SCRIPT TRAINING AND FEEDBACK TYPE
IN THE TREATMENT OF
APRAXIA OF SPEECH

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ABSTRACT

Acquired apraxia of speech (AOS) is a type of motor speech disorder (MSD) characterized by deficits in the motor planning or programming of speech movements (Duffy, 2005). Because AOS is often a chronic condition that may severely impair intelligibility and, thus, significantly reduce quality of life (Ballard et al., 2015), it is necessary to develop efficient and effective treatment protocols. A previous study by Youmans, Youmans, and Hancock (2011), demonstrated the efficacy of script training in the treatment of AOS. Furthermore, extensive research in general motor learning has shown that feedback is one of the most important components of motor learning (Schmidt & Lee, 2011). Research devoted specifically to speech motor learning has generally favored this view, though few studies have distinguished between the two major types of feedback: feedback providing knowledge of results (KR) and feedback providing knowledge of performance (KP). The present study is the first to examine feedback type in treatment for AOS, and the first to examine the utility of script training specifically for a participant with AOS, but no aphasia. The findings from this single-case experimental design study reveal that, compared to KR, KP resulted in greater improvements in speaking rate. KR and KP feedback resulted in comparable gains for accuracy, but condition differences were difficult to interpret due to unexpected rising baselines for the KR scripts. Both KR and KP scripts, but especially the KP scripts, outperformed the untreated control scripts, providing further support for the efficacy of script training for AOS.

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CHAPTER 1

INTRODUCTION

Background

Acquired apraxia of speech (AOS) is a type of motor speech disorder (MSD) characterized by deficits in the planning or programming of speech movements (Duffy, 2005). Though AOS often co-occurs with aphasia and sometimes with dysarthria, it can occur in isolation and so is justifiably considered a distinct type of MSD (Duffy, 2005). Cardinal features of AOS include slow rate, prolonged segment or intersegment durations, distortions or distorted sound substitutions, errors consistent in type, and dysprosody (McNeil, Robin, & Schmidt, 1997). Most often, AOS results from a stroke, particularly from vascular disturbances to areas in the left hemisphere, associated with the neural regions responsible for speech motor planning (Duffy, 2005).

On the surface, AOS is a relatively rare disorder, representing about 7.6% of all MSDs; however, this percentage only accounts for those individuals with a primary diagnosis of AOS (Duffy, 2005). For many more individuals, AOS is a secondary diagnosis to aphasia and dysarthria (Duffy, 2005). Combined estimates from Duffy (2005) and the National Institutes of Health (NIDCD, 2008) indicate that AOS affects approximately 160,000 people in the US and that 29,000 additional cases are diagnosed each year. AOS sometimes resolves spontaneously, but is more often a chronic condition that may severely impair intelligibility and, thus, significantly reduce quality of life (Ballard et al., 2015).

Though a number of protocols exist for the treatment of AOS, the practical constraints that govern many clinical settings, such as large caseloads and limited third-party reimbursements, highlight the need to maximize available resources. Extensive research in motor learning has yielded general principles, referred to as principles of motor learning (PML), that have been shown to maximize learning (retention and transfer) for various types of motor skills. Given that AOS is a motor disorder, these principles appear to be particularly well-suited to address the motor programming and planning deficits that are believed to be at the root of AOS.

The present study attempted to provide information that will help support evidence-based, clinical decisions in the treatment of AOS. First, it sought to contribute to ongoing research about the applicability of basic PML in the treatment of AOS. In particular, the present study examined the effects of two types of augmented feedback—feedback that provides knowledge of performance (KP) and feedback that provides knowledge of results (KR)—on retention of speech motor learning skills for adults with AOS. Second, this study aimed to replicate findings of Youmans, Youmans, and Hancock (2011), regarding the efficacy of script training in the treatment of AOS.

Treatment of AOS

In a systematic review of intervention studies published between 1951 and 2003, Wambaugh, Duffy, McNeil, Robin, and Rogers (2006) concluded that people with AOS can benefit from behavioral interventions, but cautioned that the quality of the studies available for consideration was generally weak. A follow-up review of intervention studies published between 2004 and 2012 concluded that there was strong evidence to support the efficacy of two broad categories of behavioral treatments for AOS: articulatory-kinematic and rate/rhythm approaches (Ballard et al,. 2015). In addition, Ballard et al. (2015) reported that, since the Wambaugh et al. study (2006), the overall quality and quantity of research studies had increased, though some limitations discussed in the earlier study still remained.

The same study identified motor learning guided treatments as a type of articulatory-kinematic approach, but, as Duffy (2005) points out, motor learning principles, such as the importance of intensive drill, for example, can be found in virtually all approaches to AOS. PML are largely derived from studies of motor learning in limb systems and are believed to promote “long-term learning of motor acts,” as opposed to mere “acquisition” (Knock, Ballard, Robin, & Schmidt, 2000, p. 654). Given that speech is a motor task and that AOS entails deficits in the motor planning and programming of speech movements, a number of researchers have strongly recommended the application of PML in treatment (e.g. Duffy, 2005; Knock, et al., 2000; McNeil, Robin, & Schmidt, 1997). While this is a reasonable hypothesis (Maas et al., 2008), it is still uncertain whether the same principles apply for both the learning of novel limb movements in normal individuals and the relearning of speech movements in individuals with disordered neurological systems (Knock et al., 2000; Bislick, Weir, Spencer, Kendall, & Yorkston, 2012).

Nonetheless, growing research suggests that the application of PML in the treatment of AOS is worthy of continued investigation. Maas et al. (2008) and Bislick et al. (2012) have conducted reviews of research studies incorporating PML in the treatment of MSDs generally. Both reviews concluded that the approach is promising, but both also called for more high-quality studies (Maas et al., 2008; Bislick et al., 2012).

PML tend to be expressed in conceptual dyads, such that one term is associated with increased performance or acquisition, while the other is associated with increased learning or retention. These dyadic terms do not exist in simple opposition, however. For example, research in novel learning of limb movements suggests that blocked practice results in more rapid acquisition, while random practice results in greater retention (Knock et al., 2000); however, principles may interact differently across populations and tasks (Maas et al. 2008). To choose just one example, constant practice may be more beneficial during the early stages of treatment, or in cases of more severe impairment, while variable practice may be more efficacious in later stages, or in milder cases (Maas et al., 2008). For this reason, Bislick et al. (2012) call for more studies that use controlled designs to investigate principles believed to promote learning.

The present study does just this, by using a controlled design to compare the effects of two conditions of augmented feedback considered pertinent to motor learning: knowledge of performance (KP), which provides information about the nature or quality of the movement (e.g. "Your wrist was locked on that one.") and knowledge of results (KR), which provides information about the outcome of a movement in relation to its goal (e.g. "That took 37 seconds.") (Schmidt & Lee, 2011).

Many clinicians would agree that, in speech therapy, feedback is often provided, but that focused questions about its type, timing, and frequency are less often considered. In actual practice, typical speech therapy likely employs both KP and KR, in an attempt to help the client attain greater accuracy on the subsequent trial.

Unfortunately, the enquiring speech pathologist is unlikely to find many specific recommendations about feedback in textbooks and manuals. In their classic treatment manual for speech-language pathologists, for instance, Roth and Worthington (2016) note the need for "frequent feedback" for script-training in the treatment of AOS (p. 360), but say nothing about the type of feedback that should be administered. Duffy (2005) is more explicit, citing KR as "a general principle of AOS treatment" (p. 512), and adding that feedback provided by the clinician can be "reinforcing and encouraging" (p. 512). In a nearly perfect contradiction of Roth & Worthington's advice, however, Duffy (2005) suggests that feedback is most efficacious when delivered at a reduced frequency (30-60%) and with a 3- to 4-second delay. In their *Management of Motor Speech Disorders in Children and Adults*, Yorkston, Beukelman, Strand, and Hakel (2010) are even more prescriptive, claiming that KP promotes performance during the session, but impedes learning. On the other hand, the authors continue, while KR may facilitate learning, it may also cause the client to become frustrated or discouraged. Though similar statements abound in the speech motor learning literature (see Ballard et al., 2012; Maas et al., 2008; Knock et al., 2000), they are usually presented far less categorically. Indeed, since there have been no studies comparing the effects of KR and KP in the treatment of speech disorders, the authors' claim, here, might be more accurately described as a question that begs further research.

Researchers in motor learning are emphatic about the centrality and importance of feedback. According to Schmidt and Lee (2011), "Much research suggests that the provision of augmented information [i.e. feedback] is the single most important variable for motor learning (except for practice itself, of course) (p. 427). Similarly, Newell, Carlton, and Antoniou (1990) argue that, while many tasks can be learned with only intrinsic sensory feedback, there are certainly many others that cannot be learned as quickly or as well, without some form of augmented feedback (1990). Nevertheless, writing in 2008, Maas et al. (2008) reported that there has yet to be a study that compares the effects of KR and KP on speech motor learning (p. 289). In 2012, Bislick et al. and Ballard et al. still identified this as an area that required study.

Feedback on motor performance can be divided into two broad forms: intrinsic (or inherent) feedback and extrinsic (or augmented) feedback. Intrinsic feedback about motor performance comes from sensory mechanisms, while extrinsic, or augmented feedback, comes from external sources, such as a buzzer on a timer, or a verbalized judgment from another person (Schmidt & Lee, 2011). KP and KR are both examples of extrinsic, or augmented feedback.

Though not always explicitly noted in research studies, further distinctions can be made. As Schmidt and Lee (2011) point out, augmented feedback can be *concurrent* (delivered during the movement) or *terminal* (delivered after the movement). Terminal feedback can be provided *immediately* after the trial, or it can be *delayed* for some interval. It may be *verbal* or *nonverbal*. Finally, feedback can be given for an average performance over a number of trials (*accumulated*), or it can be given after each trial (*distinct*). Schmidt and Lee (2011) advise that these variables should be considered independently of one another, but there are obvious limitations to this. For example, KR feedback is, by definition, terminal feedback, though this is not the case for KP feedback, which can be administered concurrently (see McNeil et al., 2010).

Several hypotheses have been advanced to explain how augmented feedback works. Earlier behaviorist models suggested that feedback shaped human behavior much the way rewards and punishments shape the behavior of animals (see Thorndike, 1927); however, subsequent research has cast considerable doubt on this explanation. More recently, it has been suggested that augmented feedback works because it performs three non-mutually exclusive functions that can be described as informational, motivational, and associational in nature (Schmidt & Lee, 2011).

