Perspectives on Behavior Science (2020) 43:387–413
https://doi.org/10.1007/s40614-020-00243-1

ORIGINAL RESEARCH

Systematic Review of Verbal Operants in Speech Generating Device Research from Skinner's Analysis of Verbal Behavior

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Published online: 25 March 2020

Abstract

Skinner's (1957) book *Verbal Behavior* is a critical tool in designing effective communication programs for individuals with limited speech. The purpose of this systematic review was to analyze the speech generating device (SGD) research literature from Skinner's taxonomy of primary verbal operants. An extraction procedure yielded 56 studies published between 1995 and 2018, with a total of 221 participants, most of whom had autism spectrum disorder (ASD) or an intellectual and developmental disability (IDD). The large majority of SGD studies (42) targeted multiply controlled mands, whereas only a handful of studies targeted verbal operants that were not mands. Few studies employed procedures for fading contrived sources of stimulus control to promote spontaneous responding, and few studies targeted more sophisticated, topography-based responses (e.g., typing, speech). Results of the review highlight the need for better dissemination of Skinner's *Verbal Behavior*, the need for research to evaluate effects of SGD in teaching a greater variety of spontaneous verbal operants, and the need to focus on application of SGD with populations beyond individuals with ASD and IDD.

Keywords Augmentative and alternative communication · Speech generating device · Verbal behavior · B. F. Skinner · Autism spectrum disorder · Intellectual and developmental disability · Applied behavior analysis

The use of speech-generating devices (SGD) as augmentative and alternative communication (AAC) systems for individuals with disabilities has become common practice

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in educational and clinical settings (McNaughton & Light, 2013). Although SGD are applicable for populations beyond individuals with autism spectrum disorder (ASD; e.g., cerebral palsy, dementia, and traumatic brain injury; Brunner, Hemsley, Togher, & Palmer, 2017), their use in ASD intervention has and continues to receive considerable attention in the literature (Ganz et al., 2017; Lorah, Parnell, Whitby, & Hantula, 2015; Muharib & Alzrayer, 2018). It has been estimated that 30% of individuals with ASD do not acquire functional speech capabilities (Wodka, Mathy, & Kalb, 2013). This highlights the necessity of developing strategies to increase the verbal repertoires of individuals lacking speech by using AAC, including SGD.

Skinner's (1957) book *Verbal Behavior* presents a comprehensive, behaviorally based account of what we commonly call language. Researchers and clinicians have applied Skinner's approach to successfully teach individuals with limited communication abilities, including those with ASD (Sautter & LeBlanc, 2006; Sundberg & Michael, 2001) and, in particular, users of AAC (Sulzer-Azaroff, Hoffman, Horton, Bondy, & Frost, 2009). Within Skinner's taxonomy, the fundamental unit of verbal behavior is the verbal operant (VO). Skinner defined primary VOs according to their differing sources of antecedent and consequent control. According to Skinner's definition as outlined in *Verbal Behavior*, the mand is the only primary VO that directly benefits the speaker. The mand is controlled by relevant conditions of deprivation or aversive stimulation, referred to as motivating operations (MOs; Laraway, Snycerski, Michael, & Poling, 2003), and is reinforced by a characteristic consequence, with the response specifying its reinforcer. For example, when food deprivation acts as a MO, it increases the reinforcing value of food, and increases the likelihood of mands for food (e.g., "I'm hungry").

Skinner defined the remaining primary VOs in terms of their sources of antecedent control and reinforcement. The tact is occasioned by an object or event, or property of an object or event, and is reinforced by generalized conditioned reinforcement. For instance, in the presence of a ball (S^D), a child says, "ball," or in the presence of a red ball, the child says "red." Generalized conditioned reinforcement from a listener maintains the tact (e.g., "Yes, that is a red ball."). The echoic is occasioned by a prior verbal stimulus, with the response bearing point-to-point correspondence and formal similarity with the prior verbal stimulus (e.g., in response to a friend who says, "Hi," a child says, "Hi"). The intraverbal is also occasioned by a prior verbal stimulus; however, the response does not bear point-to-point correspondence with the prior verbal stimulus. For instance, in response to a friend who says, "Hi," a child says, "How are you?" Other primary VOs include the textual, which is occasioned by a prior written verbal stimulus in which the response bears point-to-point correspondence with the stimulus, but lacks formal similarity (e.g., reading a book out loud), and taking dictation, which is occasioned by a prior spoken verbal stimulus in which the response bears point-to-point correspondence with the stimulus, but lacks formal similarity (e.g., writing verbatim notes from a lecture). Like the tact, the echoic, intraverbal, textual, and taking dictation are maintained by generalized conditioned reinforcement.

Skinner's analysis provides considerations relevant to those choosing to use AAC, including SGD, when teaching functional communication to individuals. First, Skinner describes a variety of controlling variables that comprise a sophisticated repertoire of verbal behavior, which includes mands, tacts, intraverbals, echoics, and the other primary VOs. Thus, Skinner's taxonomy highlights the importance of SGD training

programs that target a variety of primary VOs to promote a diverse repertoire of functional communication. Although the importance of mand training to help AAC users meet their most basic communication needs and reduce their challenging behavior is apparent (Heath, Ganz, Parker, Burke, & Ninci, 2015; Lorah et al., 2015), other primary VOs play a critical role in functional communication as well. Beginning in preschool and continuing through college, individuals with communication impairments benefit from explicit instruction in conversational skills to succeed socially (e.g., Gunning, Breathnach, Holloway, McTiernan, & Malone, 2019; Ishikawa, Omori, & Yamamoto, 2019; Mann & Karsten, 2020). For example, typical conversational exchanges involve statements in relation to current and past events (e.g., "That was a great football game on Sunday"; tact), imitating others' verbal responses (e.g., "Would you like some *raspberries?*" "*Raspberries?* Those are delicious"; echoic), and responses to others' conversational initiations (e.g., "Would you like to play with me?" "Sure."; intraverbal). Therefore, SGD interventions should seek to teach not just mands, but also tacts, echoics, and intraverbals, in promoting comprehensive functional communication.

Second, in Chapter 9 of *Verbal Behavior*, Skinner emphasized that most VOs are under the control of more than one variable (i.e., multiple control). That is, any given verbal response may be occasioned by more than one prior stimulus or a combination of prior stimuli and MOs. For instance, when a child is in a restaurant, is deprived of food (MO), and is presented with a menu, the odor of food, and a server holding a pad of paper and a pen who says, "What would you like?," he may emit the multiply controlled response, "I would like the chili." The resulting VO is partly a mand, tact, and an intraverbal, given that it is strengthened by food deprivation (MO/mand), a menu, the odor of food, a server with a pad and pen (tact), and a prior verbal stimulus in the form of a question (intraverbal). Convergent VOs are those in which multiple sources of control converge on a single verbal response in the manner described above (Michael, Palmer, & Sundberg, 2011). In contrast, according to Michael et al., divergent VOs occur when a particular variable occasions different topographies of a response. For example, a picture of a man may occasion the responses "man," "guy," "dude," "handsome," "tall," and so on.

