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Similarities between Cognitive Models of Language Production and Everyday Functioning: Implications for Development of Interventions for Functional Difficulties

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Abstract

The loss of the ability to independently complete activities of daily living, such as meal preparation and household chores, is a defining characteristic of clinical dementia; however, minor difficulties in completing everyday activities emerge in the mild cognitive impairment stage, and even healthy older adults exhibit subtle functional difficulties compared to younger adults. These functional difficulties are associated with an array of negative outcomes, including decreased quality of life, higher costs of care, and increased frustration, depression, caregiver burden, and institutionalization. While cognitive models have been proposed to explain the functional deficits seen in dementia and subtler forms of cognitive decline, in contrast to other cognitive disorders such as aphasia, there are essentially no theoretically motivated interventions to address difficulties in everyday functioning. Proposed models of functional impairment share features with cognitive processing models of language, including hierarchical organization of representations and interactive, spreading activation; thus, an examination of aphasia interventions has the potential to inform the development of theoretically motivated interventions for everyday activities. This review first addresses the shared characteristics of cognitive models of everyday function and language, with a focus on linguistic production. Next, we will present aphasia interventions that target single-word production, sentence production, short-term memory, and semantics, and discuss their implications for everyday functioning interventions. We conclude with a discussion of limitations of the language-everyday functioning comparison as well as areas of future research.

Keywords

activities of daily living; instrumental activities of daily living; naturalistic action; treatment; aphasia

Everyday activities, such as preparing a sandwich or cup of coffee, are complex tasks that require object selection/use and sequencing task steps to achieve a practical, familiar end-goal. Neurological injury or disease often results in difficulties in performing everyday tasks, which may limit independence in people with moderate to severe cognitive impairment (e.g., dementia; McKhann et al., 2011) and result in a host of negative outcomes for

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families (Alzheimer's Association, 2018). Subtle difficulties that decrease everyday task efficiency have been observed in people with mild cognitive difficulties (Seligman et al., 2014) and healthy older adults (Giovannetti et al., 2018) and may be a harbinger for future decline and disability (Mis et al., 2019; Nowrangi et al., 2016). Despite the importance of everyday functioning in late adulthood, few empirically supported interventions exist to improve everyday functioning or prevent decline. Current clinical intervention prioritizes family or paid caregivers assuming management of everyday activities. The few existing interventions for improving everyday functioning in older adults are generally atheoretical and apply a broad mix of strategies (e.g., cognitive training, exercise, wellness) with limited consideration to cognitive theory (Chandler et al., 2019).

In stark contrast to the everyday functioning literature, many interventions for aphasia are directly inspired by cognitive models of language processing, resulting in theoretically motivated treatments targeting specific language impairments/processes. Interventions for language production have targeted dysfunction at a specific level or process of the hypothesized linguistic production model, including short-term memory (Martin et al., 2021), semantic networks (Kiran & Thompson, 2003), and syntactic forms (Thompson et al., 2003).

In this paper, we argue that theoretically motivated interventions for aphasia are an instructive paradigm to guide interventions to improve everyday functioning in older adults. We focus our review on language production, which shares some conceptual similarity with goal-directed performance of everyday tasks. We first consider the parallels between cognitive models of language production and everyday function. Next, we discuss language interventions with instructive principles for everyday functioning intervention. Finally, limitations to the proposed approach and suggested areas for future study will be considered.