Perhaps most intuitively, augmented feedback is said to work because it provides information about what was right or wrong in a given trial, and, by the same token, implicit prescriptive information about what to do in the next. This hypothesis exerts its strongest explanatory power in those cases in which the learner is most in doubt concerning his or her own intrinsic "feedback" resources (Schmidt & Lee, 2011). It is less persuasive when the learner is aware of the disparity between his or her performance and the intended goal, as Duffy (2005) has suggested individuals with AOS often are.

Augmented feedback may also play a motivational role in learning. Regular feedback regarding performance may help break up the monotony of an otherwise boring task. In addition, knowing that one is close to achieving a goal might encourage additional attempts that, in the absence of such knowledge, would have been deemed fruitless (Schmidt & Lee, 2011).

A third hypothesis suggests that augmented feedback performs a guidance role for the learner. This hypothesis shares many features with the informational hypothesis. Unlike the informational hypothesis, however, in which more information naturally leads to greater movement accuracy, the guidance hypothesis suggests that too much guidance can actually impede learning (see Salmoni et al., 1984 and Schmidt & Lee, 2011). It is possible that, if feedback is offered too frequently or immediately, the learner may become overly reliant on it, and therefore fail to do the necessary work of synthesizing intrinsic and extrinsic feedback for the next performance. A surfeit of extrinsic feedback could also potentially block useful information from intrinsic feedback channels (Schmidt & Lee, 2011). Furthermore, knowledge about erred performance may only be helpful to a certain degree, since any indication of an error is likely to encourage the learner to change his or her response on the subsequent trial. Such feedback could be especially harmful, therefore, when the learner has just produced a nearly-accurate response, as it may inadvertently induce dramatic revisions in the next performance (Schmidt & Lee, 2011).

KR Feedback in Limb Motor Learning

According to Schmidt and Lee (2011), most previous research on augmented feedback in the limb motor learning literature has involved KR feedback (p. 398). Indeed, in much of the earlier literature, "feedback" is synonymous with KR (e.g. Newell, 1977). There are pragmatic reasons for this disparity. Chief among these is the fact that KR can be delivered in a categorical fashion (e.g. "You missed."), making it more conducive to controlled experimentation than KP, which is necessarily expressed in more qualitative and, thus, more complex, terms (Schmidt & Lee, 2011).

Robust performance and learning effects are often attributed to simple, verbal KR, which has been called the *sine qua non* of learning (see Annett & Kay, 1957). Many studies in KR and motor learning have adopted a standard paradigm. Because KR, as defined by Salmoni et al. (1984), is *augmented* feedback, and not *intrinsic* feedback provided by the senses, researchers have developed a method to distinguish the two in order to isolate and study the effects of the former. In the simplest scenario, this is done by blocking intrinsic feedback channels (through blindfolding, for instance) so that only the artificial feedback information provided by the experimenter is available to the participant (Salmoni et al., 1984). Using this paradigm, researchers, such as Bilodeau, have concluded that KR is a necessary condition for learning, when intrinsic feedback is unavailable (see Schmidt & Lee, 2011).

Young and Schmidt (1990) studied the effects of KR on a task designed to simulate striking a moving ball with a bat. In contrast to early experiments, in which sensory information was purposefully blocked, all participants in this study had access to intrinsic sensory feedback. At the conclusion of each trial, one group of participants was given KR feedback, and another group was given no feedback. KR feedback consisted of a score based on two aspects of the participants' performance. Significantly, participants in the KR condition had no knowledge of how the score related to the details of their performance. In other words, they received no KP feedback. Results indicated that participants in the KR group performed significantly better in both the acquisition and learning phases. Thus, without KP feedback regarding the pattern of their performance, participants receiving KR feedback were able to drastically and successfully modify their movement patterns. Young and Schmidt (1990) concluded that, while KP feedback may have also led to improvements, had it been included, KR feedback alone was a sufficient condition for acquisition and learning in a complex motor task. The authors hypothesized that simple KR feedback probably encouraged participants to engage in trial-and-error modifications of their movement patterns.

Swinnen, Walter, Lee, and Serrien (1993), meanwhile, performed a series of experiments designed to compare the effects of different types of augmented feedback, on a limb decoupling task. In general, the authors found that participants receiving feedback of one kind or another, performed better than controls receiving none. One experiment, in particular, however, compared the effects of kinematic feedback regarding details of performance (KP) with general outcome information (KR). Based on the results of this experiment, Swinnen et al. (1993) concluded, in agreement with Schmidt and Young (1990), that KR and KP were equally capable of improving performance for complex motor tasks, when the goal of the task was known in advance (p. 1341). The authors suggested that simple awareness of inaccuracy may have made participants more alert to flawed aspects of their performances.

The above studies show strong learning effects for simple, terminal KR feedback, even in relatively complex tasks (Swinnen et al., 1993). In light of the guidance hypothesis of learning, KR feedback may be particularly efficacious in that it provides just the right amount of guidance, without interfering with the learner's abilities to engage in active problem-solving. Indeed, simple KR feedback may actively encourage increasingly fine-tuned modifications from one trial to the next. Furthermore, when the goal is known in advance, simple KR feedback may be just as helpful as KP feedback in increasing performance and learning. Such a hypothesis appears particularly plausible in the case of speech production, in which, in the absence of sophisticated biofeedback technology, the clinician must often infer details about articulatory placement. This situation could make KP feedback impractical.

KP Feedback in Limb Motor Learning

Nevertheless, a number of researchers have expressed doubts about the breadth and power of KR. One common criticism is that KR research has often involved highly-constrained designs and relatively simple tasks that are not generalizable to natural learning contexts (see Swinnen et al., 1993). In this vein, Fowler and Turvey (1978) have argued that KR is insufficient for complex tasks, because categorical feedback about outcome does not direct the learner's attention to those aspects of his or her performance that need to be corrected in subsequent attempts. This is an intuitive criticism that likely gives voice to a position held, either implicitly or explicitly, by many practicing speech therapists. In addition, researchers have pointed out that, with the exception of highly-constrained canonical designs, KR feedback often offers information that is either redundant, with respect to the learner's own perceptions (see Salmoni et al., 1984), or is implicit in KP feedback itself (Ballard, 2012).

Gentile (1972), who coined the phrase "knowledge of performance" (see Salmoni et al., 1984), has argued that, of the two types of feedback, KP is more beneficial for the acquisition of closed skills. Poulton (1957) defined closed skills as those that could be executed with no reference to the environment (p. 472). Thus, a free-throw in a basketball game represents a closed skill, because the environmental conditions remain static. Poulton's own example of an overlearned phrase is even more germane to the present study (p. 472). Compared to KR, which has typically been studied in relatively simple designs, KP feedback may be particularly efficacious in more naturalistic situations (Wallace & Hagler, 1979), in which the results of a movement sequence are obvious to the learner. In these cases, knowledge about aspects of the movement pattern may offer a real benefit over KR, which is strictly redundant.

Wallace and Hagler (1979) designed a study, involving a basketball “set-shot,” to test this hypothesis. The participants (24 right-handed male graduate and undergraduate students) were instructed to shoot a “swish” (no contact with the rim or backboard), on a regulation basketball net. All participants shot from the same location in the set-shot position with their non-dominant (left) hands. Because they could see the result of each performance, all participants received intrinsic KR feedback, after every trial. All participants also received KR feedback, after every trial, in the form of a numerical rating, based on the site of the ball’s initial impact. This augmented feedback was simple and logical enough to be considered largely redundant with respect to the participants’ own intrinsic KR feedback. In addition, after every trial, half of the participants received terminal, verbal KP feedback about stance and motion, while the other half received social reinforcement (SR) feedback in the form of short verbal encouragement (e.g., “Good shot”). After 50 acquisition trials, there was a five minute break, followed by 25 performance trials in which KP and SR were not administered. Results showed that participants who received KP feedback not only did better during the acquisition phase, but also continued to improve in the performance phase, after verbal feedback was withdrawn. By contrast, the performance of participants who did not receive KP improved during the acquisition phase, but declined when verbal feedback was withdrawn. Given the short break, results of the performance phase cannot be said to represent long-term learning in any meaningful sense. Nonetheless, the fact that participants who received KP continued to improve after verbal feedback was withdrawn may indicate a learning effect for KP, especially in the context of a closed skill.

Newell (see Newell & Walter, 1981) has long argued for the value of KP, in a number of tasks of varying complexity. In a study of a simple, single-degree-of-freedom ballistic task, Newell, Quinn, Sparrow, and Walter (1983) showed that KP in the form of a velocity-time graph was more efficacious than simple KR regarding movement-time. Though KP was beneficial for this simple task, the authors argued that it would be even more so for complex tasks, involving multiple degrees of freedom (p. 257, 267).

Thus, in a subsequent series of experiments, Newell, Carlton, and Antoniou (1990) compared the effects of different kinds of information in a multiple-degrees-of-freedom task, in which participants had to draw an irregular, unfamiliar shape. Some participants received the image of the target shape, plus KR feedback in the form of an abstract numerical value indicating total area of discrepancy between the just-drawn image and the target image. Other participants were provided with KP feedback in the form of a residual image of the shape they had just drawn, superimposed over an image of the target shape. Somewhat unsurprisingly, the authors concluded that seeing the just-drawn image superimposed on the target shape was more beneficial than seeing the target shape and receiving abstract KR feedback about the total area of discrepancy. Based on these findings, Newell et al. (1990), concluded that, in the case of complex, closed skills, KP feedback is more beneficial than KR feedback alone.

As Brisson and Alain (1996) point out, however, in many of the tasks from which Newell's conclusions were derived (see Newell & Carlton, 1987; Newell & McGinnis, 1985; Newell, Sparrow, & Quinn, 1985), the "goal is isomorphic with the movement pattern used to achieve it" (p. 458). This was the case in the above experiment, in which the goal of drawing an irregular shape could only be achieved using a specific movement pattern. Similarly, in more real world examples, such as a gymnastics routine or a high-dive, the goal itself is the performance of a particular, ideal movement pattern. Because of this, Brisson and Alain (1996) argue that, in these kinds of tasks, KP may actually be interpreted by the learner as merely a very specific and detailed form of KR, thus potentially undermining researchers' attempts to document the distinct contribution of KP feedback.

This, they argue, may even be the case in tasks where the goal and the movement pattern are not necessarily isomorphic. Thus, in the case of learning a golf swing, for example, KP that provides an optimal movement pattern may encourage the learner to engage in a "pattern-matching strategy," in which the optimal movement pattern comes to stand in for the goal itself (p. 462). As a result, experiments that employ KP based on an optimal movement pattern may also inadvertently tell us more about KR than they do about KP.

