A Review of SAFMEDS: Evidence for Procedures, Outcomes and Directions for Future Research

Shawn P. Quigley^{1,2} · Stephanie M. Peterson¹ ·
Jessica E. Frieder¹ · Kimberly M. Peck¹

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Abstract SAFMEDS is an assessment and instructional strategy pioneered in the late 1970s by Ogden Lindsley. SAFMEDS was developed as an extension and improvement of flashcards. The aims of this article are to provide an overview of the literature related to SAFMEDS and to identify further research needs. The results of this review suggest that a great deal of research is still needed to clarify the SAFMEDS procedures and the benefits of SAFMEDS over traditional instruction. These conclusions are in line with broader criticisms of fluency-based instruction.

Keywords SAFMEDS · Flashcards · Fluency · Precision teaching

Lindsley (1992) described precision teaching (PT) as a method for making educational decisions based upon changes in learner performance. West, Young, and Spooner (1990) described PT as a precise and systematic method of evaluating instruction. Other proponents of PT have emphasized the standard celeration chart (SCC) as a key component of PT definitions (Kubina & Yurich, 2012). Measurement of performance (i.e., frequency via a SCC) is a clear hallmark of PT, and this measurement most often consists of timed probes to evaluate learner performance on specific skills (further information regarding measurement in PT can be found in Calkin, 2003, 2005). For example, students might be required to complete a number of multiplication facts or read a passage within a specified time limit. The number of correct and incorrect multiplication facts or words read is then charted, and teachers use this information to

Dr. Shawn P. Quigley is now with Melmark Pennsylvania.

✉ Shawn P. Quigley
shawnquigley@melmark.org

¹ Western Michigan University, Kalamazoo, MI, USA

² Center for Development and Disability, University of New Mexico Medical Group, 2300 Menaul Blvd. NE, Albuquerque, NM 87107, USA

evaluate student performance and determine future instructional needs. The timed probes can also serve as instructional opportunities themselves, especially if they are conducted repeatedly, because the learner is exposed to the instructional material multiple times.

One particular PT-style strategy that is often used for instruction and assessment is referred to as say-all-fast-minute-every-day-shuffled (SAFMEDS). SAFMEDS emerged in the late 1970s and early 1980s from the work of Ogden Lindsley (Calkin, 2003; Graf & Auman, 2005; Potts, Eshleman, & Cooper, 1993). Lindsley (1996a) began requiring the use of flashcards by students in his graduate classes in the fall of 1978. SAFMEDS typically focuses on “seeing” the stimulus, which is most often a flashcard, and “saying” a response. This is typically referred to as a see/say learning channel. A learning channel is the specification of the sensory dimensions of the stimulus and the topographical dimension of the response (e.g., see/say; Johnson & Layng, 1996). The learning channels utilized within SAFMEDS can be altered (e.g., see/write, hear/say, see/sort), but they are most commonly see/say.

Lindsley (1996a) differentiated his SAFMEDS procedure from typical “flashcard” procedures in several ways. Specifically, Lindsley stated students needed to “Say” aloud the answers to their flashcards, indicating that the typical flashcard procedure of silent card viewing was not effective. He suggested that students would benefit from viewing “All” the cards to prevent learning small portions of the material at a time. Accuracy was not enough, and students were told they needed to say the cards “Fast.” He did not want students to practice responses slowly and accurately, and then try to build speed later. He wanted students to only practice for “a Minute.” He thought practice should be brief rather than for long periods of time. Lindsley also wanted students to practice “Every Day” so that practice was distributed over time. Finally, he wanted the cards “Shuffled” before each practice to prevent serial learning. Thus, this specific combination of strategies became known as SAFMEDS.

Graf and Auman (2005) reiterated the distinction between SAFMEDS and flashcards and provided additional discussion of each of these factors, as well as rules and tips for SAFMEDS use. Their procedures suggest that learners should hold their own deck of cards to promote responses at the learner’s own pace. They suggested learners should not be allowed to make additional markings on the cards. This suggestion was to avoid stimulus control issues, such as the extraneous marks on the card cuing correct answers rather than the text on the card (e.g., Meindl, Ivy, Miller, Neef, & Williamson, 2013). The learners should also turn the card over after a response to check their answers against the answer on the back of the card. The authors also stated that practicing with multiple decks can help promote generalization. Eshleman (2000a, b) also provides similar instructions regarding SAFMEDS.