Models of Language and Everyday Action

Interactive Activation Model of Language Production

Interventions for language production have been influenced by the interactive activation model proposed by Dell (1986), which posits syntactic, morphological, and phonological representations and feedback and feedforward activation of representations (Dell, 1986). Production of single words depends on bi-directional activations among semantic, lexeme, and phoneme representation levels within a network. Successful production of a target word is dependent upon the connection weights among representations in the semantic-lexical-phonological network and the rate of activation decay that occurs over the time course of word retrieval (Dell, 1986; Dell et al., 2007; Dell, Schwartz, et al., 1997; Martin et al., 1994; Martin & Dell, 2019). Sentence production involves a hierarchical structure proceeding from the intended message to speech utterances at the lowest level (Dell, 1985; Levelt, 1999). Importantly, activation automatically spreads among target representations at the various levels as well as to related, non-target representations (e.g., activation of the representations for “cat” also activates the representation for “dog” at the semantic level). Errors in word production may occur because non-target representations have a higher activation than the correct target representations, resulting in word or non-word (commission) errors (Martin et al., 1994; Vitkovitch & Humphreys, 1991), or because no representations meet the threshold

required for production, resulting in a failure to produce a response (omission errors; Dell et al., 2004). In some related iterations of the interactive activation model, cognitive control is required to modulate automatic activation of representations, including inhibition of related, non-target representations (Hodgson & Lambon Ralph, 2008). Though still incompletely understood, several language models posit that serial ordering is facilitated by excitatory activations within the hierarchical organization of representations learned over time (Endress & Wood, 2011) as well as inhibitory mechanisms, some of which are automatic and do not require learning (Dell, Burger, et al., 1997). Neuroimaging and lesion studies implicate the prefrontal cortex in language sequencing, though the precise role of deliberate executive control in the serial ordering of language remains elusive (Friederici et al., 2011; Thothathiri et al., 2012, 2017)

Goal-Control Model of Everyday Action

The goal-control model of everyday action builds on prior theories of action in the cognitive (Cooper et al., 2014; Cooper & Shallice, 2006; Norman & Shallice, 1986) and clinical dementia (Giovannetti et al., 2008) literatures to explain errors in everyday activities across the spectrum from healthy aging to moderate-level dementia (Giovannetti et al., 2021). Similar to existing models, the goal-control model represents everyday activities as goal hierarchies, with *intentions* (i.e., higher level goals, such as “make coffee”) at the highest level of the goal hierarchy, followed by lower-level goals (e.g., “add coffee grinds”) at intermediate levels, and manual gestures (e.g., “grab spoon”) at the lowest levels. Activation within the hierarchy may spread automatically from higher to lower level goals (e.g., “make sandwich” to “grab bread”) as well as from objects or environments that “trigger” associated goals (Cooper, 2002; Cooper & Shallice, 2000, 2006; Norman, 1981; Reason, 1910; Schwartz et al., 1998). The goal-control model also posits that cognitive control is essential to modulate activations, enable smooth transitions between subgoals, and inhibit inappropriate activation from objects in the environment (e.g., objects that are semantically/perceptually similar to targets, objects used earlier/later in the sequence) (Giovannetti et al., 2005, 2008, 2010). Cognitive control is required for error-free performance even for activities that are routine and well-learned.

Uniquely, the goal-control model was developed to account for errors in everyday action in individuals with neurologic cognitive impairment and thus emphasizes *error mechanisms*. There are many potential sources of errors during everyday task execution, but two distinct mechanisms are suggested based on prior empirical data from clinical populations (Giovannetti et al., 2021). First, failure of control mechanisms leads to interference from competing goals or objects in the environment, resulting in inappropriate reaching movements (e.g., microerrors - reaching for an ice cream scoop in place of a spoon) and inefficient action performance (e.g., commission errors - mis-sequencing task steps). Second, premature decay of representation activations or degraded goal representations/task knowledge leads to failures in completing essential task steps (i.e., omissions). In prior empirical studies, these omission errors have been associated with tasks of episodic memory and semantic knowledge, while commission errors have been associated with tasks of executive functioning (Giovannetti et al., 2008; Roll et al., 2019). These two distinct mechanisms of action errors guided our search through the language intervention literature;

we reasoned that interventions that successfully treated similar error mechanisms (i.e., weak/degraded activations vs. poor control) in aphasia might be adapted to treat difficulties with everyday action.

