory, and observational learning.

Atypical patterns of attending and failure to receive relevant information are often reported alongside an ASD diagnosis (Anzalone & Williamson, 2000). For example, it is common to observe students diagnosed with ASD having a difficult time with abstract concepts and nuances while at the same time having a greater ability to learn through rote memorization than by symbolism or analogy. Deficits in executive functioning linked specifically to deficits in one's ability to organize, problem solve, and plan for future behavior (Lopez, Lincoln, Ozonoff, & Lai, 2005) are also commonly associated deficit areas for individuals diagnosed with ASD. These factors may play a role in the lack of incidental learning opportunities typically seen in teaching procedures implemented with individuals with delays or ASD diagnosis. Although not common practice, it is important to highlight the importance of the emergence of untaught behavior as a critical feature of efficient instruction.

Teachers and other educational professionals are continually challenged to develop efficient instructional practices to teach all types of learners (including those with ASD or other delays). Greer (2002) noted that little is still known about how to specially design instruction that allows for the emergence of untaught behaviors such as naming, stimulus equivalence, relational frame theory, and observational learning which focus on aspects of emergent verbal behavior.

One possible untaught behavior not often mentioned is emulation. The term emulation has been used when the goal (or end product) is the focus rather than the topography or process (Lindsay, Moore, Anderson, & Dillenburger, 2013). Emulation in this sense offers a means to develop independence because the individual does not need a model or demonstration. Oftentimes, it involves experiences with trial-and-error learning and associated problem-solving skills, allowing for the expansion of skills without direct teaching.

As indicated in the literature, many typically developing individuals come to learn a large portion of their behaviors indirectly (Greer, Pohl, Du, & Moschella, 2017; Hayes, Barnes-Holmes, & Roche, 2011; Horne & Lowe, 1996). Within the literature on atypical development, common forms of treatment to contest with deficit areas for individuals with ASD tend to be direct instructional methods or prompting delivered by the instructor. This is a concern because it can lead to stimulus control issues and prompt dependency, less independence, and less occurrences with indirect teaching opportunities. The study of emulation has the potential to impact learning and best teaching methods for individuals with atypical development as well as expand the current literature related to emergent verbal behavior.

Chapter 2

Wood (1989) distinguished emulation from imitation as a separate and unique behavioral phenomenon. Wood used the term emulation to describe a type of imitation where aspects of participants' performance were not copied. Although imitation includes a substantial body of applied literature, emulation has received very little. Two unpublished dissertations (Philp, 2016; Rothstein, 2009) recently addressed the critical attributes of emulation from a behavioral perspective. The lack of behavioral research associated with emulation may be related to the similarity of emulation, imitation, and observational learning (Byrne, 2009; Horner & Whiten, 2005). Historically, behavior analytic researchers have attempted to distinguish terminology used to describe behavioral phenomena when there were inconsistencies with the terms throughout literature in psychology and analyzed the phenomenon from a behavior analytic perspective (Greer, Singer-Dudek, & Gautreaux, 2006). These distinctions help researchers isolate critical variables and allow consumers to analyze data and findings with greater precision, and the current research will continue this process.

Emulation, imitation, and observational learning are often used interchangeably (Byrne, 2009); however, each involves separate and distinct features. The defining feature of emulation is when the end product, rather than the topographical process (as in imitation) or access to the functional reinforcer (as in observational learning), is the focus of analysis (Lindsay et al., 2013). Problem-solving skills and trial-and-error learning are also closely related to emulation and offer researchers the procedures to expand skill sets of clients without direct teaching, thereby potentially inducing emulation. Identifying potential pre- or corequisites of emulation will aid in the development of an emulative repertoire, which is important because such learning will likely decrease prompt dependency and will allow for clients to be more independent through application to functional life skills.

Conceptually, emulation has been presented in several ways within animal cognition and developmental psychology literature to explain a range of social-learning processes, imitative behavior (Bryne, 2002; Custance, Whiten, & Fredman, 1999; Hopper, Flynn, Wood, & Whiten, 2010; Huang, Heyes, & Charman, 2002; Tomasello, 1996; Wood, 1989), or within a larger taxonomy of imitation or copying behavior (Hanus, Mendes, Tennie, & Call, 2011; Want & Harris, 2002; Whiten, McGuigan, Marshall-Pescini, & Hopper, 2009). Most of the early literature surrounding the concept of emulation has been directly evaluated in the animal literature (Bryne & Russon, 1998; Horner & Whiten, 2005; Tennie, Call, & Tomasello, 2006; Zentall, 1996). A clear behavioral definition of emulation and behavior analytic evaluation is still lacking and warrants further consideration.

A number of studies have tested for the presence of emulation in animals or across species and have used variations of testing procedures such as “ghost testing” conditions, irrelevant actions, and unintentional actions (Fawcett, Skinner, & Goldsmith, 2002; Hopper, Lambeth, Schapiro, & Whiten, 2008; Horner & Whiten, 2005; Whiten et al., 2009). These procedures are commonly used as evidence in a test for null hypotheses against imitation rather than emulation (Tomasello, 1990, 1998; Tomasello, Kruger, & Rathner, 1993). For example, Tomasello (1998) noted his primate subjects did not imitate and instead attributed the behavior to a type of emulation labeled affordance learning (e.g., the organism learns about the affordances of a particular item or object). This may be in part due to the undefined critical attributes of the behavioral phenomena referred to as emulation in his study which led to data being ambiguous. This example exemplifies the call for a clear behavioral definition of the term emulation that distinguishes between the common aspects of emulation as it relates to similar yet distinct terms such as observational learning and imitation.

Distinguishing between similar behavioral phenomenon is critical to understanding behavior because it allows researchers and consumers to analyze behavior through a more precise lens. However, it is not uncommon for behavioral terminology to contain discrepancies within its own definitions, and these discrepancies may result in researchers stating that they are measuring one thing while actually measuring something different than other researchers investigating presumably the same phenomenon. Imitation and emulation are closely related; therefore, several researchers have defined imitation to mean different things in comparison (Tennie et al., 2006; Want & Harris, 2002; Whiten et al., 2009; Zentall, 2006).

There are some subtle differences within the definitions of imitation and emulation that have led to confusion between the two terms or reporting various definitions of imitation and emulation (Byrne, 2009; Holth, 2003; Hopper et al., 2010; Whiten et al., 2009). For example, Whiten et al. (2009) defined imitation as learning by copying the actions of another, whereas Hopper et al. (2010) described imitation as replication of the actions of individuals present in the environment. In comparison to these relatively simple definitions, Holth (2003) defined imitation by four, separate behavior-environmental components: (a) a model or antecedent stimulus will evoke an imitative behavior, (b) the behavior must follow the presentation of the antecedent modeled immediately, (c) the behavior must have formal similarly to that of the model, and (d) the model is the controlling variable for the emission of the behavior. These similar-but-different definitions add to the difficulty in determining if imitation and emulation are actually separate behavioral events or if emulation is simply a variation of imitation (or vice versa). Phenomena may be distinguished from similar phenomena when their critical attributes do not overlap or when an important operative attribute is always present in one and never present in the other. Thus, unpacking imitation as a distinctive behavioral phenomenon seems to be a logical starting point.

Imitation Defined

Imitation has been described as behavior that directly follows the behavior or a model with a point-to-point correspondence (Cooper, Heron, & Heward, 2007) and has been studied and observed in in early stages of typical human development (Meltzoff, 1990; Meltzoff & Moore, 1989). Various accounts of imitation are present across fields such as psychology and behavior analysis. The next section of this paper will briefly review several perspectives and discuss the importance of understanding imitation as it relates to the study of emulation.

Cognitive-Developmental Psychologist Perspective

The term imitation has been used extensively throughout developmental and cognitive psychology. A Piagetian (Piaget, 1945, 1962) perspective of imitation accounts for stages (i.e., 1-6) of imitation development (Piaget, 1945, 1962). Under this perspective, Stage 1 begins in infancy, accounting for inborn reflexes and accommodation processes inherent in newborns. Stage 2 is described as the capacity that emerges as a result of circular reactions or self-imitative actions, followed by Stage 3 which includes the next level of responding related to sensory system development. In Stages 4 and 5, children are again deemed to have gained additional capacities that allow for them to imitate actions not visible to themselves. Stage 6 is then referred to as the sensorimotor stage of imitation where children are capable of forming mental images which are stored and imitated at a later time. Piaget (1962) used the term imitation as an account of cognitive precursors to language in the typical development of language in children. Representative in the definition and account of imitation, Piaget (1945) described language development as the way a child assimilates (i.e., existing schemas) or accommodates (i.e., changing schemas or mental structures) to acquire language. This perspective differs from a behavior analytic account where language acquisition is indicated to develop through operant conditioning (Skinner, 1957). From Piaget's account of imitation, many cognitive psychologists have since studied the role of imitation in various developmental processes.

With the increased study of imitation over time, several definitions have arisen, but oftentimes are reported as patterns of behavior emitted as a function of social learning or observation (Galef, 1988). Many developmental psychologists described imitation as simply learning about and copying the topography of a model's actions (Hopper et al., 2010; Whiten & Ham, 1992; Whiten et al., 2009). Imitation as presented by many developmental psychologists is thus broad by definition. In psychology and the social sciences, terms that are broadly defined may be acceptable, but such definitions can become a concern when they are predicated into the science of behavior. Want and Harris (2002) pointed out such concerns when they noted that other processes such as local enhancement, stimulus enhancement, mimicry, or emulation may be better suited to describe what was once viewed as the result of imitation. These additional mechanisms were primarily studied in relation to social learning processes researched in object manipulation and functional tool use across species. Thompson and Russell (2004) further expanded on the use of other mechanisms involved in an imitative repertoire when they described imitation as a combination of mimicking and emulation, whereas mimicking was described as the behavior of copying the bodily movements demonstrated by a model as presented by Tomasello (1996) and emulation was described as the replication of the results of a model's actions through the use of affordances.

Along with the definition, several researchers attempted to study the underlying motivational processes associated with imitation. For example, Bandura (1986) used a four-step model to describe how motivational processes are associated with imitation. These steps included (a) attention to the model and action demonstrated, (b) the observed behavior and the consequences that follow the behavior are stored in the memory of the individual, (c) actions are imitated, and (d) the imitated actions are followed by reinforcement or punishment. Bandura provided one account of why infants and young children imitate, but problems remain when examining imitation from a behavioral perspective. Through the brief synopsis of the literature presented here on the term imitation, one can see how it leads to ambiguity within the field of cognitive and developmental psychology.

Behavior Analytic Perspective

As in other fields, behavior analytic literature has contributed to the definition and source of reinforcement of the term imitation. Imitation, by definition, has been often referred to as the immediate “copying” of a model’s behavior (Catania, 2007; Cooper et al., 2007; Zentall, 2006), which results in reinforcement of the imitator’s behavior when the behavior matches that of the model’s behavior. Baer, Peterson, and Sherman (1967) defined imitation as any behavior that follows that of a model’s behavior and is topographically controlled by the demonstrator’s behavior. The authors noted that in order for there to be a functional control present the topographical similarities demonstrated must be similar to that of the model’s behavior, which serves as a reinforcing stimulus dimension for the individual imitating. Holth (2003) presented the definition of imitation as four separate behavior-environment relations: (a) all physical movements may function as a model for imitation, (b) the imitative behavior must follow the presentation of the demonstrated behavior, (c) the demonstrated behavior and the evoked behavior must essentially have formal similarity or look and/or sound the same, and (d) the demonstrator must serve as the controlling variable for the behavior that is imitated. From a behavior analytic perspective, when evaluating an occurrence of a given behavior as imitative all four relations may be considered. Rothstein (2009) described imitation as the behavior that immediately follows that of the behavior observed. Philp (2016) similarly described imitation as when the individual copies the specific actions of those observed with point-to-point correspondence.

An account of why imitation occurs—from a behavioral perspective (e.g., using the principles of behavior)—can be found in the literature on the Verbal Behavior Developmental Theory (VBDT; Greer & Ross, 2008; Greer & Speckman, 2009). According to the VBDT, imitation (like other "copying" behaviors) is a conditioned reinforcer based on the correspondence between production responses and observation (Greer & Speckman, 2009). For example, "imitation" is what is used to account for newborns observing adults who imitate their behaviors because the observation of the movement becomes a conditioned reinforcer (Philp, 2016). Imitation as it has been described differs from emulation in that the behavior is directly copied and thus requires a model. Additional distinctions between imitation and emulation will be addressed in the next section of this paper.

Emulation Defined

Wood (1989) made a distinction between imitation and emulation, describing emulation as the process participants took to achieve the end goal using a novel or different method to reach the goal as compared to copying the exact modeled behavior (imitation). To clarify, emulation occurs when one replicates the outcomes and goals of actions without having been shown how to do so through idiosyncratic means. Hopper et al. (2008) described emulation as the focus of one's actions that result in changes to the environment. Simply said, the pivotal aspect of emulation is the end product, not the behavior(s) which brought it about.

Nielsen (2006) and Whiten et al. (2009) offered a distinction between imitation and emulation when they described emulation as how children understand the goal of the model's actions. Based on that understanding, children then reproduce the final outcome but do not imitate the exact actions modeled to achieve that outcome. The main concern with the definitions commonly presented in nonbehavior analytic literature are that the definitions are not testable.

Although several researchers outside the field of behavior analysis have studied emulation, the term has not been used often within published behavior analytic research. Early accounts of the closest form of what may have been emulation can be found in work by Baer et al. (1967) when they described what is not imitation. Baer et al. (1967) described occurrences when behaviors may appear to be alike, and therefore imitative, but are not imitative because they do not meet the criteria for imitation. Although these are very indirect links to emulation, further research is needed to determine if the differences between imitation and emulation are substantial enough to warrant a phenomenon that is separate and unique. If one were to analyze the critical attributes of imitation and emulation, one would note that the critical attributes overlap considerably. However, accounting for all behavior that appears to emerge without contacting direct contingencies is likely a critical element for analyzing and expanding the field of applied behavior analysis; therefore, emulation should be evaluated thoroughly.

Two extensive accounts of emulation from a behavior analytic perspective include unpublished dissertations that have provided the groundwork for the identification of critical attributes based on the definition of an emulation event (Philp, 2016; Rothstein, 2009). Rothstein (2009) described emulation as behavior emitted in two forms either via nonverbal problem-solving behavior or verbal behavior. In a nonverbal type of problem-solving, individuals observe their behaviors and monitor whether they establish the desired final outcome while subsequently adjusting their behaviors until the ultimate final product or outcome is achieved. Skinner (1969) described this behavior as contingency-shaped behavior that occurs when "an organism behaves in a given way with a given probability because the behavior has been followed by a given kind of consequence in the past" (p. 147). Rothstein (2009) further elaborated on this definition by describing the two forms of emulation as either (a) producing something novel through the observation of a product followed by reproducing it using verbal or nonverbal behavior or (b) manipulating environmental stimuli in a new way that results in obtaining a desired outcome.

The first form of emulation described by Rothstein (2009) can be depicted through an example involving a table setting scenario. If a child who has no experience with setting a table for dinner is presented with a completed table setting arrangement and then recreates the table setting arrangement, the child is then said to have demonstrated an emulative response. The second form of emulation described by Rothstein can be illustrated through the following example. If a child's toy ball rolls into a pond and he cannot reach it, the child is said to be emulating when he gets the ball by moving objects in the environment in novel ways (e.g., attaching sticks together to construct a pole to fetch the ball, etc.). Both forms of emulation illustrated in the examples involve different response topographies (e.g., construction and reaching) but result in the desired final outcome (e.g., the desired table setting arrangement and retrieval of the ball). Philp (2016) distinguished emulation from other terms (e.g., imitation) by describing emulation as the behavior emitted by an observer that results in the same goal produced by the model's behavior but bears no point-to-point correspondence with the behavior modeled. Much like the definition presented by Rothstein, Philp noted that the behaviors and/or sequence of behaviors emitted by the observer are not critical attributes of the emulation event, but rather that the end result or goal of the model's behavior is important.

Distinct Behavior Analytic Terms

After reviewing the nonbehavior analytic literature on emulation, one might question why there is a lack of behavioral research associated with emulation. One reason may be related to a lack of clarity between the multitude of terms used to describe the phenomena. Within the literature, similarities have been noted between terms such as emulation, imitation, generalized imitation, behavioral cusp and capabilities, and observational learning (Horner & Whiten, 2005). To address the lack of behavioral research associated with emulation, one must define similar yet distinct behaviors (e.g., emulation and imitation). Because imitation and emulation have previously been defined, this section will focus on the remaining behavior analytic terms (i.e., behavioral cusp and capability, generalized imitation, and observational learning).

Behavioral Cusps and Developmental Capabilities

Greer and Keohane (2006) presented the evolution of verbal behavior developmental processes in children which is referred to as the verbal behavior developmental theory (VBDT). The VBDT was based on work by Skinner (1957) on verbal behavior and provided researchers and practitioners a developmental trajectory of verbal-behavior-developmental cusps and capabilities. Experimental procedures described by Greer and Keohane (2006) demonstrated the importance of identifying prerequisites or corequisites needed in a child's verbal behavior development to aid in the child's progression through the capabilities described. Using the VBDT verbal milestones, one can identify missing repertoires and develop scientifically based tactics or protocols to induce such cusps or capabilities that will allow the individual child to continue to develop verbal independence.

An important concept in the study of behavior analytic development is the term behavioral cusp. Rosales-Ruiz and Baer (1996) described a behavioral cusp as a change that is difficult to achieve, but once accomplished allows subsequent development to occur with ease, allowing children to then learn things they could not prior to the acquiring the cusp.

Greer (2008) elaborated on this term when he described that once a behavioral cusp is met by a child, the child is then able to come into contact with new learning experiences. Although behavioral developmental cusps do result in new learning experiences related to consequence of behavior, this does not necessarily lead to a new way of learning. When a child acquires a developmental cusp that then leads to a novel way in which the child can learn, one can describe that as a verbal-developmental capability (Greer, 2008; Greer & Speckman, 2009). For example, "naming" (Catania, 2007; Greer & Ross, 2008; Greer & Speckman, 2009) is considered a verbal developmental capability because, in this case, the child acquires verbal behavior incidentally and is now able to learn in a new way. If thought of in this manner, all verbal developmental capabilities (e.g., capabilities allowing one to learn differently than before) are behavioral cusps (e.g., results in new opportunities to learn), but not all cusps are capabilities. For example, when the results of a new way of learning are not based on the learning experience, a cusp would not be considered a capability.

Generalized Imitation

Greer and Speckman (2009) described generalized imitation as being developed and maintained through the conditioned reinforcement for correspondence. This means that in a child's developmental processes, imitation is reinforced by the fact that it matches that of the model.

Generalized imitation is an example of cusp that is also a capability. Additionally, it is a perquisite of observational learning because it allows an individual to imitate behaviors that are modeled in the environment to access reinforcers provided for the model. This process provides the individual with new ways to learn and therefore is of great significance in the programming and further behavioral development.

Observational Learning

Often reported in the literature are problems related to the inclusion of observing the model when discussing emulation (Bryne & Russon, 1998; Greer & Speckman, 2009; Horner & Whiten, 2005; Tennie et al., 2006; Zentall, 1996). This inclusion is what leads to observational learning and emulation being confused or misinterpreted in the literature, thus warranting a clear definition of observational learning. Observational learning is considered a higher-order operant with verbal-developmental capabilities and behavioral cusps, and is similar to generalized imitation (Catania, 2007; Greer & Ross, 2008).

Observational learning can be described as the learning that occurs when an individual contacts another individual who received instruction and therefore can learn from such indirect interactions (Greer et al., 2006). This type of verbal capability is extremely important to a child’s success in the child’s environment. The role of observational learning in this sense has led researchers to identify and develop processes to assess and induce observational learning in individuals who are both typically developing and well as those who display developmental or language delays (Greer et al., 2006; Singer-Dudek, Choi, & Lyons, 2013).

Literature on the types of behaviors associated with observation included behaviors related to performance, the development of new operants, conditioned reinforcers, higher-order operants, and observational learning as a repertoire in its entirety (Greer & Singer-Dudek, 2008;

O'Rourke, 2006). These processes are related to emulation as a form of observational learning rather than imitation. Hopper et al. (2008) echoed the notion that emulation was a form of observational learning due to emulative processes being focused not on the model's actions, but on the actions related to the environmental results, whereas imitation is focused on the actions that result in changes in the environment.

Deconstructing the Term Emulation

Over the last 30 years, the term emulation has been described in a number of conceptual and experimental articles primarily reported in developmental psychology (Custance, Mayer, Kumar, Hill, & Heaton, 2014; Meltzoff, 1995; Whiten & Ham, 1992; Wood, 1989; Zimmermann, Moser, Lee, Gerhardstein, & Barr, 2017) and animal cognition (Byrne, 2002; Call, Carpenter, & Tomasello, 2005; Custance et al., 1999; Tennie, Call, & Tomasello, 2010) literature. Analyzing the research available suggested that a variety of phenomena have been measured under the broad category of emulation. This section of the paper will focus on deconstructing emulation research through an analysis of the definition(s) provided in the literature, the dependent variables associated with research in the area of emulation, what terms researchers are using to either refer to emulation or to describe a similar process, and the results of those studies. The goal of this paper is to expand the translational research in the area of emulation by bridging the gap between the terms and definitions presented in nonbehavioral literature to those within the behavior analytic literature. In order to continue to expand the research on emulation it is essential to identify the range of dependent variables conceptual and experimental researchers have used under the nomenclature of emulation. In addition, it is valuable to analyze this research through a verbal behavior lens to provide a possible account of problem-solving behavior and emergent or untaught behavior.

Numerous studies have tested for the presence of emulation in animals using variations of testing procedures such as "ghost testing" conditions, irrelevant actions, and unintentional actions (Fawcett et al., 2002; Hooper et al., 2008; Horner & Whiten, 2005; Whiten et al., 2009). Although there are considerable complications encountered by extending the nonbehavior analytic research on emulation to a behavior analytic account, doing so may provide previously unidentified sources of reinforcement for emergent behavior.

Conceptual Explanations

Several terms associated with conceptual explanations of emulation have been used to describe emulation within published literature in the fields of developmental psychology and animal cognition. Most of these terms rely on hypothetical constructs and mental processes used to describe how and why emulation occurs in animals, early in human development, and across species. The corresponding research is summarized in Table 1.

Table 1 displays terms such as social learning, affordance learning, object movement reenactment, and end-state or goal emulation that are commonly used as conceptual explanations referencing some aspect of emulative behavior. The research summarized thus far has focused on the defining features of social learning, affordance learning, object movement reenactment, and end-state or goal emulation as the four main conceptual explanations found within the literature on emulation. The evidence from the research summarized thus far indicates that very few clear conceptual explanations utilizing a behavioral account of emulation have been provided across the literature. In order to deconstruct the term emulation, a review of the major concepts related to the term is warranted.

Social learning. Social learning theory has been described as how individuals learn vicariously from others in their environment (Bandura, 1977). Social learning theory emphasizes the notion that learning does not occur in an isolated manner, but rather that individuals are said to internally process novel information within a social context because individuals are regarded as being highly influenced by other people (Bandura, 1977). Following the concepts involved within social learning theory, people are thought to learn vicariously through observing consequences, both positive and negative, that in turn influence their behavior. Social leaning theory involves both behavioral and cognitive accounts of human behavior that include four interrelated subprocesses (e.g., attentional, retention, motoric reproduction, and reinforcement or motivational processes; Bandura, 1977). From a behavior analytic perspective, motivation is described in terms of reinforcement as one of the four principles of social learning theory, while other principles such as attention, retention, and memory have been linked to more cognitive processes (Grusec, 1992).

