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Review Article

Errorless, Errorful, and Retrieval Practice for Naming Treatment in Aphasia: A Scoping Review of Learning Mechanisms and Treatment Ingredients

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ABSTRACT

Purpose: Increasingly, mechanisms of learning are being considered during aphasia rehabilitation. Well-characterized learning mechanisms can inform "how" interventions should be administered to maximize the acquisition and retention of treatment gains. This systematic scoping review mapped hypothesized mechanisms of action (MoAs) and treatment ingredients in three learning-based approaches targeting naming in aphasia: errorless learning (ELess), errorful learning (EFul), and retrieval practice (RP). The rehabilitation treatment specification system was leveraged to describe available literature and identify knowledge gaps within a unified framework.

Method: PubMed and CINHAL were searched for studies that compared ELess, EFul, and/or RP for naming in aphasia. Independent reviewers extracted data on proposed MoAs, treatment ingredients, and outcomes.

Results: Twelve studies compared ELess and EFul, six studies compared ELess and RP, and one study compared RP and EFul. Hebbian learning, gated Hebbian learning, effortful retrieval, and models of incremental learning via lexical access were proposed as MoAs. To maximize treatment outcomes within theorized MoAs, researchers manipulated study ingredients including cues, scheduling, and feedback. Outcomes in comparative effectiveness studies were examined to identify ingredients that may influence learning. Individual-level variables, such as cognitive and linguistic abilities, may affect treatment response; however, findings were inconsistent across studies.

Conclusions: Significant knowledge gaps were identified and include (a) which MoAs operate during ELess, EFul, and RP; (b) which ingredients are active and engage specific MoAs; and (c) how individual-level variables may drive treatment administration. Theory-driven research can support or refute MoAs and active ingredients enabling clinicians to modify treatments within theoretical frameworks.

In cognitive neurorehabilitation, theories of learning can advance clinical practice by elucidating "how" treatments can be administered and "to whom" to confer durable change to treated systems (Baddeley, 1993; Maas et al., 2008; Maier et al., 2019; Middleton et al., 2020, 2016; Stark, 2005; Vallila-Rohter, 2017). The learning mechanisms underlying aphasia interventions are underspecified or not consistently identified. Thus, clinicians may have difficulty making informed decisions about which treatment elements are essential for learning and whether a treatment is appropriate considering a client's language and learning profile. Minor variations in therapy administration that are common to aphasia treatment (e.g., opportunity to make errors, effort of retrieval, and feedback) can have a profound influence on how learning unfolds and how information is retained. Minor

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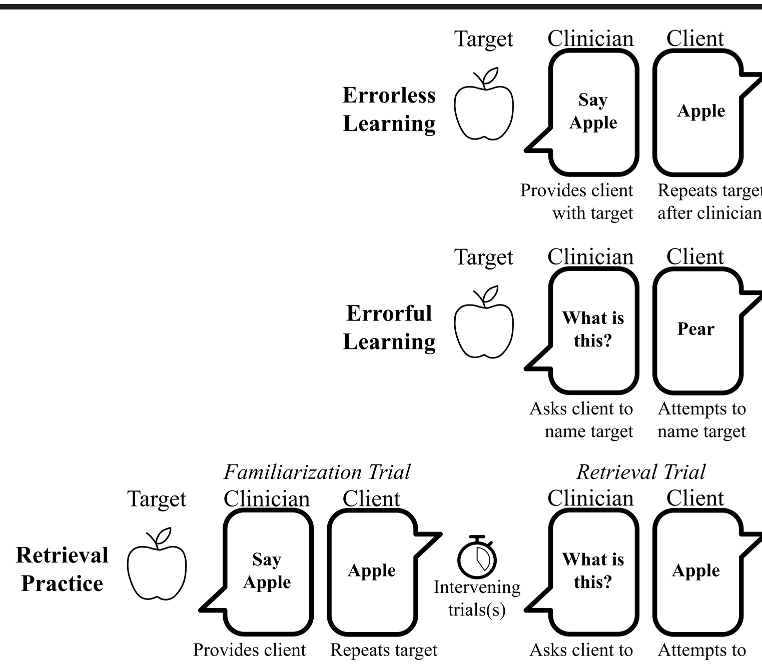
manipulations to learning tasks have been found to affect learning in educational contexts and psychology (Karpicke, 2017; Kornell et al., 2009; Pashler et al., 2005; Rawson & Dunlosky, 2011) as well as in clinical populations including individuals with amnesia (Clare & Jones, 2008), Parkinson's disease (Foerde & Shohamy, 2011; Kearney et al., 2019), Korsakoff's syndrome (Komatsu et al., 2000), multiple sclerosis (Chiaravalloti & DeLuca, 2002; de Lima et al., 2020; Sumowski et al., 2010), and traumatic brain injury (Ownsworth et al., 2017; Sumowski et al., 2014).

Task manipulations that influence error rate and participant effort have been applied to neurorehabilitation within three learning-based approaches: errorless learning (ELess), errorful learning (EFul), and retrieval practice (RP). Historically, ELess has been evaluated as an alternative to traditional trial-and-error approaches (i.e., EFul) to minimize error learning (for reviews, see Clare & Jones, 2008; Middleton & Schwartz, 2012). ELess was formally considered in aphasia by Fillingham et al. (2003), who proposed that ELess would maximize opportunities for individuals to produce the correct name in the presence of a target object, resulting in superior naming outcomes relative to EFul. In aphasia, ELess naming treatment typically involves repeated correct stimulus–response association, often through repetition practice, whereas EFul takes the form of confrontation naming with little or no support to control for errors (see Figure 1). Ultimately, comparisons of ELess and EFul aim to elucidate whether the incidence of errors influences learning outcomes.

