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Chaining Techniques: A Systematic Literature Review and Best Practice Recommendations

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by

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Abstract

Chaining is a technique that has been widely used across various disciplines to teach individuals diagnosed with developmental disabilities to complete complex behaviors. Given the amount of research conducted on these procedures and how commonly they are used in applied settings, a systematic literature review was conducted to provide a summary of current research, best practice guidelines, and directions for future research. Studies that (a) discussed the types of chaining and procedural variations, (b) compared chaining procedures, and (c) provided guidelines for future implementation were included in this literature review. These articles were then reviewed to provide a summary of current chaining techniques and procedural variations, comparative effectiveness of chaining procedures, and best practice recommendations for clinicians.

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Chapter I: Introduction

Behavior analytic procedures have been applied across disciplines to teach a wide variety of skills across many populations. One of the most widely used behavior analytic instructional methods is chaining. A behavior chain refers to the sequence of temporally related, discrete responses that have been broken down into smaller component parts, referred to as a task analysis, to then teach each component to pre-determined criterion levels using prompting and differential reinforcement (Cooper et al., 2020; Spooner & Spooner, 1984; Slocum & Tiger, 2011). Each step of the task analysis is trained individually and subsequently linked together to create a new response (Cooper et al., 2020; Slocum & Tiger, 2011). A behavior chain is also defined by the stimulus change that completing one response within the chain produces, which functions as a conditioned reinforcer for completing that step as well as a discriminative stimulus for the following response in the sequence. Completion of the complete behavior chain produces reinforcement that functions to maintain all previous responses in the chain (Cooper et al., 2020).

By dividing a behavior chain into its smaller components, chaining allows for easier acquisition of complex tasks. Discrete behaviors can also be linked together to form more complex behavior chains through chaining procedures. These chains are often seen in independent living and self-help tasks, such as hand washing and recipe following. Additional behavior analytic principles, such as prompting, modeling, and error correction, can be incorporated into chaining procedures to create increasingly complex repertoires that promote independence and adaptiveness (Cooper et al., 2020).

Chaining has been shown to be effective in teaching numerous skills, including vocational (Walls et al., 1981), self-help (Chazin et al. 2017; Shrestha et al., 2012), and leisure

skills (Lambert et al., 2016). The current body of research on chaining techniques supports the effectiveness of this procedure and its use in applied settings. However, much of this research was conducted decades ago and includes gaps and inconsistencies. An in-depth review of chaining is needed to continue providing evidence-based strategies to clinicians and to provide directions for future research to continue advancing behavior-analytic technologies. The purpose of the present paper is to perform a systematic literature review of the chaining literature from both within and outside of the field of behavior analysis, from which best practice recommendations and directions for future research are derived.

Chapter II: Methods

Several methods were used to identify articles to include in this review. First, two electronic databases, Google Scholar and PsychInfo, were searched to find articles to include in this review. One journal, the *Journal of Applied Behavior Analysis*, was also specifically searched to identify articles to include. Lastly, forward and backward searches were conducted on key research articles, such as those that first identified a novel procedural variation. Search words such as “chaining”, “response chaining”, “chaining methods”, “chaining techniques” “comparison”, and “procedural variations” were used in isolation and together to yield potential articles for inclusion. These key words needed to be present in the title or abstract of the paper to be included in this review.

The articles chosen to include in this review were limited in several ways. First, the studies must have been peer-reviewed and published in English. This eliminated papers completed as a degree requirement, such as a thesis or dissertation, unless this research had then been published in an academic journal. Second, articles included in this review had to include a procedural variation within a chaining technique or compare two methods of chaining. Third, all research studies were required to include human subjects. No animal studies were included. Lastly, only articles focusing on behavior modification were included. This eliminated articles that implemented chaining procedures outside of the scope of behavior analysis.

Chapter III: Results

Table 1 provides a comprehensive view of research articles included in this review that provide experimental data. One systematic literature review research article was included, written by Spooner and Spooner (1984), which provided an overview of chaining procedures at the time that it was published. The results of this search yielded a total 34 research articles that met these criteria. A summary of the findings from this research is provided below.

Types of Chaining

There are four types of response chaining commonly mentioned within the literature: forward chaining (FC), backward chaining (BC), reverse chaining (RC), and total task chaining (TTC). All types of chaining begin by breaking down the desired response sequence into smaller component steps and teaching one or several of these steps to a pre-determined criterion prior to linking the steps together to form the terminal response. Chaining procedures may also involve other procedural variations, such as prompting procedures.

