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Can script training improve narrative and conversation in aphasia across etiology?

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Abstract

Script training is an effective treatment of stable (e.g., stroke-induced) and progressive aphasia of varying severities and subtypes. The theoretical underpinnings of script training are discussed and include fluency-inducing conditions, speech shadowing, principles of neuroplasticity, and automatization. Script training outcomes are reviewed, with a focus on discourse in persons with stable aphasia (PWSAs) and in persons with primary progressive aphasia (PWPPAs). PWSAs and PWPPAs are able to acquire and maintain short scripted monologues or conversational dialogues, with some evidence of generalization to untrained topics and settings. Advances in both technology and access have enriched script training protocols so they now range from no-tech written script approaches to high-tech audiovisual support and avatars. Advances in audio and/or visual support promote large amounts of practice of less errorful whole-message language processing during a fluent language inducing condition. With enough practice, users decrease reliance on supports and independently produce scripted content. Script training can be delivered in a variety of settings (individual, group, telepractice), lends itself well to homework programs, and is in accordance with the principles of neuroplasticity for neurorehabilitation. Incorporating script training into therapy programming is advantageous throughout aphasia recovery following brain injuries such as stroke. It is also beneficial for persons with progressive disease for prophylaxis, remediation, and compensation. Recommendations for implementing script training in clinical practice and future research directions are presented.

Keywords

aphasia; discourse; primary progressive aphasia; script training; scripts

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Introduction

Aphasia is an acquired language disorder that results from damage or deterioration to language centers in the brain and/or to connections between those centers. Aphasia is most often caused by a stroke to the language dominant cortical hemisphere, usually the left hemisphere, accounting for approximately 89% of cases of aphasia in North America.[1] The remaining 11% of cases are caused by traumatic brain injury or brain tumors. These statistics do not account for aphasia due to neurodegenerative disease (e.g., frontotemporal dementia [FTD], Alzheimer's disease [AD]). Primary progressive aphasia (PPA) is often attributed to “rare” presentations of AD or FTD, though incidence is unknown and may be higher than previously estimated.[2] Regardless of etiology, aphasia negatively impacts the quality of life of individuals living with it and of those who are closest to them.[3-7] Persons with stable aphasia (PWSA) or with primary progressive aphasia (PWPPAs) can benefit from intervention, though the most effective approaches, and how to optimally match approaches to individuals with varied symptomatology, remain unknown. Current recommendations state that PWSAs and PWPPAs should engage in skilled and functional speech-language assessment and treatment, which can include a variety of settings, schedules, and techniques.[8-10] Given limitations on treatment delivery and receipt imposed by third party providers and limited resources, we must develop and utilize approaches and tools focused on enhancing the *quality* of the limited number of treatment sessions while also increasing the *quantity of quality practice* performed both in and out of clinical settings. Efficacy and effectiveness research should thus entail leveraging technology that is accessible to our target clinical populations, further establishing telepractice and group/peer approaches, and regularly incorporating homework to promote the ability to learn and relearn throughout the lifespan, even in the face of injury and disease progression. Script training is an aphasia treatment that accomplishes these tasks.

Scripts are brief narratives (monologic and dialogic) that describe an event or otherwise facilitate social communication. Script training provides opportunities to repeatedly engage with developed and functional discourse in a constrained manner that facilitates production. With practice, users can develop the ability to recall the script with its associated motor patterns and linguistic content and create islands of fluent language that can be automatically retrieved and used during real-world conversational settings.[11] Script training has been investigated in PWSAs, persons with apraxia of speech (AOS), and PWPPAs. Positive outcomes in script acquisition, speaking rate, and spoken language fluency during script performance are consistently reported, with some generalization to different speakers and untrained conversational exchanges. Script training is administered in various settings, including in-session (individual or group) therapy, self-directed at-home training (with and without in-session therapy), and remotely via telepractice. Many script training programs include audio and/or visual cues to aid production and/or to be used for at-home training. When such cues are incorporated, it may be considered an error-reducing treatment condition,[12] whereby speakers have more opportunities for reinforcement of errorless production and less practice with (and less reinforcement of) errors.[13] In the following sections, we briefly discuss the theoretical underpinnings of script training, including fluency-inducing conditions, speech shadowing, principles of neuroplasticity, and

automatization. These sections are predominantly focused on PWSAs, in line with the bulk of the aphasia literature to date. We then review script training outcomes in PWSAs and PWPPAs. Finally, we present recommendations for implementing script training in clinical practice and discuss future research directions.

Theoretical Underpinnings of Script Training

Fluency Inducing Conditions

Script training studies have utilized unison (or choral) production, a fluency inducing condition (FIC) that has been used by individuals with a range of communication disorders. Common script supports include audio recordings via cassette tape, CD, talking photo albums, barcode readers, personal tablets, and voice recorders. AphasiaScripts, developed by Cherney and colleagues,[14,15] uses a computer-animated avatar who models realistic articulatory movements. Videos of real speakers have also recently been introduced. The model used in the Fridriksson et al.[16] study was Visually Assisted Speech Technology (VAST; http://www.speakinmotion.com/). Similar video stimuli were introduced in the treatment package called Video-Implemented Script Training for Aphasia (VISTA) by Henry and colleagues.[17] When PWSAs speak “in time” with an audiovisual (or audio only) model during script training, the available rate and intonation cues can induce fluent production. Unison script production along with an audiovisual model has been called speech entrainment,[16] where the model “[draws] or [pulls] along” fluent spontaneous speech (p. 3816).

It is thought that unison production provides PWSAs, with and without AOS, with a time-locked and rhythmically/melodically patterned external stimulus so that lexical, semantic, and syntactic processing are linked.[16] Temporal components may aid basal ganglia functions, important for speech timing.[18] Speech entrainment may also provide support to the damaged speech and language network. Interpreted within a dual-stream model of language (for review, see Poeppel, Emmorey, & Hickok[19]), the dorsal stream (articulation) pulls along the ventral stream (language code) in typical speakers. When the dorsal stream is damaged, non-fluent aphasia often results because of the loss of entrainment between the two streams. The audiovisual model may supplement the function of the damaged dorsal stream, restoring coordination between both streams. This is supported by recent findings[20] revealing the best response to speech entrainment was in speakers with non-fluent aphasia with damaged dorsal, but intact ventral, stream structures. Additionally, when the ventral stream is damaged (e.g., fluent aphasia), phonological representations can be damaged, leading to anomia, phonological paraphasias, and/or auditory comprehension deficits. Practice with unison production may help bind sounds to stored conceptual knowledge and phonological patterns, aiding retrieval and accuracy. This hypothesis is supported by phonological component analysis treatments shown to improve naming and reduce neologisms in jargon aphasia.[21]

Studies of unison production in individuals who stutter have shown that FICs do not provide therapeutic effects after the speech model is withdrawn - effects are transient and also degrade in effectiveness with continued use.[22] Therefore, FICs are more akin to a prosthesis rather than therapeutic - inasmuch as they support function and are valuable,

they do not train behaviors or support improvements in environments where the prosthesis is not available. Yet, as evidence suggests, script training effects eclipse the prosthetic performance of a FIC and provide therapeutic support of spoken language which, in turn, improves communication.[11,12,14,16,17] Script training includes additional treatment elements that contribute to its effects, which we continue to discuss below.

Speech Shadowing

Unison production is related conceptually to speech shadowing,[23-26] a task designed to investigate normal language processing. During speech shadowing, a person is instructed to speak aloud along with an audio or audiovisual model. Normal linguistic processing is then examined by calculating speakers' accuracy relative to response latency, or the length of time the speaker is delayed from the model, with and without perturbations to the linguistic content (e.g., syntax, semantics, phonology). Healthy controls can produce novel passages mere milliseconds (< 250 ms) behind the model, meaning they are producing words *before* all of the word's acoustic information is available to them. There seems to be no difference between the closest and distant shadowers' (> 250 ms) ability to recall lexical, semantic, and syntactic elements of shadowed passages.[24] Together these findings indicate speech shadowing requires active processing of language content and not passive following of articulatory trajectories. Additionally, linguistic information seems to influence speech shadowing performance, where shadowing latencies were shorter for semantically plausible sentences versus word lists, perturbed syntax, or semantically implausible foils, and even the fastest shadowers' errors differed from typical shadowers only in their increased production of articulatory errors.