Since the development of social learning theory, many researchers have linked this theory to research conducted within human development (i.e., Nielsen, 2006), animal cognition (i.e., Zentall, 2006), and cross-species studies (i.e., Call et al., 2005; Horner & Whiten, 2005; Whiten et al., 2009; see Table 1). For example, Zentall (2006) mentioned that learning from observing the behavior of others is one of the most unrecognized aspects of human learning. He went on to state that children may be predisposed to learn from the observation of others in their environment and this predisposition is often a result of what is often termed trial-and-error learning (Boyd & Richerson, 1988). Zentall (2006) further described the process of trial-and-error learning as an advantage that involves species-typical behavior that is not reliant on environmental reinforcement. Trial-and-error learning thus is considered a social learning process where species avoid negative consequences by imitating others in their environment, leading to individual learning. In another example of the influence of social learning theory in the study of behavior, Call et al. (2005) examined social learning processes in chimpanzees and children to determine if imitation processes used in problem solving developed similarly between the two species. In regards to human development, Nielsen (2006) studied what he referred to as the "logic" of a model's demonstration paired with the communicative signals that a model provides and how that interrelates to a child's age in the influence of how children engage in social learning. Although influential in many studies related to emulative behavior, the use of social learning theory as a possible conceptual explanation of the behavior can be problematic due to the close links to mentalistic concepts. This will be further examined later in the paper.

Affordance learning. Gibson (1966) discussed affordance theory as a part of one's perceptual development whereas one perceives aspects of one's environment leading to some course of subsequent action. For example, if one has never seen a coffee mug before, one would perceive a handle and using such affordances (e.g., environmental clues) would pick up the mug. Huang and Charman (2005) and Byrne (1998) similarly described affordance learning as what an individual learns about the relationships and physical properties of the environment.

Early examples of studies based on affordance learning can be seen in work on ecological approaches to perception (Gibson, 1979). Expanding on this work, Gibson (1982) studied the perceptual learning and developmental processes and how each relates to affordance learning. These new affordances that are thus developed are considered changes in action capabilities and can include the acquisition of new motor skills such as looking, walking, writing, and so forth. With each new action capability acquired throughout one's lifespan, new affordances are learned.

Meltzoff (1995) hypothesized that infants could imitatively learn a person's intention (e.g., intended actions) through the person's unsuccessful actions. To study this concept, Meltzoff evaluated the understanding of intentions through the actions emitted by 18-month-old children in a series of two experiments. In Experiment 1, 40 children who were roughly 18 months old and who had no previously diagnosed physical, sensory, or intellectual handicap were recruited as participants. Of those participants, two groups were established as the demonstration groups and referred to as the (a) demonstration (target) and (b) demonstration (intention), and two groups were used as the control groups and referred to as the (a) control (baseline) and (b) control (adult manipulation). In the demonstration (target) condition, participants observed an adult model a specific targeted action across objects. In the demonstration (intention) condition, the experimenter emitted failed attempts (i.e., did not demonstrate the targeted actions but rather modeled the intention behind the action) to achieve the targeted actions. In the control (baseline) condition, the adult demonstration was not present, and the adult simply provided the test stimuli to the participants in order to control for the affordances present when an adult manipulates an object. In the control (adult manipulation condition), the adult manipulated the test objects for the same amount of time as in the demonstration groups, but the adult did not demonstrate the targeted or intention of the action. Results of Experiment 1 included no statistically significant difference between both demonstration groups (i.e., target and intention). Results also showed that 80% of participants produced similar targeted actions with the first object in the demonstration groups while only 20% did so in the control groups. Meltzoff interpreted these findings as a suggestion that children as young as 18 months old can understand the intentions (rather than imitate the exact actions) of adults, even when the adult fails to demonstrate such intentions. One question that remained unanswered in the first study was the importance of a "psychological understanding" of the adult's actions versus just the physical changes in the environment (Meltzoff, 1995); therefore, Experiment 2 removed the adult as the demonstrator and instead used a device to emit the actions in the demonstration intention group. Sixty 18-month-old children participated in this experiment. All children were randomly assigned to either a human demonstration condition or inanimate demonstration condition. Both conditions followed the same procedures from the first experiment with the exception of the use of a mechanical device in place of the adult in the inanimate demonstration condition. Results showed that the groups differed significantly in the production of the target act, with participants in the human demonstration condition being 6 times (60% of participants) more likely to produce the targeted action than in the inanimate demonstration condition (10% of participants produced the targeted action).

Bellagamba and Tomasello (1999) replicated and extended the Meltzoff (1995) study with 12- and 18-month-old children. Similar to the Meltzoff study, Bellagamba and Tomasello used five objects that allowed for manipulation involving targeted actions. At random, participants were assigned to one of four conditions which included (a) target demonstration, (b) intention demonstration, (c) end state demonstration, and (d) control manipulation. In each condition, the object used and the targeted action were presented in a variety of ways throughout pre- or posttargeted stages. The conditions also differed in the technique used to demonstrate the targeted action. The goal of each demonstrative condition was to elicit imitative behavior in the participants. Results of Bellagamba and Tomasello's study were that 12-month-old children did not imitate actions often when the actions involve failed attempts. These results contrasted results of the 18-month-old participants who did frequently imitation unsuccessful goal-directed actions. Results also were that all participants regardless of age (e.g., 12 or 18 months old) emitted targeted actions more frequently after observing an entire action and the results of such action than when merely observing the results alone. Results from this study replicated Meltzoff, which lead Bellagamba and Tomasello to conclude that the actions exhibited by the 18-month-old participants (following the observation of the failed attempts) provided additional evidence to support the previous notion that the infants can infer the demonstrator's underlying intentions.

Huang et al. (2002) evaluated three conditions to determine if what was previously reported as an interpretation of behavioral reenactment of "failed attempts" could be reported as social learning processes more closely linked to affordance learning such as stimulus enhancement, emulation leaning, or mimicking. Eighty children between the ages of 31 and 41 months old were recruited as participants and divided into two groups prior to implementing each condition. Four conditions were present and included (a) full demonstration, (b) fail attempt, (c) emulation learning, and (d) adult manipulation. In the full demonstration condition, the experimenter fully modeled a targeted action with each of the five objects, which was repeated three times before the object was placed back in front of the participant. The failed attempt condition involved the experimenter not demonstrating the targeted actions with each object, but rather actions that demonstrated as failing to achieve the targeted action were modeled for participants. Each failed attempt was modeled three times before the experimenter placed the object back in front of the participant. The emulation condition consisted of participants being shown each of the five objects for about 10 s. Prior to any manipulation of the objects, a screen was lowered to block such observation by the participants. After 10 s elapsed, the screen was removed and the end-state of the testing materials were displayed for each participant. Ten seconds later, the screen was raised, and participants were able to observe the final end-state product. The adult manipulation condition consisted of manipulation of the targeted objects for the same time period as in the failed-attempt and full demonstration conditions, but neither the targeted actions nor the failed attempt actions were modeled for participants. In this condition, the adult simply modeled different actions using the object three times before replacing the object in front of the participant. Overall, the general findings of the work presented by Huang et al. (2002) differ than that of the original work by Melzoff (1995) regarding what condition resulted in intentional actions made by infants. Results showed that most participants successfully completed the task presented in the emulation learning condition. Results indicated a difference between the full-demonstration and failed-attempt groups, with successful completion of the task being demonstrated highest in the emulation condition. This supported previous findings (i.e., Bellagamba & Tomasello, 1999; Meltzoff, 1995) that suggested that nonimitative processes (e.g., emulation) may influence infant responding and ways children can learn (Meltzoff, 1995). In the research presented on affordance learning, one may note the similarity surrounding the results reported for emulation learning and the failed attempt conditions. The similarities in the patterns of responding reported between failed attempts and emulation learning led Huang et al. (2002) to determine that emulation may be linked to a form of affordance learning.

Object movement reenactment (OMR). Whiten et al. (2009) described a “taxonomy” of imitative and emulative learning processes, whereas object movement reenactment (OMR) may involve aspects of both imitation and emulation responses. Custance et al. (1999) defined OMR as how an observer learns about the affordances of an object from a model. Huang and Charman (2005) further elaborated on the definition of OMR as the role of an object’s movement in increasing the likelihood of the individual replicating the observed outcome. For example, when an observer sees someone use a hammer to hit a rod into a hole (e.g., object or its parts in motion), and then the individual uses a rock to hit a rod into a hole (e.g., that movement leads to a salient outcome), it is said to exemplify OMR, whereas seeing the object's movement led the observer to reproduce the outcome.

Meltzoff (1988) studied the imitation of 36 children who were 14 months old and who had no diagnosed physical or intellectual conditions. Using six different objects and actions, Meltzoff randomly assigned children to one of three experimental conditions (i.e., baseline control, adult-manipulation control, or imitation). In the imitation condition, participants were shown six targeted actions one at a time for approximately 20 s in a predetermined test order. In the demonstration conditions (i.e., adult-manipulation control and imitation), adult participants were shown how to manipulate six different objects just out of reach such that participants could observe the event only. In the baseline control condition, participants were not exposed to the objects nor the modeling of how to manipulate the objects. Following initial sessions in all experimental conditions, a one-week delay was implemented followed by a second session in each testing condition following identical procedures to the first session. Results found that deferred imitation of multiple displays can be demonstrated by children 14 months of age. Data showed that 92% of the participants in the imitation condition imitated three or more actions modeled after the one-week delay in comparison to 13% of the control condition. Results of this study led Meltzoff to hypothesize that in delayed imitation, young children produce the required act themselves on the basis of memory, and subsequently delayed imitation was then related to recall or cued-recall memory rather than merely recognition.

Gergely, Bekkering, and Kiraly (2002) adapted procedures by Meltzoff (1988) to evaluate if young children would reenact an action based on whether it was inferred to be the most effective method used to reach the goal rather than emit delayed imitation as in the

Meltzoff study. Gergely et al. defined OMR as a form of imitative learning based on goal-directed actions that are then implemented to imitate new strategies using motor actions already in repertoire. Attempting to account for methodological variations found in imitation and emulation research, the researcher's procedures included an adult contriving a situation (e.g., being cold) to wrap her hands around a blanket followed by the demonstrator executing a head action (e.g., to provide participants with a rationale as to why the experimenter used her head rather than her hands). The purpose of the additional testing condition was to test whether participants would infer that reenacting the head action would lead to an advantage in turning on the light apparatus. Results were that 69% of participants reenacted the head action to turn on the light following the observation of the adult turning on the light with her head when her hands were free, thus replicating Meltzoff. Following the observation of the adult demonstrator turning on the light with her head while her hands were occupied (e.g., wrapped in a blanket), a drop from 69% to 21% of the participants demonstrated using their head to turn on the light. Gergely et al. suggested their results supported the notion that 14-month-old children emit automatic "emulation-like" processes where memory is utilized based on the effects actions have on the environment. Based on these results, the authors hinted towards the process that children and humans may infer effective means to meet a final goal over a simple demonstration or imitation process.

Huang et al. (2002) conducted several experiments that examined behavioral reenactment procedures and their effect on intentions demonstrated in infancy. Critical to the study of OMR was the second experiment designed to examine the influence of exposure to initial and transitional states of a given set of objects on the performance of the behavioral reenactment paradigm task in infants. Huang et al. described the behavioral reproduction of an action as occurring when an individual observes the manipulation and actions of a model who draws attention to either environmental locations (e.g., local enhancement) or important parts of an object (e.g., stimulus enhancement). In Experiment 2, Huang et al. extended the work of their first experiment (focused on affordance learning) and examined how the role of object manipulation in the form of stimulus enhancement may play a part in emulation learning. The procedure used in Experiment 2 was modeled from the first experiment except for an addition of a second novel condition referred to as the spatial contiguity condition. The spatial contiguity condition was implemented in order to analyze if participant performance of targeted actions after observing failed-attempt demonstrations was due to a type of stimulus enhancement. Researchers sought to examined if the absence of a modeled targeted action or failed-attempt would result in the infant participants emitting the targeted action with the same frequency as demonstrated following the observation.

Forty infants with an average age of 17 months participated in Huang et al.'s (2002) second study. Four conditions were used and included full-demonstration, failed-attempt, emulation-learning, and spatial contiguity conditions. In the spatial contiguity condition, the experimenter acted upon only the targeted parts of the object within close spatial contiguity and only presented each modeled action once. Results of a Tukey's HSD test indicated a statistically significant difference in the targeted actions produced as a function of the condition implemented. Participants in the full-demonstration condition produced the most targeted actions in their first acts as compared to the failed-attempt, emulation-learning, and spatial contiguity conditions (e.g., p less than .01 and .05, respectively). Results of this experiment were that emulation as well as stimulus enhancement may be accountable for the performance demonstrated in the target actions replicated from Meltzoff's (1995) study involving manipulation of five objects: (a) dumbbell, (b) box and stick, (c) prong and loop, (d) beads and cylinder, and I square and dowel. Results of the two experiments presented here are useful to the current dissertation because they examined the role of stimulus enhancement in emulation learning as well as provided a model for testing emulation learning in children. Overall, the general findings of the work presented by Huang et al. differ than that of the original work by Melzoff regarding what condition resulted in the targeted actions emitted by the infants, challenging Melzoff's previous interpretation that infants reenact the intentions of the demonstrator. Based on their results, Huang et al. proposed that nonimitative social learning influences (i.e., emulation, stimulus enhancement, and OMR) may account for the performance of targeted actions in infants even following failed attempt demonstrations. Based on their approach, Huang et al. noted that nonimitative social learning approaches as a response to the interpretation of the results demonstrated by typically developing infants can also be used to study the behavioral reenactment paradigm with atypically developing children. Custance et al. (2014) provided additional insight regarding the study of nonimitative social learning approaches with children diagnosed with autism.

Custance et al. (2014) compared object reenactment movements (e.g., learning about various ways an object can move) to imitative movements (e.g., learning about the topography of a targeted action) in their study conducted with 20 children diagnosed with autism and 20 typically developing children. Using puzzle boxes and rewards, researchers implemented four types of video demonstrations including (a) full demonstration conducted by an adult; (b) ghost conditions, which incorporated movement of objects; (c) mimed resolutions that were demonstrated with the objects; and (d) an assortment of miscellaneous actions performed using the objects. In full demonstrations, a recording of an experimenter performing all actions required that both the object movements as well as the experimenter's actions were fully visible. In the ghost condition recording, all object manipulations were performed using transparent thread in such a manner that the actions were controlled by the experimenter, but not visible to the participants. In the mime condition, the experimenter was recorded performing the same actions as in the full demonstration condition, but next to the applicable parts of the objects so that he was not touching the actual objects. In the random demonstration recording, an experimenter lightly touched the surface of the objects to ensure that the action did not mimic that in the full demonstration condition. Results were that no significant differences existed between the performances of the children with autism and those that were typically developing across conditions. Additionally, there were no major imitative deficits demonstrated by the participants with autism as hypothesized and reported in previous literature (Ingersoll, 2008; Receveur et al., 2005). Custance et al. provided several reasons as to why they did not find any specific imitative deficits related to participants diagnosed with autism. Possible explanations are that the targeted actions were relatively simple and salient as compared to other studies (e.g., Rogers, Young, Cook, Giolzetti, & Ozonoff, 2010), and that the objects used in the study were rigid, not pliable as in the use of putty, to account for motor coordination in the variance of imitative ability (e.g., Green et al., 2002; Vanvuchelen, Roeyers, & De Weerdt, 2007).

Custance et al. (2014) noted that their results may have differed from previous findings because of a lack of careful experimentation regarding OMR and imitative responses. Other research noted findings that support the notion that while imitation deficits may be present for children diagnosed with autism, the emission of imitative behaviors can be minimized in the context of object reenactment movements because the focus on the person or social interactions is necessary within the imitative act (William, Whiten, & Singh, 2004). William et al. also noted that it is important that studies distinguish between imitation and other social learning processes, including types of emulation such as OMR. Researchers have often hypothesized that children with autism learn from aspects of their environment that are nonsocial, such as object-related demonstrations that do not involve the imitation of another person (Bird, Leighton, Press, & Heyes, 2007; Williams et al., 2004). However, if this notion is accurate, Custance et al. should have observed higher rates of learning and task completion during object reenactment conditions with their participants with autism, which did not occur. Custance et al. indicated that a diagnosis of autism was not an important factor; rather, age and verbal and nonverbal IQ were related to the time taken to get to the solution or reward in the puzzle box tasks. Based on these assertions, additional considerations related to participant identification beyond that of a diagnosis of autism or developmental delay may be warranted.

Goal emulation or end-state. Goal emulation has been described as one conceptual explanation of emulation that involved an individual's sensitivity to the outcomes observed (Huang & Charman, 2005). In end-state emulation, the end result reinforces the replication of a given result without explicitly imitating the sequence or steps related to the end result (Whiten & Ham, 1992). Often reported in the literature are end-state conditions (see Table 1). For example, if someone observes a stack of unfolded towels on a table, walks away from the table, and returns to the table and folds the remaining towels based on one folded towel being present on the table. Whiten and Ham (1992) referred to this as the process of reproducing the results through use of methods other than that of the demonstrator. Goal emulation differs than the other types of emulation discussed prior in that it has been described as a fourth-level imitation process, associated only with humans (Tomasello, 1996), and has been distinguished from affordance learning and object movement reenactment by not requiring a model present to demonstrate the behaviors leading up to the final product or result (Huang & Charman, 2005). End-state or goal emulation in comparison to other types of emulation offers researchers a means to analyze if behaviors are a function of imitative or emulative responding. If a learner only observed the final product of something available in the environment, there is a greater likelihood of emulation and subsequent problem solving because there is no behavior to imitate in the environment.

Behavior Analytic Account

There are many conceptual explanations reported in the animal cognition and developmental psychology literature to describe emulation. What remains limited in comparison is the behavior analytic account of emulation. Analyzing the research on emulation through a behavior analytic lens with a specific focus on verbal behavior may offer a means to support a possible account for problem-solving behavior and emergent or untaught behavior. Each of the four primary conceptual explanations listed above (i.e., social learning theory, affordance learning, OMR, and end-state emulation) will be discussed using a behavior analytic account of behaviors described by cognitive and developmental psychologists.

Social learning theory is typically described as the theory that people learn by observing others (Bandura, 1977). The primary concern related to the use of social learning theory as a possible conceptual explanation of emulation remains the close links to mentalistic concepts used within many of the proposed descriptions of the theory. If one were to only focus on the behavior analytic aspects of social learning theory, the observing responses or aspects of observational learning serve as an important focus as it relates to emulation. Greer and Keohane (2006) emphasized the role of observation as a critical feature of child development in that it enables one to acquire new skills along with more complex behaviors without direct instruction.

Observational repertoires have also been described as fundamental components underlying the evolution and development of verbal and nonverbal behavior (Greer & Keohane, 2006). Greer and Keohane argued that the type of behavior change noted within social learning theory (Bandura, 1986) is more so related to the observational effects on behavior whereas the result of such observational behavior equates to the emission of operants that were already in the observer's repertoire.

When analyzing similar yet distinct behavior analytic phenomena related to that of affordance learning, one may benefit from analyzing the role emulation plays in verbal developmental cusps or capability over an affordance learning cognitive process. A verbal developmental cusp is described as a developmental change that affords an individual novel experiences that lead to new types of learning that were not available before and would not be available or very difficult to achieve if not present in the individual's repertoire (Greer, 2008; Rosalez-Ruiz & Baer, 1996). Greer (2008) and Greer and Speckman (2009) also described behavioral capabilities as the behavior-environmental interactions that are considered cusps because the interactions lead to the new method of learning verbal behavior. Using the definitions presented here, all developmental capabilities can be considered developmental cusps, while the opposite does not hold true in that all cusps are not necessarily capabilities (Greer & Speckman, 2009). The study of emulation as a possible verbal developmental cusp or capability will be further examined in the study presented in this paper.

From a behavior analytic perspective, the form of emulation described as OMR is more so linked to a definition of emulation as described in research by Rothstein (2009). Here, emulation involves a modeled targeted behavior observed by the learner, but the behavior of the emulator does not have to have a point-to-point correspondence with the model. Much like in the early descriptions of the term emulation, the primary concern from a behavior analytic perspective remains that when a model is present, there will always be a greater likelihood of imitation over emulation. For example, researchers reviewed above hypothesized that children with autism learn from aspects of their environment that are nonsocial, such as object-related demonstrations that do not involve imitation of another person (Bird et al., 2007; William et al., 2004). However, if this notion is accurate, Custance et al. (2014) should have observed higher rates of learning and task completion during object reenactment conditions with their participants with autism, which did not occur. Custance et al. indicated that a diagnosis of autism was not an important factor; rather, age and verbal and nonverbal IQ were related to the time taken to get to the solution or reward in the puzzle box tasks. Such considerations play an important role in analysis of emulation from a behavior analytic framework. For example, age, while closely linked to developmental scales, can instead be viewed from the behavior analytic perspective of being more closely related to the role of instructional history or histories of reinforcement/punishment. Levels of IQ represent another example where such results are based on cognitive interpretations; one can instead analyze the verbal behavior of the participants. Both of these examples support the benefits of utilizing a behavior analytic account to address the study of emulation within the definition and the variables being studied.

Goal emulation within the behavior analytic research is described as one of two possible behavior-environment relationships encompassing the term emulation. In this relation, the emulator observes a completed product in the environment and emits behavior that functions to produce a functionally equivalent product. In this type of emulation, an individual is essentially reproducing a product that is already completed using problem-solving skills (Tennie et al., 2006). Rothstein (2009) went on to describe end-state or goal emulation as a possible form of nonverbal problem solving. When analyzing the definition of problem-solving behavior as "any behavior which, through the manipulation of variables, makes the appearance of a solution more probable" (Skinner, 1953, p. 247), one may note that the creation of a final product is not a necessary feature and therefore differs slightly from that of Skinner's problem-solving definition as the product can be made on accident. According to Skinner (1953), the behavior must be emitted with a purpose related to the present problem in one's environment to be deemed problem-solving behavior. Parsonson and Baer (1978) echoed that definition when they described problem solving as the behavior emitted by an individual to produce a targeted result. Within their definition, behaviors emitted throughout a problem-solving process reinforce the subsequent behavior as they are emitted in order to achieve a final product or goal (Parsonson & Baer, 1978). The end goal or product thus becomes a natural reinforcer and does not require prosthetic reinforcement. The importance of utilizing a behavior analytic account of all forms of emulation will be discussed throughout the remainder of this paper specifically focused on the application and study of emulation.

Application of Emulation

Byrne (2002) discussed that the study of emulation has largely been used as a null hypothesis against which presumed evidence for imitation was examined. This has led to limited research that seeks to apply and study emulation as a testable hypothesis separate and apart from imitation. Within the behavior analytic literature, several theories and phenomena have been used to account for untaught behavior such as stimulus equivalence, observational learning, and relational frame theory. By studying emulation, one may gain insight into a more robust understanding of how one learns through indirect contingencies. The application of behavior analytic research in the area of emulation has the potential to identify methods in which typically and atypically developing learners can gain more independence, need less prompting, address functional life skills, experience trial-and-error learning, problem solve, and expand their skill sets without direct teaching.

Problem-Solving Skills

Many of the researchers who have studied emulation across species have examined the role of emulation in the analysis of problem-solving behaviors (i.e., Carr et al., 2016; Hanus et al., 2011; Horner & Whiten, 2005; Whiten et al., 2009). Horner and Whiten (2005) evaluated the role of causal knowledge in emulation and imitation tasks in chimpanzees and young children. Researchers implemented a series of experiments, three with chimpanzees and one comparative study with human children, to test causally relevant and irrelevant actions when presented in conditions that included an opaque or clear box. The design of the apparatus allowed for researchers to distinguish the actions of participants based on the presentation of causal information as in the use of the clear box versus the lack of causal information presented as in the opaque condition. Results of the first study were that there was no statistically significant difference between the two-action method and the emission of irrelevant actions. Regarding the reproduction of relevant and irrelevant actions, two of the four groups of subjects performed significantly better when using the opaque apparatus than the clear apparatus. Results of the second study were that subjects selected the tool at significantly higher levels than hypothesized, with a mean of 80% correct. Results of the third study were that all subjects selected the correct tool at levels higher than expected by chance, with a median of 75% correct. Overall, based on these results, the authors explained that causal structure of a task is used in emulation processes as opposed to a task lacking this type of understanding which may lead to imitation over emulation. In addition to these results, differences between chimpanzees' and children's use of causal information were discussed. Unlike the chimpanzees, children used imitation to problem solve the task given in both conditions even when emulation would have served to be more efficient. As in the research presented by Horner and Whiten, many researchers outside the field of behavior analysis consider emulation a problem-solving skill because a subject reproduces a final product (Carr et al., 2016; Hanus et al., 2011; Tennie et al., 2006).