As Brisson and Alain (1996) point out, there are many tasks in which a range of different movement patterns can be undertaken to achieve the desired outcome. This is true of striking a pitch, for instance, or serving a ball in tennis. With these kinds of tasks in mind, the authors set out to test whether KP could be beneficial, even when the learner is not provided with an optimal movement pattern, as has often been the case in experiments purportedly showing the benefits of KP. The task was similar to Schmidt and Young's (1990) simulated bat-ball task, described above. There were three groups of participants and three feedback conditions: KR-only, KP-only, and KR plus KP. As in

Schmidt and Young (1990), KR feedback consisted of a simple score. The KP-group, by contrast, received a visual display of displacement and velocity profiles, which included information about a number of potentially salient variables for the just-completed trial. Importantly, this feedback did not indicate an optimal movement pattern. Results showed that both groups receiving KP feedback demonstrated greater improvement during the acquisition phase and maintained performance levels in retention, compared to the KR-only group; however, the KP plus KR group had the highest scores in all phases of the experiment. Based on these results, the authors concluded that, even when optimal movement patterns are not identified, KP can be beneficial for learning tasks in which the goal and the movement pattern are not the same.

The above studies suggest that KP feedback may be more efficacious than simple KR feedback in promoting learning of motor skills, particularly in the context of complex skills and closed-skill tasks, in which environmental conditions remain static. Though KR-only conditions have reportedly led to comparable results in the learning of complex motor tasks, research suggests that, when there is essentially one right way to do something, feedback about particular aspects of one's performance may be more valuable than all or nothing feedback regarding correctness. In addition, Brisson and Alain (1996) showed that, even when the goal and the movement pattern are not isomorphic, KP feedback can lead to significant improvements in motor learning.

If speech, particularly scripted speech, can be considered a complex and closed-skill, the above findings may suggest a benefit for KP feedback in the promotion of speech motor skills. If Brisson & Alain's findings regarding non-isomorphic tasks hold true for speech, it may be that KP feedback about specific parameters of a performance (e.g. rate, intensity, etc.) proves more valuable than KR feedback.

KR and KP in Speech Motor Learning

In the speech motor learning literature, the bulk of the research on augmented feedback has involved combined KP and KR, particularly through the use of biofeedback. Because it provides information about aspects of performance, biofeedback can be considered KP, or kinematic feedback, by another name. Investigations into the efficacy of biofeedback in the treatment of speech disorders are becoming increasingly common (see Mauszycki, Wright, Dingus, & Wambaugh, 2016). For example, Lundeborg and McAllister (2007) and McAuliffe and Cornwell (2008) used electropalatography (EPG) in the treatment of childhood speech disorders. Though both studies reported strong positive effects for this form of biofeedback, Ballard et al. (2012) point out that neither study systematically investigated whether EPG was better at promoting acquisition or retention, or whether such detailed, concurrent, kinematic feedback was any more efficacious than simple KR feedback.

A handful of studies have investigated the effects of biofeedback in the treatment of AOS. McNeil et al. (2010) used a single-subject design to study the effects of combined KP and KR feedback, against untreated controls, on the acquisition of speech targets for two participants with AOS and concomitant aphasia. Visual KP feedback was provided by electromagnetic midsaggital articulography (EMA), and KR feedback was verbalized by a clinician. The authors reported improvement for nearly all speech targets receiving both KP and KR feedback, though generalization occurred to both intended and unintended targets, and no provision was made to disambiguate the effects of KP and KR.

In addition, Katz, McNeil, and Garst (2010) used a single-subject design to study the effects of EMA-delivered augmented feedback, against untreated controls, in the treatment of speech targets, for a participant with AOS. The authors found that combined KP and KR feedback enhanced acquisition, as well as post-treatment and long-term maintenance.

Taken together, the above studies support the efficacy of augmented feedback in the treatment of speech disorders; however, effects of KP and KR are not compared, and the emphasis is often on concurrent feedback regarding KP. It is worth noting, in this context, Schmidt and Wulf's (1997) argument that, while the kind of continuous concurrent feedback offered by the above technologies may improve performance, it can potentially degrade learning. Furthermore, the above studies employ fairly expensive and sophisticated biofeedback technology. It is all the more surprising, therefore, that despite being far easier and cheaper, simple verbal KP and KR are so rarely studied in an equally rigorous fashion.

The present study is unique among treatment studies of speech disorders that incorporate PML in their design, as it is the first to evaluate the relative effects of KR and KP in the treatment of AOS. Furthermore, in this study, all other feedback variables identified by Schmidt and Lee (2011) are kept constant. The resulting verbal, terminal, delayed, and distinct feedback is not only significantly more cost-effective than many studies incorporating biofeedback; it also more closely approximates the conditions of feedback commonly employed in traditional speech therapy.

Script Training

Roth and Worthington (2016) identify script training as 1 of 6 potentially viable treatment approaches for AOS, apart from the basic approach recommended by Darley et al. (1975). Evidence for the efficacy of script-training for AOS specifically, in this case, comes entirely from the Youmans et al. (2011) study.

As Ballard et al. (2012) point out, the minimum of three replication studies for single-subject designs has rarely been met for AOS treatment studies. To address this deficit, the present study has been partially conceived as a replication of findings by Youmans et al. (2011), regarding the efficacy of script training in the treatment of AOS. Holland and colleagues (Holland, Milman, Munoz, & Bays, 2002) developed script training as a functional communication treatment for individuals with neurogenic disorders (Youmans et al., 2011). In script training treatment, the focus is on "reinjecting islands of relatively fluent, automatic speech" for functional conversation (Youmans et al., 2011, p. 23).

In script training, the client selects several topics for scripts and may even identify particular concepts or vocabulary items that he or she would like to be included (Roth & Worthington, 2016). Once a script is constructed, training typically begins with the clinician modelling the script, one phrase at a time. Then the client produces the script, one phrase at a time, with cuing from the clinician, starting with maximum cuing and fading to none. Mastery of the first phrase is often set as a necessary condition before moving on to the second, and so on. Once an entire script is mastered, the client practices it with a range of communicative partners in a range of contexts.

Youmans, Holland, Munoz, and Bourgeois (2005) studied the effects of script training in the treatment of two adults with non-fluent aphasia. The authors hypothesized that, in the case of individuals with aphasia, script training might ease the cognitive load of real-time communication, by directing the focus of the speaker's attention away from demands associated with syntax and word-finding, and thus allowing preserved automatic speech functions to come to the fore (Youmans et al., 2005). Youmans et al. (2005) found script training to be a successful treatment, but noted that both participants fit a very narrow profile: both participants had severe expressive speech deficits, with relatively intact comprehension and cognition.

Neither participant exhibited signs of AOS; however, reasoning that aphasia and AOS often co-occur, Youmans et al. (2011) performed a subsequent study of script training in the treatment of three adults with a primary diagnosis of AOS. One participant had a secondary diagnosis of mild anomic aphasia, and the other two, a secondary diagnosis of Broca's aphasia.

The application of script-training in the treatment of AOS is potentially surprising for two reasons: First, AOS is not associated with deficits in word-finding or generating syntax, so removing this burden would not necessarily simplify the task of speaking.

Second, script training was originally based on an instance theory of automatisation (Youmans et al., 2005), which, the authors point out, is focused on acquisition (Youmans et al., 2011). This runs counter to PML which, as previously noted, are primarily concerned with retention.

Nevertheless, the authors reasoned that, just as with aphasia, AOS entails a "fundamental loss of automaticity of speech production," so a treatment that was shown to be efficacious in one case, might be so in the other (Youmans et al., 2011, p. 24). Indeed, it is certainly possible that the same treatment could work for different disorders and for different reasons. Not to mention, when applied to continuous tasks, such as speech production, instance theory happens to harmonize with certain motor learning principles. As Youmans et al. (2005) explain, instance theory proposes practicing tasks in a holistic fashion, rather than in discrete parts. In a similar vein, Schmidt and Lee (2011) warn against practicing a naturally continuous task, such as driving a car, in component parts, as this may alter the motor programming of the part. Thus, for continuous tasks, practicing the whole sequence is more likely to promote learning (Schmidt & Lee, 2011).

Finally, script training could be implemented any number of ways. Youmans et al. (2011) took advantage of this by including PML when adapting the approach for the treatment of AOS (p. 25). The first principle involved the use of blocked vs. random practice. A study by Shea, Lai, Wright, Immink, & Black (2001) suggested that ideal learning conditions might entail practicing in blocked order, before practicing in random order (Maas et al., 2008). Youmans et al. (2011) implemented this principle by switching participants to random practice after they achieved mastery in blocked practice. The authors wondered, however, if results would have been better given random practice exclusively.

Type, frequency, and timing of feedback are also important considerations from a motor learning perspective. In their study, Youmans et al. (2011) directly addressed the last two variables, but, as is true of many treatment studies, did not specify the type of feedback provided. Studies of motor learning suggest that low-frequency feedback leads to greater gains than high-frequency feedback, but frequency of feedback appears to interact with other variables, such as task difficulty and practice variability (Maas et al., 2008, p. 289). For example, low frequency feedback appears to be less efficacious during constant practice than during variable practice (Austermann Hula et al., 2008; Maas et al., 2008, p. 289). Furthermore, immediate feedback appears to be less efficacious than delayed feedback (Austermann Hula et al., 2008; Maas et al., 2008, p. 290). Youmans et al. (2011) attempted to implement these principles by providing participants with delayed feedback, during blocked practice, and summary feedback, during random practice. Because the study did not include control scripts that did not incorporate PML, the authors were unable to draw conclusions about the effectiveness of PML in promoting learning.

Research Questions

To date, no study has systematically compared the effects of KP and KR feedback in the treatment of AOS, even though the importance of feedback is widely recognized in both limb motor learning literature and speech motor learning literature. To this end, the present study seeks to determine whether KP or KR feedback leads to greater retention of speech skills in the production of functional scripts. More specifically, the present study asks whether one condition will lead to significantly greater improvements than the other in:

- percentage of script words produced correctly (PSC)
- speaking rate in words per minute (WPM)

A study by Youmans et al. (2011) suggested that script training, previously used in the treatment of aphasia, may also be a promising treatment approach for AOS. The present study aimed to determine whether these findings could be replicated in the treatment of a single participant with AOS, but no aphasia. Specifically, when compared to pretreatment measures, will script training lead to significant improvement in the above measures?