Understanding variables that control convergent and divergent VOs is essential in teaching these responses to individuals with limited speech (DeSouza, Fisher, & Rodriguez, 2019; Michael et al., 2011; Tincani, Bondy, & Frost, 2004). A particular topography of response acquired under one set of variables will not necessarily occur under the presence of a different set of variables, unless explicitly taught. For example, if a child learns to emit the response "ball" in the presence of a ball and the question "What is it?" (tact—intraverbal), the child may not emit the response "ball" in the presence of the ball by itself (tact), unless the question is also presented. Likewise, if the child learns to emit the mand "Cookie" only in the presence of a cookie plus the prior verbal stimulus, "What do you want?," he may not say, "Cookie" unless someone first says, "What do you want?" There is empirical evidence that many learned VOs are functionally independent in this manner (Lamarre & Holland, 1985; Kelley, Shillingsburg, Castro, Addison, & LaRue, 2007; Twyman, 1996).

Children with ASD and intellectual and developmental disabilities (IDD) have particular difficulties generalizing verbal response topographies across varying MOs and stimulus conditions (Ploog, 2010). Therefore, designers of verbal behavior training

programs have explicitly taught VOs in consideration of these varying conditions, with procedures for transferring stimulus control between operants and fading contrived sources of stimulus control in order to create spontaneous responding (e.g., Sundberg & Partington, 1998; Sulzer-Azaroff et al., 2009).

Given that individuals who use SGD to communicate may initially require contrived prompts and MOs in order to acquire functional verbal behavior, it is critical for instructors to fade these stimuli to promote spontaneous responding (Tincani et al., 2004). For example, instructors may employ prior verbal stimuli to increase the likelihood of mands, such as enticing individuals with prompts like, "What do you want?" However, if these verbal prompts are not faded, or avoided altogether, then individuals may not mand spontaneously in the absence of such statements, even when MOs are sufficiently strong. Although some AAC programs have been designed to teach spontaneous verbal behavior in this manner (e.g., Frost & Bondy, 2002), the extent to which SGD instructional programs have targeted spontaneous VOs in consideration of these variables remains unclear.

In addition, to extend Skinner's analysis in *Verbal Behavior*, Michael (1985) introduced the concepts of selection-based and topography-based verbal behavior. Selection-based VOs are those in which the response form is always the same and involve the speaker selecting an appropriate stimulus from an array, such as when an SGD user selects and presses the appropriate symbol to mand for a preferred item from an array of preferred item picture symbols on an SGD screen (Kagohara et al., 2010). In contrast, topography-based VOs are those in which the response form is different for each response, as in vocal verbal behavior and sign language. Given that sophisticated communicators engage almost entirely in topography-based verbal behavior, one goal of communication training programs is to establish topography-based VOs. Although modern SGD devices are equipped with both selection-based and topography-based communication capabilities—users may either select picture symbols (e.g., Kagohara et al.) or type messages (e.g., Carnett & Invarsson, 2016)—unclear is the extent to which SGD devices have been used to establish more sophisticated topography-based VOs within the research literature.

Systematic reviews have supported the efficacy of SGD to teach communication to individuals with limited speech abilities (e.g., Ganz et al., 2017; Muharib & Alzrayer, 2018); however, no reviews to date have precisely analyzed VOs targeted in the studies from the perspective of Skinner's analysis of verbal behavior. Van der Meer and Rispoli (2010) conducted a systematic literature review to assess variables related to SGD acquisition among users with ASD, including devices used, teaching strategies, modes of communication, and outcomes. They found that the large majority of studies reported positive outcomes for SGD users, and that over half of studies taught participants some type of requesting as the primary communication skill, followed by a smaller percentage of studies teaching conversation and social commenting as the primary communication skill. Although the review provides generalized descriptions of the communication skills taught in the studies, it does not identify the specific verbal operants taught (e.g., pure mands, mand-tacts, mand-tact-intraverbals), the sources of controlling variables for communicative responses, or whether stimulus control or motivational procedures were employed to promote spontaneous responding. Given the date of the review (2010), commonly used contemporary high-tech

SGD devices (e.g., iPad with SGD applications) were not evaluated, nor was it reported whether users acquired topography-based responses.

Lorah et al. (2015) subsequently conducted a systematic review of contemporary high tech devices—tablet computers (i.e., Apple iPad) and media devices (i.e., Apple iPod)—to teach communication to individuals with ASD. They reported positive results for acquisition of communicative responses for all 17 studies in their review, the majority of which targeted some kind of mand. Although this review delineated the communication skills taught from Skinner's general framework (i.e., manding or requesting versus tacting or labeling), it did not delineate the specific VOs taught from Skinner's taxonomy, whether convergent or divergent VOs were taught, whether selection-based or topography-based VOs were taught, or whether stimulus control and motivational procedures were employed to establish spontaneous or naturalistic responding. However, the authors noted the need for future research focused on communicative functions besides the mand.

Gilroy, McCleary, and Leader (2017) conducted a systematic review to evaluate the extent to which published SGD studies targeted the same communication skills as targeted in phases one through six of the Picture Exchange Communication System (PECS; Frost & Bondy, 2002). PECS is a system of AAC based, in part, on Skinner's analysis in *Verbal Behavior*, that seeks to establish increasingly complex VOs through picture exchange. The system is comprised of six phases. Phase I seeks to teach the learner to exchange a picture symbol in exchange for a preferred item from a listener (i.e., mand). Phase II targets distance and persistence, teaching the learner to travel varying distances to a communication book and to a communication partner. Phase III employs stimulus discrimination procedures to teach the learner to select the appropriate picture symbol from an array, whereas Phase IV targets assembly of a multiword sentence strip (i.e., "I want _____.") as the learner mands. In Phase V, the learner is taught to respond to others' questions (i.e., "What do you want?"), and in Phase VI, the learner is taught to comment on the environment by answering questions (e.g., "What do you see?" "What do you have?" "What do you hear?" and "What is it?").

Unlike previous reviews of SGD, Gilroy et al.'s review is noteworthy for its extensive focus on the communicative skills taught within SGD studies, in particular in relation to the PECS system, which has strong empirical support (Ganz et al., 2012). Similar to Lorah et al. (2015), Gilroy et al. (2017) reported that SGD studies tended to focus on mands targeted in the earlier phases of PECS, to the exclusion of more advanced forms of verbal behavior targeted in the latter phases of PECS. Therefore, although it is apparent that these devices are useful in teaching basic functional communication in the form of mands, their findings highlight that less in known about the extent to which SGD can be used to teach other VOs as targeted in PECS. Although these findings are important, they are limited in a few critical ways. First, although PECS is strongly influenced by Skinner's *Verbal Behavior*, the system focuses on a specific subset of convergent VOs (see Bondy et al., 2004), and does not teach the full span of VOs necessary for comprehensive functional and social communication, including pure intraverbals and pure tacts. In addition, although PECS has strong empirical support generally, studies have been variable with regard to the number of phases evaluated (Flippin, Reszka, & Watson, 2010). Ganz et al. (2012) reported that only two studies in their systematic review of PECS evaluated whether all six phases of the system were effective. Thus, in comparing the six phases of PECS to research on

SGD, results of Gilroy et al. (2017) leave open the question of whether research has substantiated use of SGD in teaching other important VOs delineated in Skinner's analysis. Moreover, as PECS is a selection-based system that focuses primarily on teaching picture exchange—phases I through IV of PECS exclusively target picture exchange in the form of multiply controlled mands—a comparison of SGD research against the PECS system does not provide information with regard to SGD users' acquisition of more advanced topography-based responses.