Taking Lindsley’s (1996a), Eshleman’s (2000a, b), and Graf and Auman’s (2005) procedures together, a basic SAFMEDS procedure could be summarized as follows. The learner:

1. Holds the complete deck
2. Shuffles the cards
3. Starts the timer for 1 min

4. As fast as possible, “Sees” front and out loud “Says” the information on the back of the card
5. Turns the card over and checks answer to determine answer correctness
6. Sorts correct and incorrect responses into piles
7. After the time expires, counts the number of responses per pile
8. Charts performance for review and instructional changes
9. Repeats daily

Based upon the needs of the learner, “tweaks” to the basic procedure and additional practice may be necessary to build fluency. For example, someone might assist a learner by manipulating the deck for them to increase fluency (Kubina, Ward, & Mozzoni, 2000), a learner might use a deck without all of the cards to provide more learning opportunities (e.g., Kim, Carr, & Templeton, 2001), a learner might vary the timing duration (e.g., 30 s instead of 1 min; Meindl et al., 2013), a learner might conduct multiple timings within a day (e.g., Nam & Spruill, 2005), or the learner might use additional error correction procedures to facilitate increased fluency (Beverly, Hughes, & Hastings, 2009).

In line with other fluency-based instructional methods, SAFMEDS is proposed to have multiple benefits beyond traditional approaches to learning that focus solely on accuracy (e.g., Graf & Auman, 2005). Haughton (1980, 1981) proposed that the benefits of fluency-based instruction could be captured by the acronym REAPS, which represents Retention, Endurance, and Application of Performance Standards (see Merbitz, Vieitez, Merbitz, & Binder, 2004 for a slightly different acronym but with similar outcomes). Building fluency in academic tasks is thought to promote retention, a measure of performance over time without practice. For example, if students in an introductory psychology course master psychology principles during a college course, and they also demonstrate mastery after a summer break with no practice, then retention is said to have occurred. Haughton suggests that retention is more likely to occur if the skills were originally mastered to a certain fluency level than if skills were only mastered for accuracy. Building fluency is also thought to promote endurance. Endurance is performance that is resistant to distractions and can be performed for long durations (e.g., Kim et al., 2001). Finally, fluency is also thought to promote the application of performance to other tasks. For example, if one is fluent on basic math facts, this will promote better success on more difficult math problems in the future.

Critiques of fluency-based instruction have been put forth by Binder (1996) and Doughty, Chase, and O’Shields (2004). In his review of fluency-based instruction, Binder stated, “Most of [the fluency-based] work has not been documented in the scientific literature, but many of the empirical generalizations derived by fluency researchers and practitioners over the last 30 years suggest opportunities for important systematic research” (p. 164). Reviewing the literature base specific to SAFMEDS will help clarify if Binder’s critique of fluency-based instruction is applicable to SAFMEDS.

Doughty et al. (2004) conducted a review of fluency-building procedures. In that review, one concern they identified across fluency-building procedures (of which SAFMEDS is one) is the lack of clear, consistent operational procedures. A second concern noted by Doughty et al. (2004) in their review of fluency building was that fluency-based research is limited by the lack of control for the confounding variables of

practice and reinforcement rate. The performance gains observed in fluency-building exercises might not be a result of requiring fluency (i.e., timed exercises) but rather the result of the additional practice opportunities fluency-based instruction affords and/or the increased rate of reinforcement experienced during fluency-based instruction. Doughty et al. identified only three studies (i.e., Evans & Evans, 1985; Evans, Mercer, & Evans, 1983; Shirley & Pennypacker, 1994) that attempted to separate practice effects and reinforcement rate from fluency-based instruction. Doughty et al. concluded that the results of these three studies provided “unconvincing” support for rate building. This conclusion was based upon the inconsistent and contradictory findings within and between the experiments.

Another criticism for fluency-based instruction, and perhaps SAFMEDS, is the methods by which the procedures are evaluated. Cooper (2005) recounted an interaction with a fellow behavior analyst at a conference. The behavior analyst asserted that fluency-based instruction (i.e., precision teaching) lacked “control and is not science” (p. 295). Cooper and subsequently Kubina (2012) have provided a thorough response to these concerns. In short, their response suggested that fluency-based research is an applied practice with an emphasis upon behavioral dynamics and not functional relationships. Behavioral dynamics relies upon the logic of replication where multiple replications suggest a correlation between two variables. As more and more replications of the correlated effect are shown, a stronger inference of a relationship can be made. So, the concern should not be the use of the behavioral dynamics approach, but rather, to what extent the replications suggest a correlational relationship between two variables.

Given this information, it is clear that a documentation of the literature base for SAFMEDS is warranted. The purpose of this literature review is to provide readers with a review of SAFMEDS literature to summarize the ways in which SAFMEDS have been utilized and evaluated. The specific questions that were addressed are as follows:

1. How do SAFMEDS procedures match up with the proposed basic SAFMEDS procedure outlined above?
2. What alternative SAFMEDS procedures are present in the literature?
3. To what extent have the proposed outcomes of SAFMEDS (i.e., REAPS) been evaluated?
4. Under what conditions and with what learner populations have SAFMEDS been evaluated?
5. Does SAFMEDS literature address concerns specific to fluency-based instruction?

