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A Preliminary Examination of the use of Simultaneous Prompting to Teach Math Content to Students with Disabilities

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ABSTRACT: *This manuscript presents an examination of 15 experimental studies that investigated the use of the simultaneous prompting procedure to teach math content to students with disabilities, which were reported to be a mild or moderate intellectual disability, autism, or hearing impairment. A nearly equal number of elementary, middle, and high school participants were involved in the investigations, which were conducted in general and special education classrooms, participants' homes, clinics, and university-based research centers. A single subject research design was used in each study, and both discrete and chained math skills were targeted. A visual analysis of the results, based on percentage of non-overlapping data, indicates variable support for the effectiveness of the procedure with all 35 of the participants. Likewise, in the studies that reported maintenance and generalization data, the results were variable. Altogether, this descriptive report serves as a preliminary examination to guide the work of teachers and researchers.*

KEYWORDS: autism, hearing impairment, intellectual disabilities, math, simultaneous prompting, single subject research

INTRODUCTION

A Preliminary Examination of the use of Simultaneous Prompting to Teach Math Content to Students with Disabilities

Simultaneous prompting is a response prompting strategy that has recently been characterized as an evidence-based practice for use with students with disabilities (Tekin-Iftar et al., 2019). Response prompting strategies can be characterized as one type of discrete trial instruction (Smith, 2001; Wilczynski et al. 2012), and involve the systematic presentation of prompts – which are intended to elicit correct responses rather than allow for errors - following the presentation of the discriminative stimulus, which is often a task directive (Collins, 2012; Wolery et al., 1992b). In addition to simultaneous prompting, examples of response prompting strategies include constant time delay, progressive time delay, and most-to-least prompting.

The distinguishing feature of the simultaneous prompting procedure is its design and pairing of training and probe trials (Gibson & Schuster, 1992). During a training trial, a prompt is provided immediately following the presentation of the discriminative stimulus. For example, when using the procedure to teach a student the name for the numeral 3, the teacher might hold up an index card with the numeral 3 written on it and present the task directive, "Name this numeral." Immediately after saying "numeral," the teacher would provide a prompt, such as saying the first two phonemes in the word "three" (i.e., /th/ and /r/). The student would then be expected to say the correct response within a predefined response interval. When the student does so, the teacher presents a response contingency, which in the case of a correct response would be an individualized reinforcer. For the example, the teacher might present descriptive verbal praise by saying, "Great! The name of the numeral is three."

With respect to simultaneous prompting, the prompt is characterized as a controlling prompt because it is designed to always ensure a correct student response during a trial. This circumstance is one reason why the procedure has been referred to as a near-errorless instructional strategy (Collins, 2012; Gibson & Schuster, 1992; Wolery et al., 1992b).

Since, during the trials that comprise a training session, a student is never provided an opportunity to respond independently to the discriminative stimulus, probe sessions are conducted for the purpose of determining whether the student can respond independently to the discriminative stimulus. Continuing with the example from above, during a probe trial that is presented during a probe session, the teacher would hold up an index card with the numeral 3 written on it and present the task directive, "Name this numeral." Afterwards, the teacher would record how the student responded during a pre-determined response interval (e.g., a period of 4 seconds). The student will have demonstrated mastery of the targeted learning outcome when he responds correctly under these conditions according to the criterion for mastery that has been established (e.g., with 100% accuracy on all probe session trials across two consecutive probe sessions).

Thus, once an initial training session has been conducted, a probe session is conducted on each subsequent day before that day's training session. This probe session/training session relationship can be characterized as a hallmark feature of the simultaneous prompting procedure.

The origins of the simultaneous prompting procedure can be traced to a review of the literature pertaining to instructional strategies that had been employed with students with moderate and severe disabilities (Wolery et al., 1986). As reported by Wolery et al. (1992a), one of the useful findings from this review pertained to an unexpected outcome from investigations of the most frequently reported instructional strategy: the system of least prompts.