Forward Chaining

FC consists of teaching the discrete behaviors of a task in their naturally occurring order, beginning with the first response. Access to reinforcement is provided for successfully completing the first response of the chain at the given prompt level. Once the first response within the behavior chain has been mastered, the next behavior of the task is added to the sequence. The first step is completed independently by the learner, and training is implemented on the second step. Both steps must be completed to criterion to contact reinforcement. Adding steps of the behavior chain is repeated until all steps within the task have been mastered. Once this occurs, all behaviors in the chain must be completed correctly to contact reinforcement

(Cooper et al., 2020). An analysis shows that FC definitions within the literature vary in the amount of detail that is provided to the reader, such as the differences in definitions provided by Spooner and Spooner (1984) and Slocum and Tiger (2011) but provide an overall consistent and cohesive procedural definition of FC.

Several advantages and disadvantages of FC are mentioned within the literature. One advantage of FC is that it allows the learner to complete the steps in their natural order, closely resembling the natural environment and facilitating generalization. Resemblance to the natural environment allows FC to be combined with other behavior analytic procedures fairly easily and increases the ease of implementation by others (Cooper et al., 2020). Additional advantages include its usefulness in breaking down long response chains into shorter ones (McWilliams et al., 1990) and reducing the number of errors a learner engages in by only teaching one step at a time (Walls et al., 1981). Weiss (1978) also speculates that because each response taught using FC is directly reinforced at some point during teaching, all responses are stronger than if taught using a different chaining method.

Because the first response in the chain is taught first, contrived reinforcement is often delivered to the learner for correct completion of steps. This may be considered a disadvantage to FC because requires additional resources. Other disadvantages of FC include the potential for extinguishing the chain by not continuing to provide this reinforcement after learning all target steps (Cooper et al., 2020), the potential for slowed skill acquisition if the learner remains on the same step for too long (Lambert et al., 2016), and its limited efficiency in teaching chains that require that the entire chain to be completed each time it is performed, such as with hand washing or brushing teeth.

Backward Chaining

Another variation of chaining technique is BC, which begins by teaching the last response in a behavior chain first. The untrained steps of the behavior chain are completed for the learner, and the learner is then only responsible for independently completing the mastered steps. Once the last step of the chain is mastered, earlier responses of the chain are taught (Slocum & Tiger, 2011). Once all components of the chain have been taught and mastered, the skill must be completed in the correct sequential order, beginning with the first step, to earn reinforcement. Definitions of BC within the literature present an overall cohesive definition of this procedure.

Limited advantages of BC are provided within the literature. Because BC begins with teaching the last step, the learner contacts the terminal reinforcer associated with the chain each time. Unlike FC, this eliminates the requirement for contrived reinforcers and strengthens the discriminative properties of the stimulus that is present at the time of reinforcement delivery. The discriminative properties of all stimuli are also strengthened by the repeated reinforcement of the entire chain, potentially creating a stronger behavior chain (Cooper et al., 2020). Early research has also proposed that BC may be useful in teaching behavior chains containing skills not currently in the learner's repertoire, although these claims don't appear to have been empirically validated (Foxx, 1982).

Disadvantages of BC mentioned within the literature include the potential for limited progression of skill acquisition when using this procedure, similar to FC (Spooner et al., 1986). An additional disadvantage of BC is the potential need for increased training time, as the passive participation in early steps of the chain may limit the rate of learner's acquisition (Cooper et al., 2020; Spooner et al., 1986).

Reverse Chaining

Reverse chaining (RC), a variation of BC, involves using prompting to teach the steps in the response chain leading up to the last step, and allowing the learner to complete the last step independently. This procedural variation is meant to encompass the benefits of backward chaining while providing exposure to all steps of the chain, increasing the efficiency of BC (Spooner et al., 1986). By increasing the contact that the learner has with earlier steps within the behavior chain, they will theoretically be able to complete those steps more independently once a training step and reduce the overall time to acquisition (Spooner et al., 1986).

Although not a widely used method of chaining, RC has been investigated in several studies. These studies, however, have produced inconclusive results. Spooner et al. (1986) investigated the effectiveness of RC and BC when teaching a vocational task and found that the reverse chaining method resulted in a slower rate of learning. No discernable difference between the two methods was found when comparing time to criterion. The results of this research challenge the notion that RC is a more effective alternative to BC. Contrary to these results, Hsu and Dunn (1984) investigated the effectiveness of RC when compared to FC when teaching a motor task. Results indicated that RC may be superior to FC, because it required fewer trials and prompts to reach mastery criteria. Because the research on RC is limited, it is difficult to conclude the effectiveness of this procedure.

Total Task Chaining

When using TTC, all steps within the chain are trained and completed each time the activity is presented (Cooper et al., 2020). Reinforcement is provided for the correct completion of the entire chain. Mastery is achieved when all steps within the chain can be independently performed to criterion. Within the literature, total task chaining is sometimes called total task presentation (Spooner, 1984), concurrent chaining (McDonnell & McFarland, 1988), or whole

task presentation (Cooper et al., 2020). Although known under several names, the definition of total task chaining within the literature is well-established and cohesive across multiple disciplines.