Skinner's (1957) *Verbal Behavior* is an important conceptual tool in designing effective verbal behavior programs for individuals who use AAC and SGD. Systematic reviews of SGD research highlight that these devices are effective in teaching basic functional communication to individuals with limited speech abilities (e.g., Muharib & Alzrayer, 2018). However, no systematic review to date has precisely evaluated whether all primary VOs described in Skinner's *Verbal Behavior* have been targeted within the published SGD research literature. Also unknown is the degree to which more sophisticated topography-based responses (i.e., speech, typing) and divergent VOs have been established with these devices. Finally, the extent to which researchers have employed motivational and stimulus control procedures to establish spontaneous VOs in the absence of contrived instructor prompts is unclear. Given these issues, the purpose of this systematic review was to evaluate the VOs targeted for acquisition within the published SGD research from the perspective of Skinner's (1957) *Verbal Behavior*.

Method

This systematic review identified peer-reviewed studies that evaluated the use of SGD with touchscreens to teach one or more VOs. We used the same extraction procedures described in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Moher Liberati, Tetzlaff, Altman, & the PRISMA Group, 2009). Following extraction, the resulting articles were coded according to the article coding categories described in the following section.

Inclusion Criteria

In order to be included in the systematic review, a study must have used an SGD with a touchscreen and must have sought to teach one or more VOs with the device. The study could have targeted other types of communication (e.g., picture exchange, speech) as long as at least one participant was exposed SGD intervention to teach at least one VO. The VO could be of any topography (e.g., selection-based/SGD, speech), as long the study sought to employ the SGD to teach verbal behavior. The device could have used a digitized touch screen (e.g., tablet computer) or overlay. Both group and single-subject studies were included. Single-subject studies must have had at least one baseline (1) and one intervention (2) phase, whereas group studies must have included at least one group receiving the intervention with at least one measurement without intervention and at least one measurement with intervention. All studies that fit these criteria were included, regardless of year of publication.

Search Strategy

The article extraction occurred in January through March 2018. First, ERIC, Google Scholar, PsycINFO, and Science Direct databases were searched online, using combinations of the following search terms with Boolean operators and truncation: communication, speech generating device, voice output, multimedia device, handheld computer, training, autism, and disability. The selection of search terms, including broad terms such as communication and disability, was intended to yield as many relevant results as possible. All search results were screened when feasible, but for combinations that returned several hundreds or thousands of results, the top 100 results were screened. This decision was made because the results after the first few dozen were rarely relevant.

Following this search, indexes of the eight journals with the highest number of relevant articles were searched for any additional relevant articles, including in-press articles. These journals were *Analysis of Verbal Behavior, Augmentative and Alternative Communication, Journal of Development and Physical Disabilities, Journal of Applied Behavior Analysis, Research in Autism Spectrum Disorders, Developmental Neurorehabilitation, Focus on Autism and Other Developmental Disabilities*, and *Research in Developmental Disabilities*.

The abstracts of these articles were then screened using the determined inclusion criteria. Following exclusion of articles when it was clear by their abstracts that they did not meet the established criteria, the remaining studies were divided into two batches, which were each read and screened by two authors. For each study, two authors separately decided whether it met inclusion criteria, and then compared results. Interobserver agreement was 100%.

Article Coding

In addition to citation and year of publication, the extracted articles were coded according to the dependent variable categories below (article coding form is available at https://osf.io/5zcwv/). As with the extraction procedure, the articles were divided into two batches; each batch was assigned to two of the authors. The two authors separately coded each article in their batch. Then, the two authors compared the coding and resolved any disagreements until interobserver agreement was 100% for each coding category. In cases where there was insufficient information provided by the authors to determine information for a particular category, that category was coded as unspecified.

Design We coded whether the article evaluated an SGD intervention in a single-subject or group design. To count as a single-subject design, the study must have employed at least an A-B design with repeated measures. To count as a group design, the study must have included at least one group receiving the intervention with at least one measurement without intervention, and at least one measurement with intervention.

Authors' Dependent Variable Definition This was the authors' definition of the dependent variable(s) as they reported in their study.

Verbal Operants Targeted for Acquisition We evaluated and coded each targeted primary VO in the study based on the author's description of the response(s) targeted in the study, including the antecedents and consequences for each response. We coded each VO according to Skinner's taxonomy based on the authors' description of antecedents and consequences regardless of whether the authors used Skinner's terminology to describe their dependent variable(s). We included any verbal behavior measured as a result of SGD intervention regardless of form, including SGD responses, but also vocal behavior. We coded the target verbal operants targeted in each study excluding any prompts that were faded during intervention. We coded multiply controlled/convergent VOs, as appropriate. For example, if the experimenters sought to teach individuals to mand for preferred items in the presence of the items only, then we scored the verbal operant as a mand-tact. We coded the following verbal operants:

Mands VO under the control of a motivating operation; response specifies its reinforcer (e.g., child says, types, or selects a symbol for "ball," and teacher gives a ball).

Tacts VO in response to a prior nonverbal stimulus (e.g., child says, types, or selects symbol for "ball" when presented with a ball); educational or generalized conditioned reinforcement.

Intraverbals VO in response to a prior verbal stimulus in which the response does not bear point-to-point correspondence with the prior verbal stimulus (e.g., child says, types, or selects a symbol for "ball" in response to a therapist who asks, "What is it ?"); educational or generalized conditioned reinforcement.

Echoics VO in response to a prior verbal stimulus in which response bears point-to-point correspondence and formal similarity with the prior verbal stimulus (e.g., child vocally says "ball" in response to interventionist who says, "ball"); educational or generalized conditioned reinforcement.

Textuals VO in response to a prior textual verbal stimulus with point-to-point correspondence, but no formal similarity (e.g., in response to typed word "ball," child vocally says, "ball"); educational or generalized conditioned reinforcement.

Transcription VO in response to a prior spoken verbal stimulus with point-to-point correspondence, but no formal similarity (e.g., child types "ball" in response to spoken word "ball"); educational or generalized conditioned reinforcement.

Convergent and/or Divergent VO A response was scored as convergent if more than one variable controlled a single response. For example, child says, types, or selects a symbol for "cracker," in the presence of cracker, and the teacher gives child cracker (mand-tact). A response was scored as divergent if a single variable controlled more than one response. For example, a child says any approximation of cracker (e.g., "ca," "crack," or "cracker") and receives a cracker (mand).

Topography-based and/or Selection-based VO We recorded whether a targeted VO was topography-based (e.g., spoken or typed) or selection-based (e.g., pressing a word/symbol button on a touch screen).

Antecedent Stimuli Based on the authors' description of the research procedures, we coded the prior stimuli that were present and in view of the participant when the targeted VO was emitted.

Consequent Stimuli Based on the authors' description of research procedures, we coded the consequences provided by the interventionists in response to the targeted VO.