Neuroplasticity in the Injured Brain

The goal of aphasia neurorehabilitation is to provide planned experiences, or instances, to induce brain changes that will result in improved daily life functioning. Neuroscientific principles should thus be incorporated into treatment elements and schedules, with a particular focus on activity- (or use-, experience-, learning-) dependent plasticity, which is the ability to alter the structure and function within the nervous system as a result of experience. This type of plasticity is available throughout the lifespan, allowing us to adapt to novel events even with finite neural resources, and should be levereaged for neurorehabilitation. Several principles of activity-dependent plasticity were described in the seminal paper by Kleim and Jones[27] (see Table 1, p. S227). We will briefly describe those principles that most clearly contribute to the success and potential of script training.

Using spoken language with script training—The "use it or lose it" principle of activity-dependent plasticity states that if intact brain networks are not used regularly for a behavior, the cortical networks and the behaviors they support will degrade over time. For PWSAs, spoken language is at risk for falling into disuse because of the participation restrictions caused by their aphasia. Additionally, many individuals with aphasia report intense emotions such as frustration, anger, and helplessness during and following failed communicative acts that involve spoken language.[28,29]

Script training engages the impaired spoken language system through speaking fluently in correct, connected, and meaningful sentences. This fosters holistic language processing throughout conception, lexical retrieval, syntactic assembly, phonological organization, and phonetic production. Moreover, because of the fluent language inducing condition (FLIC) present in script training protocols incorporating unison production (via clinicians or other audio and/or visual models), negative experiences that accompany communication for PWSAs may be alleviated. Successful practice with meaningful spoken language may contribute to greater satisfaction and compliance with therapeutic exercises and thus an increased likelihood for improved outcomes.

Improving spoken language with script training—"Use it and improve it" establishes that adaptive brain reorganization and associated behavioral improvement is induced and shaped by experience. Neurorehabilitation can address this principle through thoughtful design of challenging therapeutic exercises that should improve behavior and shape neural circuitry. New experiences can then be designed to build upon those improved behaviors, expanding skills (e.g., by adding linguistic and/or phonetic complexity, by practicing with different partners, etc.) and inducing additional adaptive brain changes.

Script training addresses this principle by facilitating intensive practice of verbal production and promoting behaviors that are difficult for PWSAs. Scripts can be tailored to individual abilities, relying on relative strengths while targeting areas for improvement. For example, scripts for a speaker with moderate Broca's aphasia and concomitant AOS may initially need to be grammatically simple and practiced at a reduced rate. As PWSAs improve, demands can be increased by adding content, increasing complexity (phonological, semantic, and/or syntactic), increasing speaking rate, and/or introducing different environments. The quantity and quality of the activity, paired with its functionality, increases the likelihood of adaptive brain changes.

Direct influence on brain areas supporting spoken language—The principle of "specificity" states that the type of tasks the person is engaged in repeating and/or learning determines the location of brain changes and the magnitude of those changes wherein. Importantly, acquisition of new skilled behaviors leads to more adaptive brain changes compared to repetition of previously acquired and/or unskilled behaviors. The goal of neurorehabilitation is to induce brain changes to replace or compensate for lost functions by recruiting healthy regions to act in place of damaged regions. PWSAs have most often sustained damage to the left perisylvian cortex and the extent and location of damage dictates the severity and characteristics of aphasia. Regions with the most potential are those areas near the site of lesion or atrophy and/or in areas of the residual language network.[30-32]

Importantly, this principle stems primarily from manipulation of simple motor behaviors in non-humans (i.e., rodents, non-human primates), where there are differences regarding acquisition versus retention of skills and for skilled versus unskilled tasks. How these findings apply to spoken language is not straightforward. PWSAs engaged with script training would be acquiring what is arguably the highest of skilled behaviors - connected spoken language. While the early stages of script training would involve acquisition of a skilled behavior, later stages would mostly involve repetition of a skilled behavior. Once

recollection and production of scripts is automatic, there may be reduced engagement of the brain regions that were being recruited during acquistion. According to this principle as well as the aforementioned "improve it" principle, as the PWSA gains new skills, it may be necessary to increase the difficulty of script training to encourage continued recruitment of specific perilesional and residual speech and language areas.

Increasing quantity of practice with script training—The next two principles, "repetition matters" and "intensity matters", prescribe intensive repetition of a task to acquire proficiency, induce brain changes, and promote automaticity. Specifically, a greater number of repetitions within a given time window are more powerful when compared to less repetitions during the same amount of time. Without sufficient practice, adaptive brain and behavioral changes are unlikely to be maintained or generalized outside of therapy sessions. Once more, understanding how motor skill acquisition in non-humans informs cognitive-linguistic-motor behaviors in humans is not straightforward. The dosage research underlying these principles is largely based on studies of non-humans in highly controlled environments where they can engage in targeted motor tasks with far greater number of repetitions in a single hour or day compared to humans. Additionally, PWSAs "in the wild" are at risk of reduced communicative opportunities and reduced desire to participate, and therapy schedules do not lend well to the number of repetitions and intensity required for meaningful change. (Of note - these schedules are not driven by PWSAs, who list a desire to participate in more speech-language therapy as one of their top therapy goals.[29])

Script training allows PWSAs to complete quality and complex language production in and out of clinical settings, which can facilitate the repetition and intensity required for change. In addition, script training with audiovisual modeling is a FLIC, which facilitates practice and engages linguistic processing. Further, neuroimaging evidence establishes that simply observing spoken language activates motor areas involved with language production,[33-36] meaning PWSAs can increase their practice time (i.e., activation of specific speech-language areas) by observing and/or listening to the models, even without overt production.

Script training and personally relevant narratives—The principle of "salience matters" dictates that experiences must be important, even critical, for survival so the organism can assign appropriate attention and motivation to them. Thus, the brain's adaptability is gated by neuromodulation systems in the brain (i.e., cholinergic, dopaminergic), and the more salient the experience, the more likely it is to be encoded into a change in the brain's structure and function.[27,37] For PWSAs, the loss of communication abilities is devastating and their desire to re-acquire them is of utmost importance.[29,38]

Since the inception of script training, most protocols have utilized personally relevant scripts.[39] The salience of scripts is readily understood when they address the top goals of PWSAs (e.g., to advocate, educate, communicate basic needs, express opinions, tell stories, etc.).[29,38] There is some evidence supporting an advantage for acquisition (but not generalization) of personally relevant content versus generic content.[40] Additional nascent evidence from our work and others[41] indicates personally relevant scripts are motivating to PWSAs, facilitating buy-in and practice time.

Neuroplasticity and Automatization

Automatization is the process of performing a task with little attention or effort.[42] It is required for proficiency of many skilled behaviors, including normal language development and second language acquisition.[43-46] In line with neuroplastic principles, automatization arises following repeated practice of a task and is attained when it can be produced by retrieving memories (stored instances) of previous task performance.[42] Automatic processing is fast, controlled, effortless, autonomous, and unavailable to conscious awareness or memory. This allows goal-directed, automatized behaviors to be conducted unconsciously and run to completion without intention or stopped quickly in response to an error or stop signal. The goal of script training is to provide a platform with ample practice opportunities so users can automatize language production so it resembles the automatic language processing experienced by typical speakers prior to the onset of aphasia.[15,47] Persons participating in script training may also leverage other intact automatized language-related processes, including access to semantic knowledge, long-term memory, and linguistic rhythm.[18]

Neuroplasticity in Progressive Disease

The principles of experience-dependent plasticity also apply to aphasias arising from progressive etiologies. Neurons in persons with Alzheimer's disease still demonstrate dendritic branching, indicating intact neurons can increase the number of connections with other neurons to receive more signals.[48] This corresponds with evidence showing that persons with Alzheimer's disease respond to interventions targeting affected behaviors, like cognition, and are still capable of implicitly learning new perceptual skills.[49,50] While the brain's ability to adapt declines as the disease progresses,[50] there is compelling evidence supporting treatment-induced brain and behavioral changes for prophylaxis, remediation, and neuroprotection.