Hypotheses and Predictions

When comparing the efficacy of KP and KR feedback, two possible hypotheses deserve consideration. Compared to KP feedback, KR feedback may be more efficacious in promoting retention of speech skills. KR feedback provides simple, concrete information about performance outcome. Thus KR feedback may provide just the right amount of information to encourage, but not interfere with, active problem-solving. If this consideration holds true, the present study should show significantly greater post-treatment effect sizes for scripts receiving KR feedback. Alternatively, compared to KR feedback, KP feedback may be more efficacious in promoting retention of speech skills. If KR feedback is redundant, with respect to intrinsic feedback, as is likely the case for individuals with AOS (Duffy, 2005), specific information about details of performance may be more salient. Furthermore, KP feedback may be more efficacious in the case of closed-skills, such as speech production. If these considerations hold true, the present study should show significantly greater post-treatment effect sizes for scripts receiving KP feedback.

Lastly, the present study hypothesized that script training treatment will result in significantly greater post-treatment effect sizes for scripts receiving treatment, compared to scripts receiving none.

CHAPTER 2

METHODS

Participant

The participant was a 47-year-old female, monolingual speaker of English, with a primary diagnosis of AOS. As in Youmans et al. (2011), the Western Aphasia Battery (WAB; Kertesz, 1988) was administered. Though the participant had previously been diagnosed with aphasia, at the time of this study she was not classified as aphasic, according to the WAB. The Apraxia of Speech Rating Scale—3.0 (ASRS; Strand, Duffy, Clark, & Josephs, 2014) was also used to judge samples obtained from the ABA-2 (Dabul, 2000) and other speaking tasks. Two raters independently scored the participant's speaking samples, yielding ASRS scores of 17 and 20. An ASRS score greater than 8 indicates the presence of apraxia.

Design

The present study used a single-subject, multiple-baseline, alternating treatments design (ATD) to compare the effects of KP and KR on retention of target scripts. An ATD is ideal for a single-subject study, because it allows the participant to serve as his or her own control (Knock et al., 2000). In the present study, the participant received both treatments in all sessions, but each treatment condition was randomly paired with a particular script and counterbalanced across sessions to control for order-effects (see

Figure 1). In a second treatment phase, each treatment condition was randomly paired with a new script. Three baseline measures were collected for all scripts prior to treatment, probes were administered for all scripts once a week, and three follow-up probes were collected during the two weeks following treatment. Phase 2 scripts were probed during initial baseline and during phase 1 (the multiple baseline aspect of the design). Order of conditions (KR, KP) within each session was counterbalanced: the order was randomly determined for the first session in a week, and reversed for the second session in that week. This strategy was adopted to avoid confounding effects related to condition order (e.g., fatigue).

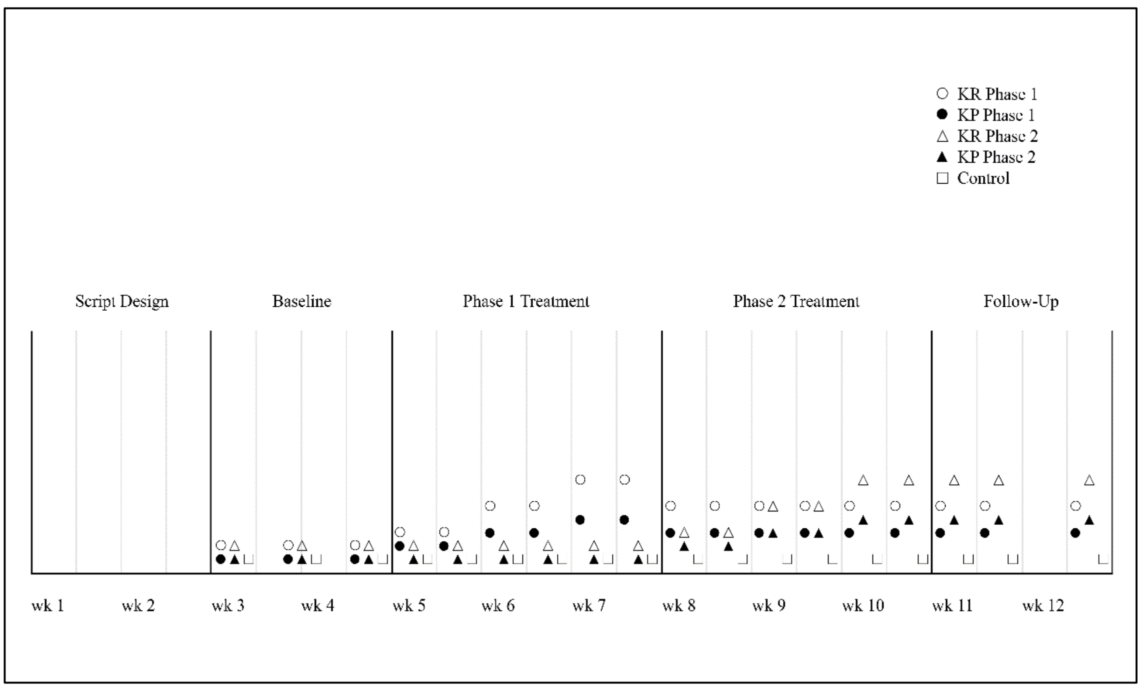

Figure 1. Treatment schedule with fictional results

One potential confounding factor, in an ATD, may arise if a particular script possesses some unknown feature that enhances the participant’s performance, relative to the other scripts. A given script may be less phonotactically challenging, for instance, or more psychologically motivating. The present study attempted to control for this potential confounding factor in several ways. First, 3 pre-treatment baselines were taken for all scripts included in the study. This allowed experimenters to observe differences in script difficulty, before treatment, and measure degree of change for each script, after treatment. In addition, the present study was comprised of two phases of treatment. In the first phase, the KP condition was paired with one script, and the KR condition with another. In the second phase, each condition was paired with a new script, allowing examiners to track performance across two scripts. Lastly, the present study controlled scripts for word and syllable length. Each script contained five utterances of one or two sentences. Mean number of words and syllables for each script were calculated by dividing the total number of words and syllables for each script by number of sentences. Mean number of words and syllables were then compared across scripts, using a t-test. No significant differences for number of words or syllables were found across scripts ($p \geq .634$). See Appendix A for all five scripts.

Another potential confounding factor in an experimental design such as this is the presence of unintended transfer-effects across behaviors. For example, a script receiving one treatment condition could indirectly benefit from the treatment applied to another script. It is possible, however, that script training largely succeeds in its goal of creating “islands,” and only islands, of fluency (Youmans et al., 2005, p. 23). By its very nature, in other words, script training may be relatively impervious to transfer-effects, desirable or otherwise. In addition, the present study included an untreated control script that received neither treatment condition, as well as weekly probes for all scripts. This measure should reveal the presence or absence of unintended transfer-effects across scripts.

Procedures

Treatment was carried out by a graduate student clinician. The participant was seen for two 60-minute sessions each week, for 12 weeks.

Prior to treatment, in weeks 1 and 2, the participant and the clinician worked together to create functional scripts. The participant was encouraged to choose topics that were personally relevant and motivating. Once topics were chosen, the participant and the clinician worked together to determine specific word choice and phrasing for each script. A total of 5 scripts (4 treated scripts, and 1 untreated control) were chosen for the study. Each script contained 5, roughly equal, lines, of one or two sentences. Once scripts were chosen, prompt phrases, to be delivered by the clinician, were developed and inserted for each line. Scripts were then randomly allocated to conditions (phase 1 KR, phase 1 KP, phase 2 KR, phase 2 KP, control).

Baseline and Probe Procedures

In weeks 3 and 4, 3 pre-treatment baseline measures were taken for all 5 scripts. At the beginning of each baseline session, the participant was audio-recorded speaking on each script. The clinician delivered the scripted prompt for each script line, but gave no cuing or feedback. As memory was not a variable of interest to the study, the participant was allowed to consult a written script, whenever she felt it necessary. She was instructed to read the script silently to herself to refresh her memory, but to put the script face down on the table before beginning the utterance. This way the participant was not reading the script aloud.

Probes for all 5 scripts were administered in the same fashion, once a week, at the start of the session, during the treatment phases, starting with week 5 and ending in week 10. Two follow-up probes were administered the week after the cessation of treatment and 1 more follow-up probe was administered 2 weeks after the cessation of treatment.

Treatment Procedure

The first treatment phase spanned weeks 5 through 7. In this phase, KP feedback was provided for the training of script 4, and KR feedback for the training of script 2. The second treatment phase spanned weeks 8 through 10. In this phase, KP feedback was provided for script 5, and KR feedback for script 3.

In the interest of replication, the present study employed relevant treatment procedures described in Youmans et al. (2011). Scripts were trained one phrase at a time and the cuing hierarchy, from maximum cuing to none, was as follows: choral production of target phrase, choral production of phrase with fading clinician participation, clinician model of target phrase, independent production by the participant with written cue cards, and independent production with no cuing.

Given that providing feedback after every trial is impractical, as well as potentially detrimental to learning (see Winstein & Schmidt, 1990), feedback was provided for 50-60% of the trials (see Winstein & Schmidt), regardless of the participant's performance, according to a predetermined and randomized schedule.

The particular contents of KP feedback naturally depended upon the productions of the participant. Feedback included information about segmental features, such as articulatory placement, manner, or voicing, and suprasegmental features, such as rate, syllable stress, or sound segmentations. As Newell and Walter (1981) point out, for practical reasons, kinematic feedback for complex tasks often limited to reflecting a "single discrete parameter" (p. 246). Similarly, to help keep total feedback time between both conditions relatively constant, and in order not to overload the participant with too much information, KP feedback in the present study tended to be limited to one aspect of the performance per attempt.

KR feedback entailed positive and negative verbal feedback regarding total accuracy. Positive feedback included statements, such as, "That was perfect!" or "You got it exactly right that time!" Negative feedback included statements, such as, "Not quite that time." or "Almost."

Research in motor learning suggests that slightly delayed feedback is more conducive to learning than immediate feedback (see Maas et al., 2008). Thus, for all trials designated for feedback, the present study introduced a roughly 3-second delay between the completion of the participant's attempt and the provision of feedback.