This strategy involves the presentation of a series of progressively more intrusive prompts. That is to say, during a training trial the student is initially presented the discriminative stimulus/task

directive without any subsequent prompt. If the student does not make a correct response during the response interval, the task directive is repeated, and the student is presented with the least intrusive prompt from among the hierarchy of prompts that have been identified for use. If, once again, the student does not make a correct response during the response interval, the task directive is repeated and the student is presented with the next prompt in the hierarchy. This prompt is more intrusive than the previous prompt but less intrusive than the subsequent prompts in the hierarchy. Wolery et al. (1992a) remarked that it was anticipated that initial training trials would establish the level of prompt a student needed to be provided in order to be able to perform a targeted task. Over time, as the student gained proficiency in performing the task, it was anticipated that a less intrusive prompt in the hierarchy would be used during future trials. Ultimately, the goal was to either reach a point in time when the student could perform the targeted learning outcome void the presentation of any prompts, or when the student consistently performed the targeted learning outcome after being provided a prompt that was relatively less intrusive than any preceding prompt. In fact, considering the procedure was being used with students who demonstrated moderate or more significant intellectual disabilities, there was the recognition that a student may never demonstrate the ability to perform a skill in the absence of any prompts. So, the belief was that a systematic progression through a prompt hierarchy – from least intrusive to most intrusive – would result in the identification of the type of least intrusive prompt a student indicated he needed to receive to be able to engage in a targeted learning outcome.

However, Wolery et al. (1992a) reported that certain investigators identified some participants who demonstrated independent responding after participating in trials during which only the most intrusive prompt was provided. That is to say, the participants progressed from (a) emitting correct responses to a discriminative stimulus when a controlling prompt was presented to (b) emitting correct responses to the discriminative stimulus independently, without the provision of any prompt. In other words, the participants skipped all of the steps involving the progressive use of less intrusive prompts.

This experience resulted in the design, and subsequent investigation of, the procedure now known as simultaneous prompting. A key, relative benefit of simultaneous prompting compared to the system of least prompts would be that when simultaneous prompting proved to be effective, it also would prove to be more efficient than the stepwise approach just described because simultaneous prompting would allow for bypassing a systematic progression through a less intrusive prompt hierarchy.

Recently, Tekin-Iftar et al. (2019) conducted a meta-analysis of select experimental studies involving the simultaneous prompting procedure, and concluded that it is an evidence-based practice for students with disabilities. By using rigorous selection criteria intended to identify studies that exemplified high-quality research in accordance with the research design employed (see Kratochwill et al., 2013), Tekin-Iftar et al. eliminated a large number of investigations that

had reported on the use of simultaneous prompting. Following a three-step process, they progressed from the identification of 70 reports of investigations of simultaneous prompting, that had been published in peer-reviewed journals, to a detailed analysis of 27 upon which their meta-analysis was based.

With respect to their conclusions, Tekin-Iftar et al. (2019) remarked that simultaneous prompting can be characterized as an evidence-based practice for use with students with disabilities. Yet, Tekin-Iftar et al. also identified three focal points for future research: (a) the procedure's effectiveness with students with particular disabilities (e.g., autism spectrum disorder), with specific attention given to different age groups; (b) the relevance of its procedural parameters (e.g., what differential results would be realized if probe sessions are conducted on a less frequent basis); and (c) the types of skills for which simultaneous prompting is best suited (i.e., skills across academic (e.g., writing, vocabulary development, and math content) and functional (e.g., self-help, communication, leisure, and vocational) domains). With the identification of the last focal point for future research, Tekin-Iftar et al. established the fact that an instructional strategy might be identified as an evidence-based practice under certain circumstances but as a different type of practice under other circumstances. In particular, another way simultaneous prompting might be characterized is as a promising practice.

The term promising practice has been used to characterize a practice that has some supporting evidence of its effectiveness, but this evidence does not allow for the practice to be designated an evidence-based practice (The IRIS Center, 2006a). This circumstance appears to be the case with respect to reports of the use of simultaneous prompting to teach math content to students with disabilities. Presently, fifteen reports of experimental studies have been identified in peer-reviewed journals, but this number would be reduced significantly if the rigorous selection criteria used by Tekin-Iftar et al. (2019) were applied. For example, three investigations that were comparison studies would be eliminated, as would a number of other studies that do not meet Kratochwill et al.'s (2013) evaluation criteria which were used by Tekin-Iftar et al. One reason for this circumstance might be that those other studies (9 total) were published at the same time, or before, Kratochwill et al.'s criteria, meaning the investigators did not design their investigations with these criteria in mind, nor were they reviewed by journals with these criteria in mind.