With specific regard to PWPPAs, aphasia treatment leads to long-term retention of baseline speech-language abilities as well as short- and long-term improvements in abilities.[10,17,51-55] Treatment approaches have included computerized semantic naming treatment, lexical retrieval cascade treatment, reading treatment, script training, and more. Some of these approaches have been paired with errorless learning or noninvasive brain stimulation.[51,56] Primary outcomes are usually word level, with a focus on trained and untrained words or categories. Few studies have explored outcomes at the sentence level or above, or outcomes related to activity, participation, or quality of life. The long-term benefits of training in the context of continuing progression are relatively unknown, since only a few studies have followed treatment participants longer than 6-8 months post-treatment. Overall, trained behaviors (e.g., lexical retrieval, intelligibility of scripted words) have shown significant and lasting improvement in behavioral treatment studies in PWPPAs, with several studies documenting generalization. Even when gains are limited to trained items, PWPPAs can significantly improve communicative behaviors that may be relatively protected in the context of greater progression, especially when treatments, including script training, target individualized, functional aspects of communication.[54]

Script Training Approaches and Outcomes in Aphasia of Stable Etiology

We now review script training outcomes in PWSAs, focusing on discourse, followed by a section on outcomes in PWPPAs. Studies that focused on script training efficacy or utilized script training to examine treatment elements are first reviewed. This is followed by brief coverage of studies that included script training as part of a treatment package, endorsed script training, and/or otherwise addressed it in a noteworthy manner. These studies are summarized in Table 1 and serve as an accompaniment and update to table 1 in Kaye and Cherney.[14]

No-Tech and Low-Tech Script Training

Many script training studies have revolved around written scripts developed via collaboration with the PWSA and, when needed, friends and family. Scripts included monologues or dialogues consisting of 4 to 6 sentences.[47,57] Scripts were individualized and therefore differed according to severity and personal factors, including differences in overall length and semantic, syntactic, and/or phonological complexity. Scripts were often available in written form for reading and cueing/scaffolding as well as for home practice. Cueing hierarchies were commonly paired with script stimuli to facilitate acquisition. Cues offering greater support included phrase repetition, choral reading, and question prompts. Cueing strength was reduced throughout script acquisition to foster independence. Most script training protocols incorporated additional supports such as audio recordings of scripts, written cue cards, picture stimuli/photo album, and telepractice/video conference to support retrieval production.[47,57-61]

Number of patient sessions with the clinicians varied widely, ranging from 6 to 40 sessions. Most protocols also included home practice recommendations, ranging from 15-30 minutes/day for 5 days/week[60] to 8 hours/week.[57] Homework tasks included listening to a recording of the script, reading their script, and writing their script. Importantly, many protocols built in activities or phases designed to promote generalization, such as practice in simulated conversation and/or with a novel partner.[47,57,58]

Script training in this form has been administered to a wide range of aphasia subtypes, both non-fluent and fluent, and severities, from severe to mild. Relevant and consistent findings include noted increase in script mastery[61] as well as naturalness of speech during script production,[47] with generalization to standardized tests and untrained discourse[59,62] and improvements to intelligibility/naturalness as judged by naïve listeners.[47] Changes in self-reported communication confidence improved substantially post-script training in one study.[57] Group script training has proven to be effective, for example, with an overall 55% increase in correct production of script-related words.[62] Home practice also seems to be an important factor in script acquisition.[47,57-61]

AphasiaScripts

AphasiaScripts (originally developed at the Rehabilitation Institute of Chicago, now Shirley Ryan Ability Lab) is computer-based script training developed to improve access to quality treatment, increase the frequency of training instances, and reduce client costs. The clinician

is a computer-animated avatar who guides navigation of the program while providing audiovisual cues of realistic articulatory movements. The clinician/avatar also acts as a communication partner during dialogues to simulate everyday conversational practice. Written script cues are also available at certain levels of the hierarchy. Treatment often takes place in the following three phases. First, the PWSA listens and observes the avatar produce the script. Next, the PWSA practices each sentence with fading supports, ranging from unison production with written support to independent production. Finally, the PWSA practices the entire script in turn-taking style with the avatar. At the whole script level, maximal support is provided initially (i.e., unison production with written support) and cues are faded over time (i.e., removing the virtual clinician's voice, the written word and the visual cues of articulation). AphasiaScripts is available for purchase from the Shirley Ryan Ability Lab (https://www.sralab.org/aphasiascriptstm).

Script training in this form has been administered to a wide range of aphasia subtypes, both non-fluent and fluent, and severities, from severe to mild. Initial AphasiaScripts findings[28] showed significant improvements on measurements of Communication Difficulty subscale and Burden of Stroke Scale following 9-week computer training. Cherney and colleagues have consistently reported a positive impact on participant confidence.[15,63] When talking about trained topics following AphasiaScripts treatment, participants improved upon the number and percent of scripted-words produced;[11,15,41,64] grammatical productivity;[18,28] and speech rate (e.g., script-related words per minute).[11,15,41,64] Additionally, increases in SLPs ratings of participants' oral reading accuracy on the Naming and Oral Reading in Aphasia rating scale have been reported.[12,14,40]

AphasiaScripts has served as a vehicle for Cherney and colleagues to elegantly and systematically examine treatment intensity,[41] response to treatment,[15,41] cueing support (high- versus low-cueing support)[12,40,64] and script difficulty.[14] For most of their studies, participants were required to practice at-home daily with the software for at least 30 minutes. The scheduling of treatment included training 3 scripts over the course of a 9-week intervention (3 weeks per script). Regarding the intensity of training, amount of treatment completed by a participant correlated with percent change of script content for more severe aphasia and with increased speech rate in those with less-severe aphasia.[41] Regardless of aphasia severity, participants demonstrated similar responses to script training treatment,[12,41] especially regarding increases to speaking rate for those with less severe aphasia. Although there were no significant differences between script acquisition and production following high-cue (e.g., written, auditory, and oral-motor supports) or low-cue script training conditions, larger effect sizes suggested that high-cueing support was more facilitatory for improving script production, particularly for those with more severe aphasia. Personally-relevant words were also acquired more easily than generic words.[40] In summary, script training with AphasiaScripts has yielded positive results for different aphasia types and severities. Further, intensity of training, content difficulty, level of cueing support, and personally-relevant content contributed to treatment success.

Audiovisual Supported Scripts

Video-Assisted Speech Therapy (VAST) is an app-based script training program that grew from clinical observations that clinician-provided visual cues helped individuals with non-fluent aphasia and/or AOS produce sounds more accurately (D. Williamson, oral communication, September 2010). Initially, training focused on pairing articulatory placement of single sounds on photos with short auditory recordings that could be played through Language Master, an audio-recording and playback device that operated using small cards with magnetic tape. Clients practiced at home by producing the sounds along with the articulatory placement cue cards while monitoring articulation placement with a mirror. As technology allowed, the process grew into script videos focused on presenting articulatory gestures. Clients could practice the scripts speaking in time with the video model, allowing audiovisual information to guide articulation while sharing personally relevant scripts. VAST videos are available for purchase from SpeakinMotion (http://www.speakinmotion.com/).

In 2012, Fridriksson and colleagues utilized VAST in an audiovisual script training study.[16] Thirteen individuals with AOS and Broca's aphasia, ranging in severity from severe to moderate (determined by Western Aphasia Battery Aphasia Quotient [WAB AQ]) completed a 6-week training program. Standard (i.e., not personalized) and balanced scripts (3 trained and 1 untrained) were recorded at a slow rate (55 WPM). Participants practiced 3 scripts for 2 weeks (30 minutes/day, 5 days/week) at home with an iPod. Greater speech output during speech entrainment conditions and spontaneous speech on scripted topics was observed following this brief intervention.

Bilda[65] used cinematic audiovisual dialogic scripts (e.g., ordering a coffee in a cafe) to train scripts in participants with varied aphasia type and severity. Participants completed computer-based training with an SLP for 3 hour sessions for 10 days. Initially participants produced a script with various levels of support that were faded out until they completed their portion of the exchange without support. All participants significantly improved production of the targeted phrases in trained and untrained scripts, and language performance was stable at follow-up (4-weeks and 6-months).

Other References to Script Training

Several other studies have included script training within their methodology. Hinckley and colleagues used written scripts when studying context-based versus skill-based treatment[66] and dosage.[67] Dialogic, role-play scripts were supplemented with materials to enact the targeted scenario and written cue cards. Fein and colleagues[68] utilized script training to target text messaging skills post stroke in a three-phase treatment: Copy and Recall Treatment for texting (T-CART), dialogic scripted text training, and a novel text messaging generalization task. AphasiaScripts was included in a comprehensive treatment package called Aphasia Language Impairment and Functioning Therapy (Aphasia LIFT) to investigate intensive versus distributed treatment schedules.[69] Scripts have also been used to investigate the feasibility of implementing group treatment via telehealth by Steele and colleagues.[70]

In a review of technology in aphasia therapy, Holland and colleagues[71] discussed using apps to facilitate script training and provided examples of clinician responsibilities, patient goals and procedures, sample apps, and more. Szabo and Dittelman[72] discussed script training as the foundation of their mobile technology program, and recounted several ways they used different technologies and platforms (e.g., Lingraphica SmallTalk Aphasia, Alligator Apps Story Creator, etc.) to create functional and accessible scripts. Linebarger and colleagues[73] described how SentenceShaper To Go can be used to support script training and how those scripts can be used for AAC. In their research, PWSAs especially appreciated how the program facilitated more practice with personal narratives, led to more fluent speech when used to aid speech, and made it possible to speak unaided because of the practice opportunities it afforded.[74] Simmons-Mackie[75] encouraged combining AAC with script training in persons with severe aphasia throughout recovery, and emphasized its prescription does not have to wait until all possible restorative therapy options have been exhausted.