If one examines the notion of problem solving from a behavior analytic perspective, one would initially note the definition of problem solving as the manipulation of variables that lead to the presence of a probable solution by Skinner (1953), which may or may not involve behaviors that are identical to the creation of a product. Parsonson and Baer (1978) further described problem solving in terms of reinforcement value. As described, problem-solving behavior along with subsequent changes in that behavior result in a target consequence whereas the behaviors that were emitted during the process are reinforced by the product and the product is then considered naturally reinforcing. Rothstein (2009) used these descriptions and defined emulation in respects to problem solving in that emulation can be, in part, a nonverbal, problem-solving behavior.

Emulation as a Typically Developing Process

Literature on the developmental processes emulation and imitation has been evaluated in both human and animal studies (i.e., Call et al., 2005; Hopper, 2010; Hopper et al., 2008; Horner & Whiten, 2005; Tennie et al., 2006). A comprehensive review of this literature concluded that imitation and emulation develop early on in human development (i.e., Huang et al., 2002; Vanvuchelen et al., 2011). Additionally, it has been noted that typically developing children tend to imitate at earlier stages in their development than they emulate (i.e., Call & Carpenter, 2001;

Tennie et al., 2006). This may lead one to determine that an imitative repertoire precedes the development of an emulative repertoire.

Many researchers have suggested that imitation begins as early as infancy (e.g., Bellagamba & Tomasello, 1999; Field, Woodson, Greenberg, & Cohen, 1982; Meltzoff & Moore, 1989); however, Jones (2009) suggested that this might not necessarily be the case due to the lack of evidence supporting such statements. Jones proposed that true imitation typically develops around 2 years of age and other types of behaviors like emulation emerge at various ages following imitation development. Unfortunately, much like its predecessors, this work was not experimentally based, but there was a significant review supporting the notion that imitation is not necessarily inherited, but rather learned behaviors that are part of what was referred to as “a dynamic systems account” (Jones, 2009). This notion supports the development of imitation, and emulation, at the ontogenic level of behavior selection, meaning they can be taught and may be independent processes.

Call et al. (2005) provided information pertaining to imitation and emulation as developmental processes in children. The authors hypothesized that the children would manipulate the tube based on the modeled actions, and their results supported this hypothesis and added that children typically will imitate through social conditions rather than emulate; however, this study did not include a control condition. This is an important limitation because a control or comparison condition provides additional information on the development of imitative and emulative repertoires in children regardless of any manipulations.

Tennie et al. (2006) also compared emulation and imitation development in children and great apes. The results were that great apes completed the tasks through emulation and children completed the task based on imitation, replicating previous findings. Taken together, these results indicate that children required modeled actions (e.g., imitation) rather than simply the results of such actions (e.g., emulation) in social-learning scenarios. This suggests that in human development, actions may take precedence over results; however, future researchers should continue to study learning via emulation and imitation. It is possible that information is received not only through demonstration but also through final products or the results found in one's environment. Additionally, there are questions related to emulation and imitation in children with or without disabilities.

Atypical Developmental Processes

Vanvuchelen et al. (2011) reviewed the literature on imitation as it related to characteristics often associated with autism. They examined several different aspects of imitation and imitation deficits as it related to and how such deficits are observed in preschool-aged children. They concluded that there is only partial evidence that experimentally imitation deficits are unique or specific to an autism diagnosis, meaning similar deficits were seen in children without an autism diagnosis. Additionally, they indicated that imitation deficits are not universal to all preschool-aged children diagnosed with autism.

Vanvuchelen et al. (2011) noted two significant issues within the literature reviewed. One was the lack of continuity in providing a clear definition of imitation. This concern was not novel, as it was also mentioned by Bryne (2002), Sevlever and Gillis (2010), and Whiten et al. (2009); however, this concern can be extended to emulation, which is often defined in several ways and misrepresented as imitation or observational learning (Jones, 2009; Tennie, Call, & Tomasello, 2009; Whiten et al., 2009). The second noted limitation was the lack of clinical significance of the findings (Vanvuchelen et al., 2011). They were concerned with the results themselves, as well as in how such results could affect the selection of appropriate interventions selected for imitation deficits.

Young, Krantz, McClannahan, and Poulson (1994) evaluated the effects of response topographies on the formation of generalized imitative subclasses in four children diagnosed with autism. Using a multiple baseline across-behaviors design, they measured the percentages of matching and nonmatching responses emitted across three response types (i.e., vocal, toy-play, and pantomime). Results showed increased matching within response type, demonstrating that imitative behaviors were generalized from reinforced models to probe models within, but not across response types. This indicates that there may be topographical boundaries to consider in the generalization of imitation skills. To explain this possibility, the authors suggested imitation was a subclass of instructional control and other instruction-following response classes. Although imitation and emulation are not the same processes, some of these considerations should be considered when analyzing emulation in children diagnosed with ASD. Also, with no direct comparison available in the published literature, this study serves as a useful tool in the study of emulation.

Ingersoll (2008) also studied imitation skills in children diagnosed with autism. Using a counterbalanced design across participants, two imitation conditions were conducted which consisted of an elicited and spontaneous imitation task using toy sets. The author presented a modeled action three times with a corresponding verbal statement or prompt during the elicited imitation task condition. In the spontaneous imitation tasks, a contingent imitation period was implemented where the experimenter modeled toy play several times with each toy and then presented the toys in a random fashion. Results were that the participants diagnosed with autism demonstrated imitation at a significantly lower rate than children considered typically developing. The study also found that children with ASD performed significantly worse in the spontaneous over elicited condition as compared to the typically developing participants. Ingersoll echoed previous notions that individuals with autism lacked spontaneous imitation, or delayed imitation that was not prompted, over imitation tasks that were prompted by the experiment immediately following the modeled action (McDuffie et al., 2007; Whiten & Brown, 1998). This may extend to the study of emulation which is similar and possibly related to spontaneous behavior. It may also explain why some children diagnosed with autism may emit emulation, but not generalized imitation. However, there are other possible explanations such as a lack of attending to the model due to diminished social interest, direct-instruction programs to teach imitation resulting in prompt dependency, or the overall lack of joint attention (e.g., social motivation related to shared experiences or joint attention). These considerations warrant further investigation related to why spontaneous imitation, or emulation, might be a deficit typically found in children with autism.

DeQuinzio, Townsend, Sturmey, and Poulson (2007) studied imitation training using facial models for three participants were diagnosed with autism using a multiple baseline across participants design. Imitation training included modeling, promptings, differential reinforcement, and error correction for incorrect responses. Imitation was defined as copying the modeled facial gesture within 5 s of the model for a duration of 2 s and was reported as a percentage of occurrence across trials. The results were that although all participants learned to imitate, none exhibited generalized imitation of probe models. However, the authors only used one probe model during the test for generalization, and the lack of generalization may be addressed by evaluating the number of different exemplars needed to promote generalized imitation. Although emulation differs from imitation in the role of observing responses, it is possible that many of these interventions, and limitations, may be translated or modified for the study of emulation.

The study of emulation has the potential to impact learning and best teaching methods for individuals with atypical development. As indicated in the literature, many typically developing individuals come to learn a large portions of their behaviors indirectly or without direct instruction (Greer et al., 2017; Hayes et al., 2011; Horne & Lowe, 1996). Within the literature on atypical development, the most common form of treatment to contest with deficit areas tends to be direct instructional methods or prompting delivered by the instructor (O'Riordan & Plaisted, 2001; Rose & Howley, 2007). This is a concern because it can lead to stimulus control issues and prompt dependency, less independence, and less occurrences with indirect teaching opportunities like trial-and-error experiences or problem solving.

Procedures Used to Study Emulation

Over the last 30 years of emulation research, several methods have been reported as testing conditions to study emulation. The most common procedures to study emulation consistently reported in the animal cognition and developmental psychology literature include two action and bidirectional methods, irrelevant and unintentional actions, ghost conditions, and end-state conditions (Custance et al., 1999); see Tables 2 and 3. Of these methods, some researchers have studied the procedures in isolation as seen in the study conducted by Gergely et al. (2002) where irrelevant and unintentional actions were utilized, or in combination across testing conditions as in the work by Custance et al. (1999). Although published literature has provided several procedures that have been replicated over the years, it is worth noting that most of the procedures have served to tease out information pertaining to whether behavior noted within such studies is imitation or not, and if not, what type of emulation or relevant term (e.g., object-movement reenactment) fits the behavior demonstrated by subjects the best. Two of the commonly used procedures that have been used to identify emulation in human subjects (i.e., irrelevant and unintentional actions and ghost conditions) will be reviewed in further detail here along with the considerations of how one might study emulation in its own right (opposed to as a null hypothesis for imitation) using behavior analytic procedures.

Irrelevant and Unintentional Actions

Meltzoff (1995) studied whether child participants would reenact by comparing irrelevant actions to unintentional actions in a series of experiments. Experiment 1 tested if children could perform a target act when an adult demonstrated failed attempts to perform the given task. Using an assortment of test materials, the participants were randomly assigned to one of four groups. Two of the groups were demonstration groups and two of the groups were control groups. For each group, the testing materials were presented in various orders to ensure equally in presentation positions. In the demonstration group, the experimenter demonstrated each of the five objects' use in a series of three repeated demonstrations. Following demonstrations of all objects, the experimenter allowed the participants in this group to demonstrate an action using each of the five objects. During the demonstration based on intention condition, participants observed an adult who exhibited failed attempts to perform the given task, therefore resulting in target acts not being observed by the participants. In the adult manipulation group, participants either observed the full target act or an appropriate control. Participants in the control group were simply presented the materials to determine if the target acts would occur spontaneously without any type of demonstration. Results of a one-way analysis of variance (ANOVA) were that the number of target acts were statistically significant as a function of experimental group and more targeted actions were emitted in the demonstration than in the control group. The authors indicated that participants could infer the adult's intentions through observation of failed attempts. What remained unclear was the role of the experimenter in the children responding.

Experiment 2 of Meltzoff's (1995) study was conducted to test if similar participants could reenact the intended acts when the demonstration occurred completely based on the movements of the situation, or if a social learning component was necessary. Participants included 60 children who had an average age of 18 months old. Procedures were the same as in Experiment 1 except for the inclusion of an inanimate demonstration condition where an inanimate object performed the task and only that task was used. Results were that children who observed the human experimenter attempt to pull apart the objects were six times more likely to produce the targeted action (i.e., 60% of participants emitted the target response in the adult demonstration condition). In the inanimate demonstration condition, only 10% of the participants emitted the targeted action. Based on these results, Meltzoff indicated that the participants did not produce the target acts based on the observation of failed attempts by the inanimate object.

Although not directly testing for emulation, Metzoff (1995) presented methods used to test the effects of failed attempts of imitation. The methods presented in Experiment 2 are closely tied to various procedures used to test for emulation using ghost conditions. Meltzoff (1995) provided a procedure to test for emulation using irrelevant and unintentional actions. This has influenced others' work (Bellagamba & Tomasello, 1999; Huang et al., 2002) and provided research on one of the most common ways emulation has been tested in typically developing human subjects.

Ghost Conditions

Fawcett et al. (2002) first presented ghost conditions in their research and since these conditions have been used to test if emulation is in an individual's repertoire. In a ghost display condition, one would hide or discretely move the applicable parts of an apparatus to display what would appear to be the operation of the apparatus through a "ghost-like" agent. Ghost conditions are frequently used to study emulative processes because they offer a means to test if participants are imitating the actions of others or the results on the environment.

Thompson and Russell (2004) examined whether imitative learning was responsible for successful responding to a type of observational learning task or if nonimitative learning could be considered responsible for such learning. The study was conducted with 72 children between 14 and 26 months old who were presented with two tasks, one being an imitative task and the other an emulation (i.e., ghost condition) task. Results of a general log linear analysis were that performance on single-mat and double-mat tasks had more retrievals in both conditions than in the baseline. Participant performance in the ghost condition was significantly better than the modeling condition on the single-mat task, whereas there were opposite results on the double-mat task, with better performance being emitted in the modeling condition. Based on these results, Thompson and Russell indicated that performance on one of the tasks (i.e., single-mat) was better during the ghost or emulation condition than the modeling or imitation condition.

Zimmermann et al. (2017) used touchscreen devices to test the effects of ghost conditions on imitative skills of children aged 2.5 to 3 years old. Based on previous research, the authors hypothesized that young children would display a transfer deficit when taught actions via a touchscreen device as compared to real world items. Zimmermann et al. examined if 52 typically developing young children could learn how to put together a puzzle from enhanced ghost conditions on a touchscreen device. Experiment 1 tested if the participants could learn puzzle assembly skills from a two-dimensional ghost display to a three-dimensional test of the same skill. After random assignment to the two-dimensional or three-dimensional ghost condition, participants completed a short play session before moving to the demonstration phase. Following demonstration phases, a test phase was implemented with half of the participants using a touchscreen device (i.e., ghost 2D) and the other half using a real magnetic puzzle board (i.e., ghost 3D). Results of a three-factor ANOVA across model (i.e., ghost, social), transfer (i.e., 2D, 3D), and age (i.e., 1.5, 3-years-old) on goal imitation included a main effect of age, main effect of transfer, and main effect of model. A posthoc Turkey HSD test was conducted and based on those results, the authors concluded that participants learned at statistically significant better levels in the social conditions over the ghost conditions. Participants also performed considerably higher on the three-dimensional ghost conditions and the older participants scored much higher on the performance task than did younger participants.

Hopper (2010) conducted a review on experiments that used ghost conditions with human and animal participants to distinguish between imitation and emulation learning across species. Two methods he identified often in the literature to distinguish between imitation and emulation were ghost displays and end-state conditions. Ghost displays are used to establish whether a person can emulate by examining if the person can perform a task without being provided information about the movements used to complete that task, as one would in an imitative task. When using end-state conditions, one can assess goal-emulation by observing if the participant can solve a given task to establish a functionally equivalent product without being shown the movements or actions required.

Tennie et al. (2010) determined if chimpanzees are better described as being emulators or imitators. Thirty-two chimpanzees served as participants in this study. Tennie et al. divided subjects into two conditions: one baseline and the second being either a full-model condition or a “water bottle” condition (i.e., emulation condition). The full-demonstration condition provided subjects with information pertaining to the actions, goals, and results of the given tasks and the water bottle condition provided only information regarding the results and goals. Results were that five subjects were successful in completing the task in the full model condition and three subjects were successful in the water bottle condition. No statistically significant differences were noted between the two experimental conditions, and overall the results were that the full demonstration and the emulation condition led to similar levels of successful attempts to complete the peanut tasks. These results are significant because they led the researchers to analyze the role of emulation learning in relation to the success demonstrated in both experimental conditions.

Although Tennie et al. (2010) solely examined such procedures using chimpanzee subjects, the processes and findings are still worth noting when examining the literature on emulation. As this article demonstrated, many of the studies surrounding emulation as a topic within itself have been developed in the realm of animal cognition; therefore, one cannot assume that the results demonstrated here would relate across species, as the considerations mentioned as well as the measures presented in this article may be of use when studying emulation in humans. Of special interest were the measures of the probability of innovation during the problem solving of the peanut tasks as well as the comparison of conditions to determine which was the most plausible underlying learning mechanism (e.g., imitation or emulation). Accounting for the measurement of how many trial-and-error attempts are made by human participants when completing given emulation tasks may be just as useful as in animal research. Researchers also mentioned that they were able to rule out the role of stimulus enhancement in the study presented (Tennie et al., 2010). This was an important consideration made by researchers that related to the concerns regarding the role of stimulus enhancement presented in other research.

Trial-and-Error

The study of emulation has been limited within the field of behavior analysis; therefore, the procedures used to study the presence and induction of emulation are sparse. Two unpublished dissertations have studied procedures to test for emulation (Philp, 2016; Rothstein, 2009). Philp (2016) tested for both imitation and emulation in typically developing and atypically developing young children by comparing immediate and delayed testing conditions. Because this research was primarily focused on testing for the presence of emulation over the induction of emulation, one may look to Rothstein (2009) for a behavior analytic model of how to induce emulation in typically developing young children through trial-and-error experiences. Rothstein used incidental learning conditions, commonly referred to as a trial-and-error teaching, to induce emulation. By using trial-and-error, participants were presented with apparatuses or puzzle boxes that were easier to solve than in the test conditions. The trial-and-error treatment package consisted of offering participants opportunities to manipulate the boxes and reinforcement contingencies once the puzzle boxes were opened because the participant gained access to the desired item, and video clips of the removal of a preferred item from the box. To encourage the children to explore the boxes, video footage of children obtaining an object from a puzzle box, but not the process of how to do so, were not shown to participants. By controlling for only the end-state or goal to be demonstrated prior to the trial-and-error experiences, Rothstein was able to successful isolate the study of emulation. Being able to study emulation separate and apart from imitation is an important feature of the study presented here. Through the use of novel emulation probes that account for some of the concerns mentioned throughout the literature (i.e., the inability to differentiate at times if a learner is imitating or emulating), the study presented sought to expand on the limited procedures used to induce emulation in human subjects.

Source of Reinforcement

Paulus (2014) provided a theoretical perspective on how and why imitative behavior is developed in such early stages of a child's development. All accounts presented were based on a psychological account of imitation. Research in developmental psychology has sought to answer the question of how children as young as infants can learn to imitate the actions of others. Various perspectives have been provided. Guillaurne (1925) related imitative actions in infancy to signal perception through associative learning processes. Piaget (1962) later expanded on this concept stating that infants use signal perception as an index of what they can then assimilate to various actions within their action scheme. The rationale of why young children imitate were initially accounted for through only mental states or from within the skin of the individual. More recent researchers such as Meltzoff and Moore (1989) and Meltzoff (1990) continued to account for imitation in similar ways in children as young as in infancy. Although these accounts of imitation explain, according to psychology, when imitative repertoires are developed, they do not explain why imitation is maintained in not only children, but as individuals age into adulthood.

A behavioral account pertaining to the source of reinforcement for imitation was reported by Skinner (1957) and Greer and Keohane (2006). Skinner (1953) referred to the source of reinforcement for imitation as being related to the general process of behaving as another being reinforcing. Because the development of the imitative repertoire occurs as discrete sets of responses, it can easily be overlooked as behavior developed at the ontogenic level of behavior selection. Therefore, one should not accept imitation as an inherent part of one's behavior. VBDT accounts for the source of reinforcement for imitation being the correspondence itself between the individual imitating and the model's behavior (Greer & Keohane, 2006). It is hypothesized that the source of reinforcement for emulation occurs in the results of the end-goal or completion of the tasks themselves rather than the see-do correspondence that reinforces imitative responding. Du and Greer (2014) stated that it is the correspondence between the process used to complete a task to actual completion of the final product that reinforces the trial-and-error experiences in which an individual engages in terms of end-state emulation. The source of reinforcement for emulation as described here is important when defining emulation from a behavior analytic perceptive.

Proposed Behavior Analytic Definition

In order to experimentally test the concept of emulation, critical attributes of the term must be identified and defined in a conceptually systematic and technological manner. Defining emulation from a behavior analytic perspective is essential to distinguishing the term from similar terms such as imitation and observational learning. Two accounts of emulation in unpublished behavioral research (Philp, 2016; Rothstein, 2009) have provided the groundwork to identify critical attributes of the term emulation. Emulation, as presented by Rothstein (2009), can be emitted in two forms, either via nonverbal problem-solving behavior or verbal behavior (Rothstein, 2009). Rothstein (2009) further elaborated on this definition by describing the two forms of emulation as either producing something novel through the observation of a product followed by reproducing it using verbal or nonverbal behavior or manipulating environmental stimuli in a new way that results in obtaining a desired outcome.

Philp (2016) further distinguished emulation by defining emulation as the behavior emitted by an observer that results in the same goal produced by the model's behavior but bares no point-to-point correspondence with the behavior modeled. Much like the definition presented by Rothstein (2009), Philp noted that the behaviors or sequence of behaviors emitted by the observer are not significant to the term emulation, but rather the end result or goal of the model's behavior that is important.

Based on the consensus of these two descriptions, we propose that emulation can be defined by two behavior-environment relations. First, the emulator observes a behavior or sequence of behaviors being emitted to produce a given product. The emulator then emits behavior that functions to produce a similar product that was observed from a given model. In this case, the emulator does not have to produce behavior with point-to-point correspondence to the model's behavior, but any behaviors that may result in some imitation are not required. Second, the emulator observes a completed product and emits behavior that produces an equivalent product. In this relation, the behaviors or sequence of behaviors that led to the resulting product can neither be imitated nor emulated because only the final product is available. This type of emulation may result in use of emulative behaviors over other types of behaviors (e.g., imitative). Through the establishment of a clear behavior analytic definition of emulation, one can then address the next pressing concern presented in the literature, effectively studying emulation in its own right. This requires a control for testing procedures that will reliably establish the distinction between emulation and imitation.

Purpose of Study

Various behavioral terms are defined functionally through the designation of a procedure that results in changes in behavior (Holth, 2003). Emulation from a behavior analytic perspective can be distinguished from terms such as imitation based on the differences in focus and source of reinforcement. Emulation thus should be considered a separate and unique behavioral process. This distinction offers researchers a means to expand upon the literature found in other domains to that of socially significant behaviors. Although researchers have tested for emulation in typically developing children (i.e., Call et al., 2005; Tomasello et al., 1993; Whiten et al., 2009), few, if any, have studied emulation in children with developmental disabilities. Rothstein (2009) provided one example of how to test for emulation across children without delays. Philp (2016) then built upon Rothstein's findings to determine if young child with and without disabilities would imitate or emulate across various testing conditions (i.e., immediate and delayed). To the author's knowledge, no known research has examined methods to test and induce emulation in children diagnosed with developmental delays. Therefore, building upon the work of Rothstein and Philp, this study analyzed the role of emulation and possible corequisite verbal development cusps and capabilities, as well as determined if an emulative repertoire can be established in children diagnosed with developmental disabilities.

Chapter 3: Research Design and Method

Chapter Overview

Behavior analysts and psychologists have relied on multiple theories and phenomena to account for the emergence of untaught behavior. Studying emulation may provide additional insight into a more robust understanding. Emulation has been studied in animal cognition and developmental psychology but has not been directly addressed in published research from a behavior analytic perspective. The purpose of Experiments 1 and 2 was to examine the role of emulation as a behavioral phenomenon as well as examine if emulation could be induced in children with developmental disabilities. Experiment 1 will serve as the preliminary research and point of comparison for Experiment 2.

Method – Experiment 1

Experiment 1 was first conducted to test whether children with developmental disabilities had imitative and emulative skills in repertoire. Results of the initial tests were analyzed using a correlational analysis of imitation and emulation tasks. This was done to determine if any prerequisite behavioral cusps or capabilities are necessary for emulation, as well as to determine correlations between imitation and emulation as corequisites. This research sought to answer the following research questions:

- Are imitation and emulation corequisites?
- Can emulation be distinguished from similar processes as a behavioral cusp?

Participants

Twenty-five children, five females and 20 males, diagnosed with autism or related disabilities, participated in this experiment. The participants all were required to speak English as their first or second language (i.e., they must understand spoken English), be between 3-13 years old at the start of the experiment, and have a diagnosis of developmental delay, autism spectrum disorder (ASD), or a related disability. Participants were recruited from four private centers using the Comprehensive Application of Applied Behavior Analysis of Schooling (CABAS®; Greer, 1997) model of instruction where they received a range from 15-35 hr of services based on applied behavior analysis (ABA) principles.

Each participant was assigned to one of two groups (to account for the sequence in which they received the testing probes) based on submission of the written consent form, where the first to complete the form was placed in Group A, the second was rotated into Group B, the third was placed in Group A, and so forth. Each participant was assigned a number (1-26) based on the order in which they submitted their written consent form. Participant 19 was removed from the study based on exclusions in age upon verification of experiment inclusion criteria; therefore, that number will not be reported in group summaries. At the onset of the experiment, participant ages ranged from 3 to 13 years old and ranged in verbal behavior capabilities from pre-speakers to early reading and writing. All participants exhibited behaviors consistent with instructional control (e.g., sit still, responds to look at me, and has basic match-to-sample for 2-D and 3-D objects in repertoire) prior to the start of the study. Each participant was diagnosed with ASD or developmental delay as indicated on educational and medical reports. See Table 4 for a summary of participant characteristics.