Methods

Search Methods

The scientific literature base for SAFMEDS was determined using four processes. First, the terms “SAFMEDS,” “SAFMEDS and fluency,” “SAFMEDS and precision teaching,” and “SAFMEDS and flashcards” were used to perform electronic database

searchers. The databases searched were ERIC, Google Scholar (<http://scholar.google.com/>), and PsychINFO. Second, based upon the results of those searches, a reverse author search was utilized. Specifically, the researcher reviewed the citations in each paper identified in the ERIC, Google Scholar, and PsychINFO searches to find additional relevant publications that did not appear in the electronic database searches. Third, a review of online archives of the Association of Behavior Analysis International (ABAI) conference presentations (i.e., annual, international, autism, and other) from 2001 to 2013 was conducted by searching “SAFMEDS” and “flashcards” as key terms. Finally, a request for SAFMEDS references was posted to PT and behavior analysis listservs. Articles had to contain the term “SAFMEDS” for further review.

Review Methods

All articles were selected, reviewed, and scored based on specific criteria. These criteria are identified and defined below.

Conceptual/Data-Based Distinction All articles identified based upon the initial search criteria were categorized as either conceptual or data-based articles. Conceptual articles were SAFMEDS articles that discussed SAFMEDS in some manner but did not include any empirical data in relation to SAFMEDS as an independent variable. Data-based SAFMEDS articles were those where SAFMEDS was an independent variable, and empirical data that measured the effects of SAFMEDS were provided. Conceptual articles were not reviewed further but are listed in the expanded bibliography in Appendix A.

Peer Review Data-based articles were further reviewed to determine whether the reported data had been peer-reviewed prior to being made public (e.g., published in a journal, online, conference presentation). An article was considered peer-reviewed if it was published via a journal requiring independent reviewers to determine merit prior to publication. The criticisms of the peer-review process are a recognized limitation (e.g., Lee, Sugimoto, Zhang, & Cronin, 2013; Peters & Ceci, 1982). However, regardless of the criticisms, it is the process utilized for determination of merit, and therefore, only peer-reviewed published articles are reviewed here. Articles that were data-based but not peer-reviewed were not reviewed here but are listed in the expanded bibliography in Appendix A.

A total of 53 SAFMEDS references were identified. Of the 53 total references, 14 were classified as conceptual (i.e., Becker, McLaughlin, Weber, & Gower, 2009; Binder, 1996; Calkin, 2003; Eshleman, 2000a, b; Graf & Auman, 2005; Heward, 2013; Hudson, Knight, & Collins, 2012; Lindsley, 1993, 1996a, b; Potts et al., 1993; Stump et al., 1992; Tincani, 2004). The remaining 39 articles were classified as data-based. Of the 39 data-based articles, 12 were classified as nonpeer-reviewed (i.e., Baird & Stein, 2013; Breeden, 2011; Fox & Ross, 2013; George, 2010; Kelly & Al Haddad, 2013; Lin & Liu, 2009; Lin & Ying-Hsiu, 2009; Lorbeer, 2007; Miller, Garner, Jimenez, & Neef, 2012; Miller, Meindl, Ivy, Garner, & Neef, 2012; Tucci, Johnson, & Suggitt, 2013; Xiuyan, 2009). The remaining 27 articles fit the data-based and peer-reviewed criteria and were reviewed based upon the 9 domains described below.

Specific Article/Study Characteristics Each remaining article was reviewed for information specific to nine domains: (1) purpose of the study, (2) research design, (3) the content of SAFMEDS and the learning channel, (4) population, (5) adherence to the basic SAFMEDS procedure, (6) supplemental SAFMEDS procedures (e.g., practice prior to timing), (7) whether or not the procedures were altered based upon learner performance, (8) REAPS, and (9) practice effects. These nine components were chosen because of their potential in providing data to address the purposes of this literature review. Domains 6 and 7 were included to provide information specific to the SAFMEDS procedures (i.e., research question no. 1 and no. 2). Although a SAFMEDS procedure might indicate an increase in fluency, the proposed outcomes of fluency (i.e., REAPS) also must be explicitly examined (i.e., research question no. 3). Domain 8 was included to provide this information. Domains 1, 3, and 4 were included to provide information regarding the conditions and populations with which SAFMEDS has been implemented (i.e., research question no. 4). Domains 2 and 9 were included to provide information to assess general criticisms of fluency-based instruction by Binder (1996) and Doughty et al. (2004; i.e., research design concerns and control of specific confounding variables). Each of these domains are described in more detail below.