Script Training Approaches and Outcomes in Aphasia of Progressive Etiology

Audiovisual Supported Scripts

Recently, Henry and colleagues[17] introduced video-implemented script-training for aphasia (VISTA) for individuals with the non-fluent/agrammatic variant of PPA (nfvPPA). VISTA incorporates unison production (or speech entrainment) of audiovisual scripts, presented on tablets, mobile devices, or computers, as at-home practice. Participants were instructed to practice one video for 30 minutes, 5 days a week and to attend twice weekly therapy sessions (in-person or teletherapy) with an SLP. With the SLP, the participant completed several steps of recalling and organizing the contents of the script they practiced at home. The clinician provided feedback and prompts corrections to grammar and articulation. Participants focused on recall of semantic and syntactic elements, clear articulation, and organization of the scripted sentences. Finally, participants practiced saying their script from memory in monologue and dialogue conditions. The hierarchy guides the speaker from steps to recall the structural organization of the scripted narrative to retrieval and usage of the rehearsed narrative in simulated conversation to increase the likelihood of generalization to untrained speaking conditions. Additionally, in the final step of the hierarchy, participants were encouraged to engage in an unscripted conversation with an unfamiliar communication partner about the given topic. Following VISTA, people with nfvPPA demonstrated improved trained and untrained script production, improved intelligibility, and reduced syntactic errors on standardized testing, with maintenance at one-year post-treatment.[17]

VISTA has been adapted to tele-practice, for bilingual speakers, and for individuals with chronic or progressive aphasia. Dial and colleagues[55] compared treatment outcomes of persons with lvPPA and svPPA who received lexical retrieval therapy as well as persons with nfvPPA who received VISTA. For each group, they found no difference between participants who completed treatment in-person or via tele-therapy. In another study, VISTA was adapted to train the languages of a Spanish-English bilingual speaker with anomic aphasia (stroke-induced).[76] In a single-subject, multiple-baseline design, the participant

trained 8 personally-relevant scripts (4 in each language) and 2 untrained scripts. The participant demonstrated improvement speaking about trained topics in both languages, with greater gains found in Spanish (first language). Additionally, the participant showed a reduction of grammatical errors and percent unintelligible words during script production and a non-significant increase in speaking rate.

Richardson and colleagues[77] adapted the VISTA hierarchy for group treatment in PWPPAs to determine preliminary feasibility and efficacy. Four individuals (2 with logopenic variant [lv]PPA, 2 with nfvPPA) participated in a nine-week script-training group (1.5 hours/session) focused on practice with three standard and one individualized monologic scripts. VISTA-group included the following group session activities: recognizing script elements (words, phrases, sentences) from foils, articulating difficult words, re-ordering script sentences, choral reading of scripts, producing scripts with audiovisual support (individually and as a group), reciting scripts from memory, and producing scripted sentences following interview questions. Participants were also expected to complete a minimum of 2.5 hours/week of home practice that included reading the script, copying the script, speaking along with the video, and producing the script from memory. To promote compliance and completion, homework supports included videos of each script with individualized rates, typed scripts, and a notebook with task recommendations.

Focusing on script and discourse outcomes, all participants improved their production of scripted words (M = 62.5, range 15-136) and proportion of scripted words/total words (M = .23, range 0.10-0.35) by post-treatment. Gains were maintained for three participants at 1-month follow-up, with an average increase of 61 scripted words (range −5 to 141) and an average increase of 0.27 scripted words/total words (range −.13 to .46). Gist production as measured by main concept analysis (MCA) declined for the participants with lvPPA but increased for participants with nfvPPA. Notably, overall output for script-related topics and untrained discourse tasks increased for participants with nfvPPA, whereas overall output decreased for participants with lvPPA even while their use of scripted words increased. For persons with lvPPA, at least for the scripted topics, practice with scripts helped to constrain their language and reduce their tangents, fillers, and circumlocutions. This positive treatment response is consistent with Cherney and colleagues[15] work with persons with fluent aphasia, including moderate Wernicke's, where they observed "reductions in the amount of empty speech and circumlocutions following training on each script" (p 27).

There were qualitative differences in how each variant preferred to complete homework tasks and engage with supports. Specifically, those with nfvPPA preferred unison production of scripts with the video and they produced their spoken language very closely in time with the model. Those with lvPPA spent much less time practicing along with the videos, preferring to read, copy, write from memory, and recite the scripts. When they did utilize the videos, they required much slower rates than their natural rate of speech, unlike those with nfvPPA, and they were more likely to lag behind in production, by several words or even whole sentences. These different responses to stimuli are congruent with Cherney and colleagues[12] findings when they asked participants their cueing preference in AphasiaScripts. Participants with severe non-fluent aphasia preferred high cue conditions (auditory and articulatory/oral-motor cues from avatar, written cues), while those with

milder nonfluent aphasia either had no preference or preferred high cues because of the challenge. The only fluent (mild-moderate) participant preferred the low cue condition (written cues only), reporting being "overwhelmed" by too many cues in the high cue condition. So persons with lvPPA also benefited from this group script training approach, albeit in qualitatively different ways that will guide future modifications to optimize implementation. Importantly, caregivers played an important role in the implementation of homework practice and operationalizing their involvement in the future will be critical.

Other References to Script Training

Rogalski and colleagues[78,79] include script training as part of Communication Bridge, an Internet-based life participation therapy for PWPPA. Script training using written scripts was one of the more frequently assigned impairment- and compensatory- level strategies, with encouraging evidence that PWPPAs continue to utilize script strategies for up to 6 months after receiving only 8 Internet-based sessions.[78] Rogalski and colleagues present scenarios and success stories of script training in PWPPAs, even providing example approaches and goals.[79] Script training has repeatedly been endorsed as a viable treatment strategy for PWPPA.[10,78-80]

Discussion

Incorporating scripted material into in-session treatments and/or at-home practice has been an effective approach for both remediation and support of spoken language for PWSAs, and PWPPAs. Speakers are able to rehearse the scripted material, through listening/watching, reading, writing, and/or speaking. This rehearsal, along with varied scaffolding, can support the damaged speech and language system, leading to improved spoken language production for scripted topics. With frequent exposure, script training can promote automatization so that islands of rehearsed content can be produced with little effort. Even when PWSAs have a concomitant AOS, scripts can be easier to produce following repeated practice. In fact, most research with script training with PWPPAs to date has focused on its efficacy in the nonfluent/agrammatic variant, which is characterized by agrammatism and/or motor speech impairment (i.e., AOS and/or dysarthria).

Many script training protocols incorporate unison production tasks to provide support for production of complete, functional messages for PWSAs and PWPPAs. Because the improvement in fluency is often pronounced and rapid, it is tempting to suggest that unison production tasks are simply supporting speech-motor fluency, similar to FICs. However, this does not account for the lasting effects of this training observed after very little or repeated practice, effects including generalized improvement in speaking about trained and untrained topics, improved intelligibility, and production of grammatical units. Speech shadowing research can perhaps inform in this regard, as findings support the idea that speech is processed phonetically *and* linguistically *at the same time* and that this processing is "obligatory and automatic".[83] Incoming speech signals are automatically entered into processing at all levels (phonetic, lexical, semantic, and syntactic) so that information at each level can constrain and usher online processing and prediction of the upcoming message.[26] While not a therapy, the very reasons that make speech shadowing

a viable condition for linguistic experimentation seems to support it as a foundation for therapeutic application (e.g., script training) for speech and/or language disorders. Given this information, unison production tasks used in script training as described in this review may more accurately constitute a FLIC that goes beyond prosthetic effects and provides therapeutic practice for spoken language.

Script training provides opportunities for people with aphasia of stable or progressive etiology to use and improve their impaired language system, with varied supports and hierarchies depending on the protocol administered. Protocols that incorporate unison production facilitate the rehearsal of less-errorful productions and use of whole, functional language. Success at the suprasentential level, that also is inherently meaningful, may contribute to greater satisfaction, and subsequent compliance, with therapeutic exercises and to overall improved outcomes. PWSAs and PWPPAs can use scripts to build their communicative repertoire and improve their naturalness, rate, and productivity of spoken language through regular practice in the clinic and/or at home. Personally relevant scripts are therefore optimal for motivating repeated practice and achieving automaticity. Given the accessibility of script training materials, including audio and video, there are few limitations on practice opportunities, further adding to its potential.