All participants attended one of four privately funded ABA centers for individuals with developmental disabilities and ASD. All centers were located in the southern United States with three of the five (Sites 1-3) centers located in small cities, one center (Site 4) located in a major city within a special needs school setting (e.g., the ABA center was located at the special needs school), and the fifth center (Site 5) located in a separate major city. Each site housed various classrooms based on verbal behavior of the learners who attended each site and each classroom was arranged to align with the curriculum being implemented for each class of learners. For example, Site 1 housed four classrooms including early learners, early CABAS® International Curriculum and Inventory of Repertoire for Children from Pre-School through Kindergarten (C-PIRK®), advanced C-PIRK®, and Accelerated Independent Learners (AIL) classrooms. Most of the instruction across sites were implemented following a 1:1 ratio (learner-to-technician) with some instruction being implemented in small or large group settings. The duration of the therapy day varied based on individual need from 3 hr to 7 hr a day. All sites implemented a behavior analytic approach to all aspects of the day from instruction, interventions, staff training, parent training, and center management following the CABAS® model of instruction (Greer, 2002).

Informed consent and assent. Prior to the start of this experiment, written consent was obtained from each participant's parent or guardian. Verbal consent and assent were either obtained from each participant prior to implementing a session or waived via a written form completed by a parent or guardian of participants based on individuals who could not provide vocal consent or assent due to levels of verbal behavior. For participants who could comprehend and respond verbally to questions, vocal-verbal assent (i.e., agreements such as "Yes," "Sure," or "OK") was obtained. For children without the necessary levels of verbal behavior, assent guidelines were used to obtain and continually measure assent throughout the study. The assent form indicated what behaviors may indicate the participant does not want to participate in a session or the overall study and was used prior to each session as well as during each session. If any participant demonstrated either a vocal or physical response (as listed on the assent form) indicating they no longer wanted to participate in the session, the session would have been terminated. No participants revoked consent or assent to participate nor did they exhibit behaviors indicating such during Experiment 1.

Screening. All participants met the following requirements: a previously established diagnosis of ASD or related disability, exhibiting behaviors associated with instructional control(i.e., sit still, responds to look at me, and has basic match-to-sample for 2-D and 3-D objects), and having data from a previous screening using the Verbal Behavior Development Assessment-Revised (VBDA-R; Greer & Ross, 2008) conducted within 6 months of the start of the study. This assessment identifies behavioral cusps and capabilities in a participant's repertoire and was used to correlate the results of this assessment to the presence of imitation and emulation skills in repertoire.

Setting

All sessions were conducted in a room located in each center. The room was located near the participant's regular therapy rooms but was separate to allow for individual testing and contained limited visual and auditory distractors. The session room was furnished with a child-sized table, rug, chairs, and building materials required for the session. During the testing sessions, the experimenter sat next to the participant at the table. A recording device was located slightly behind the experimenter and participant for all sessions. Sessions ranged in duration from 15-60 min and were conducted in one session for all participants with the exception of Participant 24 who's session fell in between a natural break in the day (i.e. snack and play time); therefore, Participant 24 completed his testing session across two sessions within the same day with a 30-min break between the testing sessions.

Materials

Various sized building materials were used as task materials for both the imitation and emulation tests. Structure cards were established to ensure the same steps were modeled for participants in the same order during the imitation tests and structure cards were used to ensure the experimenter created the same final structures used in the emulation test. Each structure card displayed a printed photograph of one structure along with either the steps to follow to build the structure (imitation test) or the materials needed and the final structure (emulation test). See Appendices D and E to view basic and advanced picture cards used in Experiment 1. All building material used in the first experiment were items that were not found in the participant's classrooms and varied in terms of how they are typically manipulated. A brief description of each type of material used can be found in Table 6.

The Verbal Behavior Developmental Assessment – Revised (VBDA-R) was used along with associated materials as needed (Greer & Ross, 2008). Video recording equipment (i.e., computer and screen recording applications) was used to record sessions for reliability data collection. Tokens or point systems were used as reinforcers for some participants. See Appendix A for the data sheet used in Experiment 1 to record responses to imitation and emulation tasks.

Dependent Variables and Response Measurement

The primary dependent variable was correct responses to emulation and imitation tasks. Data were also collected on the duration to correct responses during emulation and imitation tasks. Correct responses were defined as the participant accurately building the structure either via imitation or emulation depending on the test. Incorrect responses were defined as inaccurately building the structure via imitation or emulation. Imitation was defined as the point-to-point correspondence between the experimenter's modeled action and the participant's action.

Emulation was defined as the duplication of the structure shown to the participant and did not require the participant to imitate or follow any order of movements; only the final product was evaluated. No response was defined as the participants not building anything at all or building a structure not related to the model provided or structure shown (e.g., stacking all square shaped blocks in a line).

Data were collected on responses to imitation and emulation test trials in a 1:1 setting (participant: experimenter). Correct, incorrect, and no responses were measured using frequency counts and the duration to complete each task was also measured. Duration was averaged by adding the durations of all trials per condition and dividing the sum by the number of trials in that condition. A one-way, independent measures ANOVA was used to analyze correct responding to emulation test across participants with particular verbal behavioral developmental cusps and capabilities in repertoire (e.g., capacity for sameness, generalized imitation, and listener literacy).

Interobserver Agreement & Treatment Integrity

Reliability data were collected by a second, trained Board Certified Behavior Analyst® (BCBA®) for 68% of imitation and emulation testing sessions. Interobserver agreement was calculated using a trial-by-trial method. An agreement was defined as both observers scoring the same response during a trial. IOA was calculated by dividing the total number of agreements by the total number of trials and multiplying by 100%. The percentage of sessions and results of IOA can be found in Table 7.

Treatment integrity data were collected for a minimum of 68% of sessions by a Board Certified Behavior Analyst® (BCBA®). The observer used Ross, Singer-Dudek, and Greer's (2005) Teacher Performance Rate and Accuracy Scale (TPRA) to conduct treatment fidelity checks throughout the study. Criterion for treatment integrity was set at 90% accuracy or higher. The percentage of sessions, number of TPRAs with and without error as well as the treatment integrity data can be found in Table 7.

Sequence of Experimental Procedures

The sequence of experimental procedures is displayed in Figure 1. First, all participants were randomly assigned to Group A (test for imitation followed by emulation sequence) or Group B (test for emulation followed by imitation sequence) and completed the test for either imitation or emulation. Second, all participants were assessed in the other testing condition opposite of their group assignment. Third, once participants completed both assessments, their results were compared to the results of the VBDA-R through visual and correlational analysis. Following the completion of all assessments, the lead experimenter analyzed each participant's data as compared to the results of their summary of verbal capabilities for prereaders (VBDA-R). During this correlational analysis, verbal behavior developmental cusps or capabilities were identified across participants to determine if any frequently corresponded to emulation in repertoire.

Procedures

Each participant was presented with five novel basic arrangements using a variety of building materials (see Appendices D and E). Reinforcement was not provided for incorrect or correct responses across tests. Tokens (based on the participant's typical token system) were delivered on a variable ratio schedule (i.e., VR 3) through the testing sessions for appropriate behaviors emitted by participants such as appropriate sitting or remaining in designated area across testing trials. All participants who scored 80% or higher on the basic set tests then completed an additional five trials that tested complex arrangement tasks.

Test for imitation. During imitation test trials, the experimenter modeled, step by step, how to correctly build or arrange the given objects to create a predetermined structure as indicated on a picture card (for the experimenter to view). Prior to demonstrating the model, the experimenter ensured that the participant was attending to the materials and her (i.e., emitting observing responses and or eye tracking of items). After ensuring the participant was attending, the experimenter constructed the given structure one piece at a time and stated, “Your turn, make the same,” and provided the necessary materials (along with nonexemplar pieces) to the participant.

Test for emulation. During emulation trials, the experimenter presented a prebuilt or prearranged structure (assembled outside the view of the participant) to the participant. After being shown the completed structure (no modeling on how to create the final structure was provided), the participant was told, “Make the same,” and provided with the necessary materials along with nonexemplar pieces.

Method – Experiment 2

The purpose of this experiment was to attempt to establish an emulative repertoire in children who did not demonstrate emulation in Experiment 1 using a trial-and-error intervention. This experiment differs from previous experiments because it examines the utility of such an intervention for children diagnosed with developmental delays or ASD. This study sought to answer the following research questions:

- Can emulation be induced through trial-and-error experiences?
- Can the source of reinforcement for emulation be isolated using trial-and-error experiences?

Participants

Participants in this experiment were recruited from Experiment 1. Following the identification of the list of participants who did not demonstrate emulation during testing trials in Experiment 1, the experimenter removed all participants who did not respond to both the imitation and emulation tests. The remaining participants who at minimum attempted to manipulate the materials in the tests conducted in Experiment 1 served as the participant pool for Experiment 2. Initial participants included six children between the ages of 4 and 13 years old (two females and four males). Participants varied in their time spent receiving ABA services ranging from 7 months to 39 months (3 years 3 months). Table 8 provides an overview of the participant's descriptions including the participant's age (reported in years), length of time receiving ABA services, gender, ethnicity, and prereader cusps/capabilities in repertoire (yes = in repertoire and no = not in repertoire). Written consent and assent procedures were the same as in Experiment 1.

Two of the six participants were removed from this study because of the emission of restrictive and repetitive behaviors. Cora was removed from the study following the second baseline and emulation testing session due to the high rates of self-injurious behaviors (self-biting) that were occurring around the time her experimental sessions were scheduled. For safety reasons she did not continue in the experiment. During trial-and-error sessions, Mike continued to engage in repetitive stereotypical behaviors (i.e., material tapping). After repeated attempts to implement the trial-and-error sessions resulting in the same emission of stereotypical behaviors he was discontinued from the study.

Setting

This experiment took place in the same session rooms as Experiment 1. Sessions were conducted once or twice a day for an average 30 min each session (duration ranged from an average of 15 min to 40 min). If sessions were run twice in one day, a minimum of three hours between sessions was required. During all testing sessions, the experimenter sat next to the participant at a child-sized table. A recording device was located slightly behind the experimenter and participant for some sessions, and at other times a second researcher was present in the room for IOA purposes.

Materials

Materials listed in Experiment 1 were used in Experiment 2 for emulation and baseline test trials. For each test trial, structure cards were used to depict the final product of a task on 8.5” x 11” white cardstock. All structures were printed in black and white with one structure printed on each page. See Appendix F to view the structure cards used in the baseline and emulation testing trials for Experiment 2. See Appendix B for the data sheet used to record responses to baseline and emulation test trials.

Trial-and-error task materials included a variety of novel wooden building materials gathered from various building kits. All kits were used in novel ways that did not resemble the intended structure, but rather allowed for various shapes and pieces that could be restructured to create novel structures. For example, a wooden boat kit was disassembled and used to make a tower-like structure. Examples of the materials used in each task in Experiment 2 can be found in Appendix G. For each trial, structure cards were used to depict the final product of a task and printed on 8.5”x11” white cardstock. All structures were printed in color as the building materials were all tan. The data sheet used in this experiment can be seen in Appendix C. Video recording equipment (i.e., computer and screen recording applications) was used to record sessions for reliability data collection when a second researcher was not able to be present. Tokens or point systems were used to reinforce appropriate behaviors (e.g., sitting and cleaning up) throughout the experiment.

Experimental Design

A multiple probe design across participants was used in this experiment (Murphy & Bryan, 1980). A multiple probe design was used based on the inability to remove or unlearn emulation once it is induced, as well as to control for possible extraneous variables through the demonstration of changes in behavior associated with the intervention implementation at different times for participants.

The sequence of experimental procedures is shown in Figure 2. Prior to implementing baseline data and or trial-and-error intervention sessions, each participant was habituated to the experimenter. Following habituation, initial data were collected for all six participants (baseline and emulation probes). After all baseline data were collected, the first participant began the trial-and-error intervention procedure with Set 1 tasks. Once the first participants demonstrated a stable change in responding in the intervention phase, probes were again conducted with the remaining participants, and the second participant began the intervention. This process continued until all participants were exposed to the intervention. Upon mastery of the Set 1 task, all participants were exposed to another set of tasks (referred to as Set 2) in the trial-and-error intervention sequence. Upon completion of both Set 1 and Set 2 trials, the participant was reassessed using Experiment 1's baseline measures, which served as a pre- and postmeasure for Experiment 2.

Dependent Variable and Response Measurement

The primary dependent variable was correct task completion and accuracy values. Correct task completion to emulation products was defined as the participant organizing materials to match the final product shown. For example, when provided with a completed magnetic square arrangement, the participant was required to demonstrate the ability to duplicate the same final arrangement to be considered a correct response by matching the model with 100% accuracy. An incorrect task completion was defined as not organizing all materials to match the final product shown. For example, if the participant skipped a step when provided with a novel arrangement of magnetic marbles, such as not placing three marbles at the base of the structure as displayed in the model, this would indicate an incorrect response to the emulation test because the final product did not make the model with 100% accuracy. An accuracy value was assigned to all completed products and ranged based on the steps required to complete the given emulation product. All accuracy values were converted to percentages for graphing purposes (e.g., the total number of pieces used correctly was divided into the total number of pieces needed to complete the structure; this number was then converted to a percentage by multiplying the number by 100). Topographically equivalent end products (i.e., structures or arrangements that look the same) were considered correct regardless of the order or behaviors emitted while arranging the individual stimuli. Correct and incorrect responses were measured using frequency counts, and the duration taken to complete each task was also measured. Mastery criterion for all emulation tasks was set at 100% (i.e., 4 out of 4 trials) during the first session.

Interobserver Agreement and Treatment Integrity

IOA and treatment integrity were collected using the same procedures as described in Experiment 1 across both baseline and emulation probes as well as trial-and-error intervention (see Table 13).

Procedure

All emulation task materials were provided to the participant at the start of a trial. Each trial lasted for a maximum of 2 min. Four tasks were presented for each set in the testing and intervention phase. Each task presented required the participant to emit multiple behaviors to complete the shown structure and each set was organized so level of difficulty of all tasks within sets was similar. Difficulty was based on the average number of component behaviors necessary to complete the task.

Habituation. Prior to collecting data on emulation tasks, the experimenter completed three 1-hr play sessions with each participant. Habituation was deemed an important first step in the implementation of trial-and-error learning (Rothstein, 2009). Rothstein (2009) demonstrated the effects of habituation when children who were habituated to the experimenter outperformed (in terms of emulating) the secondary warm-up group. During habituation sessions, the experimenter positively reinforced appropriate behaviors during various play sessions by providing social praise and other known preferred items such as edibles, bubbles, soft touches, toys, and so forth. Play sessions involved engaging in preferred tasks or activities based on preferences reported for each participant. The goal of the habituation sessions was to develop a rapport with each participant such that they would follow the experimenter’s directions (i.e., indicators they were under the experimenter’s instructional control). All habituation sessions took place in environments that were familiar to the participants such as playroom areas or the participants therapy room. This enabled the experimenter to habituate herself with each participant at a faster rate over a novel environment (e.g., experiment/testing room).

Baseline. Initial baseline measures were taken from the results of Experiment 1 in order to determine that participants did not have emulation in their repertoire. These probes served as pre- and postmeasures following the completion of the intervention phases. Additional testing sessions were conducted prior to and following the trial-and-error intervention phase. These emulation tests were implemented to control for the occurrence of emulation without the reliance on other cues from the stimuli such as color, shape, and so forth. During baseline trials, participants were shown a final product card that was voided of specific color pattern (see Appendix F) and given the discriminative stimulus, “Make this.” The participants were then given various building materials and allowed to build for 2 min. No consequences were provided for any emulation-task related response. Reinforcement in the form of praise was provided on a variable schedule for appropriate sitting, looking, and listening behaviors emitted by participants. The same termination criterion was used during this phase of the study as presented in Experiment 1. Baseline probes were conducted intermediately throughout the study.

Emulation probes. During emulation probes, participants were shown a line drawing of various common things or objects (see Appendix F) on a display card and given the discriminative stimulus, “Make this.” Materials were then provided to the participants. All materials varied significantly from the picture shown, and no describing words (e.g., “Make this chair”) related to the display shown were given to participants within the SD. These considerations were made to reduce match to sample possibilities. No consequences were provided for any emulation-task related response. Reinforcement in the form of praise was provided on a variable schedule for appropriate sitting, looking, and listening behaviors emitted by participants. The same termination criterion was used during this phase of the study as presented in Experiment 2. Emulation probes were conducted intermediately throughout the study.

Trial-and-error. During the trial-and-error intervention phase, two sets of four novel emulation tasks were presented to each participant. Each set of tasks varied in steps required (i.e., difficultly level) to complete each trial, but were similar overall across sets to account for various responding to differing levels of difficulty. The purpose of two sets was to provide participants with their own trial-and-error experiences that would enable them to learn to emulate. Trial-and-error sessions were conducted twice a day by presenting each participant with completed structures (via a model structure card) similar to the probe sessions, but simpler in overall behaviors needed to complete each tasks. These tasks were designed to be arranged more easily than test probes in order for the participants to have an easier time implementing and developing the problem-solving skills associated with emulation. With trial-and-error learning, the assumption was that through successful manipulation of tasks and materials, problem-solving behaviors would be reinforced and thus participants would be more likely to use these skills in the future. No direct teaching or reinforcement was provided by the experimenter during each trial associated with emulation responses. Participants were given 2 min to freely engage with the materials, and the only reinforcement received was social praise upon completion of the final product shown if the final product matched the picture shown (i.e., participants built a functionally equivalent final product). If participants did not build the structure shown after 2 min elapsed or indicated they were finished building during a trial by either vocally stating they were finished and or by placing their hand on the table indicating they were finished building, they were provided two additional opportunities for a total of three trial-and-error opportunities per task. Figures 3 and 4 display the overall sequence implemented during each trial-and-error session. An overall criteria of 15 unsuccessful attempts was established such that if a participant did not meet criteria for either set within 15 sessions, the trial-and-error intervention would be terminated, and a baseline and emulation test would be conducted.

Social Validity

Following the completion of Experiment 2, parents and the BCBA® programming for each participant were given a social validity questionnaire. Each question was scored on a Likert scale ranging from 1 (strongly does not agree with the statement) to 4 (strongly agrees with the statement). For example, parents and BCBA®s were given a statement such as, “I believe studying procedures to increase emulation can have a big impact on my client’s/student’s progress in his or her programming.” Parents and the BCBA® would then provide one of the following answers: strongly agree (score of 5), agree somewhat (score of 4), neutral (score of 3), disagree somewhat (score of 2), strongly disagree (score of 1).

Chapter 4: Results

Experiment 1

The purpose of Experiment 1 was to test whether participants demonstrated emulative and imitative responses during testing conditions. The participant's behaviors during testing trials were coded based on their behavior as either imitation, emulation, or not tested. Table 9 and Figure 5 display the results of the imitation and emulation tests conducted in Experiment 1. The Verbal Behavior Developmental Assessment-Revised (VBDA-R) was also conducted across all participants to assess which verbal behavior developmental cusps and capabilities were present in each client's repertoire (at the start of the experiment). Figure 6 displays the cumulative total of cusps/capabilities in repertoire across all participants. Analysis of variance (ANOVAs) were conducted to evaluate the mean differences between the emulative tasks and various cusps/capabilities.

Group A participants were initially presented with imitation tasks (basic then advanced) followed by emulation tasks (basic then advanced); see Table 9. Two participants (P3 and P7) demonstrated imitation responses to criteria (80% accuracy or higher) during basic imitation testing with scores of 80% and 100%, respectively. During advanced imitation testing, both P3 and P7 met criteria of 80% accuracy, demonstrating that basic and advanced imitation skills were in repertoire. Two additional participants (P15 and P23) demonstrated partial responding (less than criteria) to basic imitation tests with scores of 20% and 40%, respectively. Due to lower than 80% accuracy, both P15 and P23 did not continue to the advanced testing condition. The remaining eight participants (P1, P5, P9, P11, P13, P17, P21, and P25) scored 0 across basic imitation testing and did not continue to the advanced imitation testing. In emulation testing, all but two participants (P1, P5, P9, P11, P13, P 15, P17, P21, P23, and P25) scored 0 in basic emulation testing and thus did not continue to the advanced emulation testing. Participants 3 and 7 demonstrated emulation responses to criteria (80% accuracy or higher) during basic imitation testing with both scoring 80% accuracy. During advanced imitation testing, P7 met criteria of 80% accuracy, demonstrating that basic and advanced imitation skills were in repertoire, and P3 did not demonstrate advanced emulation with a score of 0 in advanced emulation testing.

Group B participants were initially presented with emulation tasks (basic then advanced) followed by imitation tasks (basic then advanced); see Table 9. Two participants (P20 and P26) demonstrated emulation responses to criteria (80% accuracy or higher) during basic emulation testing, both scoring 100% accuracy. During advanced emulation testing, both P20 and P26 demonstrated partial correct responding with scores of 60% and 40% accuracy, respectively. Four additional participants (P6, P10, P18, and P22) demonstrated partial responding (less than criteria) to basic emulation tests with scores of 20%, 20%, 40% and 40%, respectively. Due to lower than 80% accuracy, none of the four participants (P6, P10, P18, and P22) continued to the advanced emulation testing condition. The remaining seven participants (P2, P4, P8, P12, P14, P16, and P24) scored 0 across basic emulation testing and did not continue to the advanced testing conditions. In imitation testing, one participant (P26) demonstrated imitation responses to criteria (80% accuracy or higher) during basic imitation testing with a score of 100% accuracy. During advanced imitation testing, P26 demonstrated partial correct responding with a score of 40% accuracy. Seven participants (P4, P8, P10, P12, P18, P20, and P22) demonstrated partial correct responding with scores ranging from 20% accuracy to 60% accuracy across participants. Due to not meeting criteria in basic imitation testing conditions, none of the seven participants moved on to advanced imitation testing. The remaining five participants (P2, P6, P14, P16, and P24) scored 0 across basic imitation testing and thus did not continue to the advanced imitation testing conditions. See Figure 5 for the percentage of correct responses emitted during the test for basic and advanced imitation and emulation conditions for Group A and B.

Figure 6 displays the number of prereader cusps and capabilities in repertoire across all 25 participants as indicated from the scores gathered from each participant's VBDA-R assessment. According to the VBDA-R assessment, 15 participants demonstrated that instructional control was in repertoire and 10 indicated that instructional control was not in repertoire. Fifteen participants had conditioned reinforcement for faces/voices in repertoire and 10 indicated that it was not in repertoire. For conditioned reinforcement for 3D objects/visual stimuli, results indicated that 19 participants had this in repertoire while six did not have conditioned reinforcement for 3D objects/visual stimuli in repertoire. Eleven participants had capacity for sameness across senses in repertoire, with the remaining 14 not displaying capacity for sameness in repertoire. For matching two-dimensional and three-dimensional objects, 20 participants demonstrated that this was in repertoire while the remaining five did not demonstrate that this was in repertoire. Eleven participants had generalized imitation in repertoire and 14 indicated that it was not in repertoire. For listener literacy, six participants had this in repertoire while 19 did not have listener literacy in repertoire. Auditory matching was demonstrated as in repertoire for 11 participants and not in repertoire for 14 participants. Parroting was demonstrated as in repertoire for 18 participants and not in repertoire for the remaining seven participants. For echoic-to-mand, 18 participants demonstrated that this was in repertoire while the remaining seven did not demonstrate that this was in repertoire. Echoic-to-tact was demonstrated as in repertoire for 16 participants and not in repertoire for nine participants. Independent mands was demonstrated as in repertoire for 14 participants and not in repertoire for 11 participants. Results indicated that two participants had transformation of establishing operations in repertoire with the remaining 23 not displaying this in repertoire. The speaker component of naming as well as full naming was demonstrated as in repertoire for two participants and not in repertoire for 23 participants. The say-do in speaker-as-own-listener function was demonstrated by one participant as being in repertoire and not in repertoire for the remaining 24 participants. All participants (P1-P26) scored as not in repertoire for self-talk. Six participants demonstrated book stimuli conditioned reinforcement for observing (in repertoire) and 19 demonstrated book conditioned reinforcement for observing was not in repertoire. Tables 10-12 display the descriptive and ANOVA results comparing three of the most frequently missing prereader cusps/capabilities indicated in an analysis of the previous results. The three prereader cusps/capabilities included capacity for sameness across the senses, generalized imitation, and listener literacy. Each prereader cusp/capability was then compared to determine if any of the comparisons resulted in statistically significant results (p-value is less than 0.05). Results of the ANOVA comparing capacity for sameness to emulative skills in repertoire indicated a p-value of 0.55, indicating that there is not a statically significant relationship between emulation in repertoire and matching sameness in repertoire (see Table 10). Results of the ANOVA comparing generalized imitation and emulative skills in repertoire indicated a p-value of 0.84, indicating that there is no statically significant relationship between these two variables (see Table 11). Results of the ANOVA comparing listener literacy to emulative skills in repertoire indicated a p-value of 0.012, indicating a statically significant difference between the number of emulation tasks in repertoire and listener literacy in repertoire (see Table 12).