Interest in RP as a training technique developed apart from research on ELess and EFul. RP was investigated in education and psychology research as a potent method for modifying memory and acquiring knowledge (for reviews, see Karpicke, 2017; Rowland, 2014). Middleton et al. (2015) adapted the standard RP paradigm to a naming treatment for aphasia and hypothesized that EFul and ELess fail to prioritize training experiences of highest value in the RP literature—effortful yet successful retrieval (Middleton & Schwartz, 2012). In RP for aphasia, researchers provide a familiarization trial (typically in the form of repetition practice) followed by retrieval attempts that are spaced over time (see Figure 1). Comparisons of ELess and RP aim to evaluate successful naming opportunities with low effort (repetition of a word) and high effort (retrieval of a word from long-term memory) to determine whether learning is enhanced when naming is effortful and successful.

ELess, EFul, and RP have been evaluated in aphasia primarily within studies contrasting two of these broadly defined learning approaches. Within the past decade, rehabilitation research has moved toward well-defined treatment theories, which drive research with the goal of evaluating (a) the mechanisms hypothesized to grant change to a treated system and (b) the actions executed by the clinician that engage mechanisms. Well-specified treatment theories allow clinicians to identify the

Figure 1. Schematic illustrating errorless learning, errorful learning, and retrieval practice for naming in aphasia.



mechanisms that may motivate prioritizing certain treatment ingredients for a particular client.

The rehabilitation treatment specification system (RTSS) offers a means to increase the specification of treatment ingredients and learning mechanisms within a unified framework (Hart et al., 2014, 2018). The RTSS was developed by an interdisciplinary group of clinician-scientists and identifies three core components of treatment theory: targets, ingredients, and mechanisms of action (MoAs). *Targets* refer to measurable aspects of function or behavior expected to improve as a result of treatment. *Ingredients* refer to actions carried out by the clinician, whereas *active ingredients* are those actions thought to produce change in the target. Ingredients are further broken down into those that target treatment groups (e.g., organ functions, skills and habits, and internal representations) or client volition. *MoAs* are hypotheses of how ingredients induce change in specified targets. Work in aphasia rehabilitation is beginning to adopt the RTSS and apply the framework to explain evidence-based interventions (Basilakos et al., 2021; Boyle et al., 2022; Cherney et al., 2022; Fridriksson et al., 2022). Boyle et al. (2022) note that a useful next step to improve the clarity with which clinicians and researchers characterize aphasia treatments would be to apply the RTSS within systematic review studies. Applying the RTSS to ELess, EFul, and RP, as we aim to do, can clarify the effects of variation in treatment administration, characterize proposed MoAs across studies, and evaluate gaps in research such as potential active ingredients warranting further exploration. Additionally, the current scoping review will allow for integration of more than a decade of research that has been conducted since the most recent reviews of ELess in aphasia (Fillingham et al., 2003; Middleton & Schwartz, 2012). Uniquely, this review is the first to jointly evaluate ELess, EFul, and RP for naming in aphasia.

Given the potential utility of considering learning mechanisms in aphasia rehabilitation, the current scoping review aims to describe proposed MoAs and treatment ingredients in ELess, EFul, and RP interventions for naming in aphasia. Scoping reviews provide a means to identify and map existing evidence (Arksey & O'Malley, 2005) with the "intended goals" of (a) clarifying key concepts and factors related to a research topic, (b) outlining how research has been conducted in a topic area, and (c) identifying gaps within the current research (Munn et al., 2018). Our aims align with these goals and are as follows: For ELess, EFul, and RP targeting naming in aphasia,

1. describe the hypothesized MoAs (*intended goal a*; see the Description of MoAs Proposed in Reviewed Studies (Aim 1) section);
2. outline treatment ingredients (*intended goal b*; see the Outline of Treatment Ingredients (Aim 2) section);
3. consider treatment ingredients in the context of comparative effectiveness outcomes to identify ingredients that may warrant further exploration (*intended goal a*; see Description of Ingredients in the Context of Comparative Effectiveness Studies (Aim 3) section); and
4. identify gaps in the current knowledge base (*intended goal c*; see the Discussion section).

Method

Search Strategy and Selection of Sources of Evidence

PubMed, CINHAL, and OpenDissertations were searched for studies published before January 2022 using the key terms: ("errorless learning" OR "errorless" OR "decreasing cues" OR "decreasing cue" OR "errorful learning" OR "errorful" OR "increasing cues" OR "increasing cue" OR "retrieval practice" OR "testing effect" OR "spaced retrieval" OR "progressive cueing" OR "progressive cues" OR "cue hierarchy" OR "cue hierarchies" OR "cueing hierarchy") AND (aphasia OR "Aphasia"[Mesh] OR anomia OR "Anomia" [Mesh]). Subject headings "Aphasia +" and "Anomia" were used to search CINHAL and OpenDissertations. Additional studies were identified through paper references. All identified studies were imported to Covidence (Covidence Systematic Review Software, n.d.). Abstract and full-text screening were performed by two independent reviewers (K.N. and a graduate research assistant). Reviewers met prior to initiating the screening process to ensure mutual understanding of the inclusionary criteria. The inclusionary criteria are as follows: (a) population was people with aphasia; (b) target of treatment was naming; (c) compared at least two of the following: ELess, EFul, and RP; and (d) study analyzed original data. Any disagreements were resolved via discussion and consensus between the two reviewers. If a consensus could not be reached, a third reviewer (S.V.-R.) assisted in making the final decision.