Number of Participants This was the number of participants in the study who received SGD intervention.

Diagnoses We coded any diagnoses of participants reported in the study. In the cases of specific disability categories for which IDD is an inherent feature (e.g., Down syndrome), we coded the disability as IDD.

Device We coded the type of SGD device used, along with any software or apps reported.

Results

Results of the PRISMA search and article extraction are shown in Fig. 1. Of 150 articles identified through initial database searches and targeted journal searches, 60 articles were removed because abstracts indicated that they did not meet the inclusion criteria. Of the remaining 90 articles, following full-text searches, 34 were subsequently screened out for the same reason. The resulting 56 articles were coded for the systematic review. Table 1 shows the coded dependent variables for each of these articles. The extracted data are available at https://osf.io/8hukp/.

All studies that met the established criteria were published in or after 1995. Of the 56 articles published between 1995 and 2018, 54 used single-subject designs, whereas two used group designs. There were a total 221 participants who received SGD intervention across the studies, with 160 participants in the single-subject studies and 61 participants in the group studies. The large majority of studies reported (47) included individuals with ASD as participants, and 19 included individuals with intellectual and developmental disabilities (IDD), 6 included individuals with developmental delay, 4 included individuals with other types of disabilities, and 1 included individuals without a diagnosis, who were identified as typically developing.

Figure 2 shows the cumulative number of articles published per year by VOs targeted. The VOs targeted in each study are shown in Table 1. As Fig. 2 indicates, the number of SGD articles teaching any VOs accelerated after 2012. This increase in the number of SGD articles after 2012 coincides with introduction and subsequent dissemination of Apple's iPad in 2010. After 2012, 39 studies reported using an iPad or

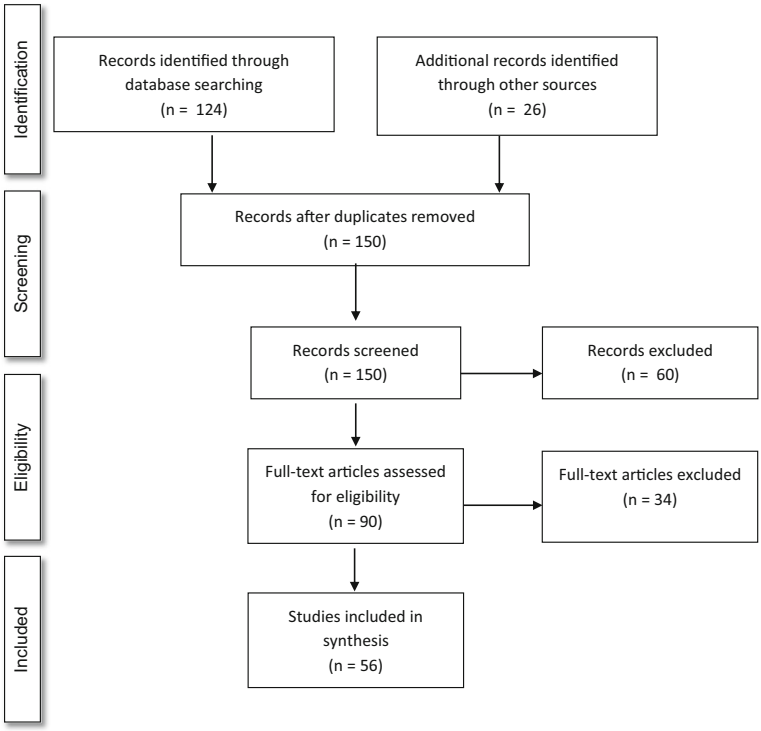

Fig. 1. Results of the article extraction procedure

iPod-based SGD, whereas only 8 studies published during this time period reported using a non-Apple-based SGD.

As Fig. 2 reflects, the large majority of studies (42) reported teaching some type of multiply controlled mand, whereas 9 reported teaching tact-intraverbals, and 4 reported teaching pure intraverbals. Further breakdown of VOs targeted in the studies is shown in Fig. 3. Of the 42 studies that reported teaching a multiply controlled mand, 18 of the VOs targeted were mand-tacts, 24 were mand-tact-intraverbals, and 1 was a mand-tact-echoic. Mands were always taught in the presence of one or more items in view, and in more than half the cases, some type of prior verbal stimulus was used to evoke the mand (e.g., "Let me know if you want something."). Two studies reported targeting some type of VO; however, insufficient information was provided about antecedents and consequences to determine which type of VO was taught, so these were scored as unspecified. Only four studies reported employing stimulus control and reinforcement procedures to teach more than one type of VO within the same study (see Table 2).

Figure 2 highlights that authors described their dependent variables in a variety of different ways. However, only 10 of 56 articles used Skinner's terminology to describe the dependent variables. None of the 10 articles using Skinner's terminology identified the dependent variable as a multiply controlled VO, despite the fact that 9 of the 10 articles targeted a multiply controlled VO. Only one article's description of the dependent variable corresponded with the controlling variables described in the study within Skinner's taxonomy (intraverbal; Lorah, Karnes, & Speight, 2015).

Table 1 SGD Studies and Study Characteristics

Citation	Authors' dependent variable definition	Verbal Operants Targeted	Convergent/ Divergent	Antecedent Stimuli	Consequent Stimuli	N	Diagnoses	Device
van Acker, R. & Grant, S. H. (1995).	Touch screen responses	Mand-tact-intraverbals	Convergent	Preferred item + "Would you like some _____?"	Access to preferred item	3	Rett Syndrome (IDD)	Amiga 500 computer
Drager, K. D., Light, J. C., Carlson, R., D'Silva, K., Larsson, B., Pitkin, L., & Stopper, G. (2004).	Accuracy in locating target vocabulary items	Tact-intraverbals	Convergent	A picture depicting a scene + interventionist questions about the scene	Feedback from a script	30[1]	Typically developing	DynaVox
Bock, S. J., Stoner, J. B., Beck, A. R., Hanley, L., & Prochnow, J. (2005).	Requesting	Mand-tacts	Convergent	Presence of preferred item	Access to preferred item	6	Developmental Delay	Go Talk
Bruno, J. & Trembath, D. (2006).	Syntactic performances - complexity of aided messages composed	Tact-intraverbals	Convergent	Story board + questions from interventionist	Unspecified	9	IDD	DynaMyte, Pathfinder, E-Talk, DynaVox
Olive, M. L., De La Cruz, B., Davis, T. N., Chan, J. M., Lang, R. B., O'Reilly, M. F., & Dickson, S. M. (2007).	Gestures, vocalizations, and VOCA use	Mand-tacts	Convergent	Presence of preferred item	Access to desired outcome/objects, paired with expansion of VOCA recording e.g., "You want more cars?"	3	ASD	Cheap Talk 4 In-Line Direct
Beck, S. J., Stoner, J. B., Bock, S. J., & Parton, T. (2008).	Accessing a picture to produce digitized speech	Mand-tacts	Convergent	Presence of preferred item	Access to preferred item	4	Children attending ASD summer school	Go Talk
Olive, M. L., Russell, B., & Tonya, N. (2008).	Requesting attention	Mand-intraverbals	Convergent	Statement that participant's mother was leaving	Access to mother	1	ASD	Touch Talk Direct