Similarities between Models of Language and Everyday Action

The previously described models of language production and everyday action share several important features, suggesting potential for theoretically based language interventions to inform everyday action interventions. Models of both processes consist of a network of representations in a hierarchical structure with overarching intentions represented at the highest levels of the hierarchy (intended message/task goal) and basic movements at the lowest levels (motor programming for speech/motor parameters for object grasping and manipulation). Activations within the network spread in a top-down and bottom-up direction among representations at various levels. Additionally, smooth execution of language and action involves domain-general cognitive control processes, with cognitive control hypothesized to be required to inhibit competing activations from related but non-target representations. Similarities exist in the left hemisphere brain structures recruited for language and action production, with representations associated with left temporal regions and production and control mechanisms associated with left lateral prefrontal cortex (Binder & Desai, 2011; Pulvermüller et al., 2005). Perhaps most importantly, common sources of failures/errors in both language and everyday action production include 1) inappropriate activation of non-target representations and 2) the premature decay of representation activations; thus, we reviewed interventions in the language literature with special attention to these two error mechanisms. Our review focused largely on language interventions that have been developed within the interactive activation framework described above, though we also mention a few successful language interventions that were not informed by the interactive activation framework because of their potential translation to everyday action.

Language Production Interventions

Aphasia interventions for people with strokes and stable deficits or primary progressive aphasia (PPA) are reviewed, with an emphasis on how each approach may be understood from the perspective of the interactive activation framework and the shared proposed mechanisms of language and action disruption. Specific implications of each intervention for everyday action are noted.

Short-term Memory Training

Influenced by interactive activation models, Martin and colleagues have developed treatment protocols to increase the activation *duration* of linguistic representations and improve language production (Kalinyak-Fliszar et al., 2011; Martin et al., 2021). In one study, participants with aphasia were trained to repeat word pairs or triplets after a 5- or 10-second response delay. The stimulus length and delay time were customized to be optimally challenging for each participant (Martin et al., 2021). After twelve training sessions, four out of eight participants demonstrated improvement in repetition of untrained words, with three participants demonstrating generalization of improvement to non-trained language tasks (e.g., picture naming, discourse production). Notably, participants with an aphasia profile

reflecting an activation maintenance deficit (i.e., errors due to premature decay) showed greater benefit from the treatment protocol, suggesting that people may be trained to extend the activation duration of linguistic representations through repeated practice using response delays (Martin et al., 2021).

Implication for everyday functioning.—In the domain of everyday action, the premature decay of goal representations has been targeted by providing individuals with cue cards describing task goal(s) (e.g., "make coffee"). Among people with dementia, this straightforward strategy significantly reduces omission errors (i.e., leaving out essential task steps), conceptualized as failures in goal activations on the goal-control model, but did not reduce commission action errors, which are conceptualized as control failures (Giovannetti et al., 2015). In contrast to the approach described by Martin et al. (2021) that improved activation duration of language representations through practice sustaining activations over a time delay, goal cue cards are an "external" compensatory strategy akin to a "crutch" that is unlikely to lead to lasting improvements. By contrast, improvements in "internal" maintenance of everyday task representations may be possible through practice in sustaining activation of action representations over a longer time course than that required for task execution. During training sessions, response delays could be inserted before participants are permitted to complete the next step of a personally relevant everyday task. According to the goal-control model, increasing the activation duration through practice with a forced response delay should benefit individuals with impairment in maintaining goal representations as compared to individuals with everyday action impairment due to deficient control mechanisms.

Speeded Training

In contrast to the response delay approach, other interventions have emphasized speed of responses in therapeutic protocols. Noting that fluent naturalistic speech requires word retrieval to occur both accurately and *rapidly*, Conroy and colleagues (2018) theorized that therapies focused on training single words will generalize to naturalistic speech only if word retrieval is practiced at a rapid rate comparable to fluent natural discourse. In terms of the interactive activation model, the semantic and phonologic representations of the target word must reach an activation level over and above competing representations (Dell, 1986; Dell et al., 2004); thus, difficulty in resolving competition in a timely manner may result in decay of representation activations (before execution) or increased interference from competing representations.