Experiment 2

The purpose of Experiment 2 was to test whether a trial-and-error intervention would establish an emulative repertoire in five children who did not emulate in the first experiment. The participant's behaviors during intervention sessions were recorded as either a correct or incorrect emulation response and total percentage of task completion accuracy. Figure 7 displays the results of the testing trails and trial-and-error intervention sessions for each participant. Figures 8-11 display the pre- and postscores from emulation testing conducted initially in Experiment 1 (pretest) and again after the completion of Set 2 in Experiment 2 (posttest).

Figure 7 displays the number of correct responses to tasks emulated during testing trials as well as in the trial-and-error intervention sessions across Sets 1 and 2 on the primary axis and the accuracy value across emulation tasks on the secondary axis. Keith's data included an overall increase across baseline and emulation testing trials, with an initial score of 1 (baseline testing) and 0 (emulation testing) to a final score of 2 (baseline testing) and 2 (emulation testing). During trial-and-error intervention sessions, there is an overall ascending trend in Set 1 with some variability prior to meeting criteria of 100% accuracy in eight sessions. In Set 2, there is a descending trend followed by a significant increase in correct responding and overall achieved criteria in nine sessions.

Carl's data included a slight descent in correct responding across initial baseline and emulation testing trials with initial scores of 2 and 1, respectively (baseline testing) and two scores of 0 (emulation testing) to a final score of 3 (baseline testing) and 0 (emulation testing). During trial-and-error intervention sessions, there was an overall ascending trend in Set 1 meeting criteria of 100% accuracy in four sessions. In Set 2, there was an overall ascending trend across tasks emulated and accuracy value with some variability in accuracy value responding. Carl met criteria for Set 2 in six sessions.

Megan's data included stable responding across all initial baseline and emulation testing trials with initial scores of 1 across all three probe sessions (baseline testing) and 0 (emulation testing). Final emulation and baseline probe scores included no changes in responding with a score of 1 (baseline testing) and 0 (emulation testing). During trial-and-error intervention sessions, there was an initial descending trend followed by a slight ascending trend culminating in data being variable after the sixth data path across Set 1. Megan did not meet the criteria for Set 1 within the criteria established for Experiment 2; therefore, Set 1 was discontinued after 15 sessions and probes were reintroduced.

Gary's data included stable responding across all initial baseline and emulation testing trials with an initial scores of 0 across all four probe sessions in both baseline and emulation tests. Final emulation and baseline probe scores included no change in responding with scores of 0 for both baseline and emulation testing. During trial-and-error intervention sessions, there were high rates of variability in both correct responding and across accuracy values for Set 1. Gary did not meet the criteria for Set 1; therefore, Set 1 was discontinued after 15 sessions and probes were reintroduced.

Upon completion of the trial-and-error intervention, each participant was reassessed using the initial emulation and imitation testing condition from Experiment 1. Figure 8 display the pre- and postscores from emulation testing conducted initially in Experiment 1 (pretest) and again after the completion of Set 2 in Experiment 2 (posttest) for Keith. Keith's correct responding to basic emulation tasks increased from a score of 0 during preintervention assessment to a score of 80% accuracy following the trial-and-error intervention. Keith increased from a no score (i.e., not testing due to low levels of responding across basic tasks) to a score of 60% in advance emulation testing. Keith also increased in basic imitation testing from a preintervention score of 60% accuracy to a postintervention score of 100% accuracy. An increase was also documented from a no score in advanced imitation (i.e., not testing due to low levels of responding across basic tasks) to a score of 80% in advance imitation testing.

Figure 9 displays the pre- and postscores from emulation testing conducted initially in Experiment 1 (pretest) and again after the completion of Set 2 in Experiment 2 (posttest) for Carl. Carl's correct responding to basic emulation tasks increased from 40% accuracy during preintervention assessment to a score of 100% accuracy following the trial-and-error intervention. Carl increased from a no score (i.e., not testing due to low levels of responding across basic tasks) to a score of 80% in advance emulation testing. Carl also increased in basic imitation testing from a preintervention score of 40% accuracy to a postintervention score of 60% accuracy.

Figure 10 displays the pre and post scores from emulation testing conducted initially in Experiment 1 (pretest) and again after the completion of Set 2 in Experiment 2 (posttest) for Megan. Megan's correct responding to basic emulation tasks increased from 20% accuracy during preintervention assessment to a score of 80% accuracy following the trial-and-error intervention. Megan increased from a no score (i.e., not testing due to low levels of responding across basic tasks) to a score of 40% in advance emulation testing. Megan demonstrated no change in basic imitation testing with a preintervention score of 40% accuracy and a postintervention score of 40% accuracy.

Figure 11 displays the pre and post scores from emulation testing conducted initially in Experiment 1 (pretest) and again after the completion of Set 2 in Experiment 2 (posttest) for Gary. Gary's correct responding to basic emulation tasks increased from 20% accuracy during preintervention assessment to a score of 40% accuracy following the trial-and-error intervention.

Gary demonstrated no changes in basic imitation testing conditions with a no score (a score of 0 on both occasions).

Social Validity

Following the completion of Experiment 2, parents and the BCBA® programming for each participant were given a social validity questionnaire. Each question was scored on a Likert scale ranging from 1 (strongly does not agree) to 5 (strongly agree). Questions were related to both the use of the trial-and-error intervention as well as the overall utility of having emulative repertoire. Keith's mother and his supervising BCBA® completed the questionnaire and data showed that both parties scored 5 (strongly agree) across all five questions in the questionnaire. Carl's mother and BCBA® returned the social validity questionnaire and both stated that they strongly agreed (scored all 5) across all questions presented. Megan's mother completed the questionnaire and data indicated scores of 5 (strongly agree) across all five questions in the questionnaire. Also noted by Megan's mother was a statement indicating, "She tried making Legos with the set of instructions the other day which I never saw her do." Megan's BCBA® scored 5 (strongly agreed) for all questions related to the significance of increases in emulation and the impact that can have on a learner and overall results of study. She scored 4 (agree somewhat) as it pertained to the importance to effective instruction and the use of the trial-and-error intervention to increase emulation skills. This was following the trial-and-error intervention and helps illustrate the socially significant changes that were noted after the conclusion of the intervention. Gary's parents did not return the social validity questionnaire, but the BCBA® programmer indicated a score of 5 across all questions.

Chapter 5: Discussion

Experiment 1

Experiment 1 tested whether children with autism or developmental disabilities had imitative and emulative skills in repertoire. The purpose of doing so was to determine if any prerequisite verbal behavioral cusps or capabilities would indicate a statistically significant relationship with an emulative repertoire. The study also sought to determine if correlations existed between imitation and emulation and if emulation would be distinguishable as a behavioral cusp. This research was established to answer the following research questions: Are imitation and emulation corequisites? Can emulation be distinguished from similar processes as a behavioral cusp?

The differences between Group A and Group B did not differ significantly, indicating that the order of testing conditions between imitation and emulation did not affect the overall results. A majority of the participants did not meet the criteria (i.e., 80%) in the test for basic imitation and emulation, and therefore the complex test was not conducted. Four of the 25 participants met the criteria demonstrating that emulation was in repertoire while only three of the four demonstrated that they had imitation in repertoire. These results differ slightly from previous research in which the behavior of children with developmental disabilities was under the control of seeing and doing (i.e., imitation) more than the emission of trial-and-error for emulation (Philp, 2016). This may mean that imitation is not necessarily a prerequisite for emulation and that imitation and emulation may instead be more closely aligned as corequisites.

Due to limited published data comparing imitation and emulation with individuals with developmental disabilities, additional direct comparisons are difficult. Consistent with results of Philp (2016) and Custance et al. (2014), the overall results displayed that imitation occurred at a higher rate when looking at overall completion of tasks accurately across both the imitation and emulation tests. The results of Experiment 1 indicated that some imitation skills or partial imitation (nine participants demonstrated some imitative skills) occurred at a higher rate than did partial emulation (four participants demonstrated some emulative skills) across both groups of participants. These results align with some aspects of previous research such as Custance et al. (2014), in which the authors determined that children with disabilities "benefitted more" from seeing a model demonstration compared to the use of a ghost condition only (p. 35).

Custance et al. (2014) identified several significant predictors related to emulative responding in children with developmental disabilities, including age along with verbal and nonverbal IQ. It is important to note that in their study, diagnoses did not play a significant role as indicated by their results. In this respect, results of the current study were consistent with those of Custance et al. (2014). Other factors that were deemed more statistically significant were verbal behavioral cusps or capabilities in repertoire for each participant can be closer linked to what was referred to as verbal and nonverbal IQ.

Results of Experiment 1 differed from those of Philp (2016) who found that participants with ASD were more likely to imitate (overemulate). The results of Experiment 1 differed in that some participants performed better on emulation tasks than on imitation tasks in Experiment 1 via either full correct responding or partial responding. Similar to that of Philp (2016) study were the results that indicated a majority of the participants tested were missing emulation as a developmental cusp. One area accounted for in the current study as compared to Philp (2016) was that all of the participants in Experiment 1 had a medical diagnosis of ASD prior to the start of the study. When analyzing why a majority of the participants did not emit emulative behaviors during the emulation test in both Philp (2016) and in the context of the current study, one may benefit from a deeper analysis of the ANOVA results.

Results of the current study indicated that three verbal behavioral developmental cusps/capabilities were significantly lower within repertoire across participants who did not demonstrate emulation: (a) capacity for sameness, (b) generalized imitation, and (c) listener literacy. When visually analyzing the cumulative number of participants with each particular cusp or capability in repertoire, initial reductions in overall totals were noted across the three selected cusps/capabilities. From these data, the experimenter identified the three cusps/capabilities that warranted further analysis.

Of the three cusps/capabilities identified, listener literacy was the only area to demonstrate statistical significance as related to correct emulative responding. This may be due in part to the fluency of the responding need to perform listener skills associated with having listener literacy in repertoire. Keohane, Delgado, and Greer (2009) noted the importance of building listener literacy for children who display language deficits. Skinner (1957) and Keohane et al. (2009) noted the importance of including listener skills that involve responding appropriately to the language emitted by others as a better indicator of the production responses associated with speaking skills. For example, the act of orienting toward environmental stimuli labeled by others or following spoken instructions are aspects of listener skills. The importance of building listener skills is highlighted in the results of the study whereas more of the higher order speaker developmental cusps were not indicated in repertoire; however, four of the participants still responded correctly to the emulation test.

The significance of having skills associated with listener literacy in repertoire is an area that warrants further study. Analyzing the importance of having listener literacy in repertoire helps explain why this area was statically significant over others as indicated in the ANOVA results. Once a learner has demonstrated listener literacy, significant gains have been demonstrated across higher levels of verbal behavior (e.g. self-talk), mastery of objectives that were not able to be mastered prior to the onset of listener literacy (Greer et al., 2005), and improvements in rate of learning (Greer & Ross, 2008).

Self-talk as a bidirectional verbal operant occurs within an individual and is related to the development of the say-do correspondence commonly associated with imitation and an imitative repertoire. When self-talk is present, learners can function as both the speaker and the listener (Greer & Ross, 2008). The development of listener literacy serves as a prerequisite to further development such as self-talk, in that listener literacy is a prerequisite to the joining of the listener and speaker. The joining of the listener and speaker within the individual as seen when a person engages in self-talk can be associated with basic and advanced problem-solving behaviors. The statistically significant relationship identified in the ANOVA results may play a part in not only the development of emulation but also in the development of what are considered problem-solving behaviors.

Limitations

A major limitation of this study was the overall number of participants. The overall sample size was small for the type of analysis conducted and should be considered when analyzing the current results. Having only four participants who demonstrated emulation in repertoire limits the overall validity of the findings. Future studies should strive to include a larger number of participants with both emulative and nonemulative repertoires to further support the research. Because the first experiment only tested for imitation and emulation in children with developmental disabilities, it is unclear if previous research-based interventions would induce emulation in this population or if additional measures such as the induction of the listener literacy cusp would result in the induction of emulation in children with developmental disabilities. Although data indicated a statistical significance among the two variables, this limitation indicates that further research is needed. Research may also be needed to determine if listener literacy is an influential cusp in regards to acquiring an emulative repertoire or if further studies are needed to analyze additional verbal behavioral developmental cusp and capabilities as they relate to emulation.

Experiment 2

Based on the limitations and the utility of the results of Experiment 1 in isolation, Experiment 2 was developed to test if previous research (Rothstein, 2009) on the use of trial-and-error experiences could be used to establish emulation in children who did not demonstrate such responding in Experiment 1. Some children with developmental disabilities may benefit from opportunities to respond to trial-and-error experiences. Data collected in Experiment 1 also support previous findings that emulation is a developmental cusp and that emulation and imitation are not corequisites (Philp, 2016; Rothstein, 2009). Additional testing is warranted to validate such theories and was therefore addressed in Experiment 2.

Experiment 2 tested the performance of children with developmental disabilities on emulative tasks before and after the implementation of a trial-and-error intervention as well as correct responding to emulative opportunities during trial-and-error opportunities. The purpose of this study was to see if an emulative repertoire could be established in children who did not demonstrate emulation in Experiment 1. This experiment differs from previous experiments because it examined the utility of the trial-and-error intervention across a different population (i.e., children diagnosed with developmental delays or ASD) and tested for a different type of emulation. Overall, results of Experiment 2 indicated that varying levels of accuracy during trial-and-error experiences can lead to the development of an emulative repertoire in children diagnosed with developmental disabilities.

Two of the four participants met criteria (100% accuracy) on both sets of trial-and-error tasks during the intervention condition as well as increased task completion accuracy for both baseline and emulation probes administered throughout Experiment 2. This indicates that increases in trial-and-error experiences lead to increases in emulative responding (across tasks completed and tasks accuracy) for some individuals with developmental disabilities.

The remaining two participants did not meet the established criteria on the first set of trial-and-error experiences, nor did they increase in responding from the preintervention test. However, in a return to test from Experiment 1 for imitation and emulation, both participants demonstrated an increase (more significant for Megan) in correct responding to emulation tasks. All participants thus demonstrated increases in emulative responding and two participants also demonstrated increases in imitative responding following the trial-and-error intervention. These data differ from previous comparison studies in that imitation responding was not deemed in repertoire after or prior to emulation. Previous studies indicated that in both typically developing as well as developmentally delayed children, imitation is developed prior to an emulative repertoire, but this was not demonstrated in the findings of the current study nor in the first study as seen in the results from Participant 20 who demonstrated high rates of correct responding across basic and advanced emulation tasks and only partially correct responding across basic imitation tasks.

The experimental procedures used also differed from previous studies in the following ways: (a) the type of emulation tested, (b) the tasks used to test for emulation, and (c) the population tested using trial-and-error experiences. As previously noted, several types of emulation have been reported within the literature. Most of the prior studies focused on testing for what was described as the first type environmental/ behavior relation involved in emulation (Call et al., 2005; Philp, 2016; Rothstein, 2009; Tomasello et al., 1993). This type of emulation was described as the emulator emitting behavior that functions to produce a similar product that is observed from a given model (model may represent an individual acting as a demonstrator producing a product or a completed product modeled by machines or other devices in absence of an individual present in the environment). In this case, the emulator does not have to produce behavior that has a point-to-point correspondence with the model's behavior. This type of emulation is commonly studied through the use of puzzle boxes. Rothstein (2009) noted that a limitation to her second study was that the second type of emulation was neither tested nor induced in her study. The results of the second study presented here indicate that the second type of emulation, in which the emulator observes a completed product in the environment and emits behavior that functions to produce a functionally equivalent product, can in fact be induced using trial-and-error experiences related to final product development. Because the type of emulation differed from previous studies, the tasks associated with the intervention warranted change. Unlike many studies which incorporated the use of some type of puzzle box (Carpenter et al., 2005; Huang et al., 2006; Philp, 2016; Rothstein, 2009; Want & Harris, 2001), the current study used various novel building materials and presentations of a final product to participants. The use of these materials allowed for similar trial-and-error experiences as with the puzzle boxes.

Another major difference between this experiment and other studies was that not only was emulation tested, it was also induced in children diagnosed with developmental disabilities. Most of the research regarding emulation has been conducted with typically developing children

(Gergely et al., 2002; Hopper et al., 2008; Horner & Whiten, 2005; Huang & Charman, 2005; Meltzoff, 1995; Nielsen, 2006; Rothstein, 2009; Simpson & Riggs, 2001; Tennie et al., 2006, 2010; Thompson & Russell, 2004). To the author's knowledge, only two studies (one published and one not published) have tested for emulation in children diagnosed with disabilities (Custance et al., 2014; Philp, 2016), and only one unpublished study (Rothstein, 2009) has actually tried to induce emulation in typically developing children. The lack of research studying emulation in children with developmental disabilities as well as the induction of emulation with the same population makes this study important to filling the gaps found in the literature.

Limitations

The present study provided a research-based means to examine the utility of trial-and-error experiences on the test for one type of emulation across a new and previously unresearched population; however, the study and test of only one type of emulation served as a limitation to this experiment. Experiment 2 included testing probes that were novel as well as testing probes from the first experiment, but both still focused on the same type of emulation. It would have been beneficial to include at least one opportunity to participate in the second type of emulation to determine if the same intervention would be useful to increase accurate responding to both types of emulative tasks. To add to the limited literature in this area, future research should be conducted that incorporates a test and induction of both types of emulation with children with developmental disabilities.

Another limitation involved the difficulty of the product structure cards in the second experiment versus the use of the actual objects arranged in a predetermined structure as used in the first experiment. The use of the final product cards in the second experiment may account for some of the variability in correct responding indicated in the results. For example, Set 1, Task 4 used various stick building materials to create a structure that had pieces in both a flat position (touching the table surface fully) and in a more three-dimensional or upward position. This detail was not immediately noted by many of the participants and prompted behaviors that are typically associated with frustration to be emitted from participants (e.g., statements such as “I did it,” grunting noises, and at times swiping of stick materials) when asked to build the structure again having not noted the three pieces in the upward position. It is unclear if the use of picture cards in the baseline probe condition in the second experiment lead to less correct responding by participants than did the tests for emulation in the first study when final products were shown to the participants. Future studies may want to consider this concern if and when testing for this type of emulation.

Last, a limitation first mentioned in Rothstein (2009) warrants further consideration as it pertains to the current study. Rothstein mentioned that emulation, as described from a behavior analytic perspective, does not allow for any verbal antecedents to take place prior to the emission of emulative behaviors. In both Experiment 1 and Experiment 2, the participants were told to “make this” as a verbal antecedent. When examining the proposed definition of emulation one can note that the need to produce a given product or final structure should in fact evoke a response from individuals. Although this may have presented as a limitation, other measures were taken to eliminate the possibility of imitation responses, such as the establishment of the final products outside of the participants’ view, the elimination of color or shape-controlling appropriate responses but use of final product cards, and the lack of identifier words such as the word “chair” in the S^D to reduce the possibilities of a participant emitting a match to sample response.

General Discussion

A review of the literature on emulation yielded some ambiguities related to the definitions presented, the best procedures to test for emulation, and if emulation can in fact be induced in children diagnosed with developmental disabilities or autism spectrum disorder. One of the main reasons as to why this may be the case is related to the fact that there is limited literature on the study of emulation in its own right. The experiments presented here were conducted to fill in the gap found in the literature in not only the study of emulation, but also to extend this work to a different group of participants consisting of children diagnosed with ASD. The results of this body of work not only provide a foundation for the development of a clear and more precise definition of emulation, but also offer the framework for studying a possible new account of untaught behavior, thus influencing the way in which children with developmental disabilities and language delays are taught.

Recommendations

Future studies could also continue to focus on factors associated with isolating the source of reinforcement as it relates to the correspondence of the finished product with the model. As reported in previous works, trial-and-error behavior should continue when that correspondence does not exist, and when the correspondence does exist, the behavior should cease. Factors that may affect such behavior, such as the role of the experimenter after habituation, should be considered and studied further.

Future research should look to optimize treatment factors through parametric analyses regarding the use of trial-and-error experiences to induce emulation. Such factors include the number of tasks presented, the number of sessions required, and the time provided for participants to engage in trial-and-error attempts. It is important to note that during the intervention, some participants (at times) exhibited undesirable behaviors or diminished in their attempts to manipulate the provided materials. This was attributed primarily to the learner's histories with learning tasks that typically involve high rates of reinforcement or at minimum social contact through the implementation of correction procedures, both of which provide feedback for the learner. Because the participants were not given behavior-specific feedback related to the task, many would vocally prompt for such feedback such as, "Is this it?" Future research may also want to evaluate the impact of instructional histories within their participants by analyzing factors such as how long each participant has received special instruction or other therapies.

Additional studies are needed to examine possible changes warranted in the standard protocols or instructional programming implemented with children with disabilities. For example, one should look to include interspersing object manipulation within procedures like listener emersion (Greer, Stolfi, Chavez-Brown, & Rivera-Valdez, 2005) and when testing or implementing the mirror protocol (Du & Greer, 2014) to test for generalized imitation. Based on the results of Experiment 1, further study is needed to examine if verbal behavior developmental cusps or capabilities can be used to induce emulation in children with developmental disabilities. Future studies should also examine whether emulation incidentally emerges in repertoire if a child has a given verbal behavior developmental cusp or capability in repertoire such as listener literacy, as indicated in the results of Experiment 1.

Interpretation of Findings

Emergent behavior has been defined as behaviors (or behavioral relations) that emerge incidentally from teaching procedures that are not directly taught (Catania, 2007). Research has provided several examples in the literature of emergent behavior such as naming, observational learning, and relational frame theory (RFT). The work presented here focuses on emulation as a higher-order skill that is reinforced through the production of a product in the learner's environment. Essentially, the learner emits behaviors to create a targeted product or structure in which the final production of the product serves as the reinforcement that leads to the learner more likely emitting similar behavior in the future. This source of reinforcement differentiates emulation from imitation where the reinforcement is from a see-do correspondence.

VBDT (Greer & Keohane, 2005; Greer & Speckman, 2009) is a developmental trajectory that provides a framework regarding the context of verbal behavioral developmental cusps and capabilities. Behavioral cusps have been described as what allows an individual to come in contact with new contingencies in the environment (Rosales-Ruiz & Baer, 2009). Some cusps are also capabilities which allow an individual to learn in new ways. A large body of research (basic and applied) has identified specific reinforcers that result in such cusps and capabilities, along with various interventions that can be implemented to induce these cusps and capabilities when they are missing (Greer & Du, 2015). Greer and Du (2015) also noted that "cusps appear to emerge as a result of the onset of new learned reinforcers" (p. 19). Based on the descriptions of a verbal behavior developmental cusp as well as the previous studies conducted by Rothstein (2009) and Philp (2016), the current experiments provide additional evidence that supports the notion that emulation is a developmental cusp. One could also contend that trial-and-error experiences result in the acquisition of a newly learned reinforcer in the reinforcement of the production of a final product. This is important to better understand how emulation can play a part in a leaner's success in the classroom and in the future (e.g., job training, life skill acquisition, etc.).