Data Extraction

Data extraction was performed by two independent reviewers (K.N. and S.V.-R.) using an electronic form developed by K.N. All disagreements between the reviewers were resolved via discussion and consensus. After data extraction, the first author summarized the data and shared it with the co-authors who alerted the first author to information that required clarification. Data were collected on (a) interventions compared, (b) proposed MoAs, (c) cues, (d) feedback, (e) treatment design and schedule, (f) number of treatment items, (g) naming attempts per session, and (h) error rates. Data extraction aimed to characterize minor variations in treatment ingredients that may influence learning (e.g., corrective vs. informative feedback). Variables for which data were sought are defined below:

1. Cue type: Cues were defined as the amount of phonemic, orthographic, or semantic information provided by the clinician (e.g., spoken and written word, word initial cues). When cues were provided within a cue hierarchy, they were defined by both (a) the cue direction and (b) when movement along the cue hierarchy occurred. Cue direction: *Decreasing*: most informative to least informative cueing. *Increasing*: least informative to most informative cueing. When movement occurred: *Within trial*: movement along the cueing hierarchy occurs within a single trial. A*cross sessions:* movement along the cueing hierarchy occurs across sessions.
2. Feedback: *Implied corrective:* accuracy conveyed through trial advancement or movement along the cueing hierarchy. *Explicit corrective:* accuracy conveyed verbally. *Informative*: participant provided with the correct response.
3. Treatment design: *Parallel*: interventions administered in separate blocks within the same session. *Alternating*: interventions are administered in alternation across sessions or weeks. *Sequential*: training of one condition completed before training of subsequent condition. *Interleaved*: interventions administered in the same block within the same session.
4. Items: number of items targeted within a cycle of training per condition.
5. Schedule: frequency and duration of training.
6. Naming attempts: number of naming attempts per item per session.
7. Error rates: proportion of accurate responses during training. If error rates could not be calculated by data provided within the paper, they were extracted from figures using WebPlotDigitizer (Version 4.5; Rohatgi, 2020). Error rates could not be estimated in all papers; however, these papers were included in the scoping review. Error rate data were extracted to determine if participants made more errors in ELess relative to EFul training.

To minimize the risk of bias when synthesizing results and contextualize comparative effectiveness statements (Boyle et al., 2022), data on outcomes and analysis methods were extracted and are included in Table 1. Data were collected on the following:

1. level of analysis (single case, multiple case, group),
2. timing of testing (1 week, 1 month, etc.),
3. comparative effectiveness as stated by authors,
4. dependent variable used to assess outcomes (e.g., number of trained items named accurately, difference scores between pre- and posttreatment probes of trained items),
5. statistical methods applied (none, chi-square test, analysis of variance, etc.), and
6. correction for multiple comparisons, when applicable.

A scoping review protocol was drafted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (Tricco et al., 2018). As scoping reviews allow for changes to the protocol given sufficient justification, the following changes were made to the unregistered review plan.

1. Data on outcomes and analysis methods were not collected for studies where authors reported more errors during ELess relative to EFul training as this is a minimally necessary criterion for a treatment to be considered “errorless” or “errorful.” Inclusion of these studies in the outcomes section may confound conclusions drawn.
2. Data on dependent variables used to assess outcomes were collected to provide context for comparative effectiveness statements.
3. Decreasing and increasing cue hierarchies were considered as ELess and EFul, respectively. Historically, decreasing cue hierarchies were used in the first application of ELess techniques to neurorehabilitation (Glisky et al., 1986). In naming treatment for aphasia, cue hierarchies have been used to compare outcomes following training with low and high error rates.

Results

Sources of Evidence

A total of 84 unique studies were screened. After screening, 21 papers advanced to the full-text review. Two studies were excluded during the full-text review. Conroy (2008) was a dissertation of later published research, and Lambon Ralph et al. (2010) amalgamated data from other included papers. Data extraction was performed with 19 studies, all of which were included. One study (Thomas et al., 2012) was removed from the comparative effectiveness data extraction because the participant produced more errors during ELess compared to EFul training. Twelve studies compared ELess and EFul (Abel et al., 2005, 2007; Choe et al., 2017; Conroy et al., 2009a, 2009b; Fillingham et al., 2005a, 2005b, 2006; Lacey, 2010; Lacey et al., 2004; McKissock & Ward, 2007; Thomas et al., 2012), six studies compared ELess and RP (Friedman et al., 2017; Middleton et al., 2019, 2015, 2016; Schuchard & Middleton, 2018a,

Table 1. Treatment ingredients and outcomes across studies comparing errorless learning, errorful learning, and retrieval practice for naming in aphasia.