A review of the treatment studies that incorporate script training with PWSAs and PWPPAs has shown that it can be an effective treatment in increasing the number of script-related words produced, the rate of speech, number of grammatical units, intelligibility, content information units (CIU), type token ratio (TTR), and mean length of utterance (MLU), self ratings, dialogue communication ratings, social validity, and reducing the number of errors (Table 1). PWSAs and PWPPAs have also reported improvement on psychosocial indexes and surveys of communication confidence following script training. While the research focus in PWPPAs has been on script training in persons with nfvPPA, there may be no need to constrain it to that variant given the success of script training in fluent stroke-induced aphasias and the preliminary findings by Richardson et al.[77] in persons with lvPPA. In addition to treatment outcomes, script training has been useful for investigating treatment dosage, personal relevance and context, cueing support, and script difficulty. Following the review of theoretical underpinnings and treatment outcomes presented here, we believe there are no disadvantages to incorporating script training into therapy programming. It has ample value as a standalone treatment, and can also complement other evidence-based aphasia treatments. Still, despite the many advantages of script training, we find in our experience that few clinicians incorporate script training in their treatment or utilize it for at-home practice. Perhaps the following brief discussion of barriers and recommendations may increase utilization.

Developing Written Scripts

It is clear that the personal relevance of treatment materials has a natural, functional application and that such considerations need to be incorporated into planning and implementation of script training. Though they have proven to be effective, general scripts are likely not the best candidates since they may lack a functional application in everyday conversation. Scripts should be personalized whenever possible, not only by topic but also

linguistic complexity, phonological complexity, script length, and presentation rate. Early work with AphasiaScripts development allowed for four weeks to assess needs, identify and prioritize potential script topics, and develop severity-appropriate scripts.[15] However, that amount of time is not usually clinically feasible. We have found that 30-45 minutes is ample time to collaborate with individuals to develop personalized (topic, complexity, etc.) written scripts that are 6 sentences to 20 sentences in length. (Participants are "primed" before the script development session, where they are asked to think about a topic the week prior, write down notes or ideas if possible, and bring a picture or item related to the topic). Alternatively, Cherney et al.[14] have worked to develop script templates that can be personalized to address both relevance and clinician efficiency, if time pressures are insurmountable.

Audio and/or Visual Supports

We can lean upon basic research on visual and audiovisual speech perception as well as existing script training approaches so as not to find this aspect of script training too daunting. With regard to the auditory signal, Rosenbeck and colleagues[84] suggested clinicians should focus on manipulating rate and emphasis to aid PWSA during script training. These suggestions align with what clinicians have long intuitively implemented in response to patient communication needs. In practice, individualized speaking rates can quickly be determined by calculating speaking rate during passage reading or picture description tasks. At this time, specific contributions of the audio aspects have not been systematically explored.

Visual features of the videos may not affect participants' script training practice. For example, in the psychophysics literature, Jordan and Thomas[85] demonstrated that there was no significant difference in speech perception between presenting videos of an entire face versus only the lower face to control participants, as in VAST (though this may need to be further explored in clinical populations). Further, the most important visual features of models are not related to color but rather contrast (light and dark), highlights and shadows, and realistic/dimensional shape cues.[85] With mobile and accessible technology, videos of an audiovisual model can be practiced anywhere, providing the amount of practice necessary for neuroplastic change. There are many low-tech options to provide audio support, and existing platforms for developing audiovisual support such as VAST and AphasiaScripts. As demonstrated, audio/videos can also be incorporated into individual or group sessions (e.g., VISTA). However, it is important to remember that audiovisual cues during training may not be preferred by all persons with aphasia, particularly those with lvPPA.

There is much to explore and apply from the motor learning (and related speech-language) literature regarding techniques employing audiovisual stimuli, especially with regard to dosage and practice schedules (i.e., randomized, blocked, distributed, asynchronous, etc.).[86] Further, there is solid information about overtraining for generalization from the motor learning literature, readily applicable with script training. Together with the historic emphasis on building in generalization tasks, and new hierarchies to be explored in different populations that focus on generalization from the onset (e.g., VISTA), we hope to learn more about script training generalization in the near future.

At-Home Practice and Teletherapy

Script training can be used to boost the amount of practice between less frequent individual and group therapy sessions. This can be especially useful for many patients who live in rural areas or have transportation issues. Recent studies[17,54,55,60,61,70] have implemented script training via a combination of face-to-face and HIPAA compliant video conferencing (e.g., Zoom, Fuze, BlueJeans) sessions, and no differences in performance between delivery methods were noted. Importantly, the bulk of AphasiaScripts positive findings have resulted from the participants practicing at home with the computer software and the avatar, coming in occasionally to the lab to be supervised on the procedures by the clinician. Though more research is needed, the implementation of script training and its compatibility with telepractice could play a role in reducing rural and other disparities in access to speech-language services.

Compensation and Planning Ahead

We recommend that clinicians consider the functional impact of script training for all individuals with aphasia, regardless of etiology or type of aphasia. Especially in the case of progressive disease, personal relevance and training schedules may be especially critical. Apart from providing the support for increasing functional communication, functional scripts provide opportunities for augmentative and alternative communication (AAC) (e.g., using unison speech production as a FLIC) for PWSAs and PWPPAs, and voice banking for PWPPAs as the disease progresses. For our friends with PPA that we have now known for several years, most often the scripts (i.e., their life stories) that we have helped them to create have become their most treasured possessions. Importantly, dementias with prominent aphasias, such as PPA, tend to progress relatively slowly (J. Knoefel, written communication, October 2019), so PWPPAs have time to incorporate and benefit from behavioral treatments and/or compensatory techniques to maintain communication. Healthcare providers, social workers, physicians and speech-language pathologists (SLPs) should consider all speech-language treatment, including script training, as a necessary component of care for PWPPAs.[8,17,54]

Goal Writing

Clinicians may cite concerns of how to incorporate script training into treatment plans in a way that allows for reimbursement. We highlight two recent resources that provide excellent information about developing and implementing treatment plans involving script training. Haley et al.[87] presented their FOURC model for goal-writing, with the following steps: 1) **C**hoose communication goal, 2) **C**reate client solutions, 3) **C**ollaborate on a plan, and 4) **C**omplete and continue. In this paper, they provide an excellent case presentation in which they developed a relevant script training plan and cooperatively formulated person-centered goals for a PWSA. Rogalski and Khayum[79] also provide great examples of person-centered goals for script training for PWPPAs for both impairment-level and compensatory-level intervention.

Conclusion

Current literature suggests that script training is a viable, functional treatment for language production for persons with stable or progressive aphasia. Script training can be implemented into normal treatment sessions or provided as at-home practice, either as a standalone approach or a complementary treatment to other evidence-based approaches. Script training is more than a FIC and supports whole-language processing through supplementation of damage language networks. We have designated script training a FLIC that has greater potential to support communication behaviors outside the original stimulus. As a natural and functional task, PWSAs and PWPPAs are motivated to practice scripts which, in turn, supports the principles of neuroplasticity and its effectiveness. While research should continue to optimize script training, this should not prevent researchers and clinicians from utilizing script training in their repertoire of treatment approaches for all aphasia subtypes across etiologies.

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Learning Objectives:

After reading this article, the learner will be able to:

1. Define and identify important aspects of script training.
2. Recognize the principles of plasticity for neurorehabilitation and how they apply to script training.
3. Have applicable tools for implementing script training in their clinical practice when treating persons with aphasia due to stable or progressive etiology.
4. Describe the research evidence in support of repetition, use of shadowing, and audiovisual tools as related to script training.