The repeated, increasingly-speeded production (RISP) therapy developed by Conroy et al. (2018) included two phases. The first phase was designed to improve naming *accuracy* through a standard cueing hierarchy. In the second phase, a *speeded component* was added requiring the participant to produce the target word within progressively shorter timeframes, from three seconds to one second. A beep signified the end of allotted time, and corrective feedback with practice was provided if the target was not named. In a sample of 20 individuals with aphasia, RISP was better than standard therapy in improving naming accuracy and connected speech (Conroy et al., 2018). Individuals with stronger executive functioning were more likely to maintain training benefits at follow-up timepoints.

Implication for everyday functioning.—Conroy et al. (2018) posited two explanations to account for the benefit of RISP therapy, each with implications for everyday functioning interventions. First, the RISP technique may be more engaging and motivating than standard therapy, thus more effectively employing executive and attentional networks associated with learning. Consistent with this account, therapies incorporating features of gamification designed to make interventions more enjoyable through engagement of reward processes may be more effective at inducing consistent, long-term gains in everyday functioning (Johnson et al., 2016). Though not explicitly linked to the interactive activation framework by the RISP developers, it is conceivable that rewarding activities more strongly activate goal hierarchies than activities performed with less motivation.

A second explanation posited by Conroy et al. (2018) for the positive benefits of training *speed* in addition to accuracy is that speeded demands may increase the precision of representation activations more than just accuracy training alone. Everyday action interventions have demonstrated that repeated practice with everyday tasks improves performance, even in people with marked cognitive impairment (Foloppe et al., 2018; Zanetti et al., 1997), and future work should evaluate whether speeded practice offers further improvement in the precision of execution.

Additionally, observations of everyday task performance, particularly when performed by "experts" or after tasks are well practiced, suggest that encouraging rapid execution of everyday tasks in real life (not just during training) may lead to benefits. Contrary to the literature on speed-accuracy trade-offs, under some specific conditions, individuals perform tasks more accurately when performed more quickly (Beilock et al., 2004, 2008; Giovannetti et al., 2007). From the perspective of the goal-control model, speeded execution may preclude premature decay of goal representations or may limit interference from competing, off-task goals; further study is required to evaluate whether (and how) speeded performance might be an effective strategy for improving performance in real-life settings.

Training Atypical/Difficult Exemplars

Another approach to language intervention has been to manipulate the difficulty of material to be trained. The complexity account of treatment efficacy (CATE) argues that training more difficult material will lead to generalization to simpler, untrained material (Kiran & Thompson, 2003; Thompson et al., 1997, 1998, 2003). In language, this phenomenon has been observed when training naming, grammar, and phonology (see Kiran & Thompson, 2003 for a review). CATE effects on naming have been explained according to the interactive activation model (Kiran & Thompson, 2003). For instance, training semantic features of atypical category exemplars activates and strengthens the larger semantic network through spreading activation, leading to improvements in naming untrained, typical category exemplars. Thus, training features associated with *penguin*, an atypical *bird*, also activates semantic features shared by many typical birds (e.g., has *feathers* and *lays eggs)*, leading to a stronger and more robust network of representations and improvements in naming *robin*, even without explicit training (Kiran & Thompson, 2003). By contrast, typical exemplars, which are named more easily and quickly, will not extend activation to the wider category network encompassing atypical exemplars.

To test this hypothesis, Kiran & Thompson (2003) used a semantic feature treatment that entailed naming as well as a range of activities designed to strengthen semantics: picture sorting, attribute identification, and answering yes/no questions pertaining to semantic features of the target item. Training atypical exemplars in this way resulted in generalized improvements on untrained, typical exemplars, with maintenance of training effects at six-to-ten weeks follow-up. Treatment benchmarks were met more quickly when training atypical exemplars versus typical exemplars first (e.g., 8 weeks vs 25 weeks for one participant; Kiran & Thompson, 2003). Additionally, as participants' naming improved overall, their error pattern shifted from neologistic/unrelated/no-response errors to a greater proportion of semantic/phonological errors, which was interpreted as a result of improved (though still not wholly accurate) activation of the relevant semantic and phonological representations (Kiran & Thompson, 2003).