Implications

With the rise in the number of children diagnosed with ASD or related disabilities comes a need to identify effective instructional methods that not only teach these individuals but close the gap between their typically developing peers' learning and skill acquisition. Emulation as demonstrated in the work presented here offers a means to develop more learner independence through the lack of a model or demonstrator having to be present in one's environment, problem solving, and the expansion of skills without direct teaching. Thus, the acquisition of emulation plays a vital role in how children with disabilities are taught and how that can impact their future.

An unexpected result of Experiment 1 emphasizes the need to examine the methods in which children with disabilities or ASD are taught. Specifically, Participant 7's results in the first study were that he emitted behaviors indicating that he had both imitation and emulation in repertoire during the initial testing conditions. Anecdotal notes taken during this portion of the study indicated that this participant emitted high rates of vocal stereotypy such as the emission of palilalia as well as other behaviors such as limited eye contact or orienting towards the experimenter. The behaviors described here are typically associated with a learner who not only has lower levels of verbal behavior in repertoire, but also a learner who will require the need for intensive adult lead interventions in order to be successful. Although this statement may seem to overgeneralize what may occur for some learners, it is safe to state that it is common practice that such individuals in a traditional educational setting would be provided with high rates of prompting and teacher-directed instruction. What the data from the first study demonstrate is the importance to analyze how learners such as Participant 7 are taught. For example, these results indicate that learning via imitation is not necessarily the most efficient teaching method for this child and the individuals programming or teaching him should evaluate his current curriculum or programming to increase opportunities to emulate. By evaluating and changing such programs for learners who have emulation in repertoire, practitioners and teachers are increasing his independence, decreasing the likelihood of prompt dependency, and setting the stage for continued learning without having to be directly taught.

Emulation has been described in other disciplines as “a challenging middle ground between imitation and invention” (Mayernik, 2016, About the Book section, para. 1). Others have similarly described emulation as being closely linked to problem solving and innovative behaviors (Philp, 2016; Rothstein, 2009). According to the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev.; *DSM-IV-TR*; American Psychiatric Association, 2000), a core deficit commonly associated with an ASD diagnosis is the emission of restrictive behavior commonly manifested in the emission of highly fixated behaviors. Results from the second study indicate that with the implementation of a trial-and-error intervention, participants were not only able to acquire emulation but increases in novel or innovative behaviors associated with problem solving were observed. An example of Keith’s responses to the emulation probe conditions prior to, after implementation of one set of trial-and-error experiences, and at the conclusion of the second set of trial-and-error experiences can been seen in Figure 12. It is clearly seen in the sample provided that as the participant was exposed to more opportunities to engage with trial-and-error experiences, the more innovative his final products became. This is an important finding that supports the idea that emulation is a critical feature seen in how children engage in contingency-shaped problem solving. There is a need to expose all types of learners (not only those who are typically developing) to opportunities that allow for such problem solving to occur as these contingency-shaped behaviors are linked to many of the activities that individuals face not only in their childhood, but also into adulthood (e.g., many activities of daily living such as folding clothes, making a bed, and driving, as well as many job tasks such as filing papers, stocking shelves, writing reports, etc.).

Conclusion

In sum, the data from the present studies suggest that children with ASD diagnosis or related disabilities can emulate. The use of trial-and-error experiences was effective in establishing a shift to conditioned reinforcement for the correspondence between the observed product and the final product in those individuals who did not previously demonstrate reinforcement for such production. The social significance of the results of these studies are noteworthy because these increases are not only in innovative or creative behaviors across participants, but also in general problem solving. These findings present information that can contribute not only to future research, but also towards the development of best teaching practices for individuals with ASD. By continuing to study emulation in this capacity, children with disabilities will be better suited to learn how to do things without the support of others, leading to more independence and self-sufficient responding that is similar to what is transitionally afforded to their typically developing peers.

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Table 1

A Summary of the Research Related to Conceptual Explanations of Phenomena Closely Linked to Emulation

Authors & Date of Study	Field of Study	Term(s) Used	Definition Provided
Tomasello, 1987	Animal Cognition	emulation	The reproduction of the results produced by a model through the use of methods other than that of the demonstrator.
Wood, 1989	Developmental Psychology	end state emulation	A response method that differed from imitation in that individuals use novel methods to reach the same end-state as a demonstrated action.
Tomasello 1990	Animal Cognition	emulation	"re- produce the completed goal . . . by whatever means it may devise (p. 284)."
Whiten & Ham, 1992	Animal Cognition	goal emulation	A type of social learning that involves copying as a result of a goal-directed sequence.
Nagell, Ogluin, & Tomasello, 1993	Comparative Psychology; cross-species	emulation	Learning from the observation of various functional relations related to a given task.
Meltzoff, 1995	Developmental Psychology	1)behavioral re-enactment	1) The natural tendency of young children to pick up behavior from adults, to re-enact or imitate what they see (Meltzoff, 1988a, 1988b, 1990b, 1995; Piaget, 1962).
		2)intentional actions	2) Intentional acts progress through a) simple body acts, to (b) actions on objects, to (c) using one object as tool to act on a second object.
Tomasello, 1996	Animal Cognition	1) emulation	1) When an individual observes and learns affordances of the behavior demonstrated by another person or animal and then uses that affordance to devise its own behavioral strategy.
Byrne & Russon, 1998	Animal Cognition	1) goal emulation 2) priming	1) The purpose or the goal towards which the demonstrator is striving is made overt as a result of its actions, and so becomes a goal for the observer, too. The observer attempts to "re- produce the completed goal.

			2) Cognitive term used to describe the process of "priming" brain records of stimuli used in emulation (Byrne 1994; 1995a).
		3)emulation learning	3) Learning through observation about the properties of objects and possible relationships between objects (Call & Tomasello, 1994).
Custance, et al., 1999	Comparative Psychology	1. goal enhancement	1. an observer has its attention drawn to a goal or reward, but rather than copying the model's behavioral strategy, the observer works out for itself which actions to use (Bryne, 1994; Tomasello, 1990; Whiten & Ham, 199, Wood 1989)
		2.affordance learning	2. an observer learns about the affordances of an object from a model.
		3. object movement reenactment	3. OMR- an observer learns how an object, or the various parts of an object, move (e.g. Heyes, 1998)
		4. final state-recreation	4. an observer sees the final state or result of a model's manipulations and tries to re-create that result in a similar set of objects
Gergely, Bekkering, & Kiraly, 2002	Developmental Psychology	1) emulation	1) The achievement of a goal reliant on motor actions already in one's repertoire.
		2) behavioral reenactment	2) A form of imitative learning of goal-directed actions to imitate new strategies.
Want & Harris, 2002	Developmental Psychology	1. "blind" imitation	1) Whether children's social learning involves copying the actions themselves ('blind' imitation or mimicry)
		2. mimicry	2) the specific actions of the model
		3. emulation	3) the effects of those actions
Bard, 2002	Developmental Psychology	emulation	Process of observing a model and learning the causal relation between the object and the goal of the demonstrator. Considered a possible foundational aspect related to higher-level knowledge.
Byrne, 2002	Animal Cognition	emulation	Described in three ways (as cited in Byrne, 1998): 1) learning physical properties of objects, 2) learning the relationships between objects, and 3) understanding cause-and-effect relationships and changes of state of objects

Huang at al., 2002	Developmental Psychology	emulation learning	Learning that occurs when an individual learns something about the changes of state in the environment through observation as a result of the behavior of the model but not about the model's behavior or behavioral strategy (Wood, 1989).
Thompson & Russell, 2004	Developmental psychology	emulation/ affordance learning	When an individual matches the achievement of the demonstrator (same species) by focusing not on the demonstrator's behavioral strategies but on the environmental outcomes caused by its actions. This is achieved through the perception of dynamic affordances (Gibson, 1979) of the objects being manipulated.
Call at al., 2005	Animal Cognition	1) emulation 2) goal emulation	1) A social learning situation that involves the reproduction of environmental results based on demonstrations. 2) Learning about an object related to the goal of the demonstrator whereas the learner is capable of copying the actions and the goal.
Tennie, Call, & Tomasello, 2006	Cross Species	1)Emulation 2) OMR	1) Results learning 2) A form of OMR (not defined).
Horner, & Whiten, 2005	Animal Cognition/ Cross Species	Emulation	Referred to as the process of an observer learning about the results of actions from watching a model (Tomasello, 1987).
Huang, Heyes, & Charman, 2002	Developmental Psychology	1) local or stimulus enhancement 2) emulation learning 3) mimicking	1) Drawing attention to a particular environmental locations or relevant part of objects. 2) Learning about stimulus consequences of an observed demonstration (referred to as the affordances of objects) 3) Reproducing the body movements of the model's object manipulations without explicitly encoding the goals of the model.
Nielsen, 2006	Developmental psychology	emulation	Refers to instances in which children attempt to produce the same result as a model using their own

			behavioral strategies. Children are said to "understand the goal of the model's actions" (p. 555).
Zentall, 2006	Animal Cognition	(1) opaque imitation	(1) type of imitation that involved behavior that is demonstrated by the animal or person in which he/she cannot see the behavior when it is performed
		(2) goal emulation	(2) the nonmatching form of imitation in which an observer may "understand" that a particular observed behavior has certain consequences, but it may also recognize that the goal could be achieved by any one of the larger class of behaviors (Ham, 1992).
Hamilton, 2008	Developmental Psychology	Emulation	The process of goal-directed imitation (Bekkering, Wohlschlager, & Gattis, 2000).
Hopper et al., 2008	Animal Cognition	Emulation	A form of observational learning that focuses on the model's environmental results.
Whiten, et al., 2009	Cross Species	1) affordance learning 2) OMR 3) end-state emulation	1) Learning about operating characteristics of objects or environments (i.e., of properties, of relationships, of functions). 2) Copying the form of a caused object movement (imitative or emulative) 3) Copying only the end or outcome of an action sequence (also referred to as results or goal emulation).
Jones, 2009	Developmental Psychology	emulation	Refers to behavioral matching as a result of social learning whereas the individual does not emit behaviors of specific actions, but of the features and affordances of objects.
Rothstein, 2009	Behavior Analytic	emulation	A non-verbal problem solving behavior or verbal behavior that can be emitted in two forms:1) creating something new by observing a product and reproducing it (can include vocal reproductions); 2) obtaining a product through manipulating stimuli in the environment in a novel way.

Miller, Rayburn-Reeves, & Zentall, 2009	Behavior analytic/109nima behavior	Emulation	Learning how the environment works
Hopper, 2010	Cross Species	1) goal-emulation 2) affordance learning 3) OMR	1) A form of emulative learning that is described as the attainment of the same goal observed through a novel method. 2) Learning about the physical properties of the environment and relations among objects (Byrne, 1998). 3) When a learner copies the object's movement.
Tennie, Call, & Tomasello, 2010	Cross Species	1) emulation 2) OMR	1) A type of social learning that occurs when an observer ''picks up'' on changes in the environment that result from the model's actions (p. 1). 2) A possible perceived result of emulation.
Hopper et al., 2010	Developmental Psychology	emulation	The replication of the environmental changes that occur as a result of actions whereas on demonstrates learning from only the actions.
Linsay et al., 2012	Developmental Psychology	Emulation	When the goal or function of a behavior is the focus rather than the topography. Equates to imitation of an 'operant', rather than topography.
Custance et al., 2014	Developmental Psychology	1) goal emulation 2) OMR	1) When an observer achieves the same goal as demonstrated using different behavioral means (Call & Carpenter, 2002). 2) A form of emulation whereas learning occurs via observation about the ways in which objects move.
Carr, Kendal, & Flynn, 2016	Developmental Psychology	1) emulation 2) affordance learning	1) Involves learning about object properties, affordances, and causal relations (Want & Harris, 2002). 2) A form of emulation where an individual learns about the affordances of the action(s) and the

		3) goal emulation	properties of an object (beyond simple object movement re-enactment). 3) The observer reproduces the model's goal but uses their own method; a weak form of innovation.
Philp, 2016	Behavior Analytic	Emulation	The duplication of the outcome or products of the behavior (does not involve imitating or emitting the exact movements presented by the model) to produce the results of the model's movements (Tomasello, 1999).
Renner, Abramo, Hambright, & Phillips, 2017	Animal Cognition	Emulation	When a learner copies the end result but utilizes unique and undemonstrated actions.
Subiaul, Patterson, & Barr, 2017	Developmental Psychology	Emulation	Mirroring others' goals and intentions (emulation).

Table 2

A Summary of the Procedures Reported in the Literature and Used to Study Emulation

Procedure	Description
Two-Action Procedure	An approach to test for imitation is the two-action procedure whereas participants are exposed to a model/demonstrator that responds by moving a manipulandum in one of two different directions controlling for socially mediated effects, stimulus enhancement, and appropriate control related to testing for emulation.
Bidirectional Methods	A variation of the two-action procedure, the bidirectional control method whereas an observer and demonstrator are placed in separate chambers, facing each other, with a clear wall between them. Observer are then exposed to a demonstrator that manipulates an object in one way followed by tests to see if the observers copy the demonstrated behaviors or employ other behaviors to achieve the given outcome. This method allows one to compare symmetrical behaviors.
Irrelevant and Unintentional Actions	The use of failed attempts to complete a given task in order to test if participants can re-enact the intended actions of others.
Ghost Conditions	Rather than use a model to demonstrate object movement, ghost conditions imply some type of hidden mechanism to make an object move in a desired ways; this methods suggest that there is no social context within emulation.
End-State Conditions	A mean to assess goal-emulation by observing if the participant can solve a given task to establish a functionally equivalent product without being shown the movements or actions required to complete the targeted task.

Table 3

A Summary of the Dependent and Independent Variables Associated with the Study of Emulation

Authors & Date of Study	Subjects/ Participants	Dependent Variable(s)	Procedure Used
Heyes & Dawson, 1990	rats	Response acquisition, reversal of a left-right discrimination, and responding in extinction	Bidirectional control procedure
Meltzoff, 1995	18-month-old children	Ex 1- occurrence of targeted behavior, latency to produce targeted acts; Ex 2- number of children who produced the target act of pulling apart the dumb bell	irrelevant and unintentional actions
Custance et al., 1999	capuchin monkeys (Cebus apella)	7 point scale- rating the confidence of the movements emitted by the monkeys regarding task	two-action technique
Gergely et al., 2002	14-month-old children	percentage of re-enacted head action	irrelevant and unintentional actions
Huang et al., 2002	17- month-old and 19-month-old infants	1. yes/no response to if the target act was performed within a given period; 2. The latency of the produced target acts	irrelevant and unintentional actions
Klein & Zentall, 2003	Pigeons (Columba livia)	Matched movements (push or pull)	Bidirectional control procedure
Thompson & Russell, 2004	14- to 26-month-old children	performance of target actions/no target action; statistical analysis; mean latencies to target action and standard deviations by condition and task; numbers of successful children who also performed nontarget actions	Ghost conditions
Huang & Charman, 2005	17-month-old children	responses to five objects were coded; primary score was if the	irrelevant and unintentional actions

		target action was produced as the child's first act	
Call et al., 2005	Chimpanzees (Pan troglodytes) & human children (Homo sapiens)	percentage of participants who could open the tube, the average latency taken to open the tube, the percentage of participants who matched the results of the tube, and the percentage of participants who copied the actions of the demonstrator	irrelevant and unintentional actions
Tennie et al., 2006	Chimpanzee, non-human great apes, & human children	number of successful chimps and matched movements (push or pull)	Ghost conditions
Horner & Whiten, 2005	Chimpanzees & human children	EX 1-data analysis: coding of targeted behaviors- recorded each occurrence of the four behaviors; EX 2- correct tool selection	irrelevant and relevant actions
Huang, Heyes, & Charman, 2006	31- and 41-month-old children	children's first action	irrelevant and unintentional actions; end state conditions
Nielsen, 2006	12-24 month old children	successful opening of a box using a targeted action	irrelevant and unintentional actions
Hopper et al., 2008	Chimpanzees & 3-4-year old children	Response rates in experimental and control conditions, first responses, total responses compared to chance responses, patter of responses, & comparisons between conditions	Ghost conditions
Rothstein, 2009	24-36 month old children	Ex1- correct response to emulation probes with boxes, correct responses as construction of PVC Pipe structure; Ex 2- same as first	"Trial and Error" as incidental learning was defined as presenting each participant with apparatuses similar to the test boxes, but simpler and with the same goal

Miller et al., 2009	Dogs (Canis familiaris)	percentage of dogs that matched the targeted screen-push responses (based on their first trial)	Bidirectional control procedure
Tennie et al., 2010	chimpanzees (Pan troglodytes)	trial and error attempts; number of successful chimpanzee subjects (i.e. opened the box and go the food); ad 2- whether the opening technique (pull or push) matched what they had witnessed.	Ghost conditions
Hopper et al., 2010	3- and 4-year-old children	percentage of participates who could operate and retrieve the reward from the pan-pipe apparatus	Ghost conditions
Tennie, Greve, Gretscher, & Call, 2010	Great apes/chimpanzees & 2 yr. old children	success, first attempts, and matching score	Two-action tasks
Hanus et al., 2011	Chimpanzees (Pan troglodytes)	frequency of chimpanzee's' spitting behavior and whether or not subjects were successful in retrieving the peanut	End state conditions
Simpson & Riggs, 2011	3- and 4-year-old children	Frequency of irrelevant and relevant actions; frequency of imitation or emulation coded responses	Two testing conditions: immediate and delayed across irrelevant and relevant actions
Custance et al., 2014	children with and without an Autism diagnosis	statistical analysis: mean and SDs (mixed two-way analyses of variance with two-tailed pairwise post hoc comparisons. Because there were clear directional a priori predictions for post hoc comparisons, Bonferroni corrections were not applied.)	Ghost conditions
Philp, 2016	3-& 4-year-old children with and without developmental delays	unconsequated responses during the test interval; number of 5s intervals participants interacted with a puzzle box in the free play setting	Two testing conditions: immediate and delayed

Renner et al., 2017	capuchin monkeys	frequency of manipulative actions	End state conditions

Table 4

Participant Descriptions Onset of Experiment 1 (Group A)

Participant	Age	Gender	Classified Diagnosis	Number of pre-reader cusps/capabilities in repertoire	Length of Time Spent in ABA Services (weekly average in hours)	Location of Services
P1	10	male	Medical/ ASD	10	35 hrs.	Site 1
P3	6	male	Medical/ ASD; GDD	13	30 hrs.	Site 2
P5	6	male	Medical/ ASD; GDD	2	30 hrs.	Site 1
P7	11	male	Medical/ ASD; SD	13	25 hrs.	Site 1
P9	3	male	Medical/ ASD; LD	3	30 hrs.	Site 2
P11	6	female	Medical/ ASD; LI	2	30 hrs.	Site 2
P13	4	male	Medical/ ASD; LD	16	30 hrs.	Site 3
P15	5	male	Medical/ ASD	10	30 hrs.	Site 5
P17	7	male	Medical/ ASD	1	35 hrs.	Site 1
P21	12	male	Medical/ ASD; LI	7	20 hrs.	Site 2
P23	3	male	Medical/ ASD; LD	9	30 hrs.	Site 3
P25	9	male	Medical/ ASD; GDD	9	30 hrs.	Site 1

ASD- Autism Spectrum Disorder; GDD- Global Developmental Delay; SD- Speech Delay; LI/LD- Language Impairment/Disorder; ADHD- Attention Deficit Hyperactivity Disorder; SLD- Specific Learning Disorder with Impairments in Reading and Math; A- Anxiety

Table 5

Participant Descriptions Onset of Experiment 1 (Group B)

Participant	Age	Gender	Classified Diagnosis	Number of pre-reader cusps/capabilities in repertoire	Length of Time Spent in ABA Services (weekly average in hours)	Location of Services
P2	13	female	Medical/ ASD; ID; ADHD	6	30 hrs.	Site 2
P4	5	male	Medical/ ASD	9	30 hrs.	Site 1
P6	4	male	Medical/ ASD; LI	9	30 hrs.	Site 1
P8	6	male	Medical/ ASD; GDD	9	30 hrs.	Site 1
P10	8	female	Medical/ ASD; ID	3	30 hrs.	Site 2
P12	7	female	Medical/ ASD; GDD; ADHD	12	30 hrs.	Site 1
P14	5	male	Medical/ ASD; GDD	10	30 hrs.	Site 3
P16	8	male	Medical/ ASD	1	30 hrs.	Site 5
P18	12	female	Medical/ ASD	13	30 hrs.	Site 4
P20	9	male	Medical/ ASD; A	15	30 hrs.	Site 5
P22	11	male	Medical/ ASD; ID/LI	10	20 hrs.	Site 2
P24	8	male	Medical/ ASD; GDD	6	35 hrs.	Site 1
P26	10	male	Medical/ ASD; ADHD: SLD	16	10 hrs.	Site 1

ASD- Autism Spectrum Disorder; GDD- Global Developmental Delay; SD- Speech Delay; LI/LD- Language Impairment/Disorder; ADHD- Attention Deficit Hyperactivity Disorder; SLD- Specific Learning Disorder with Impairments in Reading and Math; A- Anxiety

Table 6

Materials Used in Experiment 1 and 2

Material	Description
Tri-Mag Blocks	48 triangular shaped magnetic blocks, varying in primary colors and connected by magnets via twisting and turning the triangles to create different shapes
Kanoodle	12 connected marble pieces varying in color and arrangement; connected by placing pieces either next to one another in a 2-D format or by stacking via a 3-D format
Magnetic Building Block Cubes	Seven irregularly shaped pieces varying in color; connected via magnets via turning and rotation of shapes
CONDIK Magnetic Blocks	30 magnetic tiles (14 triangular and 16 square shaped) varying in color (each side of the shape being a different color); connected via magnets placing pieces either next to one another in a 2-D format or by stacking via a 3-D format
EMIDO Building Bars	480 pieces varying in shape (straight lines, circles, triangles, and squares), size (large and small versions of all shapes), and color; connected by snapping together; can combine to create arbitrary shapes or structures.

Table 7

The Percentage of Sessions and Range of Interobserver Agreement and Treatment Integrity for Groups A and B

	Group A Imitation Test	Group A Emulation Test	Group B Imitation Test	Group B Emulation Test
Percent of Sessions	67%	67%	69%	69%
Agreement (IOA)	100%	100%	100%	100%
Number of TPRAs with error	0	0	0	0
Number of TPRAs without error	10	10	9	9
Percentage Accuracy	100%	100%	100%	100%

Table 8

Participant Descriptions and Summary of Pre-Reader Cusps/Capabilities

	Keith	Carl	Megan	Gary	Mike	Cora
Age/Gender	5/male	11/male	8/female	4/male	6/male	13/female
ABA Services (in months)	20 months	31 months	39 months	7 months	32 months	27 months
Ethnicity	Caucasian	Caucasian	Caucasian	Caucasian	African American	Caucasian
Pre-Reader Cusps/Capability in Repertoire						
IC[1]	yes	yes	yes	yes	yes	yes
CRV/CRF[2]	yes	yes	yes	no	yes	no
CR 3D[3]	yes	yes	yes	yes	yes	yes
CFS[4]	no	no	no	yes	yes	yes
Matching[5]	yes	yes	yes	yes	yes	yes
GI[6]	no	yes	no	no	no	no
LL[7]	no	no	no	no	no	no
AM[8]	yes	yes	no	yes	yes	yes
P[9]	yes	yes	no	yes	yes	yes
EtM[10]	yes	yes	no	yes	yes	no
EtT[11]	yes	yes	no	yes	yes	no
IM[12]	yes	yes	no	yes	yes	no
TEO[13]	no	no	no	no	no	no
SN[14]	no	no	no	no	no	no
FN[15]	no	no	no	no	no	no
SDC[16]	no	no	no	no	no	no
ST[17]	no	no	no	no	no	no
CRB[18]	no	no	no	no	no	no

[1]Instructional Control; [2]Conditioned Reinforcement for Faces/Voices; [3]Conditioned Reinforcement for 3D Objects/Visual Stimuli; [4]Capacity for Sameness Across Senses; [5]Match 2D and 3D Objects; [6]Generalized Imitation; [7]Listener Literacy; [8]Auditory Matching; [9]Parroting; [10]Echoic-to-Mand; [11]Echoic-to-Tact; [12]Independent Mands; [13]Transformation of Establishing Operations; [14]Speaker Component of Naming; [15]Full Naming; [16]Say-Do in Speaker-as-Own-Listener Function; [17]Self-Talk; [18]Book Stimuli Conditioned Reinforcement for Observing

Table 9

Each Participant's Results for Imitation and Emulation Testing Conditions in Experiment 1.