A benefit of this procedure is that is allows the instructor to take advantage of tasks that must be fully completed on a regular basis, such as hand washing, in order to capitalize on instructional time and increase learner participation throughout all steps of the task (McWilliams et al., 1990). TTC may also be easier to implement in natural settings, especially for those with little behavior-analytic training, because training is not focused on one response within the chain. TTC often results in faster rates of acquisition because learners are not limited to demonstrating criterion on one step at a time, although these results vary within the literature (Chazin et al., 2017; McWilliams et al., 1990). A disadvantage of TTC is that because each step is trained every time the chain is presented, errors are more likely to occur, which may function as a form of punishment for some learners and impact acquisition.

Chaining Procedural Variations

BC, FC, and TTC are all well-established chaining procedures within the literature. Procedural variations may be implemented within chaining procedures to increase the efficiency and effectiveness of these teaching methods. Several variations are mentioned with the current chaining literature and are discussed below.

Leap-aheads

Leap-aheads were introduced as a procedural variation to increase the efficiency of BC. Instead of teaching each step individually, this method involves “leaping ahead” in the component skill sequence by combining several of the components into “functional clusters”. These functional clusters are then taught one at a time before probing steps in additional clusters,

instead of each skill being taught individually, which is meant to decrease training time (Spooner et al., 1986). This method, while theoretically significant in terms of efficiency, has limited supporting research.

Spooner et al. (1986) first investigated the use of leap-aheads by including this procedural variation into BC and RC procedures to teach a vocational skill. BC with leap-aheads resulted in a higher rate of acquisition and a more drastic decrease in errors, while the RC with leap-aheads resulted in a higher rate of correct responding. From these results, Spooner et al. (1986) concluded that BC with leap-aheads was the superior procedure, but the results of this study and the effectiveness of leap-aheads could be argued as fairly inconclusive. More recently, Valentino et al. (2015) investigated the use of BC with leap-aheads to teach intraverbal storytelling to young children diagnosed with autism, and found that the use of leap-aheads in this procedure effectively taught this skill to the participants. Although proven to be effective in teaching these skills, additional research is needed to draw conclusions regarding the use and effectiveness of leap-aheads.

Clustered Chaining

Procedurally similar to leap-aheads, clusters in chaining procedures are also mentioned within the literature. To use this variation, the steps of a task are divided into functional clusters, similar to when using leap-aheads, and steps within that cluster are taught to criterion. When all the steps within that cluster have been mastered, training on the steps in the following cluster are taught to criterion, until all steps within the task have been trained (Valentino et al., 2015). Unlike when using leap-aheads, all steps within the task are explicitly trained. Valentino et al. (2015) used a clustered forward chaining procedure to teach a young adult diagnosed with autism to follow a recipe and found that the use of clusters was effective in teaching this skill.

Shorter Total Cycle Response Sequences

A third procedural variation used with chaining procedures is the use of shorter total cycle response sequences. Used by McWilliams et al. (1990), these sequences were developed as a method to teach learners lengthy behavior chains. Similar to leap aheads and clusters, these behavior chains were divided into shorter response sequences, and learners can then be taught to engage in each sequence to criterion before learning the next sequence. When all sequences were mastered, they were linked together using a FC procedure. The effectiveness of this procedure was demonstrated when teaching bed-making skills to adolescents diagnosed with various developmental disorders. McWilliams et al. (1990) also stated specific advantages to using this procedural variation that may be especially salient when teaching long behavior chains, including a reduction in instruction time when compared to TTC to teach the same long behavior chain. Using this method also decreases the likelihood of imposing an artificial response ceiling, which may occur when using FC or BC. Additional advantages include a more manageable method of teaching all behaviors in a long behavior chain simultaneously.

Completion of Untrained Steps

For BC and FC procedures, there are several variations for the completion of the untrained steps within the behavior chain: teacher completion, learner completion, and no completion. Teacher completion of untrained steps involves the teacher completing the task in the presence of the learner. Some research suggests this exposure may be beneficial to the learner and aid in skill acquisition (Griffin, et al., 1992). Learner completion requires the learner to be prompted to complete each untrained step, and no completion results in terminating completion of the chain after the trained step.

Bancroft et al. (2011) compared these variations of untrained steps using a FC procedure to teach leisure skills to children and adolescents diagnosed with autism. First, student completion and teacher completion of the chain were compared. These results showed that both methods of completion were successful in teaching the chain, but that for two of the participants, student completion of the chain resulted in acquisition in fewer sessions. During the second experiment of the study, all three completion variations were compared. These results showed that, for most participants, student completion again resulted in the fastest acquisition, followed by no completion. Teacher completion resulted in the slowest acquisition. Results of both experiments showed that student completion resulted in the fewest number of trials to mastery for most participants, with teacher completion resulting the fewest number of sessions to mastery for the other two participants. When comparing all three completion methods, no completion resulted in the shortest session duration. Bancroft et al. (2011) concluded that all options may be viable, and dependent on the learner.