CATE also has been applied to address syntactic deficits with generalization to spontaneous discourse (Thompson & Shapiro, 2005). In the context of syntax, CATE is conceptualized from a psycholinguistic approach that emphasizes language properties (e.g., argument structure) and processes (e.g., merge) that do not directly map on to interactive activation models. Procedurally CATE training includes complex sentences with object-relative clausal embedding (e.g., "The man saw the artist who the thief chased") with generalization to related but simpler object cleft (e.g., "It was the artist who the thief chased") and object-extracted "who" syntactic structures (e.g., "Who has the thief chased?") (Thompson et al., 2003).

Implication for everyday functioning.—The CATE approach contrasts with current convention in neurologic rehabilitation for everyday tasks where complex activities are trained only after simple tasks are mastered and errors should be prevented during rehabilitation training (Wilson et al., 1994). However, similarities between language and action models suggest the CATE approach might hold promise for improving everyday action as well as language. Data from training a range of motor tasks show learning is facilitated by training on more difficult, complex activities/actions as compared to training on simple activities/actions (Carey et al., 2005; Simon & Bjork, 2001), lending support to use of complexity manipulations in everyday functioning interventions. For example, assuming overlap among representations for similar tasks, training on cooking a complex sandwich (e.g., croque monsieur) may lead to improvements in making less complex sandwich types (e.g., ham sandwich).

Another method of increasing complexity when practicing everyday tasks is to require interleaving of different superordinate goals. This type of practice would likely lead to more errors, which in contrast to some accounts, have been shown to facilitate learning in some conditions (Middleton et al., 2015). For example, a target task like breakfast preparation may be trained by requiring individuals to alternate between steps of making toast and making coffee, which might improve performance on simpler subtasks when performed in a more simplified context (e.g., making coffee without the toast task). In fact, alternating practice between simple actions, though slower and more error-prone, leads to better retention of skills as compared to massed practice of the same actions (Simon & Bjork, 2001).

Different accounts have been proposed to explain the benefits of complexity training on motor tasks, but from an interactive activation framework and similar to the hypothesis proposed by Kiran and Thompson (2003), complex actions involve a larger network of goal representations than simple actions. Strengthening the multiple representations for a complex task within a goal hierarchy may include and consequently strengthen a smaller set of subordinate goals that represent simple tasks. From the goal-control framework, complexity manipulations could have the greatest effect in individuals who experience everyday action difficulties due to weak goal representations but may be detrimental to individuals with control deficits who might experience greater interference under complex conditions.

Further, studies of everyday functioning interventions also should consider the insight provided by analyzing errors. It is important to know whether errors during practice facilitate or impede learning. Also, language error type analyses have suggested that semantic/phonological errors reflect stronger activation of linguistic representations than unrelated and no-response errors, thus providing evidence for therapeutic effectiveness in activating target representations. In everyday functioning, interactions with distractor objects that are similar in function to the target object, such as an ice cream scoop for a sugar spoon, may signify greater activation of the semantic network than interactions with an unrelated object or a failure to respond, thus helping to guide the course of intervention.

Script Training

The interventions discussed so far were designed to address language impairments occurring after stroke, which typically involves an abrupt onset of linguistic impairment, followed by a period of improvement over several months before reaching a point of relative stability in the absence of any further cerebrovascular injuries (Pedersen et al., 2004). Relatively fewer interventions have been tailored to the needs of participants with aphasia due to neurodegenerative diseases, which typically involve an insidious onset with progressive decline in linguistic abilities over time (Karbe et al., 1993). Due to these differences in disease course and progression, interventions for these populations may have different priorities in treatment outcomes, such as a focus on preserving, rather than improving, abilities over time, and prioritizing skills with the greatest impact on a patient's daily life (Khayum et al., 2012). There is also a need for interventions to address severe deficits in everyday action, which may arise due to multiple mechanisms within the goal-control model, accompanying a dementia syndrome.