PML were also incorporated into the practice schedule for each session. Sessions began with 5 large practice blocks, in which each of the 5 script lines were practiced 5 times, in the original script order, before moving on to the next script line. Large block practice was followed by 10 small practice blocks, in which each script line was practiced 2 times, in the original script order, before moving on to the next line. The entire script was practiced 2 times, in this manner. Small block practice was followed by two blocks of serial practice, in which the script was practiced in order, with one attempt for each line. Completion of serial practice meant that the entire script was practiced 2 times, in this manner. Finally, the script entered 3 blocks of random practice, in which the order of script lines was randomized within script, and each line was practiced once before moving on to the next line. If random practice was completed, it meant that the entire script was practiced 3 times, in this manner.

The entire practice schedule was not completed in every session. As expected, the pace of practice gradually increased over the course of the treatment study. In the first session, the session time expired before commencing serial practice. By session 4, serial practice was routinely broached. By session 10, random practice was routinely broached, but very rarely completed, just as the session expired.

The procedure for each attempt of a script line was as follows: For each attempt of a script line, the participant's production was prompted by the clinician's scripted prompt phrase. After the participant's attempt, the attempt was scored as accurate or inaccurate. After a 3-second delay, the appropriate type of feedback was provided or not provided, according to the predetermined feedback schedule discussed above. The participant was then given a brief instruction about the cuing level for the next production (e.g. "Let's say it together this time.") and the next production was prompted by the clinician uttering the prompt phrase. An example treatment protocol for one condition, from a single session is included in Appendix B.

Data Analysis and Predictions

Baseline and weekly probes were administered for all 5 scripts. Scripts were analyzed for percentage of script words produced correctly (PSC) and speaking rate in words per minute (see Youmans et al. 2011). Analysis was performed by a blinded scorer. PSC was defined as the number of script words correctly produced divided by the total number of target words in the script multiplied by 100. The number of script words correctly produced was based on how the produced script phrase compared to the target script phrase. An accurate production was considered to be a word-for-word correct production of the target script. Errors included alternative word choices (e.g., *film* instead of *movie*), circumlocutions, speech sound errors (substitutions, omissions, distortions, additions, metatheses), and unintelligible words. Contractions (e.g., *I'm*) were counted as two words, and non-communicative repetitions of words (e.g., for *I… I… I would like…* only one *I* would be counted). Attempts at self-correction were not considered errors but would affect the speaking rate measure. See Appendix C for detailed scoring manual.

Speaking rate was measured as the number of communicative words per minute (WPM). Following Youmans et al. (2011), calculation of WPM excluded any non-communicative repetitions, interjections, and unrecognizable words, but included acceptable and recognizable communicative words, even if they were not script words (e.g., *film* was counted, even if the script used the word *movie*). See Appendix D for detailed scoring manual.

Significance of treatment effect was calculated using a variation of Cohen's (1988) *d* statistic (see Beeson & Robey, 2006). Effect size *d* is computed as (post-treatment mean score – pre-treatment mean score) divided by pre-treatment standard deviation. Effect sizes were pooled across the two treatment phases. Following Maas & Farinella (2012), changes were considered significant if greater than or equal to 1, indicating a change that exceeds the baseline standard deviation.

Reliability

Baseline and weekly probes were audio recorded. Once all probes were administered, audio files of each session were placed in a randomized order and rated by a blinded scorer. To test for reliability, 4 of the 12 probes (25%) were randomly selected and independently scored by a second blinded scorer. Averages were computed for each session. For PSC, the average discrepancy between raters across the 4 sessions was 2.1% (SD = 1.2%, range = 1.0 – 3.1%). On average, 94% of the scores were within 10% of each other (SD = 7%, range = 84% - 100%). Correlation coefficients ranged between 0.77 and 0.95 across sessions (mean = 0.88, SD = 0.08). For WPM, the average discrepancy was 9.1 seconds (SD = 1.8, range = 7.0 – 11.3). The correlation coefficients ranged from 0.89 to 0.95 (mean = 0.93, SD = 0.02). Thus, overall reliability was good.

CHAPTER 3

RESULTS

Percent Script Words Correct (PSC)

Data plots for PSC are presented in Figure 2, and effect sizes are provided in Table 1.

Data plots for WPM are presented in Figure 3, and effect sizes are provided in Table 2.

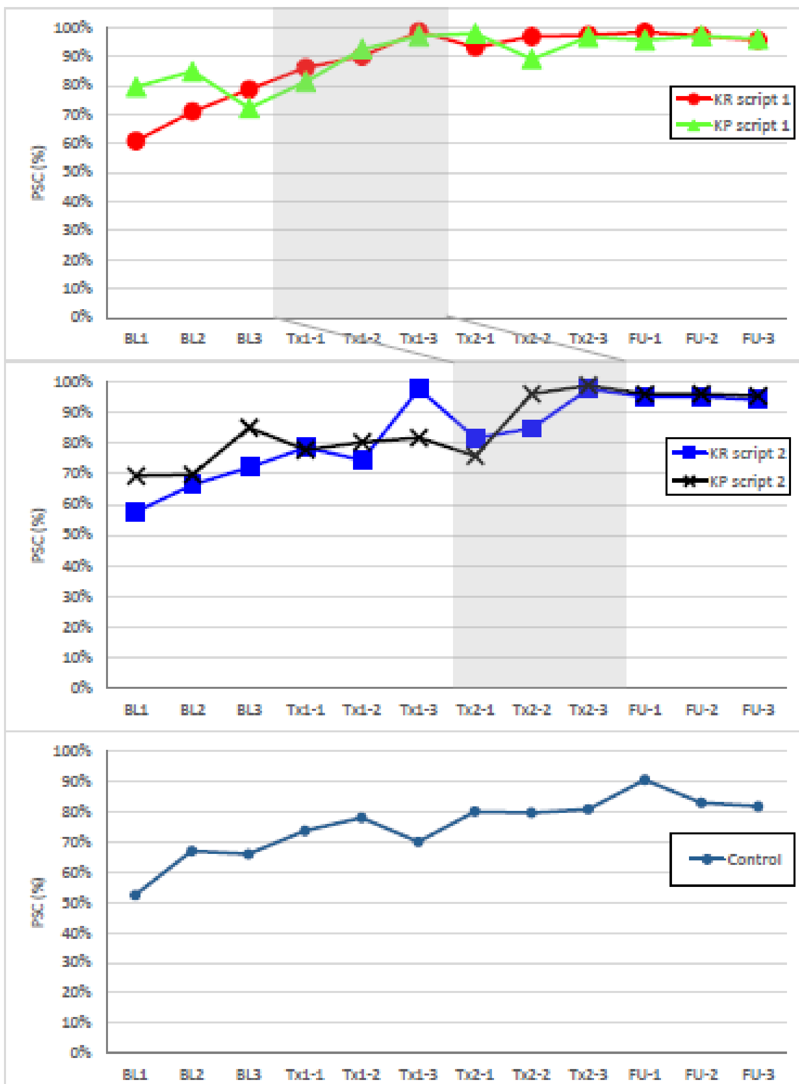

Figure 2. Percent script words correct for all scripts

PSC			
		d	change
KR	Phase 1	2.94	26.2%
	Phase 2	1.51	20.3%
	Combined	***2.23***	***23.3%***
KP	Phase 1	2.59	16.5%
	Phase 2	2.84	18.4%
	Combined	***2.71***	***17.5%***
Control	Phase 1	2.57	20.9%
	Phase 2	1.97	17.3%
	Combined	***2.27***	***19.1%***

Table 1. Effect sizes for percent script words correct

Visual inspection of the results for PSC reveals some important differences scripts. Performance on KR script 1 improved steadily, and in an essentially linear fashion through the first 3 baseline measures (i.e. before treatment) to the conclusion of the treatment phase. Furthermore, an accuracy of 93% or greater (mean = 96.33%) was maintained on the remaining 6 post-treatment probes. For this script, percent change from the initial to the final probe was 35%. By contrast, performance on KP script 1 demonstrated a clearer treatment effect. As expected, no improvement in performance was noted on this script for the initial 3 baseline measures, while accuracy steadily increased after initiation of treatment. As with the KR script, near perfect accuracy was achieved by the conclusion of treatment (97%) and maintained at level of 89% accuracy or greater (mean = 95.5%), for the 6 remaining post-treatment probes. For this script, percent change from the initial to the final probe was 36%.

A roughly similar pattern was observed in the second treatment phase. With the exception of one baseline measure, which showed a slight decrease, performance on KR script 2 generally rose in a near-linear fashion, from 58% to 98% accuracy, through the 6-week baseline phase (i.e. without treatment). Performance dipped to 82% accuracy on the first treatment probe, but then rose to 98% accuracy by the conclusion of the treatment phase, and was maintained at a level of 94% accuracy or greater for the remaining 3 post-treatment probes. For this script, percent change from the initial to the final probe was 16%. Performance on KP script 2, again, showed a clearer treatment effect. Performance on the initial 6 baseline measures spanned the values of 68% to 85%, but did not exhibit linear change. Nevertheless, though performance again decreased somewhat at the initiation of the treatment phase, performance on KP script 2 showed steady improvement, from 76% to 99%, throughout the duration of treatment. Furthermore, a minimum accuracy of 95% was maintained across the remaining 3 post-treatment probe measures. For this script, percent change from the initial to the final probe was 26%.

Performance on the control script, finally, demonstrated overall but gradual improvement that did not appear clearly associated with treatment phases. The lowest accuracy rating (58%) occurred, as expected, with the initial baseline measure, while the highest accuracy (91%) was achieved on the initial follow-up probe. For this script, percent change from the initial to the final probe was 30%. Notably, performance on the control script never reached the accuracy rate of 98% or greater achieved for the KR and KP scripts in treatment.

Roughly equal effect sizes for percent script words correct (PSC) were observed for both treatment scripts (KR = 2.23, KP = 2.71), as well as for the control script (2.27). It should be noted that effect size for the KR condition must be interpreted with caution in light of the rising trend during baseline for these scripts. Nevertheless, numerically the KP condition showed a larger effect size.