Research design is reported as “Between-subject,” “Within-subject,” or “Mixed.” A between-subject design was noted when the combined performance of participants within a control condition was compared to the combined performance of the same or different participants in an experimental condition (Johnston & Pennypacker, 2009). A within-subject design was noted when individual performance of participants was compared across control and experimental conditions. If the within-subject design was noted, it was further specified as either baseline logic or behavioral dynamics. This distinction is important in the PT literature and specifies different goals of measurement. According to Cooper (2005) and Kubina (2012), baseline logic designs seek steady-state responding across all conditions to determine functional relationships, whereas behavior dynamics searches for transitory states of behavior across conditions to determine predictable patterns of behavior at the correlational level (see Marr, 1992 for further discussion regarding this distinction). Baseline logic was noted when learner’s performance was evaluated using a commonly accepted within-subject experimental design (i.e., reversal/withdrawal, multiple baseline, changing criterion, or multiple treatment). Visual representation of performance across control and experimental conditions, such as a graph of learner performance, was required for the study to be categorized as baseline logic. Behavioral dynamics was noted when change in learner performance was presented on a standard celeration chart and did not include a standard within-subject research design. If the design included only intervention data or only baseline and intervention data, with no further experimental manipulation of the independent variable, but data were presented on a standard celeration chart, the article was coded as behavioral dynamics design. In some cases, multiple designs were used. Therefore, mixed design was noted if multiple analyses (between-subject, within-subject/baseline logic, and behavior dynamics) were included in the manuscript. For example, Kim et al. (2001) evaluated learner’s ability to maintain fluent rates of performance in the face of distractions and over longer periods of time (i.e., 20 min). Changes in performance were documented using a standard celeration chart but were replicated within a reversal design. This article was noted as “Mixed – baseline logic/behavioral dynamic” for satisfying both criteria.

Adherence to the basic SAFMEDS procedure, described in the introduction above, was also evaluated. If the SAFMEDS procedure in the study used the general steps described above, this was noted. *Supplemental SAFMEDS* was scored to document any additional procedures researchers might have included with the basic SAFMEDS procedure. *Alteration to the SAFMEDS procedure* was scored to determine if the researchers changed the SAFMEDS procedure based upon learner performance. The documentation of procedural changes is important when evaluating a specific procedure. Adherence to the basic SAFMEDS procedure, supplementary SAFMEDS procedures, and alteration of SAFMEDS procedures were each reported as “Yes,” “No,” or “Unknown.” Adherence to the basic SAFMEDS procedure was marked as “Yes” if the authors used a SAFMEDS procedure that matched the nine basic steps described above. All nine components had to be described for “Yes” to be scored. “No” was scored if there was any description of the SAFMEDS procedures that deviated from the basic SAFMEDS procedure. “Unknown” was scored if there was not sufficient information to determine what the specific SAFMED steps were. The use of supplementary SAFMEDS procedures was scored as “Yes” if any additional components beyond the basic nine steps described above were utilized. The additional components were noted. “No” was scored if there were no additional steps beyond the basic nine. “Unknown” was scored if there was not sufficient information to answer the question. Alteration of SAFMEDS was scored “Yes” if the authors described changes to the SAFMEDS procedures they made based upon learner performance. The alteration(s) of procedures were noted if they were described. An indication of “No” was scored if the SAFMEDS procedures were not changed during the study. An indication of “Unknown” was provided if there was not sufficient information to answer the question.

REAPS and practice effects were scored as “Yes” or “No.” REAPS was scored as “Yes” if at least one purpose of the study was to directly evaluate one of the proposed outcomes of SAFMEDS. That is, at least one experimental arrangement directly assessed one component of REAPS (retention, endurance, or application of...). “No” was scored if there was not at least one experimental arrangement with the purpose of assessing one component of REAPS.

Practice effects is a broad label referring to the critique some researchers have made about PT procedures. Specifically, Doughty et al. (2004) have suggested that much of the fluency-building research has not controlled for the confounding variables of multiple practice opportunities (i.e., number of exposures to the stimuli) and rate of reinforcement. Thus, we wanted to determine if the studies controlled for these effects. Practice effects were scored as “Yes” if the authors utilized procedures that controlled for practice opportunities (e.g., yoking of exposure to stimuli between fluency conditions and accuracy only conditions) or reinforcement rate (e.g., time-based schedule as opposed to ratio-based). “No” was scored if there were no procedures controlling for practice opportunities and reinforcement rate.

Interobserver Agreement

Each of the identified articles were reviewed independently by two authors. Each author reviewed the articles and determined how to score each of the nine domains. Results from the independent reviews were compared on a point-by-point basis and interobserver agreement (IOA) was calculated by dividing agreements by agreements plus disagreements. Agreement was 99%.

Results

Adherence to the Proposed Basic Procedure and Procedural Variations

None of the peer-reviewed, empirical articles followed the proposed basic SAFMEDS procedures derived from Lindsley (1996a), Eshleman (2000a, b), and Graf and Auman (2005; see Table 1). SAFMEDS procedures for 11 of the articles could not be ascertained due to insufficient description of the procedure. The SAFMEDS procedures described across projects generally fit within the basic framework but either altered one or more components within the basic procedure (e.g., duration of timing) or added components (e.g., practice and error correction procedures outside of the timings). The duration of the fluency timings was consistent across most articles (1 min); however, this varied from 30 s to 2 min in three articles. The most frequent addition to the basic SAFMEDS procedure was multiple timings and some form of practice with the cards before the fluency timings. As with the basic procedure, it was difficult to determine if the described procedures were in fact altered (i.e., 8 articles) or added to (i.e., 18 articles) due to a lack of description of the SAFMEDS procedure implemented.