	Experimental design					Outcome			
Study	**Comparison**	***N***	**Cues**	**Feedback**	**Intensity and design**	**Analysis level**	**Timing**	**Results**	**Statistics**
Lacey et al. (2004)	ELess vs. EFul	1	Study 1 & 2[†]: **ELess:** Decreasing cues, within trial **EFul**: Increasing cues, within trial	Study 1: **ELess:** Corrective (I) Informative (–) **EFul**: Corrective (I)	Study 1: Design NS - 20 items - Trained over 35 (EFul) and 40 (ELess) sessions - Naming attempts NS	Study 1: SC SC	 Tx 1 m	 ELess < EFul ELess < EFul	 None None
			[†]*Study 2 included a spaced retrieval manipulation*	Study 2: NS	Study 2: Design NS - 10 items - Trained over 8 sessions - Naming attempts NS	Study 2: SC	 Tx	 ELess = EFul *%acc-tx*	 None
Abel et al. (2005)	ELess vs. EFul *Combined ELess and EFul condition not included*	10	**ELess:** Decreasing cues, within trial **EFul:** Increasing cues, within trial	Corrective (I)	Alternating tx - 25 items (10 items trained/session) - Trained 5×/wk for 4 wks - Each item trained in two sessions - 5 trials/session - Naming attempts based on accuracy	G MC	Same day Same day	ELess < EFul ELess = EFul *Diff score: same-day posttest minus pre-tx baseline*	Mann–Whitney *U* test[a] Fisher test[a]
Fillingham et al. (2005a)	ELess vs. EFul	7	**ELess**: Spoken and written word **EFul**: Word initial phoneme and grapheme	None	Parallel tx - 20 items - Trained 2×/wk for 5 wks - 9 naming attempts/ session	MC MC	1 wk 5 wks	ELess = EFul ELess = EFul *#acc-tx*	NS NS
Fillingham et al. (2005b)	ELess vs. EFul	7	**ELess**: Spoken and written word **EFul**: Word initial phoneme and grapheme	None	Parallel tx - 20 items - Trained 2×/wk for 5 wks - 3 naming attempts/ session	MC MC	1 wk 5 wks	ELess = EFul ELess = EFul *#acc-tx*	NS NS
Fridriksson et al. (2005)	RP vs. EFul	3	**RP:** None **EFul:** Increasing cues, within trial	**RP:** Informative (–) **EFul:** Corrective (I)	Sequential tx - 15 items (3 items trained/session) - Trained 2×/wk for 4-7 wks - 1×/trial, number of trials/session NS	G	Collapsed post-tx probes (2, 6, and 12 wks)	RP > EF *#acc-tx*	Chi-square

(*table continues*)

Table 1. *(Continued).*

Study	Experimental design: Comparison	*N*	Cues	Feedback	Intensity and design	Outcome: Analysis level	Timing	Results	Statistics
Fillingham et al. (2006)	ELess vs. EFul	11	**ELess:** Spoken and written word **EFul:** Increasing cues, within trial	**ELess:** None **EFul:** Corrective (I)	Sequential tx - 30 items - Trained 2×/wk for 5 wks - ELess: 9 naming attempts/session - EFul: naming attempts based on accuracy	MC MC	1 wk 5 wks	10/11 ELess = EFul 1/11 ELess < EFul 9/11 ELess = EFul 2/11 ELess < EFul *#acc-tx*	Chi-square[a] Chi-square[a]
Abel et al. (2007)	ELess vs. EFul *EFul only conditions with semantic vs. phonological cues not included*	4	**ELess:** Decreasing cues, within trial; Cue direction reversed if not correct **EFul:** Increasing cues, within trial	Corrective (I)	Alternating tx - 30 items (6 trained/ session) - Trained 5×/wk for 2 wks - 6 trials/item, each item seen in 2 sessions - Naming attempts based on accuracy	MC	4–6 days	ELess = EFul *Diff score: #acc-tx at posttest minus #acc-tx in first 2 sessions*	Exact sign test, one-tailed
McKissock et al. (2007)	ELess vs. EFul *Additional manipulation: feedback*	5	**ELess:** Spoken word **EFul-nofb**[b]**:** None **EFul-fb**[b]**:** None	**ELess**: NS **EFul-nofb:** None **EFul-fb:** Corrective (E) Informative (+/–)	Parallel tx - 30 items - Trained 1×/wk for 8 wks - 1 naming attempt/ session	G G MC MC	2 wks 12–14 wks 2 wks 2 wks	ELess > EFul-fb > EFul-nofb = untreated ELess = EFul-fb > EFul-nofb = untreated ELess = EFul-fb 4/5 EFul-fb > EFul-nofb 1/5 EFul-fb = EFul-nofb *#acc-un&tx*	ANOVA with post hoc analysis ANOVA with post hoc analysis Chi-square[a] Chi-square[a]
Conroy et al. (2009a)	ELess vs. EFul	7	**ELess:** Decreasing cues, across sessions **EFul:** Increasing cues, within trial	**ELess:** Corrective (I) **EFul:** Corrective (I)	Parallel tx - 40 items - Trained 2×/wk for 5 wks - 10 naming attempts/ session	G MC MC	Post tx 1 wk 5 wks	ELess = EFul ELess = EFul ELess = EFul *#acc-tx*	ANOVA NS[a] NS[a]
Conroy et al. (2009b)	ELess vs. EFul	9	**ELess:** Spoken and written word **EFul**[b]**:** Increasing cues, within trial	**ELess:** Corrective (E) Informative (–) **EFul**: Corrective (I)	Parallel tx - 40 items - Trained 2×/wk for 5 wks - 10 naming attempts/ session	G MC MC	Post-tx 1 wk 5 wks	ELess > EFul (*p* = .06) 8/9 ELess = EFul 1/9 ELess > EFul ELess = EFul *#acc-tx*	ANOVA Chi-square[a] Chi-square[a]