Be that as it may, there are several reasons why the published studies of investigations of simultaneous prompting to teach math content to students with disabilities are worthy of examination. One reason is that simultaneous prompting has been identified, broadly speaking, as an evidence-based practice for students with disabilities. Thus, teachers might be inclined to consider it to teach math to these students, but be hesitant to do so because Tekin-Iftar et al. (2019) indicated that it has not specifically been established as an evidence-based practice for this purpose. Yet, Dr. Bryan Cook has noted that teachers need a way to prioritize non-evidence-based practices that have some research support though not enough to be established as an evidence-

based practice (The IRIS Center, 2006a, p. 1). Dr. Cook reasoned that (a) it would be a rare day when a teacher only used evidence-based practices to present all of her instruction and that (b) not all non-evidence-based practices are the same. In other words, considering that simultaneous prompting already has been identified as an evidence-based practice for students with disabilities through a rigorous evidence-based review, it is reasonable to think that it is more appropriate to use in certain circumstances than other practices that have only been characterized as non-evidence-based practices. Hence, it would be appropriate to provide teachers with evidence that would indicate simultaneous prompting is at least a promising practice with respect to using it to teach math content to students with disabilities.

A second reason why an examination of all of the published studies of simultaneous prompting to teach math content is warranted is because making teachers aware of the studies would open the door for them to access the studies for the purpose of considering exactly how the various parameters of the procedure have been adjusted and still resulted in the presentation of effective math instruction. Not only did Tekin-Iftar et al. (2019) comment on the need to examine the parameters of simultaneous prompting, but a recent review of the use of simultaneous prompting to present effective instruction to students with autism also revealed how numerous variations of the procedure's parameters (e.g., the use of different response contingencies) across 28 experimental studies still resulted in the provision of effective instruction (Morse, 2022). This line of reasoning is in keeping with Dr. Cook' remarks about considering appropriate ways to change the parameters of evidence-based practices. He stated that there is a need to provide teachers with ways to consider how to make slight adjustments to an evidence-based practice so that it fits a teacher's unique context (The IRIS Center, 2006b, p. 5). When special educators do so on behalf of students with disabilities, the result is individualized instruction as called for in the Individuals with Disabilities Education Act (2004).

A third reason why an examination of all of the published studies of simultaneous prompting to teach math content is warranted is because an examination of them would not only alert researchers to empirical work that has been performed to date but also provide them guidance regarding additional research that needs to be conducted. Over time, this work could lead to establishing the procedure as an evidence-based practice for teaching math content to students with disabilities.

Consequently, this manuscript addresses the call for additional work to identify the types of academic skills for which simultaneous prompting is best suited. Specifically, this manuscript reports on the use of simultaneous prompting to teach math content to students with disabilities. The manuscript does so by presenting its content as a descriptive report rather than a formal evidence-based review. A descriptive report has been identified as an appropriate first-step with respect to investigating a new area of scientific inquiry, and characterized as the equivalent of good newspaper reporting which answers the five basic W questions (i.e., who, what, why, when, and where) (Vetter, 2017). The determining factor for settling on this approach is the limited number

of studies available – which would be reduced significantly if the same inclusion criteria for an evidence-based review that were used by Tekin-Iftar et al. (2019) were applied.

Specifically, this manuscript summarizes the information presented across the 15 experimental studies referred to previously with respect to the following topics: participant characteristics, settings, targeted learning outcomes, research design and implementation, a visual analysis of demonstrations of effect based on percentage of non-overlapping data, plus task maintenance and generalization. Altogether, the purposes for examining this information were to determine (a) whether it supports characterizing simultaneous prompting as a promising practice for teaching math content to students with disabilities, (b) the extent to which it can alert teachers to the ways the procedure has been used to teach discrete and chained math tasks, and (c) ways it can inform researchers about work performed to date and future research needs.

METHOD

Search Procedures

A systematic review was conducted to identify reports of studies, that have been published in English in peer-reviewed journals, involving the use of the simultaneous prompting procedure to teach math content to students with disabilities. Since Gibson and Schuster's (1992) investigation has been identified as the seminal study involving this response prompting procedure (Tekin-Iftar et al., 2019), this review centered on the timeframe 1992-2022 (final search was conducted on August 31, 2022). Studies for this descriptive report were located through the following process, which built upon Tekin-Iftar et al.'s process with an exception (see #3 below).