Evaluation of REAPS

Seven of the 27 articles evaluated one or more proposed outcomes of fluency-based instruction (i.e., REAPS). Retention and application were evaluated the most (i.e., four times each). Endurance and stability were evaluated twice each. Two articles evaluated at least two components of REAPS (i.e., Kim et al., 2001; Olander, Collins, McArthur, & McDade, 1986). One article evaluated four components of REAPS (i.e., Hughes, Beverly, & Whitehead, 2007).

Conditions and Learner Populations

The purpose of research across the 27 articles varied but had a general theme of increasing a specific behavior(s) in an applied setting. In fact, 23 of the 27 studies attempted to increase fluency with content specific to a need for the participant (e.g., material specific to a college course). A see-say learning channel was specified in 23 of the 27 articles. Five of the 27 articles specified different or additional (some arrangements utilized more than one channel) learning channels from the see-say (i.e., Eaton & Fox, 1983; Fox & Ghezzi, 2003; Nam & Spruill, 2005; Polson, Grabavac, & Parsons, 1997; Ragnarsdottir, 2007). Only one article specifically addressed potential performance difference between learning channels (i.e., Nam & Spruill, 2005). Thirteen of the 27 articles described participants as undergraduate or graduate students. Ten of the 27 articles described participants as children under the age of 19. The remaining three articles described participants as adults. Ten of the 27 articles described participants with special needs (e.g., learning disability) or other limiting impairments (e.g., traumatic brain injury).

Fifteen of the 27 articles utilized a within-subject behavioral dynamics design. Additionally, three articles utilized mixed within-subject designs (i.e., behavioral dynamics and baseline logic). Given SAFMEDS is based upon PT principles, it is not surprising to see 67% of the articles utilizing a behavioral dynamics design solely or in

Table 1 Description of factors related to SAFMEDS research

Author, year	Research purpose	Population	Content/learning channel	Research design	Basic SAFMEDS procedure	Supplemental SAFMEDS procedure	Alteration of SAFMEDS procedures	REAPS	Practice effects
Beverly, Hughes, and Hastings (2009)	Evaluation of SAFMEDS to build high frequency performance with basic statistic facts	Undergraduate students	Statistics terms/sec-say	Mixed; between and within	No	Yes; multiple daily timings	Yes; e.g., number of timings, error correction	No	No
Bolich and Sweeney (1996)	Development of fluency with Hebrew	11-year-old female	Hebrew sight words/sec-say	Within; behavioral dynamics	No	Yes; multiple daily timings and pretiming practice	Unknown	No	No
Bower and Orgel (1980)	Evaluation of errors on performance	Undergraduate students	Education and psychology facts/sec-say	Within; behavioral dynamics	Unknown	Unknown	Unknown	No	No
Byrnes et al. (1990)	Evaluation of SAFMEDS for preparation of test taking	4 secondary-age students with learning disabilities	Government facts/sec-say	Within; baseline logic	No	Yes; pretiming practice and 2-min timings	Unknown	No	No
Calkin (1996)	Development of fluency with Russian	Adult female	Russian words/sec-say	Within; behavioral dynamics	Unknown	Unknown	Unknown	No	No
Casey et al. (2003)	Increase fluency of math facts	Elementary students with learning disabilities	Math facts/sec-say	Within; baseline logic	No	Yes; pretiming practice	Unknown	No	No
Chapman, Ewing, and Mozzoni (2005)	Application of precision teaching with individuals with an acquired brain injury	5 participants between 11 and 19 years of age	Math facts and orientation facts/unknown	Mixed; baseline logic and behavioral dynamics	Unknown (computer-based)	Unknown	Unknown	No	No

Table 1 (continued)

Author, year	Research purpose	Population	Content/learning channel	Research design	Basic SAFMEDS procedure	Supplemental SAFMEDS procedure	Alteration of SAFMEDS procedures	REAPS	Practice effects
Clorfene et al. (1998)	Teaching taxonomy via SAFMEDS	6th grade science students	Taxonomy/see-say	Within; behavioral dynamics	No	Yes; practice outside of timings	Unknown	No	No
Cobane and Keenan (2002)	Self-management of positive and negative thoughts	66-year-old female	Positive and negative thoughts/see-say	Within; behavioral dynamics	No	Yes; multiple daily timings	Yes	No	No
Cunningham, McLaughlin, and Weber (2012)	Evaluation of SAFMEDS and verbal prompts on fluency	8-year-old male with a learning disability	Math facts/see-say	Within; baseline logic	No	Yes; practice outside of timings	Unknown	No	No
Eaton and Fox (1983)	Using precision teaching methods in college courses	Undergraduate students	Precision teaching facts/see-say and see-mark	Within; behavioral dynamics	Unknown	Unknown	Yes	No	No
Eshleman (1985)	Evaluation of SAFMEDS	Undergraduate students	Various facts/see-say	Within; behavioral dynamics	Unknown but it was implied	Unknown	Yes	No	No
Fox and Ghezzi (2003)	Comparison of fluency techniques and practice effects	Undergraduate students	Logical fallacies/see-click	Between	Unknown (computer--based)	No	No	No	No
Hartnedy, Mozzoni, and Fahoun (2005)	Application of precision teaching to the neuropsychiatric population	2 male children; 8 and 10 years of age	Math facts/see-say	Within; baseline logic	No;	teacher-directed as opposed to student-directed	Yes; pretiming practice and error correction	No	No
No									
Hughes, Beverly, and Whitehead (2007)	Evaluation of precision teaching on word reading frequency	7 children; ages 11 and 12	Sight words/see-say	Within; behavioral dynamics	Unknown but it was implied	Yes; error correction procedures	Yes; timing length	Yes; retention, endurance, stability, and application	No