(*table continues*)

Table 1. *(Continued).*

	Experimental design					Outcome			
Study	Comparison	*N*	Cues	Feedback	Intensity and design	Analysis level	Timing	Results	Statistics
Lacey (2010)	ELess vs. EFul *Additional manipulation: spacing of trials*	7	**ELess:** Decreasing cues, within trial **EFul:** Increasing cues, within trial	**ELess:** Corrective (I) Informative (–) **EFul:** Corrective (I)	Parallel tx - 20 items - Trained 2×/wk until criterion or plateau reached - Naming attempts based on accuracy	MC	Post-tx	6/7 ELess = EFul 1/7 EFul > ELess *#acc-tx*	Chi-square
Thomas et al. (2012)	ELess vs. EFul	1	**ELess:** Decreasing cues, within trial **EFul:** Increasing cues, within trial	**ELess:** NS **EFul:** Corrective (I)	Alternating tx - 40 items - 1-2×/wk for 3wks - 14 for ELess and accuracy dependent for EFul	*Excluded from comparative effectiveness section as more errors were produced during ELess relative to EFul training.*			
Middleton et al. (2015)	ELess vs. RP *Additional manipulation: cueing (RP)*	8	**ELess:** Spoken and written word **RP:** Cued trials: Word-onset (spoken and written) Uncued trials: None	Informative (–/+) *After 8-s trial*	Sequential tx - 54–116 items - Each item trained in 1 session - 2 naming attempts/ session (1 fam, 1 tx)	G G G	Same day 1 day 1 wk	ELess = cued RP = uncued RP ELess < cued RP; ELess < uncued RP ELess < cued RP; ELess = uncued RP *%acc-tx*	Reg Reg Reg
Middleton et al. (2016)	ELess vs. RP *Additional manipulation: within session spacing during a single session*	4	**ELess:** Spoken and written word **RP:** None	Informative (–/+) *After 8-s trial*	3–4 sequential tx cycles - 180–288 items (trained in sets of 60–72/cycle) - Each item trained in 1 session - 4 naming attempts/ session (1 fam, 3 tx)	G G	1 day 1 wk	ELess < RP ELess < RP *%acc-tx*	Reg Reg
Choe et al. (2017)	ELess vs. EFul *Independent home-computerized practice*	2	**ELess:** Decreasing, within trial **EFul:** Increasing, within trial	None	Sequential tx - 12 items - P1: Trained avg 5×/wk for 5 wks - P2: Trained avg 7×/wk for 7 wks - ELess: 7 naming attempts/session - EFul: 6 naming attempts/session	SC (P1) SC (P2)	3–5 wks 5–7 wks	ELess = EFul ELess = EFul *16-pt naming scale score-tx*	Friedman Friedman

(*table continues*)