1. Searches of Academic Search Complete, ArticleFirst, EBSCOhost, Education Journals (ProQuest), Education Source, ERIC (ProQuest), ERIC (USDE), JSTOR, PsycINFO, ScienceDirect, Worldcat.org, and Web of Science using the following keywords singularly and in various combinations: simultaneous, simultaneous prompting, response prompting, disability, disabilities, special education, mathematics, and math.
2. A review of the reference lists of the identified articles from the search described above, as well as the previous reviews of the simultaneous prompting procedure (Morse, 2022; Morse, 2004; Tekin-Iftar et al., 2019; Waugh et al., 2011).
3. Unlike Tekin-Iftar et al.'s (2019) review, the current review included comparison studies, as well as studies published since December 5, 2017. Furthermore, only the portion of each report that pertained to the exclusive use of simultaneous prompting to teach math content was included in this review (e.g., if a report included an investigation of the use of simultaneous prompting to teach science content to one participant and math content to another, only the part of the report pertaining to the teaching of math content was included in this review).

Inclusion and Exclusion Criteria

An investigation was included in the examination if it met these criteria:

- employed an experimental design;
- investigated, in some manner (i.e., effectiveness, efficiency), the simultaneous prompting procedure to teach math content; and
- included one or more participants who had been identified with a disability.

Analysis

Given the purposes of this report that were explained above, each study was examined, broadly speaking, with respect to three categories of variables: demographic, procedural, and effectiveness. Key features of this report's analysis of each study's experimental design were (a) evidence of the systematic manipulation of the independent variable, (b) reporting of independent and dependent variable reliability data, and (c) one or more data points in a baseline phase that allowed for a comparison with subsequent data points in the intervention phase (i.e., in some of the comparison studies only one data point that indicated 0 level of responding was included in the baseline phase).

RESULTS

Fifteen studies were identified that met the inclusion criteria. Table 1 and table 2 summarize information of particular relevance to this report.

Descriptive Analysis

Participants

The reviewed studies included 53 participants, and a math skill was a targeted learning outcome for 35 of them: 10 females and 25 males. The studies were fairly evenly distributed across age-groups that roughly correspond to K-12 grade levels: 7 studies included participants ages 5-10/elementary school (e.g., Ackerlund Brandt et al., 2016), 7 studies included participants ages 11-13/middle school (e.g., Rao & Mallow, 2009), and 6 studies included participants ages 14-18/high school (e.g., Karl et al., 2013). Some studies were counted in more than one category since they included participants across two or more age groups. Of particular note is that no studies involved preschool-age participants (i.e., 3 or 4 years old).

For the participants in the studies whose targeted learning outcome was a math skill, 26 were identified with an intellectual disability (e.g., Jimenez & Saunders, 2019), eight with autism (e.g., Leaf et al., 2010), and three with a hearing impairment (Coleman et al., 2015). Two participants included in these counts were identified as having both an intellectual disability and autism (see Akmangolu & Batu, 2004). Among those with an intellectual disability for which relevant data were reported, 20 were noted to have a moderate intellectual disability (e.g., Creech-Galloway et al., 2013) and two a mild intellectual disability (e.g., Birkan, 2005).

Only one study directly reported the race or ethnicity of the participants (Jimenez & Saunders, 2019) while the other 14 studies did not (e.g., Ramirez et al., 2014). Jimenez and Saunders reported that the participants included one African-American and two Caucasians.

Settings, Instructional Arrangements, History With Simultaneous Prompting, and Targeted Learning Outcomes

Across studies, investigations were conducted in public schools, participants' homes, clinics, and segregated facilities. In 9 of the studies that were conducted in public schools, 6 were conducted in self-contained classrooms (e.g., Rao & Kane, 2009), one in a room "off of" a self-contained classroom (Fickel et al., 1998), one in a resource room (Karl et al., 2013), and one in a general education classroom (e.g., Heinrich et al., 2016). Three investigations were conducted in the participants' homes or a clinic (e.g., Ackerlund Brandt et al., 2016), two studies were conducted in classrooms in a segregated facility (e.g., Akmangolu & Batu, 2004), and one study was conducted in a room in a private education center (Celik & Vuran, 2014).

Twelve studies used a 1:1 instructional arrangement (e.g., Rao & Mallow, 2009) while three studies used a small group arrangement that involved either a 4:1 (e.g., Fickel et al., 1998) or 5:1 (Gursel et al., 2006) pupil:teacher ratio. In two studies the authors remarked that one or more of the participants had a prior history with simultaneous prompting (e.g., Karl et al., 2013), while in two studies the participants were reported to have a history with a procedure similar to simultaneous prompting or behavioral intervention services (e.g., Leaf et al., 2010). Eleven studies either specifically stated that the participants did not have a prior history with simultaneous prompting or simply did not address this topic (e.g., Celik & Vuran, 2014).