Table 1 (continued)

Author, year	Research purpose	Population	Content/learning channel	Research design	Basic SAFMEDS procedure	Supplemental SAFMEDS procedure	Alteration of SAFMEDS procedures	REAPS	Practice effects
Kim, Carr, and Templeton (2001)	Evaluation of fluency building on endurance and stability	3 undergraduate females	Hindi characters/see-say	Within; behavioral dynamics	No	Yes; multiple daily timings, reduced decks and partial deck	No	Yes; endurance/-stability	No
Korinek and Wolking (1984)	Comparison of study methods	Female graduate student	Observational learning facts/see-say	Within; behavioral dynamics	Unknown	Yes; additional study time outside of the timings	Unknown	No	No
Kubina, Ward, and Mozzoni (2000)	Application of precision teaching with a person with a traumatic brain injury	44-year-old male	Answers to anterograde and retrograde questions/see-say	Mixed; behavioral dynamics and baseline logic	No	Yes; multiple daily timings	No	No	No
McDade and Olander (1990)	Comparison of 3 methods for creating SAFMEDS	Undergraduate students	Psychology facts/see-say	Between	Unknown	Unknown	Unknown	No	No
McDade, Austin, and Olander (1985)	Comparison of SAFMEDS and computer testing	Undergraduate students	Psychology facts/see-say	Between	No	Yes; pretiming practice	Unknown	No	No
Meindl et al. (2013)	Evaluation of stimulus control/stimulus generalization	Graduate and undergraduate students	Course relevant material/see-say	Mixed; within and between	No	Yes; pretiming practice, time, and multiple timings	Unknown	No	No
Nam and Spruill (2005)	Evaluation of generalization across learning channels	3 children; ages 10–12 with special needs	Math facts/see-say; hear-say; see-write	Within; behavioral dynamics	No	Yes; multiple timings	Unknown	Yes; application	No
Olander et al. (1986)	Retention of learned information	Undergraduate students	Biology concepts/see-say	Between	No	Yes; pretiming practice	Unknown	Yes; retention and application	No

Table 1 (continued)

Author, year	Research purpose	Population	Content/learning channel	Research design	Basic SAFMEDS procedure	Supplemental SAFMEDS procedure	Alteration of SAFMEDS procedures	REAPS	Practice effects
Polson, Grabavac, and Parsons (1997)	Evaluation of stimulus equivalence via computer-based SAFMEDS	Undergraduate students	French words/see-type	Within; behavioral dynamics	Unknown (computer--based SAFMEDS)	Unknown	Unknown	Yes; application	No
Ragnarsdottir (2007)	Teaching reading via precision teaching and direct instruction	8-year-old with autism	Letters, sounds, and words/multiple channels	Within; behavioral dynamics	Unknown	Unknown	Unknown	No	No
Stockwell and Eshleman (2010)	Teaching terms via SAFMEDS	Female graduate student	Terms/see-say	Within; behavioral dynamics	No	Yes; pretiming practice and multiple timings	Unknown	Yes; retention	No
Togade, Ormandy, and Stockwell (2012–2013)	Teaching Tagalog via SAFMEDS	2 graduate students	Tagalog/see-say	Within; behavioral dynamics	No	Yes; multiple timings, 30-s timing and deck size	Unknown	Yes; retention	No

Only data-based, peer-reviewed SAFMEDS articles are presented here. Additional SAFMEDS references can be found in Appendix A

combination with a baseline logic design. A within-subject baseline logic design was utilized four times. Similarly, a between-subjects design was also used four times. Only one study examined the relation between the independent and dependent variables via a combination of between- and within-subject designs (i.e., Beverly et al., 2009).