Table 1 (continued)

Citation	Authors' dependent variable definition	Verbal Operants Targeted	Convergent/ Divergent	Antecedent Stimuli	Consequent Stimuli	N	Diagnoses	Device
Johnson, R. K., Hough, M. S., King, K. A., Vos, P., & Jeffs, T. (2009).	Symbol identification; navigation; providing logical answers	Tact-intraverbals	Convergent	Picture + interventionist question, e.g., "What is this a picture of?"	Unspecified	2	Non-fluent aphasiaapraxia of speech, right hemiparesis from left CVA's	Dialect by Zygo with Speaking Dynamically Pro
Banda, D. R., Copple, K. S., Koul, R. K., Sancibrian, S. L., & Bogschutz, R. J. (2010).	Requesting	Mand-tacts	Convergent	Presence of preferred item + playing of a video model to demonstrate skill	Access to preferred item	2	ASD, IDD	Dialect by Zygo with Speaking Dynamically Pro
Choi, H., O'Reilly, M., Sigafoos, J., & Lancioni, G. (2010).	Requesting and rejecting	1. Mand-tact-intraverbals 2. Mand-tact-intraverbals	Convergent	1.Instructions to engage in activity + missing item 2. Activity + wrong missing item + "Is this what you asked for?"	1. Access to missing item 2. Removal of wrong item	4	ASD, IDD	Vantage, Tech Speak, Springboard SGD
DiCarlo, C. F. & Banajee, M. (2000).	Communicative behaviors	Mand-tacts	Convergent	Presence of preferred item	Access to preferred item	2	IDD	Alpha Talker
Kagohara, D. M., van der Meer, L., Achmadi, D., Green, V. A., O'Reilly, M. F., Mulloy, A., ... & Sigafoos, J. (2010).	Requesting	Mand-tact-intraverbals	Convergent	Presence of snack + "Let me know if you want something."	Access to snack	1	ASD, OCD, ADHD	iPod Touch with iMainGo2
Sigafoos, J., Wermink, H., Didden, R., Green, V. A., Schlosser, R. W., O'Reilly, M. F., & Lancioni, G. E. (2011).	Requesting and speech production	Mand-tacts	Convergent & Divergent	Tray of toys + "Let me know if you want to play with a toy?"	Access to toy	1	Klinefelter Syndrome (IDD)	iPad Touch with Proloquo2Go
Trottier, N., Kamp, L., & Mirenda, P. (2011).	Communicative acts	Tact-intraverbals	Convergent & Divergent	Game/activity + prompt from peer, e.g., "Point to 'my turn."	Continued social interaction	2	ASD	Vantage Lite; Springboard Lite

Table 1 (continued)

Citation	Authors' dependent variable definition	Verbal Operants Targeted	Convergent/ Divergent	Antecedent Stimuli	Consequent Stimuli	N	Diagnoses	Device
van der Meer, L., Kagohara, D., Achmadi, D., Green, V. A., Herrington, C., Sigafoos, J., ... & Rispoli, M. (2011).	Requests	Mand-tact-intraverbals	Convergent	Tray of snacks + "Let me know if you want a snack?"	Access to snack	3	ASD, IDD	iPod Touch with Proloquo2Go
Achmadi, D., Kagohara, D. M., van der Meer, L., O'Reilly, M. F., Lancioni, G. E., Sutherland, D., ... & Sigafoos, J. (2012).	Requests	Mand-tact-intraverbals	Convergent	Presence of preferred item + "What do you want?" or similar	Access to preferred item	2	ASD	iPod Touch with Proloquo2Go; MainGo2 speaker
Kagohara, D. M., van der Meer, L., Achmadi, D., Green, V. A., O'Reilly, M. F., Lancioni, G. E., ... & Sigafoos, J. (2012).	Naming pictures by touching icon on SGD	Tact-Intraverbals	Convergent	Presentation of picture, "What do you see?"	Continuation to next picture	2	ASD, IDD, OCD, ADHD	iPod Touch with Proloquo2Go; iPad with Proloquo2Go
van der Meer, L., Sutherland, D., O'Reilly, M. F., Lancioni, G. E., & Sigafoos, J. (2012).	Requests	Mand-tact-intraverbals	Convergent	Tray of preferred items + "Let me know if you want this."	Access to preferred item	4	ASD, IDD, Developmental Delay	iPod Touch and iPad with Proloquo2Go
Boesch, M. C., Wendt, O., Subramanian, A., & Hsu, N. (2013).	Requests	Mand-tacts	Convergent	Presence of preferred item	Access to preferred item	3	ASD	Logan ProxTalker
Dundon, M., McLaughlin, T. F., Neyman, J., & Clark, A. (2013).	Requests	Mand-tact-intraverbals	Convergent	Presence of preferred item + "What do you want?"	Access to preferred item	1	ASD, Developmental Delay	iPad Choice Board and Go Talk Now Free
Sigafoos, J., Lancioni, G. E., O'Reilly, M. F., Achmadi, D., Stevens,	Requests	Mand-tact-intraverbals	Convergent	Interruption of toy play + "My turn now. Let me	Immediately given toy	2	ASD	iPad with Proloquo2Go

Table 1 (continued)

Citation	Authors' dependent variable definition	Verbal Operants Targeted	Convergent/ Divergent	Antecedent Stimuli	Consequent Stimuli	N	Diagnoses	Device
M., Roche, L., ... & Marschik, P. B. (2013).				know if you want to play with the toy?"				
Strasberger, Sean. (2013).	Mands	Mand-tacts	Convergent	Presence of preferred item	Access to preferred item	4	ASD	iPod Touch with Proloquo2Go
van der Meer, L., Kagohara, D., Roche, L., Sutherland, D., Balandin, S., Green, V. A., ... & Sigafoos, J. (2013).	Multistep Requesting	Mand-tacts	Convergent	Presence of preferred item	Access to preferred item	2	ASD, IDD, Developmental Delay	iPod Touch with Proloquo2Go
Ward, M., McLaughlin, T. F., Neyman, J., & Clark, A. (2013).	Requests	Mand-intraverbals	Convergent	Engaging in activity + "What do you want?"	Moving to the next activity	1	ASD	iPad with Go Talk Now Free
Achmadi, D., Sigafoos, J., van der Meer, L., Sutherland, D., Lancioni, G. E., O'Reilly, M. F., ... & Marschik, P. B. (2014).	Requests	Mand-intraverbals	Convergent	Interrupted toy play + "Let me know if you want more."	Access to toy + verbal social reinforcement	4	ASD, Developmental Delay, "High Functioning" ASD	iPad Touch with Proloquo2Go
Couper, L., van der Meer, L., Schäfer, M. C., McKenzie, E., McLay, L., O'Reilly, M. F., ... & Sutherland, D. (2014).	Requests	Mand-tact-intraverbals	Convergent	Removal of preferred item, statement + "Let me know if you want more."	Access to preferred item/activity+ verbal social reinforcement	9	ASD, IDD	iPod Touch or iPad with Proloquo2Go
Gevarter, C., O'Reilly, M. F., Rojeski, L., Sammarco, N., Sigafoos, J., Lancioni, G. E., & Lang, R. (2014).	Mands	Mand-tacts	Convergent	Presence of preferred item	Access to preferred item	3	ASD	iPad with GoTalk and Scene and Heard
Hill, D. A., & Flores, M. M. (2014).	Requests	Mand-tacts	Convergent	Presence of snack	Access to snack	5	ASD, IDD	iPad with Proloquo2Go