Eleven studies reported a targeted math skill that was a discrete task: identifying numerals (e.g., Akmangolu & Batu, 2004), answering basic addition facts (e.g., Ackerlund Brandt et al., 2016), answering basic multiplication facts (e.g., Rao & Mallow, 2009), identification of math symbols (Gursel et al., 2006), identification of geometric figures (Heinrich et al., 2016), subitizing (Jiminez & Saunders, 2019), telling time (Birkan, 2005), identification of length (long) and quantity (few) (Celik & Vuran, 2014), and defining math vocabulary by signing (Coleman et al., 2015). Six studies reported a targeted math skill that was a chained task: calculating elapsed time (Ramirez et al., 2014), use of the Pythagorean theorem (Creech-Galloway et al., 2013), solving a linear equation with one variable (Heinrich et al., 2016), addition problem solving speed (Jiminez & Saunders, 2019), decimal subtraction with regrouping (Rao & Kane, 2009), and computing percentages in applied problems (Karl et al., 2013). Two studies that are included in both of the above counts reported measures of a discrete and chained math skill (i.e., identifying geometric figures and solving a linear equation with one variable by Heinrich et al., 2016; subitizing and addition problem solving speed by Jiminez & Saunders, 2019).

Two studies reported one or more participant's acquisition of non-target information that was not a math skill: the ability to demonstrate manual signs for picture symbols (Fickel et al., 1998) and naming provinces presented as unmarked outlines on a map of a country (Gursel, et al., 2006). In both instances this information was presented as a targeted learning outcome for another student in the instructional group.

Research Design and Reliability

Each investigation used a single subject research design. In the twelve investigations that examined the effectiveness of the simultaneous prompting procedure exclusively, multiple probe designs were used most often (ten studies; e.g., Gursel et al., 2006), followed by multiple baseline designs (two studies; e.g., Ramirez et al., 2014). In the investigations that involved a comparison of the simultaneous prompting procedure to another procedure, either an alternating treatments design (one study; Ackerlund Brandt et al., 2016) or a parallel treatments design (two studies; e.g., Leaf et al., 2010) was used.

Independent variable reliability was reported in all of the investigations and averaged 80% or higher in each (e.g., Birkan, 2005). Likewise, dependent variable reliability was reported in all of the investigations and averaged 80% or higher in each (e.g., Ramirez et al., 2014).

Replications of Effect/Percentage of Non-Overlapping Data (PND)

Across all 15 studies, 28 of 35 participants for whom a math task was a targeted learning outcome were reported to have met the criterion for mastery that had been established for all of their tasks. Regarding the other 7 participants who were not reported as having met their criterion for mastery for all of their tasks, each participant was reported to have met their mastery criterion for some of the tasks and/or have demonstrated progress towards mastery of a task after implementation of the simultaneous prompting procedure (e.g., Creech-Galloway et al., 2013).

A total of 43 demonstrations of effect were reported across 28 participants in the fourteen studies from which this information could be obtained. An effect was defined as a stable or contra-therapeutic data trend in the baseline phase followed by an increased level of performance during the intervention phase - when simultaneous prompting was used to teach a targeted math skill - with the PND equaling or exceeding 50%.

Overall, the average percentage of all non-overlapping data across studies was 88%, with a range of 41%-100%. Based on guidelines cited in Tekin-Iftar et al. (2019) as reported by Scruggs and Mastropieri (2001), studies that reported PND scores at or above 90% were noted to be "very effective," between 70%-90% "effective," and between 50%-70% "questionable." Nine studies reported an average PND of 90% or greater (e.g., Karl et al., 2013), three studies 70%-90% (e.g., Fickel et al., 1998), and two studies 50%-70% (e.g., Ackerlund Brandt et al., 2016).

Maintenance and Generalization

Maintenance data were reported in 11 of the 15 studies (e.g., Birkan, 2005) while generalization data were reported in 10 of the 15 studies (e.g., Fickel et al., 1998). While the data were highly variable across studies and participants, most of the data indicated that the use of the simultaneous prompting procedure to teach a math skill resulted in some measure of maintenance or generalization.