Studies that assessed retention compared performance at one point of time with performance at a later point with no programmed instruction between the assessment dates. Retention tests at 3 weeks (Togade, Ormandy, & Stockwell, 2012–2013), 7 weeks (Stockwell & Eshleman, 2010), 5 to 9 weeks (Hughes et al., 2007), and 8 months (Olander et al., 1986) indicated minimal decreases in the rates of correct responses during retention probes, suggesting that retention was very high. Only Olander et al. compared the retention of students instructed with SAFMEDS procedures to students instructed with nonfluency-building methods. The students who received fluency-based instruction had better retention of skills than the students who received nonfluency-based instruction.

Hughes et al. (2007) and Kim et al. (2001) assessed endurance and stability. Endurance was assessed by requiring extended timings (i.e., 3 and 20 min) and measuring the rate of correct responses per minute. Endurance was noted if the learner's performance remained at levels consistent with 1-min timings throughout the extended timings. Stability was assessed in a similar manner. Instead of altering only the timing duration, distractions such as a radio playing music and additional students making noise were added to the environment. Stability was noted if the learner's performance remained at previous levels despite the distractions.

Application was assessed in multiple ways. Hughes et al. (2007) provided reading passages with words that were different from the training passages and measured the number of correct and incorrect words read. Nam and Spruill (2005) assessed the application of multiplication facts via tests of different learning channels (i.e., see/say and hear/say) and different visual representations of the math problems (i.e., vertical alignment versus horizontal alignment). Polson et al. (1997) tested application by training English to French translation or French to English translation and then presented the words in a reversed fashion to determine if symmetry emerged (see Malott (2008) for an introduction to symmetry and other equivalence relations). The general findings across the studies indicated that when the application test was introduced, performance initially decreased but quickly returned to previous levels.

SAFMEDS was evaluated approximately 47% of the time with undergraduate or graduate students, approximately 37% with children, and approximately 11% of the time with adults. Gallander, North, and Sugar (2001) found that undergraduates were enrolled as participants approximately across 68% of psychological research projects at three different probe dates spanning 20 years (i.e., 1975, 1985, and 1995). The reduced reliance on undergraduate participation is perhaps suggestive of SAFMEDS alignment with PT as an applied science (i.e., evaluating strategies within real-world contexts).

Addressing Fluency-Based Criticisms

None of the identified literature utilized an experimental arrangement that addressed practice effects and reinforcement rate criticisms put forth by Doughty et al. (2004).

Discussion

SAFMEDS is an assessment and instructional strategy pioneered by Lindsley in the 1970s (Calkin, 2003; Graf & Auman, 2005; Lindsley, 1996a; Potts et al., 1993). Practitioners have been utilizing SAFMEDS for educational and therapeutic purposes ever since its inception by Lindsley. One purpose of this project was to document SAFMEDS research to provide further information for practitioners when using SAFMEDS and to guide future research. Twenty-seven total peer-reviewed publications are not overwhelming given a brief Google Scholar search yields about 3800 hits for “precision teaching” or 425 results for “standard celeration chart.” Regardless, the information contained in this publication provides a broad and in-depth analysis of SAFMEDS research and application for researchers and practitioners.

A small percentage of the studies evaluated the proposed outcomes of a fluency-based strategy (i.e., REAPS). The limited data is suggestive that fluency-building exercises produce high rates of skill retention over time. Similar evidence is found for endurance and stability. Specifically, fluency-building exercises can increase continued, stable responding. The application component of REAPS was evaluated three times, each with varying procedures and definitions of application. However, the research is limited by a lack of replication and the concerns noted below regarding procedural differences that limit generalizability of this conclusion. Further, few of the studies compared SAFMEDS to other fluency-based techniques or nonfluency-based instruction methods. Studies that provide such comparisons could strengthen the position that SAFMEDS leads to better application of learning than traditional instructional approaches. At present, there is not enough data to support such a conclusion.

This publication might have been enhanced with the inclusion of additional literature. The search method used may have excluded articles that implemented a SAFMEDS procedure and referred to it by another name (e.g., flashcards). Although other singular terms (e.g., “flashcards”) might have revealed further references, there were two major barriers to inclusion. First, the number of hits that resulted from including terms such as “self-study” and “flashcards” was far too numerous for review (i.e., hundreds to thousands across multiple search engines). Second, without the inclusion of the term “SAFMEDS,” it becomes more difficult to be sure the “self-study” or “flashcard” procedure represented the basic ideas presented by Lindsley (1996a), Eshleman (2000a, b), and Graf and Auman (2005). Therefore, only articles that contained the term “SAFMEDS” were kept for further review. It is hoped that these procedures best reflect the true status of the SAFMEDS literature base.

Binder (1996) stated that fluency-based practices have not historically followed general dissemination practices (whether right or wrong is beyond the purpose of this paper). The outcome of this literature review suggests that a fair amount of SAFMEDS literature exists but nearly 31% were not disseminated using the peer-review process (i.e., 39 total peer-reviewed references with 12 references not peer-reviewed). It is difficult to know to what extent this represents the complete literature base for SAFMEDS (i.e., the true number of peer-reviewed and nonpeer-reviewed evaluations) in order to apply Binder’s above statement to SAFMEDS. Personal correspondence with a researcher in the field is suggestive that this critique is likely applicable to SAFMEDS (J. Eshleman, personal communication, July 11, 2013).