Table 1 (continued)

Citation	Authors' dependent variable definition	Verbal Operants Targeted	Convergent/ Divergent	Antecedent Stimuli	Consequent Stimuli	N	Diagnoses	Device
Kasari, C., Kaiser, A., Goods, K., Nietfeld, J., Mathy, P., Landa, R., ... & Almirall, D. (2014).	Spontaneous communicative utterances, which included comments, requests, and protests and excluded scripted and nonsocial utterances.	Unspecified	Unspecified	The interventionist modeled and expanded target language on the SGD in conjunction with spoken language following the modeling and expansion protocols of JASP+EMT; the SGD intervention followed a written protocol	Unspecified	61[2]	ASD	iPad or DynaVox
King, M. L., Takeguchi, K., Barry, S. E., Rehfeldt, R. A., Boyer, V. E., & Mathews, T. L. (2014).	Requests	1. Mand-tacts 2. Mand-tact-intraverbals	Convergent	1. Presence of preferred item 2. Presence of preferred item + "What do you want?"	1. Access to preferred item 2. Same	3	ASD	iPad with Proloquo2Go
Lorah, E. R., Crouser, J., Gilroy, S. P., Tincani, M., & Hantula, D. (2014).	Mands	Mand-tact-intraverbals	Convergent	Presentation of four preferred items + "Pick one."	Access to preferred item	4	ASD	iPad with Proloquo2Go
Lorah, E. R., Parnell, A., & Speight, D. R. (2014).	Tacts	Tact-intraverbals	Convergent	Presentation of one of four stimuli (dog, ball, crayon, or book) + "What do you see?"	Social praise	3	ASD, IDD	iPad with Proloquo2Go
Roche, L., Sigafoos, J., Lancioni, G. E., O'Reilly, M. F., Schlosser, R. W., Stevens, M., ... & Carnett, A. (2014).	Selecting icon to produce speech or saying item name	Mand-tact-intraverbals	Convergent & Divergent	Removal of preferred book or crayon + verbal cue, e.g., "Let me know if you want it back?"	Access to removed preferred item	2	ASD and Developmental Delay	iPad with Proloquo2Go

Table 1 (continued)

Citation	Authors' dependent variable definition	Verbal Operants Targeted	Convergent/ Divergent	Antecedent Stimuli	Consequent Stimuli	N	Diagnoses	Device
Shih, C-H., Chiang, M-S., Wang, S-H., & Chen, C-N. (2014).	Requests	Mand-tact-intraverbals	Convergent	Interruption of video playing computer screen + "If you want to continue watching videos, please touch the communication request symbol on the screen."	Restarting video + vocal stimulus, "I want to continue watching videos."	2	ASD	Touchscreen computer with Communication Request and Automatic Response Assistive Program (CRARAP)
Stasolla, F., De Pace, C., Damiani, R., Di Leone, A., Albano, V., & Perilli, V. (2014).	Requests	Mand-tacts	Convergent	Presence of preferred item	Access to preferred item	3	Rett Syndrome (IDD)	iPad with Proloquo2Go
Waddington, H., Sigafoos, J., Lancioni, G. E., O'Reilly, M. F., van der Meer, L., Carnett, A., ... & Sutherland, D. (2014).	Requesting communication sequence (pressing symbol for item + symbol for "Thank you.")	Mand-tact-intraverbals	Convergent	A tray with the two preferred items + "Would you like anything?"	The interventionist said "You're welcome" and released the preferred item	3	ASD	iPad with Proloquo2Go
van der Meer, L., Sigafoos, J., Sutherland, D., McLay, L., Lang, R., Lancioni, G. E., ... & Marschik, P. B. (2014).	Communication acts	1. Mand-tact-intraverbals 2. Mand-tact-intraverbals 3. Tact-intraverbals	Convergent	1. DVD player + "What do you want to do?" 2. DVD player + "Do you want to stop?" 3. Pointing at character on DVD screen + "Who is that?", "What is he/she doing?", "How is he/she feeling?"	1. Play video 2. End session 3. Unspecified	1	ASD, IDD	iPad with Proloquo2Go
Chung, Y. & Douglas, K.H. (2015).	Peer interaction behaviors, including gestures, signs,	Unspecified	Unspecified	Not specified, but therapists were trained	Unspecified	3	ASD	iAdapter4 or iPod

Table 1 (continued)

Citation	Authors' dependent variable definition	Verbal Operants Targeted	Convergent/ Divergent	Antecedent Stimuli	Consequent Stimuli	N	Diagnoses	Device
	speech, SGD use, and vocalizations			to use verbal cues, e.g., "What do you want to read today?"				Touch with Proloquo2Go
Lorah, E. R., Karnes, A. & Speight, D. R. (2015).	Intraverbals	Intraverbals	Convergent	Question	Social praise	2	ASD	iPad with Proloquo2Go
McLay, L., van der Meer, L., Schäfer, M. C., Couper, L., McKenzie, E., O'Reilly, M. F., ... & Sutherland, D. (2015).	Requests	Mand-tact-intraverbals	Convergent	Withdrawal of preferred item + "Let me know if you want more."	Access to preferred item	4	ASD	iPad with Proloquo2Go
Nepo, K., Tincani, M., Axelrod, S., & Meszaros, L. (2017).	Mands and vocal responses	Mand-tact-intraverbals	Convergent & Divergent	Presence of preferred items + "What do you want?"	Access to preferred item	3	ASD, OCD, IDD, ADHD, Schizoaffective Disorder	iPod Touch with MyTalk Mobile
Xin, J. F. & Leonard, D. A. (2015).	Requests, responses, and social comments	1. Mand-tacts 2. Tact-intraverbals 3. Tact-intraverbals	Convergent & Divergent	1. Presence of desired toy 2. Question from interventionist during activity 3. Comment from interventionist during activity	1. Access to toy 2. Social praise 3. Social praise	3	ASD, IDD	iPad with Sonoflex app
Agius, M. M. & Vance, M. (2016).	Requests	Mand-tacts	Convergent	Presence of preferred item	Access to preferred item	3	ASD	iPad 4 with SoundingBoard app
Carnett, A. & Ingvarsson, E. T. (2016).	1. Mands for unknown information ("I don't know, please tell me.") 2. Intraverbals	1. Mand-intraverbals 2. Intraverbals	Convergent & Divergent	1. Question "What do you do with a ____?" or similar 2. Same	Information and/or praise and next question	1	ASD	iPad Mini with Proloquo2Go

Table 1 (continued)