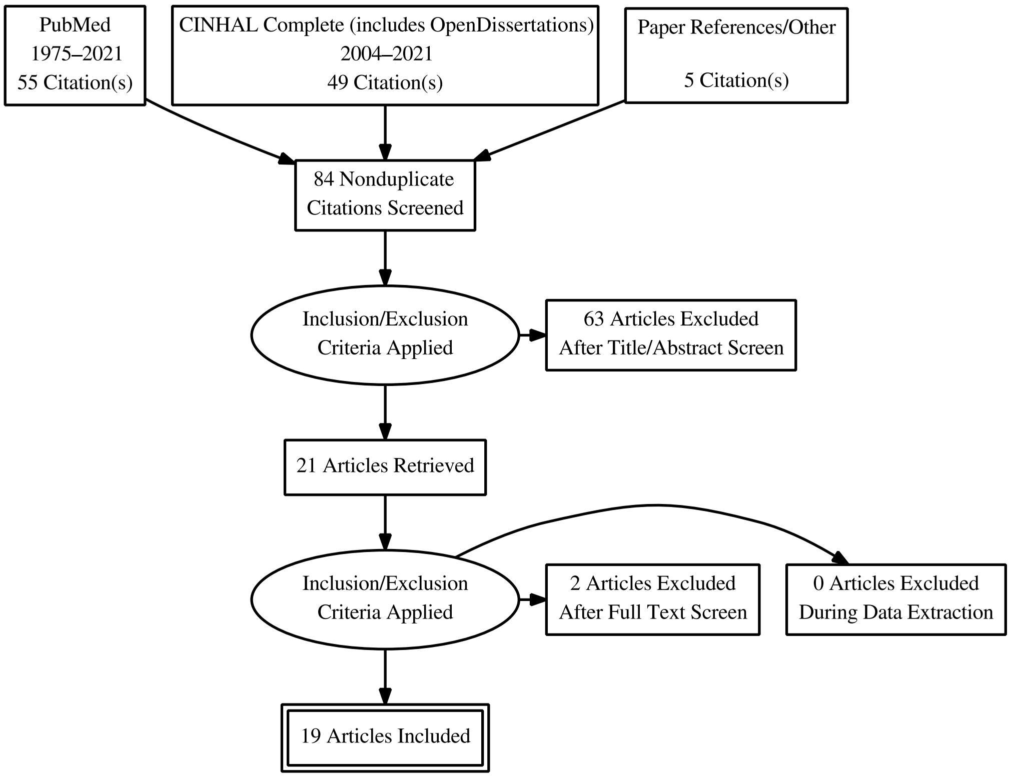
Table 1. *(Continued).*

	Experimental design					Outcome			
Study	**Comparison**	***N***	**Cues**	**Feedback**	**Intensity and design**	**Analysis level**	**Timing**	**Results**	**Statistics**
Friedman et al. (2017)	ELess vs. RP *Additional manipulation: overlearning (advanced to ELess/RP after test–study phase)* *Combined ELess & RP condition not included*	3	**ELess:** Spoken and written target to read or repeat **RP:** None	**ELess**: None **RP:** Informative (–/+)	Parallel tx - 18–22 items - Trained 2×/wk for 3–4 m - 2–3 naming attempts/session	G	1 m	ELess < RP	Chi-square
						G	4 m	ELess < RP	Chi-square
								%acc-tx	
Schuchard & Middleton (2018a)	ELess vs. RP *Additional manipulation: stage of impaired lexical access at the item level*	10	**ELess:** Spoken and written word **RP:** None	Informative (–/+) *After 8s trial*	Parallel tx - 44 items - Each item trained in 1 session - 3 naming attempts/ session (1 fam, 2 tx)	G	Post-tx	Stage 1 Items: ELess < RP Stage 2 Items: ELess > RP *%acc-tx*	Reg
Schuchard & Middleton (2018b)	ELess vs. RP *Additional manipulation: stage of impaired lexical access at the participant level*	2	**ELess:** Spoken and written word **RP:** None	Informative (–/+) *After 8-s trial*	3 cycles of parallel tx - 108 items (trained in sets of 36) - Each item in 1 session - 4 naming attempts/ session (1 fam, 3 tx)	G†	1 day	Treatment by pt interaction P1: ELess < RP P2: ELess = RP	Reg
						G†	1 wk	ELess < RP	Reg
						MC	1 wk	ELess = RP	Reg
						†1 pt per group		*%acc-tx*	
Middleton et al. (2019)	ELess vs. RP *Additional manipulation: within session spacing during multisession training*	4	**ELess:** Spoken and written word **RP:** None	Informative (–/+) *After 8-s trial*	2 cycles of interleaved tx - 96 items (trained in sets of 48) - Trained 2×/wk for 2 wks - 3 naming attempts/session (Session 1: 1 fam, 3 tx Sessions 2–4: 3 tx)	MC	1 wk	3/4 ELess < RP 1/4 ELess = RP	Reg
						G	1 m	ELess < RP	Reg
								%acc-tx	

Note. ELess = errorless learning; EFul = errorful learning; RP = retrieval practice; (I) = implied feedback; (E) = explicit feedback; (–) = informative feedback on incorrect trials only; (–/+) = informative feedback on correct and incorrect trials; NS = not stated; Fam = familiarization; Tx = training; wk(s) = week(s); Pt = participant; SC = singe case; MC = multiple cases; G = group; #acc-tx = number of trained items named accurately; #acc-un/tx = number of trained or untrained items named accurately; %acc-tx = percentage or proportion of trained items named accurately; Diff score = difference between pre- and posttreatment assessment; Reg = regression models.

[a]Did not correct for multiple comparisons. [b]Aimed to increase errors via guessing.

Figure 2. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram showing sources of evidence, studies screened, studies retrieved for full-text review, and studies included.



2018b), and one study compared RP and EFul (Fridriksson et al., 2005; see Figure 2).

Description of MoAs Proposed in Reviewed Studies (Aim 1)

MoAs were proposed or referenced by authors; however, studies typically did not seek to confirm a particular MoA. In some instances, studies attributed a theoretical framework describing an MoA to other researchers but did not espouse it as the definitive explanation (e.g., Middleton et al., 2015, 2016 and Hebbian learning for ELess). Additionally, in some instances, authors reported that findings were not consistent with the proposed MoAs (e.g., Lacey, 2010), suggesting that alternative mechanisms may be responsible for the treatment effect. Learning mechanisms are not mutually exclusive and may be best applied under specific learning contexts and with certain learners.

Errorless Learning

ELess prioritizes accurate naming of targets. Nine studies (Choe et al., 2017; Conroy et al., 2009a; Fillingham et al., 2005b, 2006; Lacey, 2010; Lacey et al., 2004; McKissock & Ward, 2007; Middleton et al., 2015, 2016) acknowledged Hebbian learning as an MoA that has been proposed for ELess. Hebb (1949) posited that repeated patterns of neuronal firing between cells strengthen the relationship and efficiency of firing between the involved cells. The implication is that if a stimulus elicits a response, the likelihood of making that response again, given the stimulus, increases. In purely Hebbian learning in which there is no error correction, the strengthening of the relationship between the stimulus and response occurs regardless of response accuracy (Fillingham et al., 2003).

Models of lexical access have been applied to explain learning under ELess naming treatment in five studies (Abel et al., 2005, 2007; Middleton et al., 2019; Schuchard & Middleton, 2018a, 2018b). Abel et al. (2005, 2007) applied the weight decay model of lexical access (see Dell et al., 1997) to ELess and EFul. However, they found that a semantic–phonological model of lexical access better aligned with treatment response. Semantic–phonological models of lexical access have been considered more recently as MoAs in ELess and RP by Schuchard and Middleton (2018a, 2018b) and Middleton et al. (2019) and will be discussed in the RP section. Four studies (Conroy et al., 2009b; Fillingham et al., 2005a; Friedman et al., 2017; Thomas et al., 2012) did not explicitly cite a learning mechanism in ELess.