Group A (Experimental Sequence: Imitation then Emulation)												
	P1	P3	P5	P7	P9	P11	P13	P15	P17	P21	P23	P25
Imitation Testing												
-Basic	0	1	0	1	0	0	0	0	0	0	0	0
-Advanced	NT	1	NT	1	NT	NT	NT	NT	NT	NT	NT	NT
Emulation Testing												
-Basic	0	1	0	1	0	0	0	0	0	0	0	0
-Advanced	NT	0	NT	1	NT	NT	NT	NT	NT	NT	NT	NT
Overall Results	I/E	I/E	I/E	I/E	I/E	I/E	I/E	I/E	I/E	I/E	I/E	I/E
Indicated Score	NiR	IR	NiR	IR	NiR	NiR	NiR	NiR	NiR	NiR	NiR	IR

0=imitation (I)/emulation I skills not demonstrated; 1= imitation/emulation skills demonstrated; NT- not tested due to not meeting criteria (i.e., 80% accuracy) in basic testing conditions; NiR- not in repertoire; IR- in repertoire.

Group B (Experimental Sequence: Emulation then Imitation)													
	P2	P4	P6	P8	P10	P12	P14	P16	P18	P20	P22	P24	P26
Emulation Testing													
-Basic	0	0	0	0	0	0	0	0	0	1	0	0	1
-Advanced	NT	NT	NT	NT	NT	NT	NT	NT	NT	0	NT	NT	0
Imitation Testing													
-Basic	0	0	0	0	0	0	0	0	0	0	0	0	1
-Advanced	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	0
Overall Results	I/E	I/E	I/E	I/E	I/E	I/E	I/E	I/E	I/E	E-IR	I/E	I/E	I/E
Indicated Score	NiR	NiR	NiR	NiR	NiR	NiR	NiR	NiR	NiR	I NiR	NiR	NiR	IR

0=imitation (I)/emulation I skills not demonstrated; 1= imitation/emulation skills demonstrated; NT- not tested due to not meeting criteria (i.e., 80% accuracy) in basic testing conditions; NiR- not in repertoire; IR- in repertoire.

Table 10

ANOVA Results Comparing the Capacity for Sameness Cusp to Emulative Skills in Repertoire

ANOVA

correct emultation tasks

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9.631	1	9.631	4.130	.055
Within Groups	48.977	21	2.332		
Total	58.609	22			

Table 11

ANOVA Results Comparing the Generalized Imitation Cusp to Emulative Skills in Repertoire

ANOVA

correct emultation tasks

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.932	1	7.932	3.287	.084
Within Groups	50.677	21	2.413		
Total	58.609	22			

Table 12

ANOVA Results Comparing the Listener Literacy Cusp to Emulative Skills in Repertoire

ANOVA

correct emultation tasks

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	15.675	1	15.675	7.667	.012
Within Groups	42.933	21	2.044		
Total	58.609	22			

Table 13

The Range of Interobserver Agreement Across Responding to Emulation Tasks

	Percentage of Sessions	Baseline Probes	Emulation Probes	Trial-and-Error Intervention
Keith	88%	100%	100%	100%
Carl	60%	100%	100%	100%
Megan	60%	100%	100%	100%
Gary	67%	100%	100%	100%

Figure 1. *Sequence of experimental design for Experiment 1.*

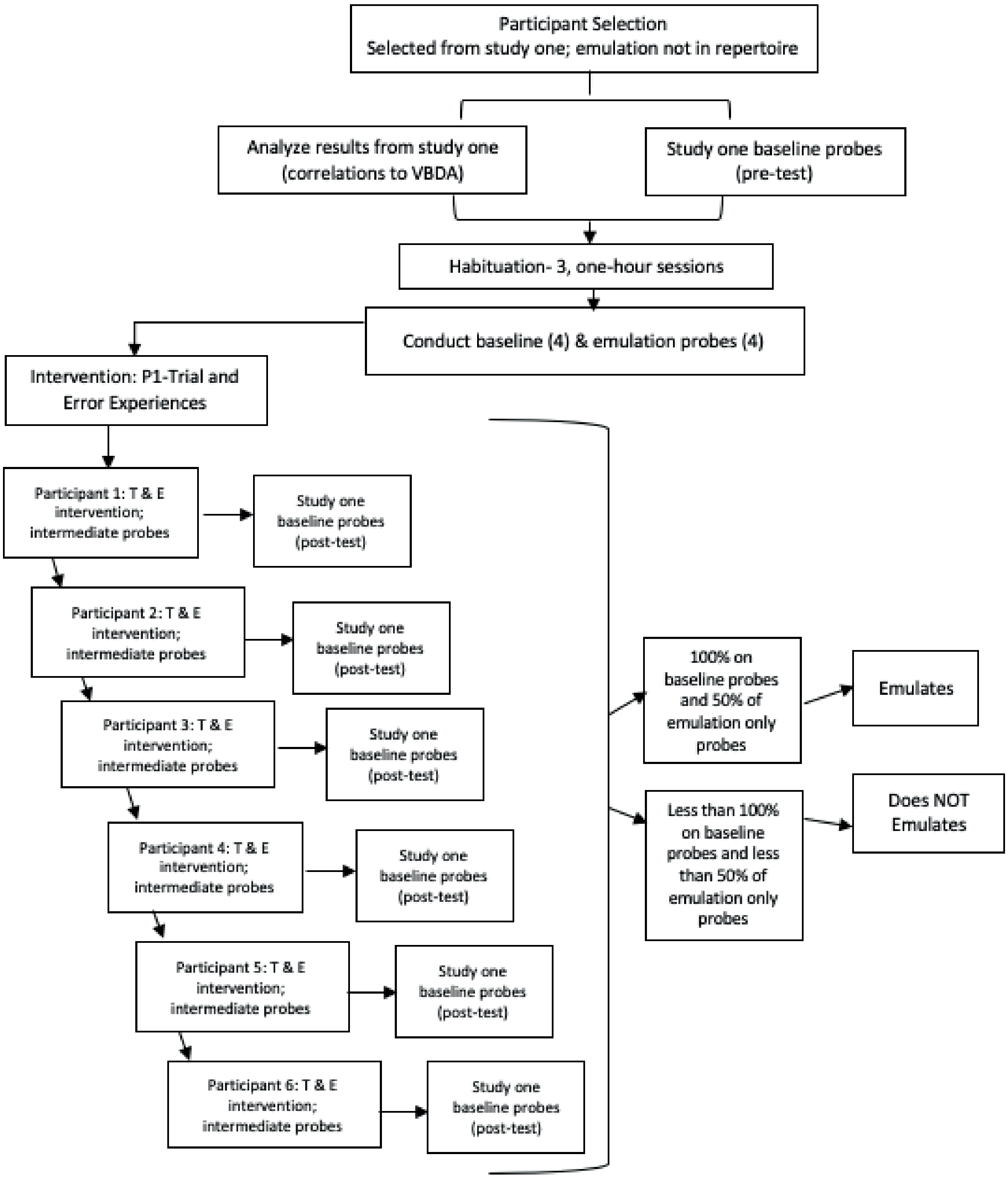


Figure 2. *Sequence of experimental design for Experiment 2.*

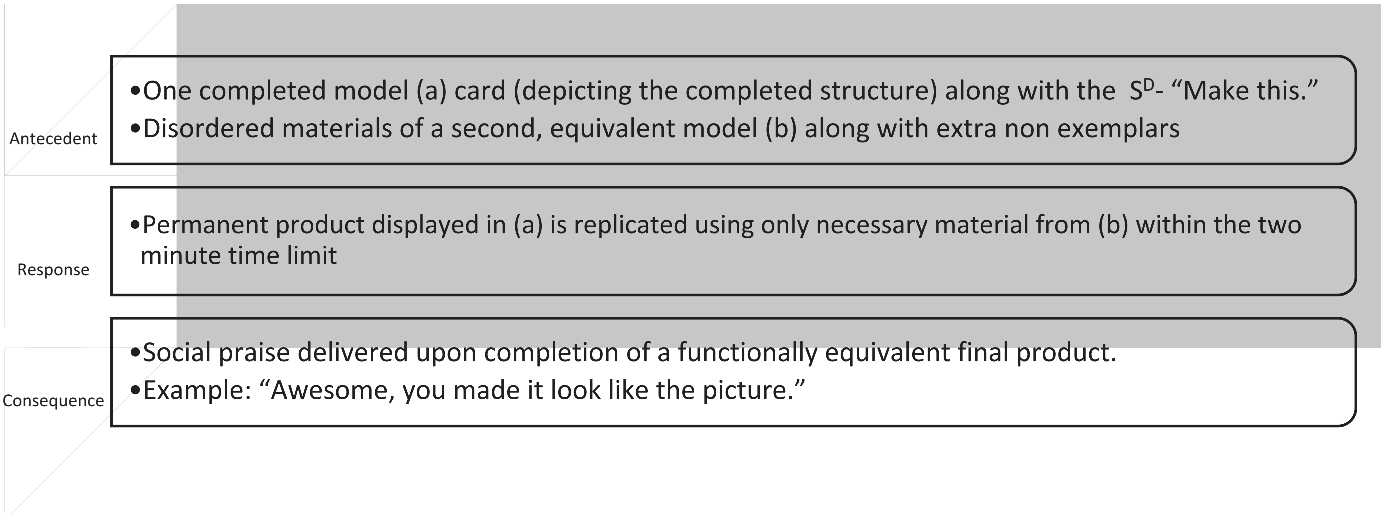


Figure 3. *Correct emulation sequence in trial-and-error phase.*

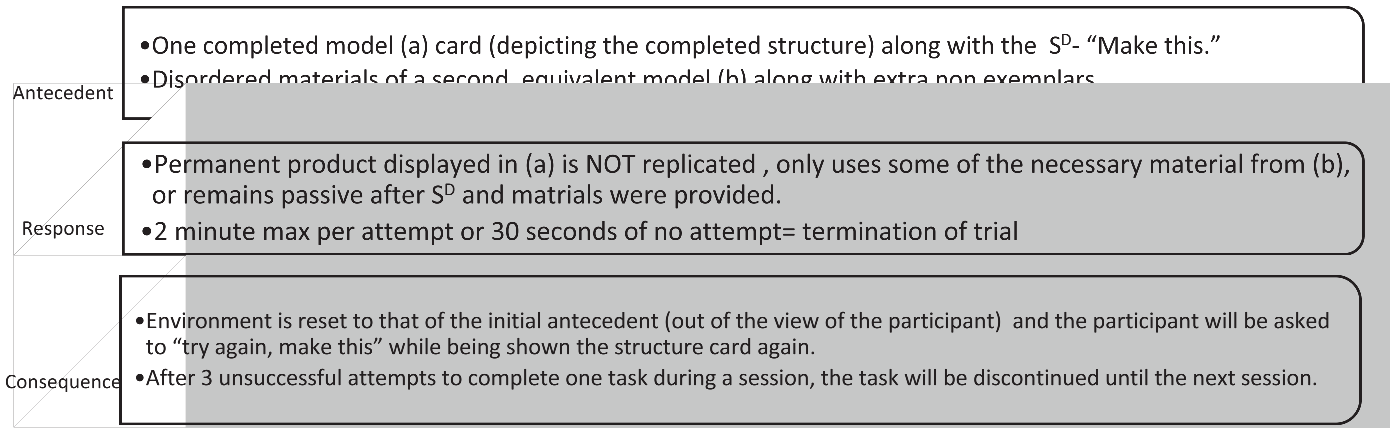


Figure 4. *Incorrect emulation sequence in trial-and-error phase.*

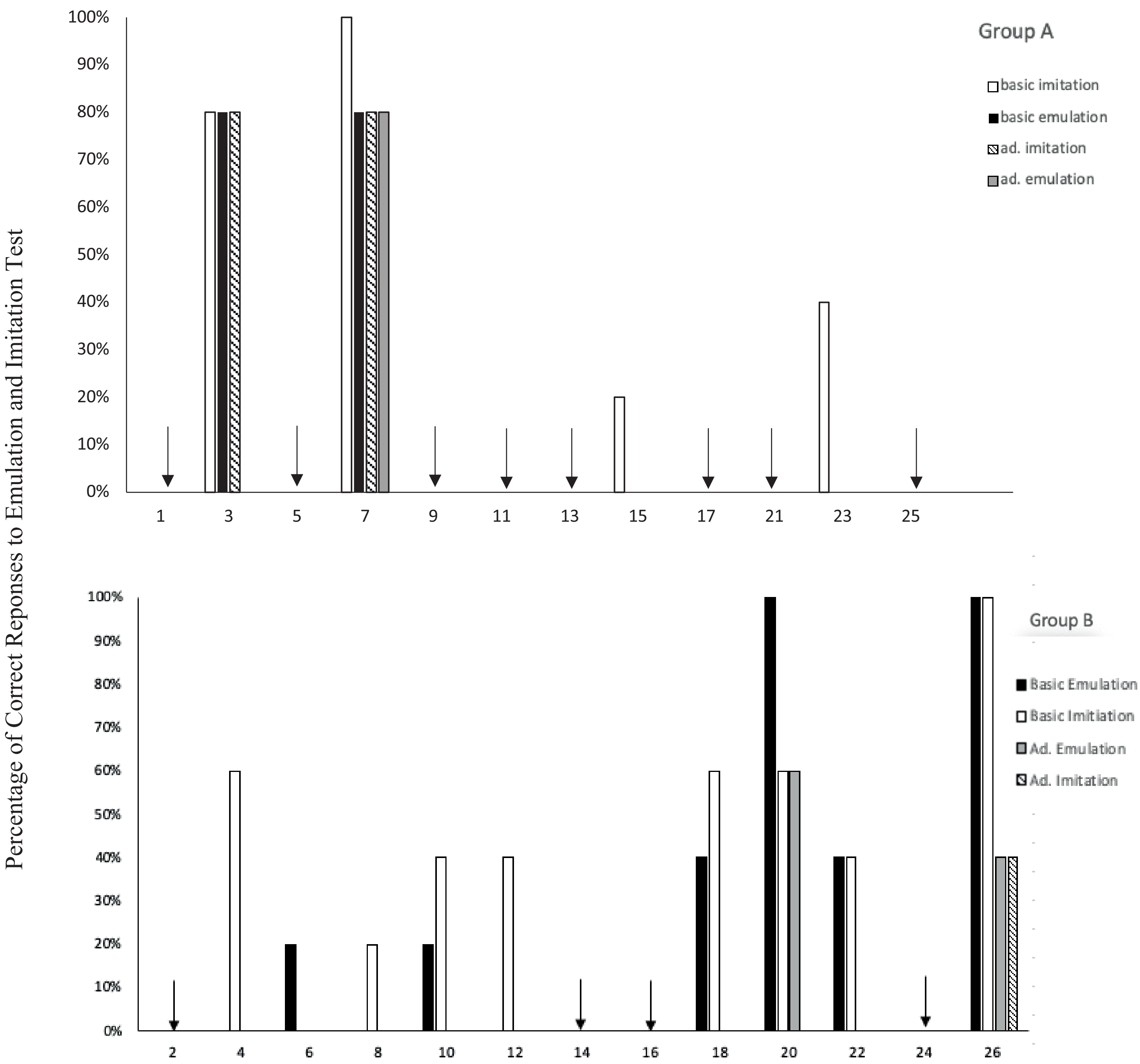


Figure 5. *Percentage of correct responses emitted during the test for basic and advance imitation and emulation.*

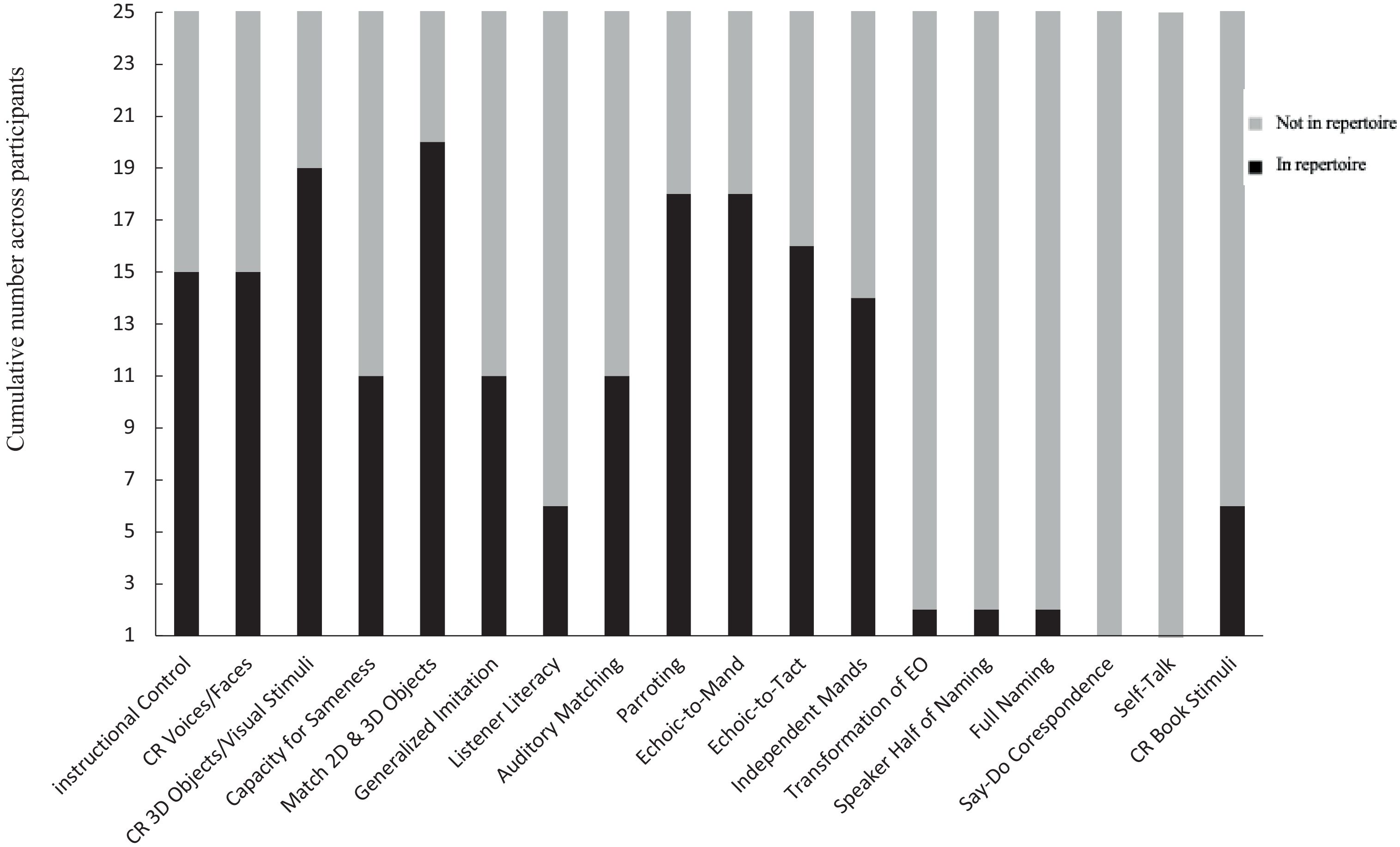


Figure 6. *Cumulative number of pre-reader cusps/capabilities in repertoire across participants.*

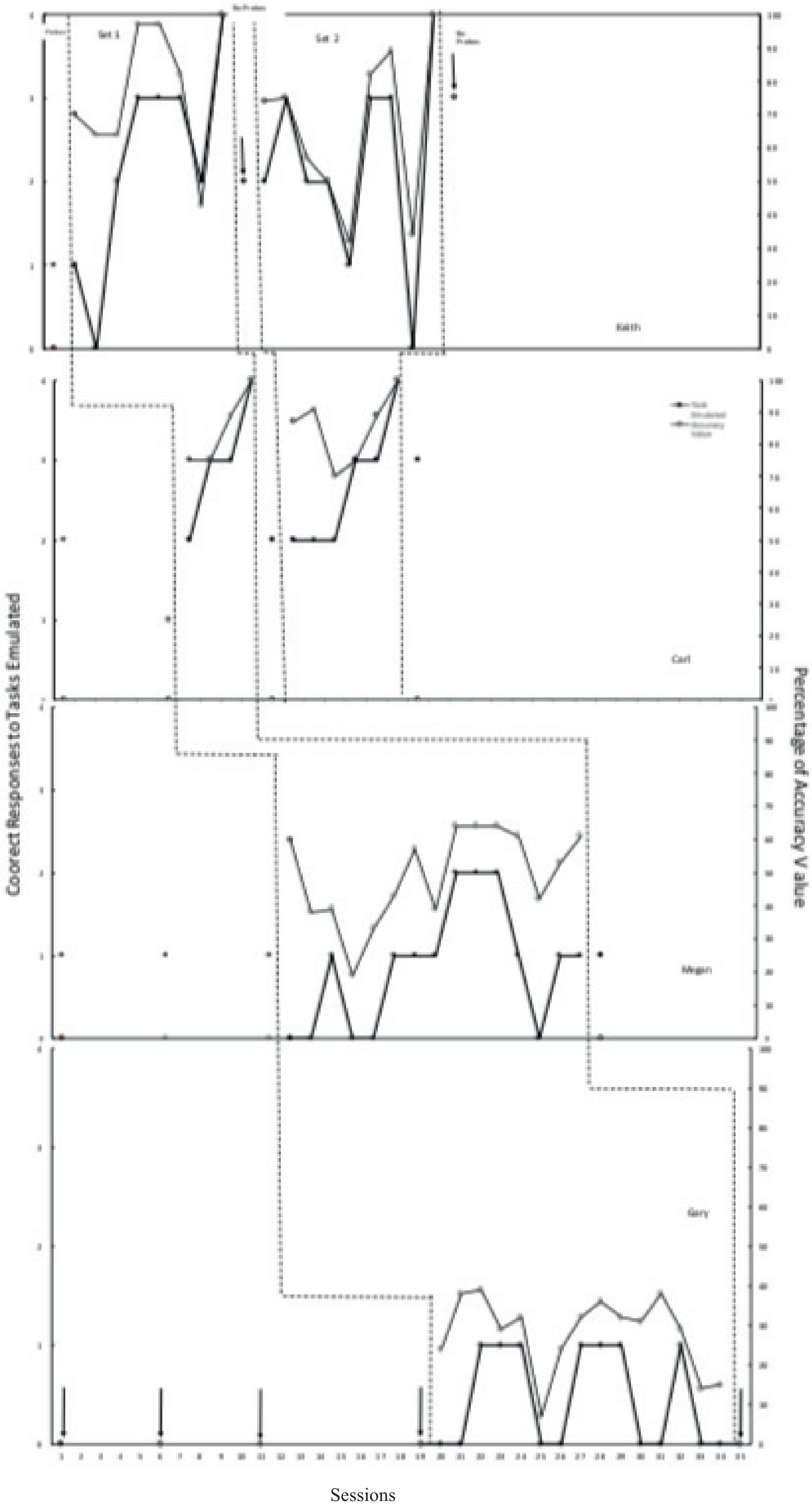


Figure 7. *Number of tasks emulated and accuracy value across participants.*

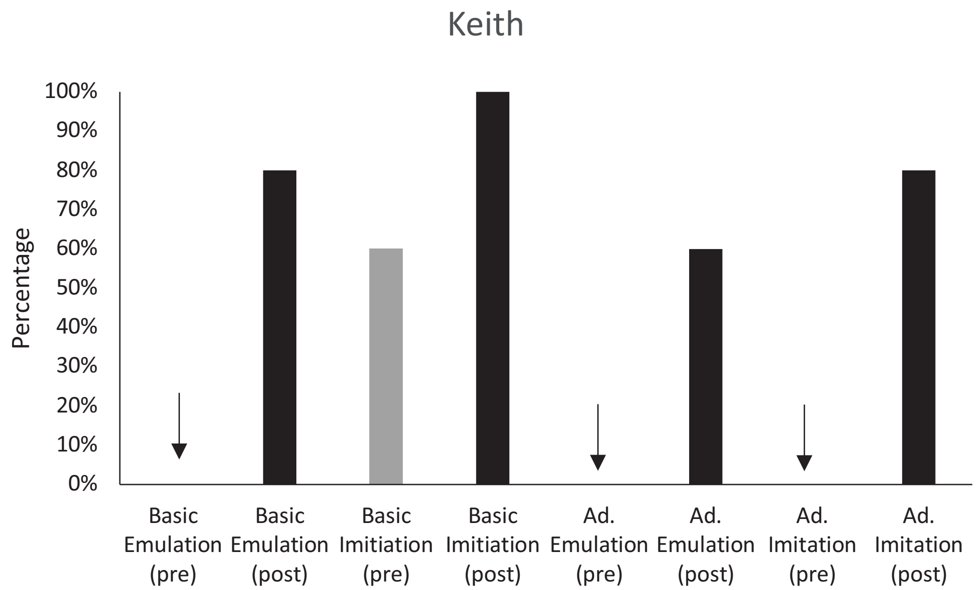


Figure 8. *Pre and post scores from emulation testing conducted initially in Experiment 1 (pretest) and again after the completion of Experiment 2 (posttest) for Keith.*