Henry et al. (2018) applied a script training treatment to ten participants with non-fluent/agrammatic variant primary progressive aphasia (nfvPPA), a type of frontotemporal dementia characterized by agrammatism and apraxia of speech (Bonner et al., 2010). This therapy [video-implemented script training for aphasia (VISTA)] used a speech entrainment model in which participants repeatedly imitated an unimpaired speaker on a predetermined script. Scripts were developed in a collaborative process between the speech therapist and participant to be tailored to their ability level and applicable to individual needs and interests. Activities during sessions ranged from structured exercises to promote memorization and fluency of scripts to functional activities promoting integration of scripts

into conversational speech, as well as articulatory drills and visual placement cues to address speech sound errors. Participants were also provided with videos of an unimpaired speaker's mouth producing the script for additional practice. VISTA training improved intelligibility of words and reduced grammatical errors in trained scripts, addressing core features of nfvPPA, and gains were maintained through one-year follow-up. Subjective reports also indicated that participants found the treatment reduced frustration and increased confidence in their communicative abilities. Treatment response related to larger gray matter volumes in the middle and inferior temporal gyrus, regions involved in syntactic production and visuo-motor speech abilities, suggesting that intervention relied on relatively intact linguistic abilities in the participants with nfvPPA (Henry et al., 2018). Though this script training intervention was not directly informed by a cognitive language model, it may be conceptualized within the interactive activation framework as improving activation of a damaged representation network by accessing intact components of the representation hierarchy (i.e., speech motor schema). The general rationale of the approach is to selectively preserve and strengthen a circumscribed set of personally meaningful linguistic representations that may be incorporated into multiple contexts to improve functional communication.

Implication for everyday functioning.—Script training has been applied to everyday functioning in at least one case with some success. In a case study with an individual experiencing significant impairments in everyday activities after anoxic brain injury, Bickerton et al. (2006) found that reciting a verbal script listing the steps for making tea while engaged in the activity improved the patient's ability to correctly perform task steps and self-correct performance errors. This patient had impairments in long-term task knowledge, maintenance of task goals, and control of competing activation, suggesting that an approach such as script training may be effective in individuals with impairments in everyday activities arising from multiple deficits. Similar to the VISTA approach in targeting relatively intact representations (e.g., visuo-motor linguistic abilities) within the larger representation hierarchy, Bickerton et al. (2006) relied on the patient's intact phonological loop and verbal representations to promote the activation of everyday action representations.

A strength of the Henry et al. (2018) intervention is the highly personalized material used in treatment. Though participants showed some improvements in intelligibility of untrained material, the focus of treatment was on improving and preserving speech performance on a limited but highly personalized set of material that would have the greatest impact on the individual's quality of life. Although the participant in the Bickerton et al. (2006) study showed no generalization to other activities and no benefit with verbal script when using a new object (i.e., alternate cup) to make tea, the Henry et al. (2018) study suggests that even improvements confined to one specific set of material can have a significant impact on a patient's quality of life if the activity is personally relevant and tailored to their individual needs. Future interventions should accommodate this level of personalization to enact meaningful change in the individual's quality of life.

Summary and Future Directions

In this paper, we have made the case that theoretically informed interventions for aphasia serve as instructive paradigms for development of interventions in everyday action. Cognitive models of language production and everyday action share a number of similarities, including hierarchical structure, spreading activation, and involvement of domain-general processes, that make this comparison useful. The language interventions considered, hypothesized target mechanisms within the interactive activation model, and potential parallel targets in action are summarized in Table 1.