Words Per Minute (WPM)

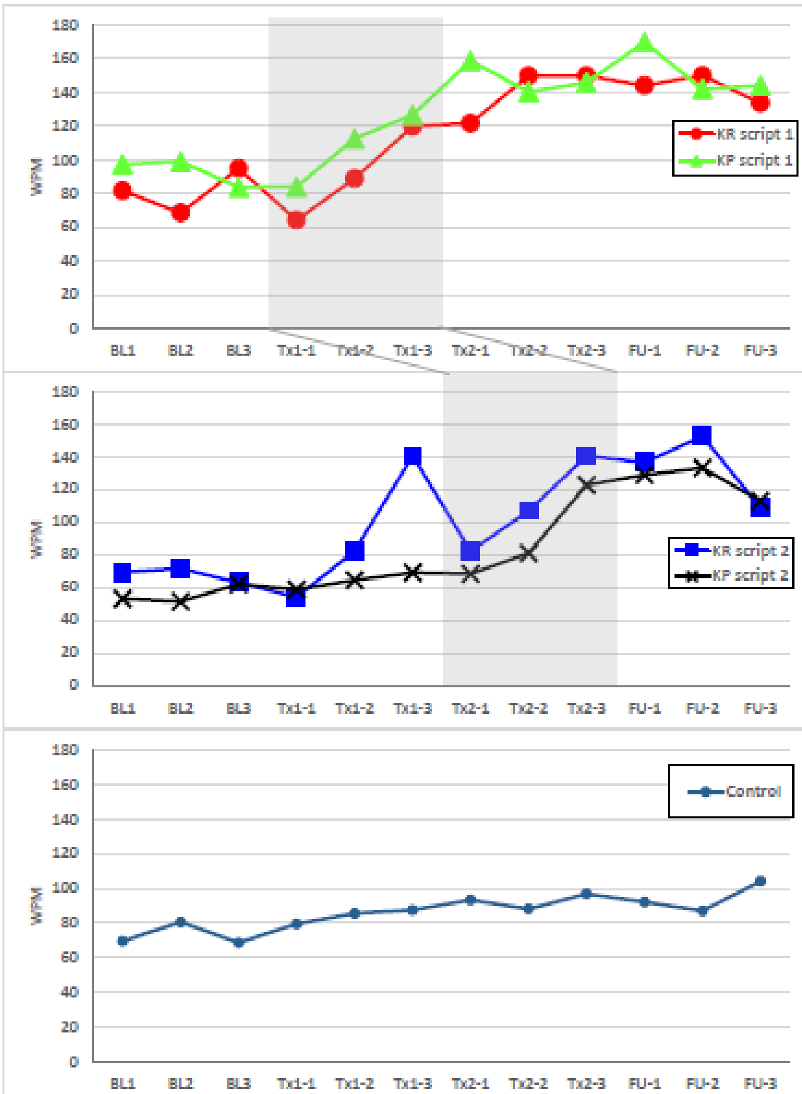

Figure 3. Words per minute for all scripts

WPM			
		d	change
KR	Phase 1	4.55	60
	Phase 2	1.70	52
	Combined	3.12	56
KP	Phase 1	6.84	57
	Phase 2	9.60	65
	Combined	8.22	61
Control	Phase 1	3.12	21
	Phase 2	2.01	16
	Combined	2.56	18

Table 2. Effect sizes for words per minute

Visual inspection of the results for WPM reveals some striking differences between scripts. During baseline, scripts were roughly comparable with each phase, with ranges between 60 and 100 WPM for KR1 and KP1 scripts, and between 45 and 80 WPM for KR2, KP2, and control scripts. No rising baselines were noted for any script during the initial three baselines. Both KR1 and KP1 scripts showed a clear response to treatment, with a steady improvement following initiation of treatment. Two of the untreated scripts (control, KP2) remained stable during the first treatment phase, indicating that experimental control was maintained. However, KR2 script did show some improvement during this phase, although this was not maintained and declined at the beginning of phase 2 treatment. Gains on treated scripts (KR1, KP1) were maintained after phase 1, with WPM values relatively stable between 140 and 160 WPM.

In phase 2, both KR2 and KP2 scripts showed a clear response to treatment, with steady improvement following initiation of treatment, which leveled off after cessation of treatment. Again, the untreated control script remained relatively unchanged, except for a very slight gradual improvement that did not appear associated with treatment. After phase 2 treatment, gains were maintained at around 120 to 150 WPM, although a slight decline was noted at the last follow-up to about 110 WPM.

In terms of effect sizes, the KP scripts showed a larger effect size (8.22) than the KR scripts (3.12), with a similar amount of absolute change (increase of 61 WPM for KP, 56 WPM for KR). Both treated scripts showed larger effect sizes (standardized and unstandardized) compared to the control script ($d = 2.56$, increase of 18 WPM).

CHAPTER 4

DISCUSSION

This was the first study to systematically compare the effects of KR and KP feedback in the treatment of AOS. In addition, it attempted to replicate findings, by Youmans et al. (2011), regarding the efficacy of script training in the treatment of this disorder. Finally, it is the only study to examine the efficacy of script training on a person with "pure apraxia of speech"—that is to say, a participant who has AOS, but no diagnosable aphasia, according to WAB standards. Below, is a discussion of the role of feedback conditions, followed by a discussion of script training for AOS.

Feedback Conditions: KR vs. KP

Performance on scripts improved in both the KR and KP conditions. Greater improvement was observed for the KP condition compared to the KR condition with respect to effect sizes for both PSC and WPM. However, for PSC, both KR scripts (*People with Aphasia Training Dogs* and *Calling about Student Loan)* already showed improvement during baselines, making interpretation of gains for these scripts difficult with respect to the role of treatment. It is unclear why these scripts had rising baselines. It is possible that both of these scripts were practiced more outside the treatment context and/or were more motivating. However, scripts were created in collaboration with the participant to be functionally meaningful and relevant, in an attempt to minimize such effects. Moreover, scripts were randomly assigned to conditions to further minimize any systematic effects or bias. Thus, the fact that it was the two KR scripts that showed a rising baseline may simply reflect a coincidence. Overall, because of the rising baselines for the KR scripts it cannot be concluded that the improvement in PSC is due to script training. In contrast, the scripts trained in the KP condition showed a clear treatment effect for PSC.

For WPM, none of the scripts showed rising baselines during the initial baseline phase, and there was a clear advantage for the KP condition. The KP condition was associated both with a larger standardized effect size and a greater absolute gain in words per minute. In both cases, the gains were attributable to the treatment, given that improvements occurred only following initiation of treatment. Performance on the KR script, by contrast, showed inconsistent improvement prior to treatment, followed by relatively consistent improvement. In addition, the untreated control script did not show improvements coincident with treatment.

Taken together, the findings indicate a benefit for KP over KR feedback, at least with respect to fluency of speech utterances as reflected in words per minute. The conditions cannot be properly compared with respect to PSC given the rising baselines for the KR scripts. These findings suggest that provision of feedback that includes information about how a movement is performed may help speakers with AOS automate the process of planning and executing phrases. This finding is important because KR is often recommended (e.g., Ballard et al., 2012; Maas et al., 2008), based on the motor learning literature or findings from typical speakers (Ballard et al., 2012). As has been argued elsewhere (Maas et al., 2008), it may be the case that practice and feedback conditions that have been found to benefit learning of limb motor skills, or speech motor skills in typical speakers, may not be the optimal conditions for individuals with motor speech disorders. Indeed, speech may be unique among motor skills (Kent, 2004; but see Maas, 2017).

Nevertheless, even within the motor literature, a number of researchers have questioned the value of KR feedback. This is especially true in the case of closed-skill tasks (Gentile, 1972), in which environmental conditions remain static (e.g. a free throw, as opposed to a tennis volley), and in more complex tasks (Fowler & Turvey, 1978), in which categorical KR does not inform the learner about specific aspects of their movement pattern. Speech, whether spontaneous or rote, is unquestionably complex. Of all speech tasks, furthermore, script learning may represent a relatively closed skill, in that the movement plan may be executed with relatively little reference to changing environmental conditions.

The present study is the first to specifically examine feedback type in treatment for AOS, and suggests that KP may in fact be the optimal condition when treating AOS. Clearly, replication of these findings is needed with additional participants.

Script Training Treatment

This study was partially conceived as a replication of a study by Youmans et al. (2011), which demonstrated the efficacy of script training in the treatment of participants with a primary diagnosis of AOS. In terms of PSC, all three participants, in that study, reached mastery, defined as 90% accuracy or greater, on all of their scripts and maintained accuracy on long-term follow-up probes. Similar results were found in the present study. The participant achieved mastery on all scripts, including the control script. Youmans et al. (2011) did not use control scripts, but did employ multiple baselines to rule out improved performance prior to the initiation of treatment. In contrast to Youmans et al. (2011), the present study revealed some improvement in PSC for KR scripts prior to the initiation of treatment, as well as modest, but relatively gradual improvement on the control script. As with Youmans et al. (2011), mastery for all scripts, save the control script, was maintained in follow-up probes administered up to two weeks after the completion of treatment.

In Youmans et al. (2011), participants did not show clear and consistent gains in speaking rate. This finding is strikingly at odds with the results of the present study, which found robust effects, in terms of WPM, especially for the KP condition. Whereas Youmans et al. (2011) found that mastered scripts did not become automatic for participants, the present study found quite the opposite. One possible reason may be that feedback in the Youmans et al. (2011) study was restricted to information about accuracy of sound productions and articulatory placement and positioning, while, in the present study, KP feedback included information about prosody, including rate, as well as segmental and intersegmental pauses. This may help account for the diverging results for WPM noted in the two studies.

Though the results regarding PSC were somewhat ambiguous due to the rising baselines and the potential ceiling effects, the findings for WPM are amply encouraging. The present study is the first to apply script training to a speaker with AOS without aphasia by formal testing. This means that the gains in speaking rate observed here are likely due to improvements in planning and executing the speech movements for these utterances rather than in word finding and sentence formulation. This supports the utility of script training as a method for treating AOS specifically, as well. Not only did the participant become noticeably more fluent, she also reported increased confidence. During treatment phase 1, she was even motivated to make the difficult call to her student loan lender, because she felt so good about her performance on her script, *Calling about Student Loan*.

CHAPTER 5

CONCLUSIONS

The present study is the first to examine feedback type in the treatment of AOS, and the first study to examine the utility of script training for a participant who had AOS, but no aphasia. The findings from this single-case experimental design study reveal that KP resulted in greater improvements than KR with respect to speaking rate. Comparable gains were noted for both conditions for accuracy, but condition differences were difficult to interpret due to unexpected rising baselines for the KR scripts. Both KR and KP scripts, but especially the KP scripts, outperformed the untreated control scripts, providing further support for the efficacy of script training for AOS.

REFERENCES

Annett, J. & Kay, H. (1957). Knowledge of results and ‘skilled performance.’ *Occupational Psychology, 31*, 69-79.