DISCUSSION

A promising practice has been defined as one that has some evidence supporting its use and, for various reasons, is awaiting a rigorous, evidence-based review for the purpose of determining whether it meets criteria to be characterized as an evidence-based practice (The IRIS Center, 2006a). Hence, considering the number of studies examined in this report, and the total number of demonstrations of effect in these studies, arguably simultaneous prompting can be characterized as a promising practice for teaching math content to students with disabilities. This finding is relevant to both teachers and researchers. Given this circumstance, the remainder of this discussion focuses on implications for these two groups.

The value of this review to teachers is that it presents a number of investigations they can reference for ideas regarding how to use simultaneous prompting to teach math content to students with disabilities – even when only one student among a group of students needs to learn math content. Thus, this review can serve to heighten teachers' awareness about how the procedure has been – and potentially can be – used to present effective math instruction to these students. Similarly, there is some evidence that the same can be said with respect to students without disabilities who are exhibiting academic achievement deficits and, therefore, may be receiving services in a school's multi-tiered systems of support (MTSS) framework that is one part of the school's special education eligibility determination process (see Drevon & Reynolds, 2018). Altogether, the 15 reviewed investigations are broad based in the sense that they have been conducted across all K-12 grade levels and settings, and have addressed declarative and procedural knowledge (or discrete and chained tasks) that is at the heart of math calculation skills.

Yet, this review also identified ways in which the existing research pertaining to the use of simultaneous prompting to teach math content lacks guidance for a teacher's application of the procedure. These ways include (a) extremely limited evidence for generalizability across participants based on demographic characteristics, (b) few participants diagnosed with high incidence disabilities (e.g., a specific learning disability or emotional/behavioral disorder), (c) few studies that employed a group arrangement, and (d) use of the procedure in a general education classroom in a way that did not show it to be seamlessly integrated into ongoing routines and activities. Overall, existing data mostly supports the use of simultaneous prompting to teach math

content to students with moderate or mild intellectual disabilities or autism while in a resource or self-contained classroom.

Researchers need to extend the work that has been conducted to date in a number of ways. Additional studies will add to the relatively small number of participants who were involved in the existing studies – some of which taught a targeted math learning outcome to only one participant. Importantly, future investigations need to include diverse groups of participants and report key demographic data (e.g., race, ethnicity) so that the generalizability of the results is more certain. Other, similar diversity issues needing to be addressed include the use of the procedure with more females, preschool-age students, and students who manifest high incidence disabilities (e.g., a specific learning disability or an emotional or behavioral disorder). This research also should be extended to students without IEPs so that information can be obtained that would be relevant to general education teachers and persons involved in MTSS protocols which have, as one component, the special education eligibility determination process.

Attention also needs to be paid to the instructional arrangement, or pupil:teacher ratio, that is employed. Researchers need to be clear about the focus of their study, which most likely will employ a single subject research design due to both the research questions posed and the nature of the participants (i.e., the manifestation of their disabilities), since the focus is a key determinant in the justification of the instructional arrangement utilized. When a study's focus of an investigation is solely on the effectiveness or efficiency of simultaneous prompting, or the relevance of its various parameters, then a 1:1 arrangement is clearly justifiable. However, if the focus is on demonstrating how the procedure can be used in most school arrangements, then a pupil:teacher ratio representative of some type of group instruction should be used. The results of this review mirror that of others which revealed that little is known about the use of simultaneous prompting in small group arrangements (Morse, 2022).

Noteworthy across the studies is the fact that they addressed math content that involves declarative knowledge (i.e., discrete tasks) and procedural algorithms (i.e., chained tasks). Researchers should continue to address both types of these core math calculation tasks. However, future research also needs to address the use of simultaneous prompting to teach math reasoning tasks, such as solving word problems.

Research that extends beyond measures of the effectiveness of simultaneous prompting in teaching math content and focuses on measures of instructional efficiency are also warranted. Reasons include (a) an existing evidence base in support of measuring certain types of instructional efficiency with respect to response prompting strategies (i.e., instructive feedback; see Albarran & Sandbank, 2019); (b) the limited time available to some teachers for the presentation of remedial instruction whose purpose is to decrease, or completely eliminate, a student's academic achievement deficit (Weingarten et al., 2019); and, (c) the practical requirement to present

instruction to small groups, which allows for measuring observational and incidental learning. One topic of interest would be to extend the work of Jimenez and Saunders (2019) by studying whether, and how, a student becomes more efficient with the use of a procedural algorithm.