Kobylarz et al. (2020) also compared the effectiveness and learner preference for four variations of completion of untrained steps within a BC chaining procedure: teacher completion, participant completion, no completion, and control completion. Teacher and participant completion were the same as those used by Bancroft et al. (2011). When assessing learner preference for these variations, one participant consistently favored the no completion condition, and two other participants initially teacher completion condition before shifting to favor the no completion condition. The results of this study in terms of efficiency of procedures differs from those of Bancroft et al. (2011). Results showed that although all procedural variations established this skill across participants, the participant completion phase was the most efficient and efficacious.

Prompting Procedures

There are multiple variations within the chaining literature of whether, when, and how responses within the behavior chain are prompted.

Prompt Delay Strategies. Several research articles have investigated the use of constant time delay procedures to provide prompts within chaining procedures. For example, Schuster et al. (1988) researched the effectiveness of constant time delay procedures when teaching adults diagnosed with developmental disabilities to complete basic cooking tasks. This procedure was effective at teaching this skill, generalized to other environments, and maintained over a 3-month probe period. Griffen et al. (1992) expanded on these results by researching the effectiveness of a 5-second constant time delay procedure when delivering prompts to individuals learning to independently prepare food using direct instruction and observational learning. Results again showed that a constant time delay was effective at directly teaching cooking skills.

Progressive and unlimited time delay procedures have also been investigated as a method of providing prompts to individuals while completing behavior chains. Walls et al. (1984) investigated the use of these prompting procedures within FC and TTC techniques when teaching vocational skills to individuals diagnosed with developmental disorders. When using the unlimited time delay strategy, the researchers first modeled the task and then allowed participants to attempt to complete the task independently. Prompts were only provided after an error was made. The progressive time delay strategy consisted of systematically increasing the time delay before a prompt was given based on previous correct responding. Results showed TTC methods resulted in less training time that FC methods, but also required more prompts. The TTC method with unlimited delay also produced the most errors for any procedure. Little difference was observed between the other prompting methods used.

Pre-guidance vs. Post-guidance. An article written by Zane et al. (1981) examines the use of pre-guidance vs. post-guidance when teaching behavior chains through BC and TTC methods. When using pre-guidance, the trainer provided a model prompt to participants prior to providing the instruction. Additional prompting was provided if participants made an error completing the task. When using post-guidance, the trainer did not provide any prompts before the participant responded. Results showed the pre-guidance was more efficient for both BC and TTC methods in terms of teaching time and total errors made.

Prompting Hierarchies. Various prompting procedures have also been used within chaining procedures. When using LTM prompting, the instructor begins by briefly providing an opportunity for the learner to independently respond before providing the least intrusive physical prompt available, such as guiding the learner by the forearms or elbows to complete the task. If this prompt is unsuccessful, more intrusive prompts, such as guiding the learner by the wrists or hands, are systematically introduced until the learner successfully completes the skill. When using MTL prompting, the instructor begins by providing the most intrusive prompt available, such as guiding the learner to complete the trial using hand-over-hand guidance. The prompts are then systematically faded out as the learner begins to demonstrate independence in successfully completing the step (Libby et al., 2008). Both of these prompting procedures can also be combined with a constant or progressive time delay procedure (Cooper et al., 2020).

Libby et al. (2008) compared the effectiveness of MTL, LTM, and MTL with a 2-second time delay within an FC procedure to teach young children diagnosed with autism to build with blocks. Results showed that for two of the five participants, MTL was more effective than LTM. For the other participants, both procedures resulted in skill acquisition, but LTM prompting was most efficient. Errors per session were higher when using LTM prompting across all participants.

When comparing these procedures in addition to an MTL with a time delay procedure, LTM prompting was most efficient for all participants, following by MTL with a time delay, and MTL being the least efficient. There was little difference in rate of acquisition between LTM and MTL with time delay. Both MTL and MTL with time delay procedure fewer errors than LTM, showing that MTL with time delay may be just as efficient as LTM, but produces fewer errors during skill acquisition.

Prompt Types. Seaver and Bourret (2014) investigated the use of verbal, gestural, model, and physical response prompts within a FC procedure to teach individuals diagnosed with autism to engage in new responses. These prompt types were also then evaluated in terms of prompt hierarchies and fading techniques to determine the most efficient methods. Overall, results showed differences in sensitivity to prompts and prompt fading techniques across individuals, but were consistent within individuals. This lead Seaver and Bourret (2014) to conclude that determining a universally effective prompt across individuals may not be possible, but that it might be possible to determine the most effective prompt method through the development of individual assessment.