CEU Questions:

1. Which of the following could be considered a barrier to implementing script training into therapy?
   - **a.** Script training for aphasia has not been studied in various etiologies, types, or severities.
   - **b.** Creating scripts is too difficult and time-consuming for busy clinicians.
   - **c.** There is a lack of evidence to support the effects of script training for reimbursement purposes.
   - **d.** All of the above
   - **e.** None of the above
2. What are some salient findings of speech shadowing?
   - **a.** Speech is processed linguistically first and then phonetically.
   - **b.** Speech is processed linguistically and phonetically at the same time.
   - **c.** Speech cannot be processed by the PWSA linguistically at all levels.
   - **d.** Speech cannot be processed linguistically and phonetically at the same time.
   - **e.** Speech will likely not be processed automatically.
3. Some of the principles of plasticity for neurorehabilitation described by Kleim and Jones (2008) that were discussed in the context of script training include:
   - **a.** Use it or lose it
   - **b.** Specificity
   - **c.** Intensity matters
   - **d.** a and c
   - **e.** All of the above
4. How can clinicians increase the difficulty of scripts used in script training?
   - **a.** Increase linguistic complexity
   - **b.** Increase the script length (e.g., number of sentences)
   - **c.** Increase speaking rate
   - **d.** All of the above
   - **e.** None of the above
5. What aspects of treatment have NOT been studied using AphasiaScripts?

a. Dosage and treatment schedules

b. Importance of personally relevant content

c. Enhancement of effects with brain stimulation

d. Cueing conditions

e. Script difficulty/complexity

Table 1.

Previous research examining discourse performance and script training.

Authors	Sample	Treatment Tasks	Measures Used	Outcomes
Youmans et al., 2005[47]	2 PWSAs - 1 Broca's (severe) - 1 conduction (moderate)	*Written Scripts with Audio* - Practice with 3 personal short written scripts with hierarchy (from repetition to independent production) for phrase-by-phrase acquisition - 30-45 min/day, 3 day/week, until mastery criterion met (90% correct, 2 consecutive sessions) - 15 min/day home practice (with audio) - Generalization training initiated (more conversational style, novel partners, etc.) after mastery	*Trained Scripts* 1. % script correct 2. errors 3. speaking rate 4. social validity	*Trained Scripts* 1. Mastery and maintenance of all scripts for both participants (97-100% accuracy); 80-100% accuracy in generalization conversations. 2. Some errorless scripts in treatment and maintenance sessions. 3. PWSA-Broca's improved from 13-32 wpm to 74-111 wpm; PWSA-conduction improved from 31-38 wpm to 80-93 wpm. 4. Significantly improved naturalness, rate, and informativeness for both PWSAs as judged by unfamiliar experienced and naive listeners.
Munoz & Karow, 2007[58]	1 PWSA, Broca's aphasia (moderate)	*Written Scripts with Audio* - Practice with 2 personal short written scripts with whole-task training versus part-task training - 50 min/day, 2 day/week, ~40 weeks - 15 min/day homework - Whole-task training utilized repeated drill, hierarchy with forward chaining, and talking photo album; part-task training utilized SPPA (Sentence Production Program for Aphasia) framework	*Trained Scripts* 1. correct script words *Other* WAB	*Trained and Untrained Scripts* 1a. 100% accuracy achieved after 8 sessions with whole-task training; maintained at 80% or above in maintenance 1b. 11% accuracy highest accuracy achieved with part-task training
Cherney & Halper, 2008[11]	3 PWSAs - 2 non-fluent (moderate) - 1 fluent (mild)	*AphasiaScripts* with hierarchy (from audiovisual and graphic cues to independent production in turn-taking with avatar) - minimum 30/min day for 9 weeks, home practice - 3 personal scripts per PWSA	*Trained Scripts* 1. % script-related words 2. grammatical productivity (script-related morphemes, nouns, verbs, modifiers) 3. rate (script-related wpm) *Other* WAB, CADL-2, ASHA QCL, CETI, Interview	*Trained Scripts* 1. PWSA-non-fluent1 improved from ~36-77-% script words to ~35-82%; PWSA-non-fluent2 from ~58-95% to ~80-95%; PWSA-fluent from ~33-35% to ~38-40% 2. PWSA-non-fluent1 improved from ~35-65 script morphemes to ~34-74; PWSA-non-fluent2 from ~24-30 to ~22-48; PWSA-fluent from ~15-21 to ~14-22 (see article for nouns, verbs, modifiers) 3. PWSA-non-fluent1 improved from 22-38 script wpm to ~31-55 wpm; PWSA-non-fluent2 from ~10-21 to ~22-32; PWSA-fluent rate data were not available
Cherney et al., 2008[15]	3 PWSAs - 1 Broca's (moderate) - 1 Wernicke's (moderate) - 1 anomic (moderate)	*AphasiaScripts* with hierarchy (from audiovisual and graphic cues to independent production in turn-taking with avatar) - minimum 30/min day for 9 weeks, home practice - 3 personal scripts per PWSA (3 weeks per script)	*Trained Scripts* 1. % script-related words 2. grammatical productivity (script-related morphemes, nouns, verbs, modifiers) 3. rate (script-related wpm)	*Trained Scripts* 1. PWSA-Broca's improved from ~22-25% script words to ~70-82%; PWSA-Wernicke's from ~18-28% to ~72-88%; PWSA-anomic from ~10-32% to ~80-98% 2. PWSA-Broca's improved from ~18-36 # script morphemes to ~41-110; PWSA-Wernicke's from ~10-30 to ~39-94; PWSA-anomic from ~8-20 to ~81-104 (see article for nouns, verbs, modifiers) 3. PWSA-Broca's improved from ~6-10 script wpm

Authors	Sample	Treatment Tasks	Measures Used	Outcomes
			Other WAB, CADL-2, ASHA QCL, Interview	to ~39-50 wpm; PWSA-Wernicke's from ~8-18 to ~30-44; PWSA-anomic from ~4-10 to ~24-80
Moss, 2009[62]	4 PWSAs - 3 moderate - 1 mild	*Written Scripts* - Script training in small group setting with 3 scripts per participant; procedures not specified (but modeled after Youmans et al., 2005) - 75 min/day, 3 day/week, 4 week	*Trained Scripts* 1. % correct script-related words 2. % error 3. rate (script-related wpm) *Untrained Discourse - Cookie Theft* 1. wpm 2. %CIUs 3. CIUs/min *Other* WAB-R, CADL-2, BOSS subscales, Interview	*Trained Scripts* 1. Mean increase 55.88% across participants 2. Mean decrease 52.26% across participants 3. Mean increase 55.68 (significant) *Untrained Discourse - Cookie Theft* 1. Variable - 2 showed large decrease, 1 large increase, 1 very slight increase 2. Variable - 1 showed large increase, 2 showed a slight decrease, 1 large decrease 3. Variable - 2 increased, 2 decreased
Lee et al., 2009[41]	17 PWSAs, non-fluent aphasia - 6 mild - 8 moderate - 3 severe	*AphasiaScripts* with hierarchy (from listening with audiovisual and graphic cues to independent production in turn-taking with avatar) - 9 weeks, home practice - 3 personal scripts per PWSA (3 weeks per script); length and complexity adjusted by severity	*Trained Scripts* 1. % script-related words 2. rate (script-related wpm)	*Trained Scripts* 1. Mean increase 45.72% across participants; significantly correlated with practice time, r=.67 2. Mean increase 137.48% across participants; significantly correlated with practice time, r=.53
Manheim et al., 2009[63]	25 PWSAs - ranged from mild to severe with mean in moderate range (64.57)	*AphasiaScripts* with hierarchy (from listening with audiovisual and graphic cues to independent production in turn-taking with avatar) - recommended 30/min day, 9 weeks, home practice - 3 personal scripts per PWSA (3 weeks per script)	*Other* BOSS CD subscale, Communication-Associated Psychological Distress subscale, Mobility subscale	*NA*
Holland et al., 2010[39]	33 PWSAs - 29 non-fluent - 4 fluent - ranged from mild to severe with mean in moderate range (67.09)	*AphasiaScripts* with avatar or with recording of friend or family member - recommended 30/min day, 9 weeks, home practice - 3 personal scripts per PWSA (3 weeks per script)	*NA* Purpose was to determine preferred script topics in large sample of PWSAs	*NA*
Youmans et al., 2011[57]	3 PWSAOS, anomic aphasia AOS severity - 1 mod-severe - 1 mild-mod - 1 mod-severe	*Written Scripts with Audio* - Practice with 3 personal short written scripts with hierarchy (from observing clinician model to independent production) for phrase-by-phrase acquisition - 60 min/day, 2-3 day/week, until script mastery (≥90% accuracy for 2 consecutive sessions) - 30 min/day (15 min x2) home practice with audio and written cue cards - blocked practice for phrase acquisition, random practice for acquired phrases; knowledge of performance feedback	*Trained Scripts* 1. % correct script-related words 2. % error 3. rate (script-related wpm) 4. self-ratings	*Trained Scripts* 1. Mastery and maintenance of all scripts (72-100% accuracy) for all participants 2. Varied by session; some errorless scripts in treatment and maintenance sessions observed; more errors generally observed during acquisition 3. Highly variable 4. Measured in 2 participants; confidence, ease of speech production, and naturalness increased substantially