Austermann Hula, S.N., Robin, D.A., Maas, E., Ballard, K.J., & Schmidt, R.A. (2008). Effects of feedback frequency and timing on acquisition, retention, and transfer of speech skills in acquired apraxia of speech. *Journal of Speech, Language, and Hearing Research, 51*, 1088-1113.

Ballard, K.J., Smith, H.D., Paramatmuni, D., McCabe, P., Theodorus, D.G., & Murdoch, B.E. (2012). Amount of kinematic feedback affects learning of speech motor skills. *Motor Control, 16*, 106-119.

Ballard, K.J., Duffy, J.R., Layfield, C., Maas, E., Mauszycki, S., & McNeil, M.R. (2015). Treatment for acquired apraxia of speech: A systematic review of intervention research between 2004 and 2012. *American Journal of Speech-Language Pathology, 24*, 316–337.

Bilodeau, E.A., Bilodeau, I.M., & Schumsky, D.A. (1959). Some effects of introducing and withdrawing knowledge of results early and late in practice. *Journal of Experimental Psychology, 58*, 142-144.

Bislick, L.P., Weir, P.C., Spencer, K., Kendall, D., Yorkston, K.M. Do principles of motor learning enhance retention and transfer of speech skills? A systematic review. *Aphasiology, 26*(5), 709-728.

Brisson, T.A., & Alain, C. (1997). A comparison of two references for using knowledge of performance in learning a motor task. *Journal of Motor Behavior, 29*(4), 339-350.

Dabul, B. (1979). *Apraxia battery for adults*. Austin, TX: Pro-Ed.

Darley, F.L., Aronson, A.E., & Brown, J.R. (1975). *Motor speech disorders*. Philadelphia, PA: W.B. Saunders.

Duffy, J. R. (2005). *Motor speech disorders: Substrates, differential diagnosis, and management* (2nd ed.). St. Louis, MO: Mosby-Yearbook.

Fowler, C.A., & Turvey, M.T. (1978). Skill acquisition: An event approach with special reference to searching for the optimum of a function of several variables. In G.E. Stelmach (Ed.), *Information processing in motor control and learning* (pp. 1-40). New York, NY: Academic Press.

Gentile, A.M. (1972). A working model of skill acquisition with application to teaching. *Quest*, *17*(1), 3-23.

Katz, W.F., McNeil, M.R., & Garst, D.M. (2010). Treating apraxia of speech (AOS) with EMA-supplied visual augmented feedback. *Aphasiology*, *24*, 826–837.

Kent, R.D. (2004). The uniqueness of speech among motor systems. *Clinical Linguistics and Phonetics, 18,* 495-505.

Knock, T. R., Ballard, K. J., Robin, D. A., & Schmidt, R. A. (2000). Influence of order of stimulus presentation on speech motor learning: A principled approach to treatment for apraxia of speech. *Aphasiology, 14,* 653–668.

Lundeborg, I., & McAllister, A. (2007). Treatment with a combination of intra-oral sensory stimulation and electropalatography in a child with severe developmental dyspraxia. *Logopedics, Phoniatrics, Vocology, 32,* 71–79.

Maas, E. (2017). Speech versus nonspeech: What are we talking about? *International Journal of Speech-Language Pathology, 19*, 345-359.

Maas, E., Robin, D. A., Austermann, Hula, S. N., Freedman, S. E., Wulf, G., Ballard, K. J., & Schmidt, R.A. (2008). Principles of motor learning in treatment of motor speech disorders. *American Journal of Speech-Language Pathology, 17*(3), 277–298.

Mauszycki, S.C., Wright, S., Dingus, N., & Wambaugh, J.L. (2016). The use of electropalatography in the treatment of acquired apraxia of speech. *American Journal of Speech-Language Pathology, 25*, 697–715.

McAuliffe, M.J., & Cornwell, P.L. (2008). Intervention for lateral /s/ using electropalatography (EPG) biofeedback and an intensive motor learning approach: a case report. *International Journal of Language & Communication Disorders, 43*, 219–229.

McNeil, M.R., Katz, W.F., Fossett, T.R.D., Garst, D.M., Szuminsky, N.J., Carter, G.,

Lim, K.Y. (2010). Effects of online augmented kinematic and perceptual feedback on treatment of speech movements in apraxia of speech. *Folia Phoniatrica et Logopaedica, 62*, 127-133.

McNeil, M.R., Robin, D.A., and Schmidt, R.A. (1997). Apraxia of speech: Definition, differentiation, and treatment. In M.R. McNeil (Ed.), *Clinical management of sensorimotor speech disorders* (pp. 311-344). New York, NY: Thieme.

Newell, K.M. (1977). Knowledge of results and motor learning. *Exercise and Sports Sciences Reviews, 4*, 195-228.

Newell, K.M., Carlton, M.J., & Antoniou, A. (1990). Interaction of criterion and feedback information in learning a drawing task. *Journal of Motor Behavior, 22*(4), 536-552.

Newell, K.M., & Walter, C.B. (1981). Kinematic and kinetic parameters as information feedback in motor skill acquisition. *Journal of Human Movement Studies, 7*, 235-254.

Poulton, E.C. (1957). On prediction in skilled movements. *Psychological Bulletin, 54*(6), 467-478.

Roth, F. P., & Worthington, C.K. (2016). *Treatment resource manual for speech-language pathology* (5th ed.). Clifton Park, NY: Cengage.

Salmoni, A. W., Schmidt, R. A., & Walter, C. B. (1984). Knowledge of results and motor learning: A review and critical reappraisal. *Psychological Bulletin, 95,* 355-386.

Schmidt, R.A., & Lee, T.D. (2011). *Motor control and learning: A behavioral emphasis* (5th ed.). Champaigne, IL: Human Kinetics.

Schmidt, R.A., & Wulfe, G. (1997). Continuous concurrent feedback degrades skill learning: Implications for training and simulation. *Human Factors, 39*(4), 509-525.

Shae, C.H., Lai, Q., Wright, D.L., Immink, M., & Black, C., (2001). Consistent and variable practice conditions: effects on relative and absolute timing. *Journal of Motor Behavior, 33*, 139-152.

Strand, E.A., Duffy, J.R., Clarks, H.M., & Joseph, K. (2014). The apraxia of speech rating scale: A tool for diagnosis and description of apraxia of speech. *Journal of Communication Disorders 51*, 43–50.

Swinnen, S.P., Walter, C.B., Lee, T.D., & Serrien, D.J. (1993). Acquiring bimanual skills: Contrasting forms of information feedback for limb decoupling. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*(6), 1328-1344.

Thorndike, E.L. (1927). The law of effect. *American Journal of Psychology, 39*, 212-222.

Wallace, S.A., & Hagler, R.W. (1979). Knowledge of performance and the learning of a closed motor skill. *The Research Quarterly, 50*(2), 265-271.

Wambaugh, J.L. (2006). Treatment guidelines for apraxia of speech: Lessons for future research. *Journal of Medical Speech-Language Pathology, 14*(4), 317-321.

Wambaugh, J. L., Duffy, J. R., McNeil, M. R., Robin, D. A., & Rogers, M. A. (2006). Treatment guidelines for acquired apraxia of speech: A synthesis and evaluation of the evidence. *Journal of Medical Speech-Language Pathology*, *14*(2), xxxv–ixvii.

Winstein, C.J., & Schmidt, R.A. (1990). Reduced frequency of knowledge of results enhances motor skill learning. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 16,* 677–691.

Yorkston, K.M., Beukelman, D.R., Strand, E.A., & Hakel, M. (2010). *Management of motor speech disorders in children and adults* (3rd ed.). Austin, TX: Pro-Ed.

Youmans, G. L., Youmans, S. R., & Hancock, A. B. (2011a). Script training treatment for adults with apraxia of speech. *American Journal of Speech-Language Pathology, 20*, 23–37.

Youmans, G., Holland, A., Munoz, M.L., & Bourgeois, M., (2005). Script training and automaticity in two individuals with aphasia. *Aphasiology*, *19*, 435-450.

Young, D. E., & Schmidt, R. A. (1990). Units of motor behavior: Modifications with practice and feedback. In M. Jeannerod (Ed.), *Attention and performance XIII* (pp. 763-795). Hillsdale, NJ: Erlbaum.

APPENDIX A

SCRIPTS USED IN THE STUDY

Phrase	Prompt	Script phrase	syllables	words
1	What did you say?	I'm sorry, I have Apraxia, which means that I occasionally struggle with my speech.	23	15
2	You seem okay to me	Yeah, it's good now, but two years ago I had a head injury and I couldn't speak.	21	19
3	Oh, really?	Before that I would judge people who had a speech impediment, thinking they had a problem with their intellectual abilities.	34	20
4	And today?	Now with my personal experience I know that people with speech problems may be perfectly capable of thinking.	30	18
5	What is the problem then?	It's just that there is a disconnect between their brain and their mouth.	16	14
		Mean	***24.8***	***17.2***
		SD	*7.2*	*2.6*

Table A-2. Script 2 (KR phase 1): People with Aphasia Training Dogs

Phrase	Prompt	Script phrase	syllables	words
1	How are you keeping busy these days?	I'm working with Sharon Antonucci, who is the director of the Aphasia Center at Moss Rehab.	27	17
2	What is that about?	She developed this program, called People with Aphasia Training Dogs, to help people with aphasia.	25	15
3	How does it work?	Typically Sharon would work with people at their home with their own dog.	18	13
4	But in your case?	I'm participating in the program in another way, at the SPCA, because my dog is very protective of our home.	34	21
5	Is it working?	I think the program is effective because it's indirect speech therapy where I'm not focusing on me.	27	19
		Mean	***26.2***	***17***
		SD	*5.7*	*3.2*

Table A-2. Script 2 (KR phase 1): People with Aphasia Training Dogs

APPENDIX A (Continued)

SCRIPTS USED IN THE STUDY

Phrase	Prompt	Script phrase	syllables	words
1	Hello, how may I help you?	I want an amortized payment schedule and I would like a copy of my loan contract.	22	16
2	I'm not sure we have that on file.	I understand my loan has been sold multiple times but you should have that information available for me.	28	18
3	I will look into it for you. Do you have any other questions?	When can I expect to receive a copy of the information I'm requesting today?	23	15
4	In two weeks. Is there anything else I can help you with?	I have two problems with recent payments. I made a regular payment online and it's not showing up.	26	19
5	Okay, and the other issue?	At the same time, I submitted a principal reduction payment which is not showing up either.	25	16
		Mean	***24.8***	***16.8***
		SD	*2.4*	*1.6*