Simultaneous Prompting. Simultaneous prompting is defined as providing a prompt immediately after providing the discriminative stimulus to engage in the correct response, similar to a 0-second prompt delay. When using a simultaneous prompting, the time delay is never increased. Instead, immediate prompting is provided until the skill is mastered (Dollar et al., 2012). This prompting procedure has been used within chaining procedures only a small number of times within the literature, primarily in other disciplines, such as education. One of these studies, conducted by Dollar et al. (2012), investigated its use with a FC procedure to teach adults diagnosed with intellectual disabilities independent living and leisure skills. Results

indicated that this method of prompting was successful within a FC procedure to teach this skill to this population. Additional research is needed to apply this technology with the field of behavior analysis.

Video Modeling. Recent research as begun to include modeling and video modeling into chaining procedures. When using video modeling, the learner watches a video of another individual initiating and engaging in the target behavior (Drysdale et al., 2014). Drysdale et al. (2014) incorporated point-of-view video modeling and video self-modeling with animation into a FC procedure to teach toilet training to two young children diagnosed with autism. Results indicated that this method of toilet training was effective for the participants, and that the skills acquired were maintained and generalized across settings.

Video modeling has also been used in BC procedures. Rayner (2011) implemented a peer and adult model video prompting procedure to teach children diagnosed with autism how to tie their shoes. In this procedure, participants were shown a video of each target skill prior to an opportunity to demonstrate the skill themselves. Video prompting was slightly effective for two of the three participants, but none of the participants reached mastery criteria using only the video prompting method. A BC procedure was the implemented, and all participants met mastery criteria. Moore et al. (2013) also used a video modeling-based package with a BC procedure to teach a young girl diagnosed with autism to write her name. This intervention was successful in teaching the participant to correctly and legibly write her name and supports the effectiveness and efficacy of using video-modeling in combination with chaining procedures. This research suggests that video modeling may be effective when used within chaining procedures.

Comparative Effectiveness of Various Chaining Procedures

Comparisons of chaining procedures have been performed to identify the most effective procedure. Differences between BC, FC, and TTC are the most common procedures investigated, but several variations of these procedures have also been researched. This body of research is limited, and provides inconclusive results.

FC versus BC

Weiss (1978) and Moore and Quintero (2019) concluded that FC was more effective when compared to BC. In an experimental setting, Weiss (1978) studied the acquisition of basic response chains in humans using a simple response console and found that FC resulted in fewer errors. Because it resulted in fewer errors during acquisition, Wiess (1978) concluded that FC was superior to BC. In a rather unique applied setting, Moore and Quintero (2019) compared BC and FC to teach two Olympic weightlifting movements. For each participant one movement was trained using FC, and another was trained using BC. Across all participants, the movement that was trained using FC was mastered in fewer trials than movements taught using BC. For movements that have not been mastered using a BC procedure, the FC procedure was then implemented, and resulted in mastery of the skill for all participants.

The theoretical basis behind BC that suggests that beginning with teaching the last step of the behavior chain is more efficient due to the temporal proximity to reinforcement implies the superiority of this method. However, there is little empirical evidence supporting the superiority of BC over other chaining procedures.

Three articles provide evidence of little difference in effectiveness between FC and BC, and include articles written by Hur and Osborne (1993), Slocum and Tiger (2011), and Supawadee et al. (2009). Hur and Osborne (1993) compared the effectiveness of FC and BC when teaching a similar skill to adults with disabilities. These data show little difference between

correct responding between the two chaining methods, providing additional support for the similar effectiveness of these behavior chaining techniques.

Slocum and Tiger (2011) and Supawadee et al. (2009) compared the effectiveness of BC and FC procedures when implemented with children. The efficiency and preference between FC and BC were compared by Slocum and Tiger (2011) when teaching motor skills to children. Results demonstrated that there were no consistent differences between child preferences or acquisition for either chaining method. These results led Slocum and Tiger (2011) to conclude that BC and FC methods are equally effective in establishing behavior chains. Supawadee et al. (2009) used FC and BC to teach children diagnosed with developmental disabilities to independently dress themselves. Similarly, these authors concluded that the desired behavior chains were established using both chaining methods.

FC versus RC

Hsu and Dunn (1984) compared the use of RC and FC to teach a motor task to individuals diagnosed with developmental disabilities. Results demonstrated that RC required fewer trials to criterion and fewer physical prompts than FC. Other research articles demonstrating the superior effectiveness of reverse chaining over other chaining procedures were not found.

FC versus TTC

McDonald and McFarland (1988) compared the use of FC and TTC to teach individuals with developmental disabilities how to use a washing machine and laundry soap dispenser. Results showed that skill acquisition was more efficient when using TTC than FC for all four participants. Other articles comparing these chaining procedures were not found.

BC versus TTC

All three articles compared TTC with BC when teaching vocational tasks to individuals diagnosed with developmental disabilities. Research comparing the effectiveness of TTC with other training procedures were not found. Spooner et al. (1983) and Spooner (1984) conducted almost identical research studies, and found similar results. Spooner et al. (1983) found that rates of acquisition and accuracy rations to be great with TTC than with BC. Spooner (1984) found that TTC resulted in greater rates of learner across all participants, providing additional evidence to support these findings. When comparing training time, Spooner et al. (1984) found that TTC required additional time, but also resulted in the greater amount of behavior change per unit of time. For similar reasons, Martin et al. (1981) suggests that TTC is superior to BC. Time on task was found to be greater when using TTC, and the trainers expressed greater preference for the TTC procedure than the BC procedure.