Citation	Authors' dependent variable definition	Verbal Operants Targeted	Convergent/ Divergent	Antecedent Stimuli	Consequent Stimuli	N	Diagnoses	Device
Chen, C-H., Wang, C-P., Lee, I-J., & Su, C C-C. (2016).	Communication	Intraverbals	Unspecified	5 questions	Unspecified	3	ASD	ViewPad10 tablet PC with Picture Master Language Pro
Gevarter, C., O'Reilly, M. F., Kuhn, M., Mills, K., Ferguson, R., Watkins, L., ... & Lancioni, G. E. (2016).	Vocalizations: full words and approximations	1. Mand-tacts 2. Mand-tact-echoics	Convergent & Divergent	1. Preferred items in front of the participants but out of reach 2. Preferred items in front of the participants but out of reach + echoic prompts for vocalizations	Access to preferred item	4	ASD	iPad or iPad mini with GoTalk
Lorah, E. R. (2016).	Mands	Mand-tacts	Convergent	Presence of preferred item	Access to preferred item	7	ASD, IDD	iPad Mini with Proloquo2Go
Simacek, J., Reichle, J., & McComas, J. J. (2016).	Requests	Mand-tact-intraverbals	Convergent	Presence of preferred item + "Tell me what you want" or similar	Access to preferred item	2	Rett Syndrome (IDD)	Vmax by DynaVox; Tobii SGD with computer
Stephenson, J. (2016).	Choice making	Mand-tact-intraverbals	Convergent	Preferred items on tray/table + "What do you want?"	Access to preferred item	1	ASD, IDD	iPad with Choiceboard Creator
Tan, P. & Alant, E. (2016)	Communicative acts	Intraverbals	Unspecified	A question posed by the teacher or a comment made by the peer	Unknown	2	ASD	iPad with TouchChat
Alzrayer, N. M., Banda, D. R., & Koul, R. (2017).	Requests	Mand-tact-intraverbals	Convergent	Preferred item + "Let me know if you want this."	Access to preferred item + praise	4	ASD, IDD	iPad II with Proloquo2Go

Table 1 (continued)

Citation	Authors' dependent variable definition	Verbal Operants Targeted	Convergent/ Divergent	Antecedent Stimuli	Consequent Stimuli	N	Diagnoses	Device
Genc-Tosun, D., & Kurt, O. (2017).	Mands	Mand-tact-intraverbals	Convergent	Preferred items + verbal cue e.g., "Would you like to play a game or eat anything?"	Access to preferred item + praise	3	ASD	iPad Air and iPad mini equipped with Dokun Konus ("Touch and Speak") software
Lorah, E. R. & Parnell, A. (2017).	Tacts	Tact-intraverbals	Convergent	Teacher or child lifting flap in book, teacher pointing to animal in book	Praise + continuation of book	3	ASD	iPad with Proloquo2Go
McLay, L., Schäfer, M. C., van der Meer, L., Couper, L., McKenzie, E., O'Reilly, M. F., ... & Sutherland, D. (2017).	Requests	Mand-tact-intraverbals	Convergent	Removed toy box from the child's reach + "Let me know if you want more."	Toy box was moved within child's reach	2	ASD	iPad with Proloquo2Go
Waddington, H., van der Meer, L., Carnett, A., & Sigafoos, J. (2017).	Requests	Mand-tacts	Convergent	Toy held up by interventionist	Access to preferred item	1	ASD	iPad with Proloquo2Go
Lorah, E. R. (2018).	Mands	Mand-tact-intraverbals	Convergent	Preferred item in view/out of reach + "Pick one."	Access to preferred item	3	ASD	iPad Mini with Proloquo2Go

[1] Drager et al. was a group design.

[2] Kasari et al., 2014 had 31 assigned to SGD condition

Finally, of the 56 studies, the large majority (45) targeted convergent VOs only, whereas 7 targeted both convergent and divergent VOs, and 4 did not provide enough information to determine whether a convergent or divergent VO was targeted (unspecified). Of the seven articles that included measurement of divergent VOs, five measured speech production where multiple topography-based responses (e.g., vocalizations, word approximations, words) were recorded in response to SGD intervention. In one study, the authors accepted multiple selection-based responses (i.e., SGD symbols selections) in response to SGD intervention (Xin & Leonard, 2015). Only one study that included divergent VOs measured topography-based responses (i.e., typing words) made with the SGD device itself (Carnett & Ingvarsson, 2016).

Discussion

The purpose of this systematic review was to evaluate VOs targeted for acquisition within the SGD research literature from the perspective of Skinner's (1957) *Verbal Behavior*. Consistent with recent reviews of SGD research (Ganz et al., 2017; Lorah et al., 2014; Muharib & Alzrayer, 2018), the current review indicates that the majority of studies in the SGD research literature have targeted basic communicative skills of individuals with ASD and IDD. Of 56 SGD studies identified in this review, 42 reported targeting some type of multiply controlled mand. The large majority of studies published after 2010, when the iPad was introduced, targeted a multiply controlled mand using the iPad fitted with an SGD application. In most cases, the application was Proloquo2Go.

Also apparent from this review is that relatively few SGD studies have targeted types of verbal behavior that are not mands, including tacts, echoics, and intraverbals in the absence of a mand function. Only 14 of 56 studies targeted a VO that was not a multiply controlled mand. Thus, descriptions of the evidence base in support of SGD should be qualified by noting the paucity of other communicative functions within the published literature. This finding is consistent with Gilroy et al. (2017) and Lorah et al. (2015), who found that SGD studies tended to focus on mand, to the exclusion of more complex verbal behavior skills involving other verbal operants.

The preponderance of SGD studies focused on the mand is important to consider in the context of the populations with which researchers have conducted SGD studies: mainly, those with ASD and IDD. Forty-seven studies reported including individuals with ASD and 19 included individuals with IDD, whereas only 11 studies reported including individuals with other types of disability or typically developing individuals. Because many persons with ASD and IDD lack the most fundamental of communication skills, it is not unexpected that a substantial proportion of studies have focused on teaching some type of basic mand repertoire to these populations. In addition, although Gilroy et al. (2017) reported that few studies in their review included more sophisticated verbal behavior skills targeted in the latter phases of PECS, studies within the PECS research literature have also focused predominately on basic manding skills targeted within the first three phases of the system (Ganz et al., 2012). Researchers' choice to teach basic mands to users of SGD and PECS is likely an artifact of population characteristics and communication needs specific to persons with ASD and ID. Nonetheless, findings of this systematic review also suggest that individuals with

ASD and ID can potentially be taught VOs that are not some type of mand. Of the 10 studies identified the review that reportedly taught tact-intraverbals, 5 included participants who were identified with ASD and/or IDD. All three studies that targeted intraverbals included participants with ASD.

However, given the current technical sophistication of SGD, together with their low cost in comparison to earlier devices, our study highlights the need for researchers to focus on applications of SGD beyond the realm of ASD and IDD intervention. Individuals with significant physical and speech limitations due to disabilities such as cerebral palsy could benefit from the expansive symbol vocabularies and typed text-to-speech functions of SGD. Other persons with cognitive impairments due to dementia or traumatic brain injury could benefit from SGD use to augment or replace speech. We hope this review will spawn further SGD research to address these important, yet untapped areas, in addition to future research aimed at SGD users with ASD who are capable of typing to communicate.