Errorful Learning

In EFul, naming effort is prioritized over naming success. Four studies (Choe et al., 2017; Fillingham et al., 2005b, 2006; McKissock & Ward, 2007) have identified Hebbian learning with a monitoring system that filters out incorrect responses as a potential MoA (i.e., gated Hebbian learning). To prevent Hebbian learning mechanisms from reinforcing incorrect stimulus–response associations, during the learning process, incorrect and correct responses must be differentiated. Lambon Ralph and Fillingham (2007) describe this process as a gating mechanism thought to comprise three components: (a) detection of errant behavior, (b) memory/coding of responses and stimuli, and (c) attentional–executive skills for gating learning or correcting errors. When an error is detected, the gating mechanism is hypothesized to halt learning, or an error-correcting mechanism reinforces the correct response over the error (Lambon Ralph & Fillingham, 2007; see McClelland et al., 1999). When gating mechanisms are intact, Lambon Ralph and Fillingham (2007) propose that EFul is as effective as ELess. When any of the gating mechanisms are faulty, in the instance of an error, Hebbian learning may proceed, and errors risk being reinforced.

Three studies (Conroy et al., 2009b; Lacey, 2010; Lacey et al., 2004) identified effort as a task element essential to EFul. Effort can be driven by inherent task demands and/or client engagement (Conroy et al., 2009b; McKissock et al., 2007). Research that considers naming effort suggests that treatment ingredients that promote effortful naming provide more active engagement in the treatment process, resulting in superior attention and memory encoding (Lacey, 2010; see Robertson & Murre, 1999). The RP literature also outlines how effort can produce long-lasting change to a memory trace and will be discussed. Four studies (Conroy et al. 2009a; Fillingham et al., 2005a; Fridriksson et al., 2005; Thomas et al., 2012) do not cite an MoA for EFul.

Retrieval Practice

RP aims to achieve a balance between effortful and successful naming. In education and psychology research, there are several theories regarding the mechanisms that result in the advantage of RP over restudy (for review, see Karpicke, 2017). The RP literature in aphasia acknowledges many of these potential mechanisms (e.g., mediator effectiveness hypothesis, elaborative retrieval hypothesis), yet two mechanisms are consistently discussed.

Three studies (Friedman et al., 2017; Middleton et al., 2015, 2016) discuss effortful retrieval as a conceivable MoA underlying RP. Bjork and Bjork (1992) propose that memories have a storage strength and a retrieval strength. Storage strength is the persistent strength of an internal representation. Retrieval strength is the accessibility of an internal representation at a given time. When retrieval strength is low, retrieval is more effortful and storage strength is increased to a greater degree than when retrieval strength is high. This framework implies that, for maximal learning, RP should be "desirably difficult" (Bjork, 1994), that is, effortful to the point of maximal difficulty while still being successful.

RP for anomia has also been described within theories of lexical access in four studies (Fridriksson et al., 2005; Middleton et al., 2019; Schuchard & Middleton, 2018a, 2018b). Most notably, Schuchard and Middleton (2018a, 2018b) hypothesized that an incremental learning mechanism confers changes to each of the two main stages of lexical access as outlined in the two-stage interactive model of lexical access (Dell et al., 1997; Schwartz et al., 2006). In that model, in the first stage, a target word is selected from a cohort of coactivated words that are related to the target, which corresponds to mapping from semantics to words across weighted connections (s-weights). In the second stage, the retrieved word is mapped to its constituent phonemes via p-weights. To model naming impairment in aphasia, the s- or p-weights are reduced to heighten competition at that level, leading to naming errors (primarily word retrieval errors, e.g., horse for zebra, at Stage 1, and phonological errors, e.g., deeber for zebra, at Stage 2). Schuchard and Middleton (2018a, 2018b) hypothesized that repetition-based ELess should primarily strengthen Stage 2 because the target word can be directly activated from input phonology (Nozari et al., 2010), and thus, retrieval from semantics is not required. In contrast, RP should strengthen both stages because naming during RP requires and, thus, engages Stages 1 and 2.

Summary

Authors have hypothesized that treatment effects may be accounted for by the following MoAs: (a) ELess: Hebbian learning and incremental learning via lexical access, (b) EFul: gated Hebbian learning and effortful retrieval, and (c) RP: effortful retrieval and incremental learning via lexical access.

Outline of Treatment Ingredients (Aim 2)

Table 1 summarizes extracted study ingredients. Cueing was the primary ingredient used to differentiate between ELess, EFul, and RP. In ELess, cues act as the ingredient intended to promote successful target production. The primary ingredient differentiating EFul and RP was a maximally cued naming trial via repetition (i.e., familiarization trial) before uncued or cued naming/retrieval. In RP, but not EFul, retrieval attempts were preceded by a familiarization trial that aimed to maintain participant effort while maximizing retrieval success. RP studies were also more consistent in the provision of feedback across studies.

Feedback provision varied across studies (see Table 1). Most studies specified whether feedback was provided and what information was conveyed by feedback (i.e., accuracy and correct response). Informative feedback was typically in the form of a repetition trial, which could be considered an additional trial of repetition practice. Five RP studies provided feedback after the 8-s naming trial, which may result in a delay between participant response and feedback. The timing of feedback may be a variable of interest given that it can influence the neural systems recruited for learning (e.g., Foerde & Shohamy, 2011).