BC versus RC

No articles comparing BC and RC were found in this literature review.

TTC versus RC

One research article, written by McDonnell and Laughlin (1989), demonstrated no difference in trials to criterion between BC and TTC. This article was the only article found that demonstrated that TTC was as effective as other chaining procedures used.

FC versus BC versus TTC

Two research articles comparing FC, BC, and TTC were found in this literature review. Within an applied setting, Ash and Holding (1990) compared BC and FC in the acquisition of keyboard skills. Results showed that both FC and BC are superior to total task presentation, but that FC was superior to BC because it resulted in fewer errors and trials to mastery, as well as greater retention during maintenance trials.

Walls et al. (1981) compared the effectiveness of BC, FC, and TTC in teaching vocational tasks. There was not difference in effectiveness between BC and FC methods, but both BC and FC were shown to be more effective than TTC. Therefore, we may conclude that BC is more effective that TTC, but this claim is speculative at best. It's effectiveness over FC is not supported. Other evidence suggesting the superiority of BC over other methods was not found.

Procedural Variations

Little research comparing the effectiveness of chaining procedural variations currently exists in the literature. One article that does investigate the comparative effectiveness of procedural variations is Spooner et al. (1986). This research compared the effectiveness of BC with leap-aheads and RC with leap-aheads, and found that BC with leap-aheads was more effective in teaching the desired vocational task. No other research replicating this comparison or comparing these procedural variations within other methods of chaining, such as FC, currently exist within the literature.

Research comparing prompting procedures, including LTM and MTL, has been performed within chaining procedures. Comparisons of other procedural variations, such as teacher completion, student completion, and no completion of the behavior chain have also been investigated. The results of this research provide evidence supporting the superior effectiveness of some variations over others. However, no articles exploring the use of these procedural variations within other chaining methods was found within the literature.

Best Practice Recommendations

One of the primary criticisms of the current chaining literature provided within this review is that is provides inconsistent results regarding the comparative effectiveness of various

chaining procedures and procedural variations. Because of this, it is not ethical to provide best practice recommendations regarding this topic. However, there are several recommendations based on the current literature, outside of the comparison relations between chaining procedures, that can be provided at this time.

Both FC and BC methods can be used with errorless learning procedures, and can therefore result in fewer errors during skill acquisition. Clinicians should consider these methods of chaining for learners who may benefit from errorless learning procedures. When using these methods, probing steps beyond the target skill is recommended for several reasons. Chazin et al. (2017) suggests that although FC and BC can be used in errorless learning, these methods can also be inefficient. Both FC and BC can impose an artificial performance ceiling, in which the learner has mastered other skills, but may not have the opportunity to demonstrate mastery of these skills until all steps have been mastered (Lambert et al., 2016). Probing of all steps within the chain may identify other steps that have been learned through practice effects, and can identify steps that still need to be taught. Clinicians should regularly probe the entire response chain to determine mastered steps and to increase the efficiency of these methods to prevent loss of instructional time.

Spooner et al. (1986) suggests that ending instruction after completing the target step may result in the loss of learning opportunities through practice effects. Because of this, completion of the entire chain when using BC and FC may be beneficial to the learner. Libby et al. (2008) supports this conclusion and states that student completion of untrained steps may be most beneficial to the student in acquiring response chains. Chazin et al. (2017) also suggests that prompting through untrained steps may be the most useful in certain situations in clinical settings, such as when teaching recipe following, as this method decreases the waste of materials.

Clinicians should consider completing the response chain in some way when using BC and FC. Student completion will likely provide the most benefits to the learner and decrease time to acquisition, but this may not be possible for all learners. Clinicians may consider teacher completion in these situations, as there is some research that suggests that learners observing the correct response assists in skill acquisition, as well (Libby et al., 2017).

If considering using TTC, Chazin et al. (2017) also suggests that this method may result in quicker demonstrations of the target skill, but may also increase the probability of errors occurring, especially with longer response chains. When teaching a longer response chain, segmenting the target by using a procedural variation of chaining such as leap-aheads or shorter total cycle response sequences may be beneficial and increase the efficiency of learning.

Lastly, when teaching new response chains, clinicians should also consider using an MTL with time delay prompting procedure for learners who can tolerance physical prompting. According to Libby et al. (2017), the efficiency of this procedure is comparable to using LTM prompting, but results in fewer errors by the learner. Although it may result in more frequent errors, LTM prompting has also be shown to be effective when used in response chains, and may be effective for learners who can tolerate physical prompting when needed. For learners who do not tolerant physical prompting, clinicians may want to consider video modeling or teacher completion variation of chaining procedures, both of which have been shown to be successful in teaching various skills.