The column of Table 1, labeled Antecedent Stimuli, lists the stimuli that the authors described as being present when each targeted VO was taught. Inspection of this column reveals the presence of contrived antecedent stimuli in many of the studies, which were not faded to produce more naturalistic and spontaneous responses. In particular, a majority of the studies that targeted multiply controlled mands did not employ stimulus control transfer procedures to remove prior sources of contrived prior stimulus control. Twenty-four of 42 studies that targeted a mand used some type of prior verbal stimulus to evoke the mand (e.g., "Would you like some?," "Let me know if you want something," "What do you want?") without fading these prior verbal stimuli. As a result, in naturalistic situations where SGD users are motivated to mand, but professionals are not available to provide such contrived statements or otherwise entice these SGD users to mand for preferred items, they may remain silent. In addition, all nine studies that focused on teaching tacts employed some prior verbal stimulus to evoke the tact (e.g., "What do you see?"). Likewise, in situations where these SGD users are motivated to tact and where listeners are poised to reinforce tacts, they may fail tact unless similar contrived instructions are provided. Given the functional independence of VOs and stimulus overselectivity reported for individuals with ASD and IDD, this finding highlights the need for future studies aimed at transferring stimulus control for multiply controlled mands and tacts from contrived to natural stimuli. In particular, future studies that focus on fading prior verbal stimulus control so that SGD users mand only in the presence of preferred items (i.e., mand-tacts) or in the absence of preferred items altogether (i.e., pure mands), along with studies that target teaching tact responses in the absence of prior instructions (i.e., pure tacts) are needed.

Despite the technical sophistication and large symbol vocabularies of currently available SGD, few SGD studies have targeted topography-based responses and few studies have targeted divergent VOs. Only one study in this review, Carnett and Ingvarsson (2016), taught a participant to emit topography-based responses (i.e., typing answers to questions) with an SGD. Likewise, only four studies measured topography-based responses in the form of speech following SGD intervention. Given the potential of AAC systems to enhance users' speech (Schlosser & Wendt, 2008), additional research on the effects of SGD intervention on speech is needed.

Finally, although this review underscores the utility of Skinner's (1957) *Verbal Behavior* in analyzing the contingencies of SGD intervention, it is noteworthy that

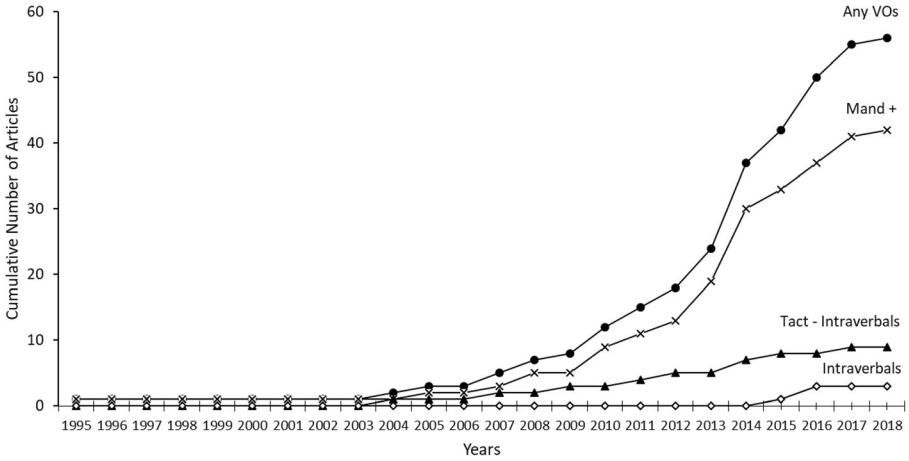

Fig. 2. Cumulative number of SGD articles published per year by verbal operants (VOs) targeted for acquisition

only 10 of 56 articles used Skinner's taxonomy to describe the study's dependent variables, and only one study's description of its dependent variable corresponded with the actual VO taught. Given common usage of SGD in clinical and educational settings, this finding highlights the need for behavior analysts to improve their dissemination of Skinner's *Verbal Behavior*, and for more researchers and clinicians to adopt Skinner's taxonomy in their work with individuals who have limited speech skills.

Limitations

The following limitations should be considered in relation to these findings. First, our descriptive review did not consider the methodological quality of the studies analyzed, nor did it consider the effect sizes of SGD intervention studies as would be done in a meta-analysis. As other reviews have established the methodological quality and treatment effects of published SGD research (e.g., Ganz et al., 2017), we do not view this as a serious limitation of the current review. Second, as our review focused on primary VOs targeted in the extracted studies, we did not consider other important

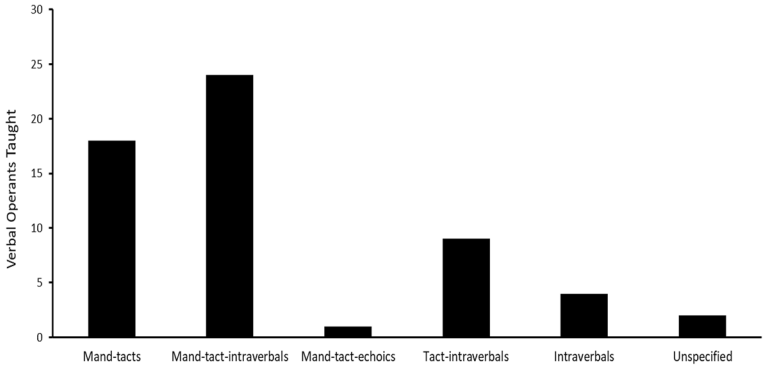

Fig. 3. Number of each type of verbal operant (VO) targeted for acquisition in the SGD articles

dimensions of SGD use targeted in some of the studies, such as how to turn on the SGD or operate SGD app menus. In addition, we did not analyze the extent to which secondary VOs, including descriptive autoclitics (e.g., sentence frames, e.g., "I want _____."), were targeted in the studies. Moreover, as this systematic review examined VOs targeted in the published research literature, the results of the review do not reveal which VOs are commonly targeted in educational, clinical, or other practice settings. If VOs not commonly targeted in the research literature (e.g., tact-intraverbals, intraverbals) are commonly targeted in real world teaching settings, this would indicate the need for more research on teaching VOs besides the mand. Thus, an important topic for future research is to examine which VOs are actually taught with SGD in real world settings to evaluate for correspondence with the published research literature. Finally, as we included the term "autism" in our initial article search, but did not include other specific disability labels (e.g., traumatic brain injury), it is possible that we oversampled for studies including people with ASD as participants. However, the large proportion of participants with ASD and IDD found in the current review is consistent with other recent reviews (e.g., Ganz et al.) that have used diverging search terms and extraction methods.

Conclusion

Skinner's (1957) *Verbal Behavior* is a useful framework for understanding all communication, including communication acquired through SGD intervention. Although this review underscores the relatively limited impact of Skinner's *Verbal Behavior* in the current SGD research base, it also highlights the utility of Skinner's taxonomy in understanding functional communication acquired with SGD intervention. We hope that future SGD researchers and clinicians will consider adopting Skinner's taxonomy in their work, taking advantage of Skinner's careful analysis in promoting functional, independent, spontaneous, and, where appropriate, sophisticated verbal behavior. Given that most SGD research to date has focused on teaching simple and contrived functional communication repertoires, our review highlights the untapped technological potential of these increasingly accessible devices.

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