Another point of discussion is the proposal of a basic SAFMEDS procedure. The proposed basic SAFMEDS procedure might be considered an ill-informed definition of SAFMEDS. Specifically, trying to define a basic process is removing a core aspect of PT (i.e., SAFMEDS is a collection of various procedures that address individualized learner needs) and/or not in line with current practices (e.g., the definition provided here is based upon SAFMEDS as an assessment practice and not an instructional practice). Precision teaching is not a curriculum or instructional method, but standard strategies have arisen through the measurement of what works for learners (Merbitz, Vieitez, Merbitz, & Pennypacker 2004). In fact, SAFMEDS is provided as an example of a standard strategy that is utilized because of its effect on learning (Merbitz, Vieitez, Merbitz, & Binder, 2004). The fact that a strategy is believed to be effective and often used but does not have a basic or standard procedure may or may not be problematic. For Doughty et al. (2004), the lack of clear procedures was a point of criticism for fluency-based practices.

Proponents of PT might suggest that this is not a problem because strategies are individualized to each learner so basic procedures are not useful. But, on a practical level, this presents difficulties for practitioners who want to implement SAFMEDS in their classrooms. How does a teacher efficiently teach 20 or more students? Use 20 individualized SAFMEDS procedures? Is it not more efficient to have data suggesting a basic procedure is effective for most learners (i.e., REAPS is realized) and then tweak the procedures for a small number of students needing further supports? A clear set of guidelines as to what constitutes the basic SAFMEDS procedure does not seem to exist, nor has it been used consistently enough in the research literature to indicate there is a “standardized” set of procedures. Furthermore, the “tweaks” and adjustments to the basic procedure are quite varied. It is not clear what effects these adjustments have, which adjustment to use over another, and whether adjustments produce more desirable effects on fluency than the basic procedure. Future research on SAFMEDS should seek to provide practitioners with a standard procedure to follow, as well as meaningful indicators for when adjustments should be made and what those adjustments should be.

The second clause of Binder’s critique suggests “opportunities for important systematic research,” and the critique is applicable to SAFMEDS. Researchers attempt to determine a relationship between two variables by holding all other variables constant. If one of the variables studied is constantly changing (i.e., the procedure for SAFMEDS), it is difficult to fully understand the relationship between the two variables. It is our opinion that research regarding SAFMEDS should start with an understanding of the procedure itself. Specifically, the parameters of the independent variable should be specified and evaluated. For example, comparison of a standard or basic procedure to varied or supplemental procedures might indicate altered procedures are generally more effective than the basic procedure (e.g., Quigley, 2014). Variations of the independent variable can then be assessed, including component analyses. Further questions, such as comparisons of SAFMEDS to other instructional strategies, can be undertaken.

Clarifying the parameters of the independent variable is also important given the reliance upon a behavioral dynamics approach to validation of SAFMEDS. Data from this literature review indicate a large reliance upon the behavioral dynamics approach (i.e., 15 of the 27 articles). If there was agreement that this logic was acceptable, there would need to be multiple studies with similar procedures and outcomes in order to

draw conclusions about the correlational relationship between SAFMEDS, performance improvement, and long-term outcomes (i.e., REAPS). However, as shown here, the 15 SAFMEDS articles using the behavioral dynamics approach had multiple variations in research purpose (e.g., language acquisition, education facts, thoughts), population (i.e., children, college-age and older adults with and without disabilities), and SAFMEDS procedures. Thus, it is difficult to determine a correlational relationship characteristic of behavioral dynamics as evidence of effect in the case of SAFMEDS. There is a need for systematic expansion and replication of SAFMEDS research to strengthen SAFMEDS claims.

In conclusion, an evaluation of the SAFMEDS data presented here is discussed in relation to general criticisms of fluency-based instruction that have been addressed elsewhere. Evaluating the application of general criticisms of fluency-based instruction to SAFMEDS (which is only a subset of fluency-based instruction) is important to avoid a logical fallacy. A logical fallacy occurs when an individual assumes something that is true of the whole is also true of its components. For example, if one assumes the statement, “Four is an even number,” is true, and we know 1 and 3 are parts of four, assuming both 1 and 3 are even would be committing logical fallacy. It is possible that individual parts of the whole fit the assumption; however, it is not necessarily true. One should not assume it to be true without careful examination first. A method for determining whether the “parts” of fluency-based instruction fit the assumption about the whole of fluency-based instruction is to review the evidence for individual parts. Assuming the identified literature represents SAFMEDS, it appears that the general criticisms of fluency-based strategies (i.e., following traditional dissemination, clear procedures, and controls for practice and reinforcement effects) also apply to the individual part of SAFMEDS.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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Appendix A: Additional SAFMEDS References not Included in the Review

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