Authors	Sample	Treatment Tasks	Measures Used	Outcomes
Youmans et al., 2011[86]* (*a participant from Youmans et al., 2011[57])	1 PWSAOS (mod-severe), anomic aphasia 125 healthy controls as raters	*Written Scripts with Audio* - See above Raters listened to script samples produced with different error rates and speaking rates; rated understandability, ease of production, naturalness, and overall quality	*Trained Scripts and Ratings* 1. % correct script-related words 2. % error 3. rate (script-related wpm)	*Trained Scripts and Ratings* 1. Significant positive correlation between participant improvement and listener ratings 2. Significant positive correlation between participant errors and listener ratings 3. Significant positive correlation between increased rate and listener ratings *(interaction between all 3 script-related variables)
Nobis-Bosch et al., 2011[59]	18 PWSA - moderate and severe - 14 Broca's - 2 global - 2 transcortical	*Written Scripts with Pictures and Audio* - Home practice with 24 template dialogues (3 turns per dialogue) via B.A.Bar training (speech is recorded, stored, and audio is replayed via bar codes available on exercise sheets with written and picture stimuli) - 2 practice sessions/day, 4 days/week, 4 weeks - practice also included naming and word-picture matching - crossover trial to compare to a visual-cognitive program	*Trained and Untrained Scripts:* 1. dialogue test linguistic rating 2. dialogue test communicative rating *Untrained Discourse:* 1. spontaneous speech assessed via interview and analyzed to basic linguistic parameters according to Aachen-Sprach-Analysis 2. verbal communicative ability assessed by ANELT *Other* Cognitive measures (pattern recognition, visual scanning); word fluency; CETI	*Trained and Untrained Scripts (dialogues)* 1. Significantly improved for trained scripts; if received script training in first phase, also significantly improved for untrained scripts 2. Significantly improved for trained scripts; if received script training in first phase, also significantly improved for untrained scripts *Untrained Discourse:* 1. Numerical improvements for several parameters (e.g., % words, TTR, MLU, etc.) for both phases of treatment, not specific to script training 2. Generalization observed in 30-50% of participants
Bilda, 2011[65]	5 PWSA - range of severity - 2 anomic - 1 Broca's - 1 Wernicke's - 1 unclassifiable by AAT	*Audiovisual Script Training* - Practice with 20 scripted dialogues with 5 levels of fading audiovisual support; audiovisual stimuli were movie-like depictions of scripted scenarios - 3 hours/day, 10 consecutive weekdays	*Trained and Untrained Scripts* 1. % accuracy *Untrained Discourse:* 1. ANELT *Other* AAT, CAL, CETI, SAQOL	*Trained and Untrained Scripts* 1a. Trained sentences from ~44% accuracy to ~77% at post treatment, 78% at 4-week follow-up and 80% at 6-month follow-up; 1b. Untrained sentences from ~50% accuracy to ~55% at post treatment, 60% at 4-week follow-up and 60% at 6-month follow-up *Untrained Discourse:* 1. Significantly improved for 2 participants
Fridriksson et al., 2012[16]* (*experiment 3)	13 PWSA, Broca's aphasia - 5 moderate - 5 severe - 3 very severe	*VAST* - Scripts were videos of a model's lower face, played on a mobile device - recommended home practice for 30/min day 5 day/week, for 2 weeks - weekly monitoring sessions with SLP - 3 shared template scripts were trained, 1 untrained (not personally relevant)	*Trained and Untrained Scripts* 1. % change of different words during speech entrainment 2. % change of different words during spontaneous speech (on scripted topics)	*Trained and Untrained Scripts* 1. Post-treatment: significant ~14% increase for trained scripts; significant ~17% increase for untrained scripts. 6-week follow-up: nonsignificant 9% increase for trained scripts; significant ~12% increase for untrained scripts 2. Post-treatment: significant ~65% increase. 6-week follow-up: significant ~54% increase

Authors	Sample	Treatment Tasks	Measures Used	Outcomes
Goldberg et al., 2012[60]	2 PWSA - 1 Broca's (moderate), mod-severe AOS - 1 conduction (moderate), moderate AOS	*Written Scripts with Audio* - practice with 2 personalized scripts - 1.3-1.5 hour/week (across 3 sessions), 3 weeks - treatment given both in person and video conference - recommended home practice (15–30 min 5 days per week) with digital recording of script saved on a personal computer or mobile phone.	*Trained Scripts:* 1. % script-related words 2. rate (script-related wpm) 3. % words with grammatical morphemes 4. disfluencies per word *Other:* WAB-R	*Trained Scripts:* 1. Participant 1 increased from 33.9-34.2% to 89.5-93.6%; Participant 2 increased from 63.9-78.1% to 99.3-100% 2. Participant 1 increased by 28-35 wpm; Participant 2 increased by 30-34 wpm 3. Participant 1 increased by 11-15%; Participant 2 increased 8% 4. Disfluencies per word varied greatly
van Vuuren & Cherney, 2014[64]	8 PWSA 7 non-fluent (mild to severe; AQ: 28.1-80.1) with mean in moderate range (58.0)	*AphasiaScripts* with hierarchy (from audiovisual and graphic cues to independent production in turn-taking with avatar) - 90 minutes/day, 6 days/week, in 3 sessions - 6 personalized scripts of equal length and equal grammatical complexity. - 3 weeks of high cue training (3 scripts) - 3 weeks of low cue training (3 scripts)	*Trained Scripts:* 1. % accuracy 2. rate (script-related wpm) *Untrained Scripts:* 1. % accuracy 2. rate (script-related wpm) *Other:* Cuing preference, WAB-R, NORLA-6	*Trained Scripts:* 1. Increased by 27%.8% 2. Rate increased by 36.6 wpm *Untrained Scripts:* 1. Increased by 7.3% 2. Increased by 7.6 wpm
Szabo et al., 2014[72]	4 PWSA - left hemisphere CVA - 3 Broca's (2 moderate,1 severe) - 1 anomic (mild)	*Written scripts with Audio and/or Visual* -written, visual and auditory cues provided on notecards, voice recorders or iPads. - 50 minutes/day, 2 days/week, range of 6-19 sessions - recommended 1-hour home practice daily - 2 personalized scripts with varying complexity - iPods/Pads were used to support retrieval / production	*Trained Scripts* 1. % script words correct 2.% script words omitted 3. rate (script-related wpm) *Other* CADL-2; WAB; RIC-CCRSA; ALA	*Trained Scripts* 1. Participants 1 increased from ~58-76% to ~95-100%; Participant 2 increased from ~10-41% to ~88-98%; Participant 3 increased from ~12-20% to ~90-100%; Participant 4 no improvement from ~30-69% to ~22-43% 2. Participant 1 decreased from ~20-42% to~ 0-11%; Participant 2 decreased from ~58-84% to ~1-10%; Participant 3 decreased from ~80-84% to ~0-3%; Participant 4 no change with ~2-45% and ~4-32% ; 3. Participant 1 increased from 15-21 to 19-37 wpm; Participant 2 increased from 14-41to 35-50 wpm; Participant 3 increased from 13-29 to 25-104 wpm; Participant 4 decreased from 48-84 to 18-50 wpm
Cherney et al., 2014[12]	8 PWSA - 7 non-fluent (1 mild, 4 moderate, 2 severe) - 1 fluent (moderate)	*AphasiaScripts* with hierarchy (from listening to taking turns with avatar) using personalized script templates - 2 phases of 3 weeks (90 min/day; 6 day/wk), with a 3-week washout period in between	*Trained and Untrained Scripts* 1. oral reading accuracy (NORLA-6) and rate (wpm), with focus on comparison between high-cue phase (written, auditory, oral-motor) and low-cue phase (written only)	*Trained and Untrained Scripts* 1a. Significantly improved and maintained up to 6 weeks follow-up for trained scripts; improvement observed for untrained scripts, but significance not addressed 1b. No significant differences between high-cue phase and low-cue phase at any timepoint, though large effect sizes in favor of high-cue phase, especially during treatment/acquisition phase

