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Brief Report

Effects of explicit instruction on acquisition and generalization of mathematical concepts for a student with autism spectrum disorder

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ABSTRACT

Background: This study investigated the effects of explicit instruction on acquisition and generalization of mathematical concepts (more, different, long) by an elementary student with autism and co- morbid intellectual disability.

Method: This study used a single-case multiple probe across behaviors design to measure the acquisition and generalization of concepts across four categories of stimuli: (a) far distractor objects, (b) near distractor objects, (c) near distractor pictures, and (d) environmental objects.

Results: A functional relation was found between explicit instruction and independent identification of mathematical concepts. Data indicate the intervention was effective and treatment effects were maintained across concepts. Variable generalization patterns were observed across concepts.

Conclusions: Explicit instruction is an effective instructional strategy for teaching mathematical concepts to learners with autism and co-morbid intellectual disability. Future research should measure the efficacy of explicit instruction for more advanced generalization of concepts and application to functional tasks.

1. Introduction

Early number sense is the broad term used to describe an individual's ability to understand numbers and operations and use mathematical concepts to make judgments (McIntosh, Reys, & Reys, 1992). Also called "early numeracy", number sense is fundamental for advanced knowledge in mathematics. Without a firm foundation of number sense, learners will struggle with both acquiring and generalizing future mathematical learning (Jordan, Kaplan, Ramineni, & Locuniak, 2009). Early measurement concepts, including more/less, same/different, longer/shorter are important components of number sense. Learners with disabilities who struggle with foundational number sense are likely to have persistent difficulty throughout their educational careers (Carlson, Jenkins, Bitterman, & Keller, 2011).

Understanding of mathematical concepts and symbols are essential components of mathematical knowledge (Skemp, 1987). Expanded vocabularies allow learners to understand commonalities and differences between items by describing their attributes (Sandhofer & Smith, 1999). Preschool students with developmental delays, including autism spectrum disorder (ASD) and intellectual disability (ID) have been found to have lower math skills than peers with more high incidence disabilities such as speech language impairments (Carlson et al., 2011). Learners with ASD/ID need high quality intensive intervention using evidence-based practices in order to demonstrate both acquisition and generalization of math concepts.

A recent review of the literature found Explicit Instruction (EI) to be an evidence-based practice for teaching mathematics to learners with ASD/ID (Spooner et al., 2017). When teachers use EI, they employ a series of supports and scaffolds to guide students

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through the learning process in small steps with clear explanations and demonstrations of the targeted skill, providing practice with feedback until mastery is achieved (Archer & Hughes, 2011). Several instructional strategies fall under the EI "umbrella", including direct instruction and multiple exemplar training. Multiple exemplar training is designed to promote generalization by teaching multiple examples of desired responses (Chadsey-Rusch, Drasgow, Reinoehl, Halle, & Collet-Klingenberg, 1993; Horner, Sprague, & Wilcox, 1982; Stokes & Baer, 1977).

Spooner et al. (2017) found eight studies published between 2005–2016 used EI to teach mathematics to learners with ASD/ID. Targeted skills included addition (Cihak & Foust, 2008; Cihak & Grim, 2008; Fletcher, Boone, & Cihak, 2010), telling time (Thompson et al., 2012), purchasing skills (Hansen & Morgan, 2008; Hsu, Tang, & Hwang, 2014), and problem solving (Root, Browder, Saunders, & Lo, 2016). One study used EI to teach mathematical concepts related to number sense to learners with developmental disability. Celik and Vuran (2014) compared the effects of direct instruction and simultaneous prompting on identification of mathematical concepts (few, old, long, thick) by four elementary students with moderate ID who did not have ASD. Results of the single-case parallel treatments design found DI effective for all four participants whereas simultaneous prompting was only effective for three participants.

Although there is limited empirical research specifically on teaching mathematics concepts to students with ASD using EI, research supports its efficacy for teaching other basic concepts and vocabulary terms. For example, Hicks, Bethune, Wood, Cooke, and Mims (2011) measured the effects of direct instruction on acquisition of prepositions. Results indicated a functional relation between DI and the students' use of and response to prepositions. Given the positive findings of explicit instruction to teach concepts to students with moderate ID, research on its utility for teaching mathematical concepts to students with ASD and co-morbid ID is warranted. Therefore, the purpose of this study was to investigate the effects of explicit instruction (i.e., a model, lead, test procedure with multiple exemplars) on the acquisition and generalization of three mathematical concepts (more, different, long) for a student with ASD and co-morbid ID.

2. Method

2.1. Participant and setting

Approval from the institutional review board, written parental consent, and verbal student assent were obtained prior to beginning the study. Teacher nomination was used to recruit a participant based on the following inclusion criteria: (a) an educational or medical diagnosis of ASD, (2) ability to indicate choices between two items using gestures or words, and (3) satisfactory performance on a prescreening measure. The prescreening measure was administered by the author in a one-on-one setting and assessed receptive and expressive identification of pictures and objects as well as the three targeted mathematics concepts (more, different, long). Performance on the prescreening measure was considered satisfactory if the participant was able to expressively and receptively identify pictures and objects of common items (i.e., iPad, pizza, tree) but unable to identify the targeted mathematics concepts.

One female student participated in the pilot study. Ruth was a 10-year-old Black female in the 4th grade and had a medical diagnosis of ASD and ID. She attended a private school for students with ASD where she received individualized instruction from Registered Behavior Technicians (RBTs) on basic academic skills, although the primary emphasis of instruction was on communication, language, and self-help skills. The majority of her instruction throughout the school day was conducted in a one-on-one format. Typical math instruction focused on numeral recognition and making sets up to five. Ruth communicated using one-word utterances. A graduate student completing a Master's degree in special education who was trained in systematic instruction techniques conducted all sessions. Sessions lasted approximately ten minutes and took place one-on-one in the afternoons at Ruth's desk.

2.2. Materials

Four example sets (far distractor objects, near distractor objects, near distractor pictures, and environmental objects) were developed by the researcher for each concept based on the guidelines outlined by Engelmann and Carnine (1982) for selecting examples for teaching concepts. See Table 1 for the positive and negative materials for each category and concept. The first example set (far distractor objects) included objects that had a high degree of similarity in irrelevant dimensions and only differed in the quality related to the concept (e.g., length). The second example set (near distractor objects) included objects with a lower degree of similarity in irrelevant dimensions and differed in more than one quality in addition to the quality related to the concept (e.g., length and color). The third example set (near distractor pictures) included pictures with a lower degree of similarity in irrelevant dimensions similar to the near distractor objects. Finally, the fourth example set (environmental objects) contained items that were common to Ruth's school environment that represented the concepts.

2.3. Experimental design

We used a multiple probe across behaviors design (Horner & Baer, 1978; Kratochwill et al., 2013) to evaluate the effects of explicit instruction on acquisition and generalization of mathematical concepts. The dependent variable was acquisition and generalization of math concepts, measured by the number of correct identifications of concepts out of six opportunities. Responses were considered independently correct if Ruth touched the correct stimuli (i.e., object/picture depicting the targeted concept) within 4 s of the instructional cue (i.e., "touch long"). There were three experimental conditions: baseline, intervention, and probe. Intervention consisted of up to four phases for each concept: (a) EI with far distractor objects, (b) EI with near distractor objects, (c) EI with near