As demonstrated through this literature review, chaining techniques are well established as effective methods within the literature, but still remain largely under researched. Gaps and inconsistencies within the literature are obvious upon a closer look. To provide clinicians with a

comprehensive summary of effective chaining techniques, additional research on all aspects of chaining is needed.

Chapter IV: Discussion

A review of the current literature shows chaining procedures are well established teaching methods within various disciplines, including behavior analysis. Definitions of these procedures are cohesive and consist across research articles, and provide clinicians with a consistent technology to use within applied settings.

Procedures such as FC, BC, and TTC have been empirically supported as effective methods for skill acquisition across populations and response targets, including communication (Valentino et al., 2015), self-help skills (Drysdale et al., 2008; Supawadee, et al., 2009; Shrestha et al., 2012), vocational tasks (Walls et al., 1981; Hur & Osborne, 1993), and leisure skills (Chazin et al., 2017). Procedural variations, including the use of prompting hierarchies (Libby et al., 2008), leap aheads (Spooner et al., 1986), and completion methods (Bancroft et al., 2011) are also explored within the literature, providing additional methods of improving clinical applications to clinicians.

Research comparing various chaining methods and procedural variations also exists within the literature. Research articles supporting the superiority of FC, BC, TTC, and RC all exist within the literature. Inconsistencies, such as differences in which chaining methods are compared to one another, exist within this literature and make a true comparison of these procedures near impossible. Superiority of procedural variations within chaining procedures also exists, but this literature is limited in scope and applicability to applied settings.

The literature supporting one chaining method over another is counterbalanced by a research that suggests there is little difference between the effectiveness of chaining methods. Four articles included in this literature review showed little difference between FC and BC methods. Very few articles showing little difference between other chaining procedures, such as

RC and TTC, were found. While this lack of research may appear to favor the superiority of these methods, it instead calls the use of the procedures themselves in applied settings into question. This also applies to procedural variations, such as leap aheads or methods of completion. Because of the limited scope of the current research, conclusions regarding the effectiveness of these methods and procedural variations within chaining methods cannot be drawn.

Future Research

Future research should address these inconsistencies within the current literature regarding the comparative effectiveness of chaining methods. Replicating current studies may be helpful in providing additional evidence for or against various chaining procedures, as well as in providing updated literature regarding these procedures, but perhaps the most effective and efficient method of establishing a hierarchy of chaining methods would be to systematically compare these methods across response classes. Systematic applications of procedural variations could then be researched to further expand the chaining literature.

Much of the current literature comparing the effectiveness of various chaining methods and procedural variations also exists outside of behavior analytic journals. Behavior analytic researchers should work to further expand the current literature regarding chaining. Chaining is a widely-used teaching method in applied behavior analytic settings, and providing additional research on these methods from within the field of behavior analysis will assist in guiding clinicians to implement the most empirically support practices derived from research designed to aid in behavior analysts in providing direct services.

Directions for future research can also be found within the current chaining literature. Based on the results of their research, Slocum and Tiger (2011) and Moore and Quintero (2019)

question whether certain response chains lend themselves better to one chaining method over another. For application in applied settings, this is an important area of research. Other potential areas of research mentioned includes variables that may contribute to the different effectiveness of chaining procedures, such as the type of task, learner characteristics, and prompting methods (Hsu & Dunn, 1984; Kobylarz et al., 2020; Slocum & Tiger, 2011) and instructional preference for chaining procedures (Slocum and Tiger, 2011; Hur and Osborne, 1993).

Chapter V: Conclusion

Although a well-established procedure within the literature, the present analysis shows limitations to the current chaining literature. Areas of future research, as well as lack of ability to provide best practice recommendations are highlighted. The present analysis also provides many areas of research to focus on to further expand our knowledge and application of these procedures within behavior analysis. Conducting this research can provide clearer best practice recommendations to practitioners to better inform treatment decisions and implement empirically-supported intervention recommendations.

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Appendix A

Table 1

Comprehensive List of Articles Describing Chaining Methods and Procedural Variations Used