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Authors	Sample	Treatment Tasks	Measures Used	Outcomes
Cherney et al., 2015[40]* (*same participants as Cherney et al., 2014[12])	8 PWSA - 7 non-fluent (1 mild, 4 moderate, 2 severe) - 1 fluent (moderate)	*AphasiaScripts* with hierarchy (from listening to taking turns with avatar) - 3 weeks (90 min/day; 6 day/wk)	*Trained and Untrained Scripts* 1. oral reading accuracy (NORLA-6), with focus on comparison of personally relevant versus generic words in scripts	*Trained and Untrained Scripts* 1a. Significant increase in both personal and generic words in trained scripts; no significant difference between personal and generic, though large effect size 1b. Significant increase in personal words in untrained scripts but not generic words
Kaye & Cherney, 2016[14]	8 PWSA - 8 non-fluent (2 mild, 3 moderate, 3 severe) - 6/8 with AOS	*AphasiaScripts* - 1 week (schedule not specified) - Participants assigned to either high or low difficulty script templates	*Trained Scripts* 1. oral reading accuracy (NORLA-6)	*Trained Scripts* 1. Significantly greater for low-difficulty script templates compared to high-difficulty templates
Rhodes & Isaki, 2018[61]	2 PWSA - 1 Broca's/severe AOS - 1 TCM/severe AOS	*Written scripts* - Practice with written scripts via telepractice with hierarchy (from model to question prompts) and homework - 2 weekly telepractice sessions (total 13 sessions); daily home practice	*Trained Scripts* 1. % accuracy of scripts *Other:* - CETI, Telepractice questionnaire	*Trained Scripts* 1. Both participants significantly improved
Ali et al., 2018[81]	1 PWSA (severe Broca's)	*Written scripts with Audio Visual* - Practice with written scripts with hierarchy (from model to independent production); audiovisual scripts used for homework - 40 sessions over 2.5 months - sessions included different conversational partners	*Trained Scripts* 1. % intelligible scripted words 2. errors per word 3. rate (script-related wpm)	*Trained Scripts* 1. improved, large effect sizes; some maintenance of effects observed 2. improved, small effect sizes 3. improved, small and medium effect sizes
Henry et al., 2018[17]	10 PWnfvPPA	*VISTA (Video-Implemented Script Training for Aphasia)* - 2 weekly sessions (50 minutes, in-person or tele) focused on recall, organization and use in conversation -daily home practice (30 min) of unison production with audiovisual model	*Trained and Untrained Scripts* 1. % correct intelligible scripted words 2. % intelligible words 3. grammatical errors per hundred words *Other* - NAT; WAB-R; AOS rating; Dysarthria rating; Post-treatment survey; Neuroimaging predictors	*Trained and Untrained Scripts* 1. significantly improved and maintained up to 1-year follow-up for trained scripts 2. significantly improved and maintained up to 6-months follow-up for trained and untrained scripts 3. significantly improved for trained and untrained scripts for subgroup (n=7) with agrammatism
Dial et al., 2019[55]* (*same participants with nfvPPA as Henry et al., 2018[17])	31 PWPPA - 10 nfvPPA - 10 svPPA - 11 lvPPA	*VISTA* administered to nfvPPA; half received in-person; half received teletherapy - 2 weekly sessions; daily home practice (30 min) (see above) LRT (Lexical Retrieval Treatment) administered to svPPA and lvPPA; results not discussed here	*Trained and Untrained Scripts* 1. % correct intelligible scripted words *Other* - NAT; WAB-R	*Trained and Untrained Scripts* 1. including all 10 nfvPPA, significant group gains for trained scripts, maintained up to 1-year follow-up; no significant difference between in-person (5 nfvPPA) v. teletherapy (5 nfvPPA)
Grasso et al., 2019[76]	1 bilingual (Spanish-English) PWSA, anomic	*VISTA* - 2 weekly sessions; daily home practice (30 min) (see above) - Phase 1 Spanish, Phase 2 English -Scripts included different levels of cognate use (e.g., dense) to evaluate cross-linguistic transfer	*Trained and Untrained Scripts* 1. % correct intelligible scripted words 2. grammatical errors per hundred words 3. wpm (words per minute) 4. % intelligible words *Other* - NAT; BNT; WAB-R; BAT; Post-treatment survey	*Trained and Untrained Scripts* 1. significantly improved and maintained at follow-up; greater gains in Spanish v. English 2. significantly improved (reduction in errors), except for cognate-dense scripts 3. nonsignificant increase 4. significant increase

Authors	Sample	Treatment Tasks	Measures Used	Outcomes
Richardson et al., 2019[77]	4 PWPPA - 2 lvPPA - 2 nfvPPA	*VISTA* modified for group setting - 90 min/day, 1 day/week, 9 weeks - minimum 30/min day home practice for 9 weeks - 3 general scripts per PWSA, 1 personal script per PWSA	*Trained and Untrained Scripts* 1. number script-related words 2. % script-related words *Untrained Discourse* 1. main concept analysis for picture description (Cat Rescue, Refused Umbrella, Broken Window), Cinderella storytelling, PB&J procedural description *Other* Naming of script-related noun images, PNT-short, CLQT, CCRSA, NeuroQOL Cognitive, NeuroQOL Communication	*Trained and Untrained Scripts* 1. All improved. Mean increase immediately post-treatment of 62.5 words (range 15-136); three participants maintained at follow up, with mean increase of 61 words (range −5 - 141). 2. All improved. Mean increase immediately post-treatment of 23% (range 10-35%); three participants maintained at follow up, with mean increase of 23.25% (range −13% - 46%). *Untrained Discourse* 1. Variable, Picture description, 1/4 increased (nfvPPA), 3/4 no change or decreased; Cinderella, 2/4 increased (lvPPA and nfvPPA), 2/4 no change or decreased; PB&J, 2/4 increased (nfvPPA), 2/4 decreased
Studies that included Script Training as a Component of Treatment Protocol				
Authors	Sample	Script Training Description		Treatment Protocol
Milman et al., 2014[82]	3 PWSA, non-fluent aphasia	- “used a script training protocol”		Integrated Training for Aphasia: - Vocabulary Training - Sentence Training - Conversation Training - Dialogue Training (where the script protocol was used but not described)
Steele et al., 2014[70]	9 PWSA	- Used “script training principles” - Intermittently developed personal scripts in individual sessions then presented in a group session		Focus on group treatment via remote access (telehealth)
Dignam et al., 2015[69]	34 PWSA	- Script training for focus on functional treatment - AphasiaScripts as a computer-based treatment		Aphasia LIFT - Impairment treatment: semantic feature analysis and phonological component analysis - Computer based treatment: used Step by Step and AphasiaScripts - Group treatment: used Aphasia Action Success Knowledge Program
Rogalski et al., 2016[78]	34 PWPPA	- Developed written scripts to facilitate speech or functional contexts; orally rehearsed to increase automaticity		Communication Bridge: - Web application with all tasks tailored to each participant’s need - Lexical retrieval: cueing hierarchy with semantic, phonological, and orthographic cues - Motor speech production: visual cues including syllable segmentation and orthographic phonetic cues, auditory cues including care partner production or recording

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Authors	Sample	Treatment Tasks	Measures Used	Outcomes
Fein et al., 2019[68]	1 PWSA, anomic aphasia	- Scripts developed for texting on phone - 3-5 exchanges by text - Practiced with clinician		Three phase treatment - Single word typing on cell phone with T-CART - Script training for texting on phone Conversational skills for initiating and responding to texts

AAT (Aachen Aphasia Test); ALA (Assessment for Living with Aphasia); ANELT (Amsterdam-Nijmegen Everyday Language Test); AOS (Apraxia of Speech); ASHA QCL (Quality of Communication Life Scale); BOSS (Burden of Stroke Scale); CADL-2 (Communication Activities of Daily Living);CAL (Communication Activity Log);CCRSA (Communication Confidence Rating Scale for Aphasia);CETI (Communicative Effectiveness Index);CIU (Correct Information Unit); CLQT (Cognitive Linguistic Quick Test); LIFT (Language Impairment and Functioning Therapy); lvPPA (logopenic variant primary progressive aphasia);MLU (Mean Length of Utterance); NAT (Northwestern Anagram Test); NeuroQOL (Quality of Life in Neurological Disorders); nfvPPA (non-fluent primary progressive aphasia); NORLA-6 (Naming and Oral Reading in Aphasia); PB&J (Peanut Butter and Jelly Sandwich); PNT (Philadelphia Naming Test); PWPPA (person with primary progressive aphasia); PWSA (person with stable aphasia); SAQOL (Stroke and Aphasia Quality of Life Scale); SPPA (Sentence Production Program for Aphasia); svPPA (semantic variant primary progressive aphasia); T-CART (Copy and Recall Treatment for texting); TTR (Type Token Ratio); VAST (Visually Assisted Speech Technology); WAB (Western Aphasia Battery); WAB-R (Western Aphasia Battery-Revised)