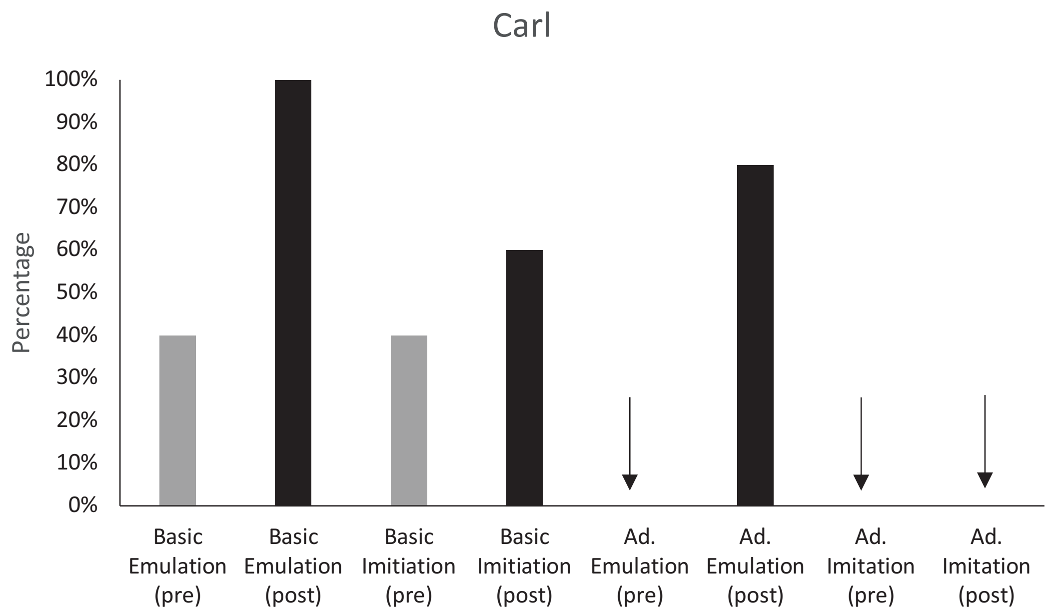


Figure 9. *Pre and post scores from emulation testing conducted initially in Experiment 1 (pretest) and again after the completion of Experiment 2 (posttest) for Carl.*

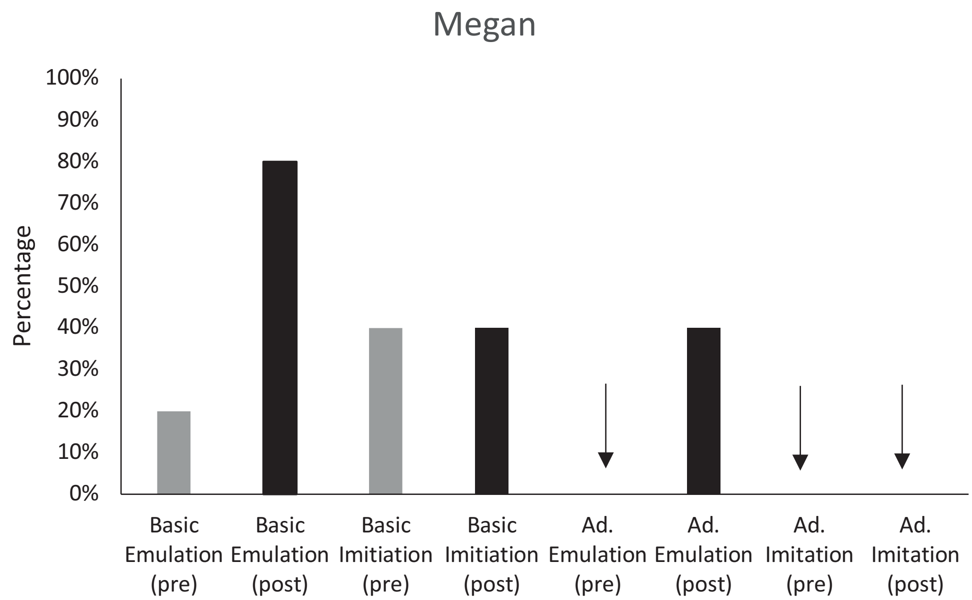


Figure 10. *Pre and post scores from emulation testing conducted initially in Experiment 1 (pretest) and again after the completion of Experiment 2 (posttest) for Megan.*

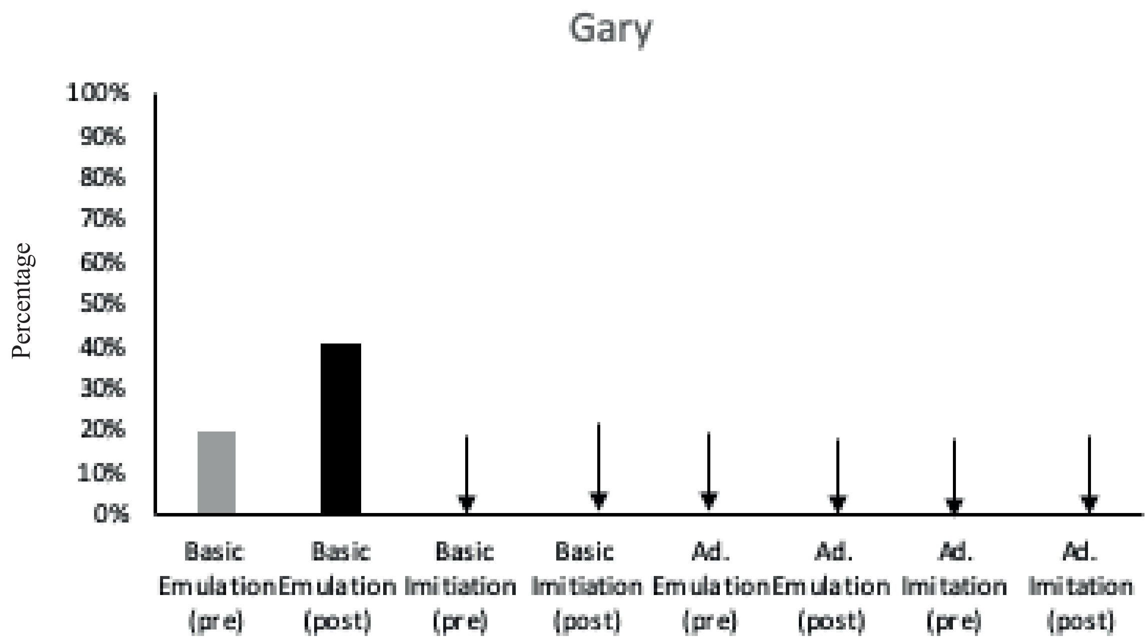


Figure 11. *Pre and post scores from emulation testing conducted initially in Experiment 1 (pretest) and again after the completion of Experiment 2 (posttest) for Gary.*

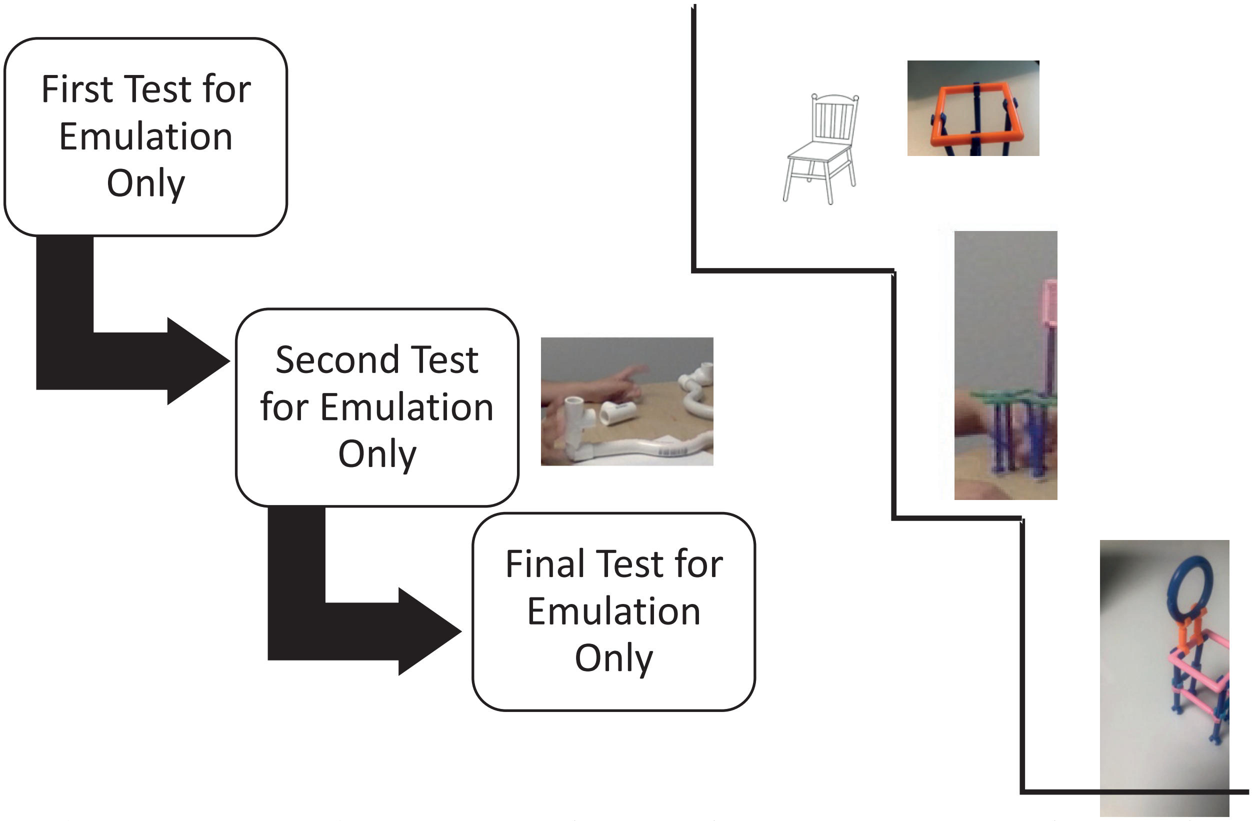


Figure 12. *A sample of responses emitted by Keith during emulation probes administered at various times in Experiment 2.*

Appendix A: Emulation and Imitation Data Recording Sheet

Participant Number: __________ Date: ____________

Imitation Probe Data- **Object Imitation**
Materials: building materials, experimenter design cards, and timer
Target Response must include point-to-point correspondence to model to be correct (+) incorrect response (-) does not match the point-to-point correspondence demonstrated and or involves no attempt.

		Correct or Incorrect response to task	Duration to complete
Basic Set (3-5 behaviors)	1 (3)		
	2 (4)		
	3 (3)		
	4 (5)		
	5 (4)		
Advanced Set (6-9 behaviors)	1 (9)		
	2 (7)		
	3 (6)		
	9 (8)		
	5 (9)		
	Totals:	/5 basic /5 advanced	

Imitation Probe Data- **Object Emulation**
Materials: building materials, final product/structure (pre-assembled outside view of participant), and timer
Target Response Correct (+) responses- organizing materials to match the final product shown
Incorrect response (-) does not organize materials to match the final product shown

	LU's	Correct or Incorrect response to task	Duration to complete
Basic Set (3-5 behaviors)	1 (3)		
	2 (4)		
	3 (3)		
	4 (5)		
	5 (4)		
Advanced Set (6-9 behaviors)	1 (9)		
	2 (7)		
	3 (6)		
	9 (8)		
	5 (9)		
	Totals:	/5 basic /5 advanced	

Appendix B: Baseline and Emulation Recording Sheet

Participant Number: _________ Total Time per Trial- 2 min. max.; 30 sec. termination if no attempt at the structure shown

Baseline and Emulation Probes- Participant will be shown a final product card that is voided of specific shape and/or color patterns. The participants will be given various building materials that do not resemble the shape of the card shown and asked to build the same design. No consequences will be provided for any emulation-task related response.

Recording Measures- Correct task completion responses to emulation products will be defined as the participant organizing materials to match the final product shown (+). An incorrect task completion response to emulation products will be defined as not organizing all materials to match the final product shown (-). An accuracy value will be assigned to all completed products and will range based on the steps required to complete the given emulation product (tally each step completed accurately).

	Trial	+ or -	Accuracy Value # of behaviors	Duration to complete	Trial	+ or -	Accuracy Value # of behaviors	Duration to complete	Trial	+ or -	Accuracy Value # of behaviors	Duration to complete	Trial	+ or -	Accuracy Value # of behaviors	Duration to complete
Baseline Probes	1				1				1				1			
	2				2				2				2			
	3				3				3				3			
	4				4				4				4			
Emulation (only) Probes	1				1				1				1			
	2				2				2				2			
	3				3				3				3			
	4				4				4				4			
	Totals	BL E	BL E	BL E	BL E	BL E	BL E	BL E	BL E	BL E	BL E	BL E	BL E	BL E	BL E	BL E
Date:																
Initials:																

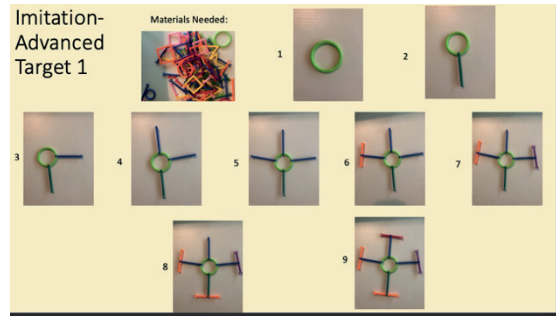
Appendix C: Trial and Error Intervention Data Sheet

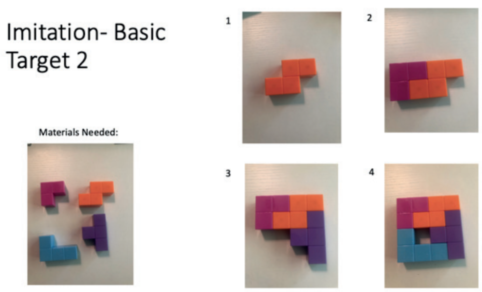
Participant Number: __________ (Check one) Data:________ IOA Data:_________

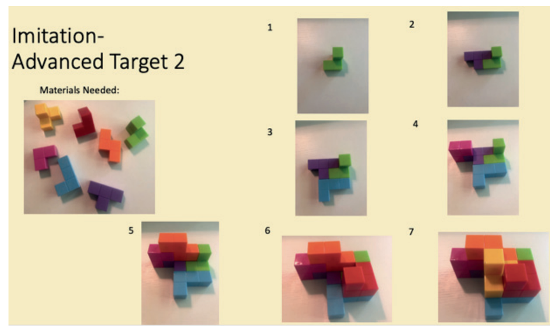
Recording Measures- Correct task completion responses to emulation products will be defined as the participant organizing materials to match the final product shown (+). An incorrect task completion response to emulation products will be defined as not organizing all materials to match the final product shown (-). An accuracy value will be assigned to all completed products and will range based on the steps required to complete the given emulation product (tally each step completed accurately).

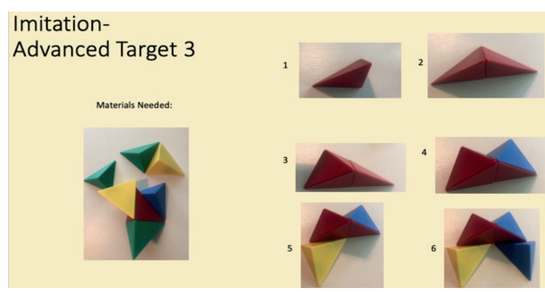
Trial and Error Intervention	1st Attempt	+ or -	Accuracy Value (# of behaviors)	Duration to complete	2nd Attempt	+ or -	Accuracy Value (# of behaviors)	Duration to complete	3rd Attempt	+ or -	Accuracy Value (# of behaviors)	Duration to complete
Rotate order of tasks each session (AM session) Date:	Task 1				Task 1				Task 1			
	Task 2				Task 2				Task 2			
	Task 3				Task 3				Task 3			
	Task 4				Task 4				Task 4			
Rotate order of tasks each session (PM session) Date:	Task 1				Task 1				Task 1			
	Task 2				Task 2				Task 2			
	Task 3				Task 3				Task 3			
	Task 4				Task 4				Task 4			
Totals												
Date and Initials												

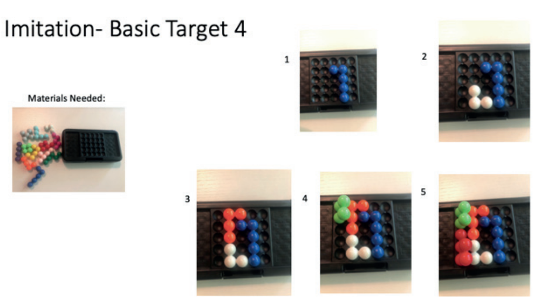
Appendix D: Experiment 1 Basic and Advance Imitation Test

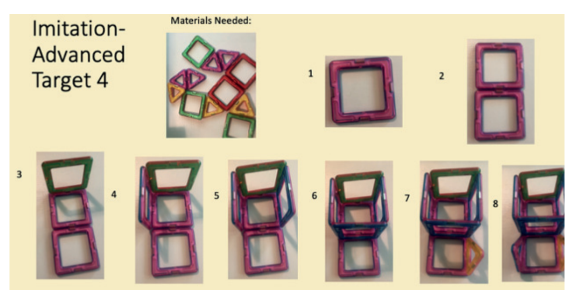


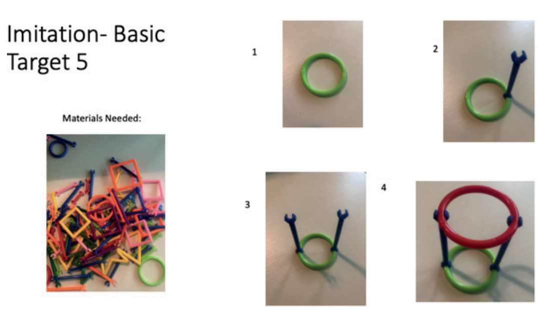


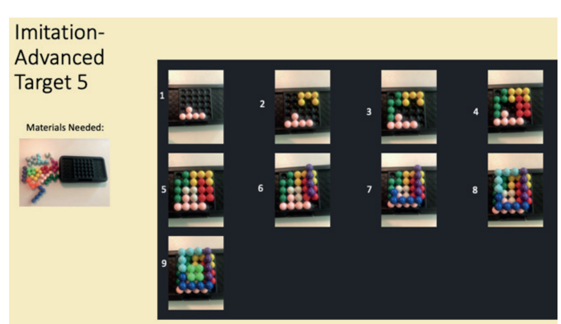








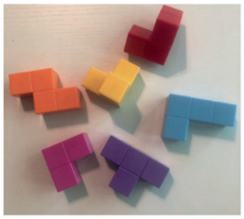




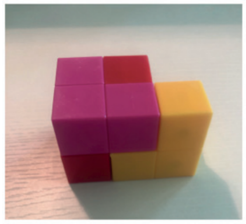
Appendix E: Experiment I Basic and Advance Emulation Test

Emulation- Basic Target 1

Materials Needed:



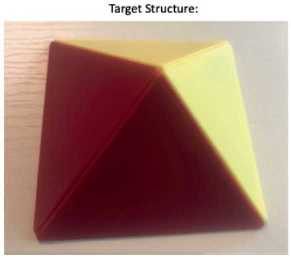
Target Structure:



Emulation- Basic Target 2

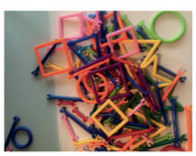
Materials Needed:

Target Structure:



Emulation- Basic Target 3

Materials Needed:



Target Structure:

Emulation- Basic Target 4

Materials Needed:

Target Structure:

Emulation- Basic Target 5

Materials Needed:

Target Structure:

Emulation- Advanced Target 1

Materials Needed:

Target Structure:

Emulation- Advanced Target 2

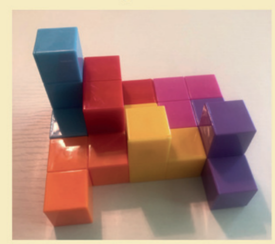
Materials Needed:

Target Structure:

Emulation- Advanced Target 3

Materials Needed:

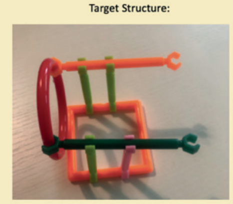
Target Structure:



Emulation- Advanced Target 4

Materials Needed:

Target Structure:



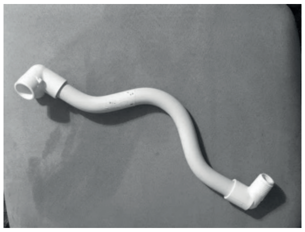
Emulation- Advanced Target 5

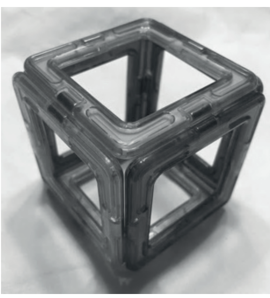
Materials Needed:

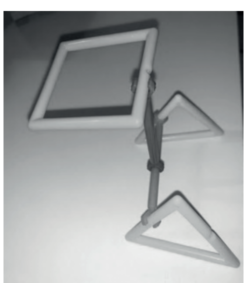
Target Structure:

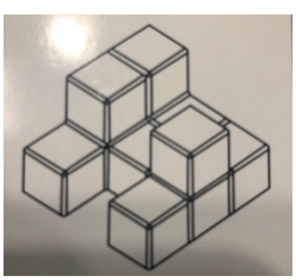
Appendix F: Materials for Baseline and Emulation Testing

Baseline Structure Cards & Materials

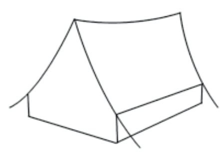


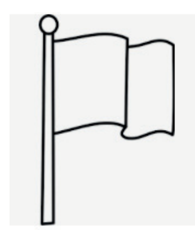






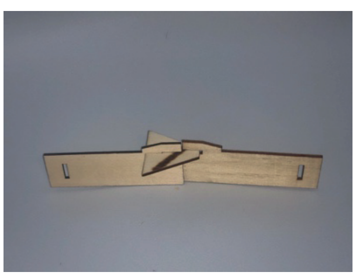
Emulation Only Structure Cards & Materials

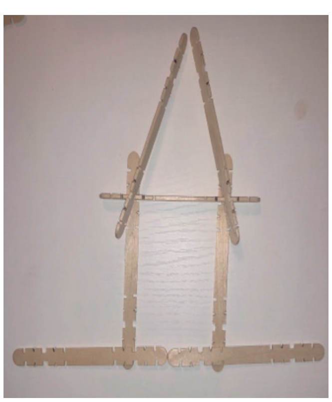




Appendix G: Sets 1 & 2 for Experiment 2 (Trial-and-Error)

Set 1





Set 2