Type	Procedural Variation	Author	Year	Journal	Findings
FC	Untrained Steps	Bancroft et al.	2011	Journal of Applied Behavior Analysis	Student completion more effective for 5/7 participants, teacher completion more effective for 2/7 participants
FC	Clustered	Chazin et al.	2017	Journal of Autism and Developmental Disorders	Clustered FC effective for 1/1 participant
FC	Simultaneous Prompting	Dollar et al.	2012	Research in Developmental Disabilities	Simultaneous prompting effective for 2/2 participants
FC	Video Modeling	Drysdale et al.	2014	Journal of Developmental and Physical Disabilities	FC effective for 2/2 participants
FC	Prompt Delay	Griffin et al.	1992	Journal of Applied Behavior Analysis	Constant time delay effective for 3/3 participants
FC	Prompt Delay	Lambert et al.	2016	Behavior Analysis in Practice	FC effective for 1/1 participant
FC	Prompting Hierarchies	Libby et al.	2008	Behavior Analysis in Practice	Study 1: LTM and MTL resulted in fewer trials to criterion and fewer errors, respectively, for 4/4 participants Study 2: MTLD resulted in fewer errors and similar time to criterion as LTM for 3/3 participants
FC	Shorter Cycle Sequences	McWilliams et al.	1990	Education and Training in Mental Retardation	Shorter total cycle response sequences effective for 3/3 participants
FC	Video Modeling	Shrestha et al.	2012	Journal of Behavioral Educations	FC with video modeling effective for 1/1 participant
FC	Prompt types	Seaver & Bourret	2014	Journal of Applied Behavior Analysis	Study 1: Model, physical and verbal plus gestural most effective for 6/10, 2/10, and 1/10 respectively. Inconclusive data for 1/10. Study 2: Delay fading and least-to-most fading most effective for 2/5 and 3/5 participants, respectively. Study 3: Most efficient prompting methods identified for 5/5 participants

Table 1 Continued

Type	Procedural Variation	Author	Year	Journal	Findings
BC	Prompt Hierarchies	Jerome et al.	2007	Journal of Applied Behavior Analysis	BC effective for 3/3 participants
BC	Untrained Steps	Kobylarz et al.	2020	Behavioral Interventions	BC with participant completion most effective for 3/3 participants
BC	Video Modeling	Moore et al.	2013	Journal of Developmental and Physical Disabilities	BC with video modeling effective for 1/1 participant
BC	Video Modeling	Rayner	2011	Developmental Neurorehabilitation	BC and video modeling effective for 2/2 participants
BC	Leap-aheads	Valentino et al.	2015	Analysis of Verbal Behavior	BC with leap-aheads effective for 3/3 participants
TTC	Time Delay	Schuster et al.	1988	Journal of Applied Behavior Analysis	FC with time delay effective for 4/4 participants
FC vs. BC	None	Ash & Holding	1990	Human Factor	FC more effective for 8/8 participants; FC and BC more effective than TTC for 8/8 participants
FC vs. BC	None	Hur & Osborne	1993	The British Journal of Developmental Disabilities	No difference between BC and FC groups
FC vs. TTC	None	McDonnell & McFarland	1988	Research in Developmental Disabilities	TTC more effective for 3/4 participants
FC vs. TTC	Prompt Delay	Wall et al.	(1984)	Education and Training of the Mentally Retarded	On average, TTC required more prompts that FC. TTC with unlimited delay resulted in more errors across 19 participants. Little difference across other conditions.
FC vs. BC	None	Moore & Quintero	2019	Journal of Applied Behavior Analysis	FC more effective for 4/4 participants
FC vs. BC	None	Slocum & Tiger	2011	Journal of Applied Behavior Analysis	No difference for 4/4 participants
FC vs. BC	None	Weiss	1978	Journal of the Experimental Analysis of Behavior	FC more effective for 10/10 participants
FC vs BC	None	Supawadee et al.	2009	Journal of Occupational Therapy, Schools, and Early Intervention	BC and FC effective for 6/6 participants
FC vs. RC	None	Hsu & Dunn	1984	Adapted Physical Activity Quarterly	All participants in RC group (15) required fewer assists and trials to criterion than BC group (15)

Table 1 Continued

Type	Procedural Variation	Author	Year	Journal	Findings
BC vs. TTC	None	Martin et al.	1981	Behavior Research of Severe Developmental Disabilities	Experiment 1: TTC more effective for 4/4 participants Experiment 2: TTC resulted in more time on task than BC
BC vs. TTC	None	McDonnell & Laughlin	1988	Education and Trainings in Mental Retardation	No difference for 4/4 participants
BC vs. TTC	None	Spooner	1984	Education and Training of the Mentally Retarded	TTC more effective for 8/8 participants
BC vs. TTC	None	Spooner et al.	1983	Education and Treatment of Children	TTC more effective for 4/4 participants
BC vs. TTC	Guidance	Zane et al.	1981	Education and Training of the Mentally Retarded	Pre-guidance more effective on average in BC and TTC across 12 participants
BC vs. RC	Leap-aheads	Spooner et al.	1986	Education and Treatment of Children	BC with leap-aheads more effective for 4/4 participants
FC vs. BC vs. TTC	None	Smith	1999	Perceptual and Motor Skills	Average errors were higher in BC and FC and TTC for 75 participants
FC vs. BC vs. TTC	None	Walls et al. (1981)	1981	Behavior Modification	On average, BC and FC resulted in fewer errors than TTC for 20 participants

Note. FC = forward chaining, BC = Backward chaining, RC = reverse chaining, and TTC = total task chaining.