Table A-3. Script 3 (KR phase 2): Calling About Student Loan

Phrase	Prompt	Script phrase	syllables	words
1	Hello. How are you today?	I'm doing well. Just on our way to the shelter. I think I'll take a latte with cardamom syrup.	25	21
2	Sounds good. That will be $3.50	Actually, I think I'll get an Americano instead, so I can get a baked good to go with it.	27	20
3	Sure, what kind of baked good can I get you?	I can't decide if I want the cinnamon sugar doughnut or the pumpkin bread.	20	15
4	They're both very good.	I'm sorry. Okay, I'm going with the Americano, if you can leave some room for cream, and the cinnamon sugar doughnut.	32	23
5	Can I give your dog a little something too?	Thank you for treating him. Positive interactions with humans are good for him.	20	13
		Mean	***24.8***	***18.4***
		SD	*5.1*	*4.2*

Table A-4. Script 4 (KP phase 1): The Coffee Shop

APPENDIX A (CONTINUED)

SCRIPTS USED IN THE STUDY

Phrase	Prompt	Script phrase	syllables	words
1	Know of any good movies?	Have you seen *Vice*? It's a dramatization of Dick Cheney's life.	16	12
2	Oh, that sounds interesting. What did you learn?	I didn't really understand how much Cheney did behind the scenes that affects our country today.	25	17
3	What did he do?	He worked with Justice Scalia to change constitutional law to give the executive branch much more autonomy.	30	17
4	Then what did he do?	With his new executive powers Cheney, not Bush, declared war on Iraq.	19	12
5	How did he manage to do that?	He was never very personable compared to other politicians, but he learned how to become a master manipulator.	34	18
		Mean	***24.8***	***15.2***
		SD	*7.5*	*2.9*

Table A-5. Script 5 (KP phase 2): Movie Summary

APPENDIX B

EXAMPLE TREATMENT PROTOCOL

Script phrase	Attempt	FB?	FB type	Accuracy	Cue Type
1	1	Y	KR		
	2	Y	KR		
	3	Y	KR		
	4	N			
	5	N			
2	1	Y	KR		
	2	Y	KR		
	3	Y	KR		
	4	N			
	5	N			
3	1	Y	KR		
	2	Y	KR		
	3	Y	KR		
	4	N			
	5	N			
4	1	N			
	2	N			
	3	Y	KR		
	4	Y	KR		
	5	Y	KR		
5	1	N			
	2	Y	KR		
	3	Y	KR		
	4	Y	KR		
	5	N			

Table B-1. Large-block practice

EXAMPLE TREATMENT PROTOCOL

Script phrase	Attempt	FB?	FB type	Accuracy	Cue Type
1	1	N			
	2	Y	KR		
2	1	Y	KR		
	2	N			
3	1	Y	KR		
	2	N			
4	1	Y	KR		
	2	N			
5	1	Y	KR		
	2	N			
1	1	N			
	2	Y	KR		
2	1	N			
	2	Y	KR		
3	1	N			
	2	Y	KR		
4	1	Y	KR		
	2	N			
5	1	N			
	2	Y	KR		

Table B-2. Small-block practice

APPENDIX B (CONTINUED)

EXAMPLE TREATMENT PROTOCOL

Script phrase	Attempt	FB?	FB type	Accuracy	Cue Type
1	1	Y	KR		
2	1	N			
3	1	Y	KR		
4	1	N			
5	1	Y	KR		
1	1	Y	KR		
2	1	N			
3	1	N			
4	1	Y	KR		
5	1	Y	KR		

Table B-3. Serial practice

Script phrase	Attempt	FB?	FB type	Accuracy	Cue Type
4	1				
2	1	Y	KR		
1	1				
3	1	Y	KR		
5	1	Y	KR		
2	1	Y	KR		
4	1				
5	1	Y	KR		
1	1	Y	KR		
3	1				
1	1	Y	KR		
4	1				
5	1				
3	1	Y	KR		
2	1	Y	KR		

Table B-4. Random practice

APPENDIX C

SCORING MANUAL FOR PSC

<u>Percent Script Words Correct (PSC): Accuracy</u>

PSC = (number of script words correctly produced / total number of target words in the script) x 100

The number of script words correctly produced is based on how the produced script phrase compares to the target script phrase. An accurate production is considered to be a word-for-word correct production of the target script.

Any word that has the following error types are **<u>EXCLUDED</u>** from the total number of correct words:

1. <u>Alternative word choices</u>, such as synonyms. For example, if the target script phrase were "*I would like a hot latte"* and the participant says *"I would like a hot coffee",* all words except "*coffee"* would be counted toward the PSC (PSC = 5 in this case).
2. <u>Circumlocutions</u>. For example, if the intended phrase were *"I would like a hot latte"* and the participant says *"I would like a hot… that drink with caffeine"*, the words "*I would like a hot"* would be counted toward the correctly produced script words (PSC = 5 in this case).
3. <u>Speech sound errors</u>. Words with the following errors are not counted for the number of correct script words:
    a. *Substitutions*: exchanging one phoneme (consonant or vowel) for another.
    b. *Omissions*: missing sounds in words.
    c. *Distortions*: approximations of a particular phoneme that are not clear or well-articulated.
    d. *Additions*: adding a sound (consonant or vowel, including schwa) to a word.
    e. *Metathesis*: the exchange or misordering of two words or sounds in an utterance (for example, saying *"gip"* for the target *"pig"*).
    f. *Overall unintelligibility*: speech that is not recognizable as a word by the listener.

APPENDIX C (CONTINUED)

SCORING MANUAL FOR PSC

NOTE 1: Contractions (e.g., *I'm, It's, We'll*) are counted as 2 words, whether they are in the script as contractions or not. They are counted as 2 words for the purpose of determining the target words in the script as well. Examples to clarify:

- If the script includes *I'm…* that is counted as 2 target script words.
  - If the participant says *I'm …* , they get credit for 2 correct script words.
  - If the participant says *I am …* , they also get credit for 2 correct script words. This is accurate in terms of communicative message, but less efficient, so they will be "penalized" in this case by taking longer to say those words. This shows up in the speaking rate measure.
- If the script includes *It is …* , that is counted as 2 target script words.
  - If the participant says *It is …* , they get credit for 2 correct script words.
  - If the participant says *It's …* , they also get credit for 2 correct script words. This is accurate in terms of communicative message, but more efficient, so they will get "credit" for this by taking shorter to say those words. This shows up in the speaking rate measure.

NOTE 2: If the speaker restarts after producing some portion of the script, count as correct any script word that was produced correctly in either the first attempt or any later attempt on that trial (even if they get the word wrong in the other attempt(s)). The reasoning is that for PSC, we want to see how many of the script words a speaker can produce correctly at least once, because in a conversation, saying a word correctly once is sufficient for the listener (in terms of message/content transmission). Any words that are correct in each attempt are counted only once. These (attempts at) self-corrections will be accounted for in the Speaking Rate measure. Example:

- Participant says *"I'd like a large hot chacly … No, I mean, I want a medium hot chocolate, pleadz"* for a hypothetical script *"I'd like a medium warm chocolate, please"* then PSC = 7.
  - Between the two attempts, 7 of the 8 target words are produced correctly (all except *please*). For example, "*Chocolate"* was incorrect on the first attempt but correct on the second attempt. Conversely, *"I'd like"* was correct on the first attempt (3 words correct) but on the second attempt, only *"I"* was correct, but *"would ('d) like"* was not (1 word correct). Because *"I"* was already correct on the first attempt, it does not get counted again for the second attempt.
  - Given that repeated attempts take more time than a single attempt, and that by their nature, repeated attempts involve repetitions of the same words, the Speaking Rate measure will capture the difficulty suggested by the repeated attempt

APPENDIX D

SCORING MANUAL FOR WPM

Words per Minute (WPM): Speaking Rate of Communicative Words

Rate is the number of communicative words (excluding non-communicative repetitions of words or phrases and excluding interjections) per minute during script production (Youmans et al., 2005, 2011). This measure requires (1) counting the number of communicative words in each script phrase, and (2) calculating duration of each produced script phrase.

(1) Count the number of **communicative words**. Communicative words include all words except fillers, interjections, word repetitions, and unrecognizable words:

- Fillers: Words like *"yes," "um," "uh," "you know",* etc. (if not part of the script).
- Interjections: Words that are unnecessary and unnatural in the fluency of speech (Hasseltine et al., 2016). This includes "meta" comments on the script or exclamations, such as *"I don't know!"* or *"I know it but can't think of it"* or *"oops"* or *"Wow I totally messed that one up!".*
- Word repetitions: Words that are repeated (e.g., due to attempts at self-correction) are counted only once. For example, if a target phrase is *"Please may I have a black coffee?"* and the participant says *"Please … please … please … may I have a black coffee?"* then the word *"please"* is counted only once.
- Unrecognizable words: Communicative words do not need to be error-free, but do NOT count words if they are not recognizable or produced with an error that results in a different word – even if the context makes clear what the intended word is. For example, if the participant says *"copy"* instead of *"coffee"*, do NOT count this word as a communicative word. The context may make it clear what is meant, but this is a different word and could be confusing. Put differently, words with sound substitutions, sound additions, sound distortions, sound omissions, and/or sound metatheses are counted toward the number of communicative words as long as the word is recognizable (e.g., saying *"executive"* for *"executive"* is fine because you can recognize the word and won't likely be confused with some other word).

SCORING MANUAL FOR WPM

NOTE: Communicative words do not need to be target script words. For example, *“feline”* would be acceptable for *“cat”* here, even though it would *not* be acceptable for PSC scoring.

(2) Measure the **duration** of the participant’s attempt at the script phrase. Mark the start of the participant’s attempt and the end of the attempt and determine the duration.

- **Start time** is where the participant begins the first attempt at a script phrase. This means that the beginning includes any whole word repetitions that may occur at the initiation of an utterance. For example, if a target phrase is *“Please may I have a black coffee?”* and the participant says *“Please please please may I have a black coffee?”* then the start time is at the beginning of the first *“Please”*. Note however that only one *“please”* would be counted toward the total number of communicative words (see above)
- **End time** is where the participant ends the script attempt. This means that the end includes any whole word repetitions that may occur at the end of an utterance (to be consistent with measurement of repetitions in initial and medial position). For example, if the participant says *“Please may I have a black coffee coffee coffee”* then the end time is after the third *“coffee”*. Note however that only one *“coffee”* would be counted for number of communicative words.