Although instructive, there are limitations to the language-everyday action comparison that should be considered. First, many interventions for aphasia are conducted in individuals with stroke, which involves a different disease course and trajectory of recovery than neurodegenerative disease, a major cause of everyday action impairment. However, for the studies we have described here, aphasia intervention took place greater than one-year post-onset, a timeframe in which significant improvement in linguistic ability is not expected and few interventions are available in clinical settings (Pedersen et al., 2004; Watila & Balarabe, 2015), and studies in individuals with aphasia due to neurodegenerative disease have also shown effectiveness (Henry et al., 2018). In the context of aging/dementia, it is also important to consider interventions that could be applied to prevent functional decline in individuals at risk for neurodegeneration. Second, cognitive models of language may also entail domain-specific abilities with no corresponding counterpart in models of everyday action and vice versa (e.g., auditory processing, spatial navigation). Third, language-based interventions focused exclusively on naming (object selection) or syntax (sequencing) without reference to general mechanisms (e.g., strengthening representation activations) may have limited efficacy in everyday action, as the findings that support the goal-control model offer no evidence for circumscribed object selection or serial ordering deficits; sequence and substitution errors are frequently observed but rarely in isolation. Thus, training general processes may be a more fruitful approach for remediating functional disability.

Despite these limitations, theoretically motivated language interventions have much to contribute to the strategic development of everyday action interventions, and there may be further potential beyond the points discussed in this brief review. For example, interventions focused on improving language articulation and phonological processing may inform strategies for lower-level motor difficulties that disrupt tool use and object manipulation (Madden et al., 2017). Additionally, mechanisms for cross-domain effects whereby language interventions (e.g., script training) impact everyday action and vice-versa warrant further study.

Incorporation of new technologies, such as virtual reality (VR) paradigms, will likely facilitate the implementation and systematic investigation of the interventions proposed in this paper (Foloppe et al., 2018; Yamaguchi et al., 2012). For example, virtual reality training paradigms for everyday activities (Giovannetti et al., 2018) may be manipulated to incorporate response delays (Martin et al., 2021) and time limits (Conroy et al., 2018), and to modify task complexity (Kiran & Thompson, 2003; Thompson et al., 2003), and new technologies that enable 3-D scanning of real objects will offer opportunities to personalize

VR training programs using participants' own objects (Bozeat et al., 2002; Giovannetti et al., 2006; Snowden et al., 1994) and personally-meaningful tasks.

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Table 1.

Examples of language production interventions, method of treatment, and target of mechanistic action.

Language Intervention	Method	Language Target	Hypothesized Parallel Target(s) in Action	References
Short-term memory	Repetition of words after a response delay	Improve ability to sustain activations among language representations (phonology, lexicon, semantics) to promote word production	• Extend activation duration of goal representations	(Kalinyak-Fliszar et al., 2011; Martin et al., 2021)
Repeated, increasingly-speeded production (RISP)	Picture naming with decreasing times allowed for responses	Rapid, accurate word retrieval on a time scale approaching fluent speech	• Use of rewarding/ motivating activities to increase activation of goal representations • Improve precision of goal activations • Increase speed to preclude errors resulting from premature decay of goal representations or interference from competing goals	(Conroy et al., 2018)
Complexity account of treatment efficacy (CATE)	Training semantic features of typical and atypical category exemplars (for picture naming) and training of related syntactic sentence structures of varying complexity	Strengthening activation of shared representations by training complex exemplars/syntactic structures	• Improving activation of goal hierarchy network through training difficult/complex tasks	(Kiran & Thompson, 2003; Thompson et al., 2003)
Video-Implemented Script Training for Aphasia (VISTA)	Development and practice of personalized scripts with speech therapist	Agrammatism and apraxia of speech impairments characteristic of non-fluent/agrammatic PPA	• Selectively preserve/strengthen circumscribed set of personally relevant goal representations in individuals with complex/severe action deficits	(Henry et al., 2018)

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