As was mentioned previously, and has been discussed in the literature for the past 25 years (Wolery & Schuster, 1997), investigations of the various parameters of simultaneous prompting are merited. A starting point with respect to using simultaneous prompting to teach math content is documenting procedural fidelity. In particular, researchers need to consistently validate the use of a controlling prompt during intervention sessions by collecting and reporting data that documents low error rates across participants (Morse, 2022; Morse, 2004). Another example of a parameter to manipulate is whether the conduct of probe sessions on a less frequent basis in a general education classroom still results in effective instruction. This parameter is worthy of investigation since daily assessments of student progress likely are not a component of most ongoing routines in general education classrooms – or most any classroom.

Overall, the design and conduct of future studies that employ a single subject research design needs to address as many of the current recommended quality indicators (see Kratochwill, et al., 2013) as possible so that, when the research is the subject of a meta-analysis, a valid conclusion can be reached regarding whether simultaneous prompting is an evidence-based practice for teaching math content to students with disabilities. The existing evidence, which is limited in this regard, is the only evidence available for examination, thereby allowing for the type of review and analysis that is the focus of this manuscript. However, this evidence establishes a foundation for additional work that could lead to a more robust conclusion.

This call for adherence to as many quality indicators as possible accounts for the fact that, in some instances, practical and ethical considerations will supersede adherence to the recommended quality indicators. For instance, when students with moderate or more significant disabilities are participants, the collection of at least five data points in each condition of a single subject research design might not be warranted because (a) one or more students display challenging behaviors after repeated experiences with failure and (b) it is unethical to withhold treatment in the case of someone who displays a noteworthy academic achievement gap and, therefore, needs to be provided as much instruction as is possible in the time-limited parameters of the school day and school year. Conversely, systematic manipulation of the treatment and the collection of independent and dependent variable reliability data must always occur. Likewise, maintenance and generalization data should be collected.

CONCLUSION

This review informs teachers about the use of simultaneous prompting to present math instruction to students with disabilities. Likewise, the information presented herein provides a foundation to

justify additional research on this topic. Noteworthy for both teachers and researchers is the fact that instructional trials predicated on simultaneous prompting can consist of the key elements of explicit, direct instruction that have been shown to be strongly correlated to effective instruction for students with disabilities (Archer & Hughes, 2011). These elements include teacher modeling, guided practice, multiple opportunities for student responding, active student responding, the provision of immediate feedback consisting of appropriate response contingencies, and a relatively fast pace of instruction. Furthermore, simultaneous prompting's probe trials function as one type of retrieval practice, which solidifies students' retention, retrieval, and generalization of acquired content (Morano, 2019). Finally, a primary reason why simultaneous prompting may be appealing to both teachers and researchers is that its basic structure presents a clear path for investigation and implementation while also establishing the occasion for the creation of a more complex, yet efficient, instructional strategy.

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Table 1

Authors	Participant Characteristics				Setting (Pupil:Teacher Ratio)	Targeted Learning Outcome (Chained or Discrete)
	Age	Gender	Disability	Race		
Ackerlund-Brandt et al. (2016)	6 years old	1 male	Autism	Not reported	University-based clinic and home (1:1)	Expressive addition - Three basic addition facts (Discrete)
Akmangolu & Batu (2004)	6, 12, and 17 years old	1 female, 2 males	Autism and Autism plus Intellectual Disability	Not reported	Classrooms at segregated facilities (1:1)	Numeral identification (Discrete)
Birkan (2005)	6 years, 4 months and 13 years, 8 months old	1 female, 1 male	Intellectual disability	Not reported	Room at a university-based research institute (1:1)	Numeral identification plus Stating time on a clock (Discrete)
Celik & Vuran (2014)	5, 6, 6, and 7 years old	1 female, 3 males	Intellectual disability	Not reported	Room in a private education center (1:1)	Length and quantity (Discrete)
Coleman et al. (2015)	7, 7, and 8 years old	1 female, 2 males	Hearing impairment	Not reported	Second grade classroom of a residential facility (1:1)	Define math vocabulary by signing the

						definition (Discrete)
Creech-Galloway et al. (2013)	15-17 years old	1 female, 3 males	Intellectual disability	Not reported	Self-contained classroom (1:1)	Pythagorean theorem (Chained)
Fickel et al. (1998)	15 years old	1 male	Intellectual disability	Not reported	Room located off a self-contained classroom (4:1)	Basic addition facts (Discrete)
Gursel et al. (2006)	12 years, 2 months old	1 male	Intellectual disability	Not reported	Classroom in a public school for students with developmental disabilities (5:1 with embedded dyads)	Expressively identify math symbols (Discrete)
Heinrich et al. (2016)	17 years old	1 female	Intellectual disability	Not reported	General education classroom (1:1)	Identify geometric figures (Discrete) and Solve a linear equation with one variable (Chained)
Jimenez & Saunders (2019)	8, 10, and 12 years old	1 female, 2 males	Intellectual disability	1 African-American, 2 Caucasian	Separate classroom within a public school (1:1)	Subitizing (Discrete) and addition problem solving speed (Chained)
Karl et al. (2013)	15, 15, 16, and 18 years old	1 female, 3 males	Intellectual disability	Not reported	Resource room (4:1)	Computing percentages in an applied problem (Chained)

Leaf et al. (2010)	5 years old	1 male	Autism	Not reported	Small research room (1:1)	Identification of correct sum for an addition fact (Discrete)
Ramirez et al. (2014)	12, 12, and 14 years old	3 males	Autism	Not reported	Self-contained classroom (1:1)	Calculate elapsed time (Chained)
Rao & Kane (2009)	Ages not provided – Two "middle school students"	1 female, 1 male	Intellectual disability	Not reported	Self-contained classroom (1:1)	Decimal subtraction with regrouping (Chained)
Rao & Mallow (2009)	Ages not provided – "7th and 8th grade"	1 female, 1 male	Intellectual disability	Not reported	Self-contained classroom (1:1)	Stating the answers to multiplication facts (Discrete)

Participant Characteristics, Settings, and Targeted Learning Outcomes

Table 2

Authors	Research Design	IV Reliability	DV Reliability	Demonstrations of Effect/PND Range	Maintenance	Generalization
Ackerlund-Brandt et al. (2016)	Alternating treatments	Yes	Yes	1/63%	No	No
Akmangolu & Batu (2004)	Multiple probe	Yes	Yes	4/50-88%	Yes	Yes
Birkan (2005)	Multiple probe	Yes	Yes	6/60-91%	Yes	Yes
Celik & Vuran (2014)	Parallel treatments	Yes	Yes	3/75-100%	Yes	No

Coleman et al. (2015)	Multiple probe across behaviors with an embedded alternating treatments design	Yes	Yes	5/91-100%	No	No
Creech-Galloway et al. (2013)	Multiple probe	Yes	Yes	3/100%	Yes	Yes
Fickel et al. (1998)	Multiple probe	Yes	Yes	3/80-92%	Yes	Yes
Gursel et al. (2006)	Multiple probe	Yes	Yes	3/100%	Yes	Yes
Heinrich et al. (2016)	Multiple probe	Yes	Yes	2/60-100%	Yes	Yes
Jimenez & Saunders (2019)	Multiple probe	Yes	Yes	1/100%	No	No
Karl et al. (2013)	Multiple probe	Yes	Yes	4/100%	Yes	Yes
Leaf et al. (2010)	Parallel treatments design	Yes	Yes	Could not be determined	Yes	No
Ramirez et al. (2014)	Multiple baseline	Yes	Yes	6/83-100%	No	Yes
Rao & Kane (2009)	Multiple baseline	Yes	Yes	1/77%	Yes	Yes
Rao & Mallow (2009)	Multiple probe	Yes	Yes	1/100%	Yes	Yes

Research Design, Reliability, Demonstrations of Effect/PND, Maintenance, and Generalization

Note. IV/DV Reliability: Yes means these data were reported in the study and the mean across sessions was 80% or higher whereas No means these data were not reported in the study; Demonstrations of Effect/PND Range: A demonstration of effect was recorded for each instance when a participant's baseline data were stable or demonstrated a contra-therapeutic data trend and the corresponding intervention phase data demonstrated an increased level and/or therapeutic trend, with the percentage of non-overlapping data (PND) equaling or exceeding 50%. The range

of these data across the total number of demonstrations of effect for each study are reported in the table. This range differs from the averages reported in the manuscript.; Maintenance/Generalization: Yes means these data were reported in the study while No means these data were not reported; Maintenance and generalization results were variable across studies.