Intensity can be measured with the number of sessions a week, number of weeks of therapy, number of naming attempts per target per session, and number of items trained. The most frequent intensity of intervention was twice a week for 5 weeks. Four of six studies comparing ELess to RP trained targets in a single session to eliminate confounds related to spacing across multiple sessions limiting generalization to treatment, which occurs over more than one session. The number of items trained per condition ranged from 10 to 288. RP studies tended to train more items, although this ingredient was likely used to achieve sufficient power with small sample sizes.

The ingredients in Thomas et al.'s (2012) study resulted in the participant producing more errors during ELess relative to EFul training. Examination of the treatment ingredients may elucidate techniques that do not produce the desired error rates in training. However, the methods of Thomas et al. (2012) were comparable to other studies and modeled after the study of Abel et al. (2005; see Table 1). Differences in training may be a consequence of the participant's cognitive or linguistic impairment profile or methodological differences not stated in text (e.g., training sets not balanced for difficulty).

Description of Ingredients in the Context of Comparative Effectiveness Studies (Aim 3)

This section first outlines the general comparative effectiveness of ELess, EFul, and RP as reported by the authors of the reviewed studies (see Table 1). Then, studies that vary in their outcomes are compared to gain insight into ingredients that may influence treatment response.

Errorless and Errorful Learning

Several studies reported comparable results between ELess and EFul conditions at immediate and follow-up testing intervals (Abel et al., 2007; Choe et al., 2017; Conroy et al., 2009b; Fillingham et al., 2005a, 2005b, 2006; Lacey, 2010). However, in at least one instance of testing, Abel et al. (2005) and Lacey et al. (2004) found an EFul advantage, whereas Conroy et al. (2009a) and McKissock et al. (2007) found an ELess advantage. A small subset of individual participants demonstrated a significant advantage for EFul (n = 2, Fillingham et al., 2006; n = 1, Lacey, 2010) or ELess (n = 1, Conroy et al., 2009a).

Studies with divergent findings may provide insight into active ingredients. Conroy et al. (2009a, 2009b) studied some of the same participants, yet one study (Conroy et al., 2009a) showed a marginal ELess over EFul advantage, whereas the other (Conroy et al., 2009b) did not. The primary methodological difference was the structure of cues. ELess consisted of repetition practice in Conroy et al. (2009a) and a decreasing cue hierarchy in Conroy et al. (2009b). In the EFul condition, Conroy et al. (2009b) utilized a staircase method of cueing such that after a correct response was produced by a person with aphasia, cues were reduced/increased until five naming attempts (correct or incorrect) were made for each target. In Conroy et al. (2009a), once an item was named correctly in an increasing cues trial, the target was repeated to achieve five naming attempts. How cues were organized and subsequent naming attempts elicited may have led to an increase in errors or reduced instances of effortful naming, ultimately influencing treatment response across studies.

Ingredients to modify the effort of naming were also evaluated by Lacey et al. (2004), who trialed two different ELess training conditions after noticing a plateau in response to ELess training. Positing that movement along the decreasing cue hierarchy within a single trial resulted in reduced effort during naming, they integrated a spaced retrieval design into the ELess conditions such that targets were trained in pairs. Thus, movement along the decreasing cue hierarchy for a single target was separated by training of the pair word. Results of only two probe sessions are reported in the manuscript but reveal equivalent gains under ELess and EFul training conditions only when manipulations were incorporated to maintain participant effort via spacing. In a follow-up study, Lacey (2010) employed a spaced design in the ELess and EFul conditions. A clear advantage for spaced ELess or EFul was not found. However, a greater proportion of participants maintained gains in EFul (n = 6) compared to ELess (n = 2) at the 6-month follow-up assessment.

Feedback has been considered as a critical ingredient in EFul. McKissock et al. (2007) observed an advantage of EFul with explicit corrective and informative feedback over EFul without feedback. In addition, except for Conroy et al. (2009a), those studies that provided implied feedback in the EFul condition led to the most consistent EFul over ELess advantages at the individual subject level (Abel et al., 2005; Fillingham et al., 2006; Lacey, 2010; Lacey et al., 2004). However, some studies report that feedback is not a key ingredient during EFul (Fillingham et al., 2005b). Fillingham et al. (2005b) considered outcomes in two separate studies: one with implied feedback

(Fillingham et al., 2006) and one without feedback (Fillingham et al., 2005b) during EFul. In both studies, ELess and EFul outcomes were equivalent, leading authors to suggest that feedback did not influence treatment response. These studies draw into question the role of feedback and, potentially, how variation in feedback (e.g., explicit, implied) may influence learning.

Reviewed studies were not sufficiently consistent in their description of intensity parameters to compare outcomes as they relate to dosage, intensity, and frequency of treatment, though these are factors that may influence outcomes. Fillingham et al. (2005a, 2005b) utilized similar methods and participants but differed in the number of naming attempts per trial (nine per session and three per session, respectively). A larger number of participants in the Fillingham et al. (2005b) study showed no improvement (n = 5) from either ELess or EFul intervention at follow-up testing 5 weeks after training compared to the Fillingham et al. (2005a) study (n = 1), suggesting that increased naming attempts may contribute to retention of treatment gains.

Errorless Learning and Retrieval Practice

At retention and follow-up intervals, RP outperforms ELess (Friedman et al., 2017; Middleton et al., 2015, 2016, 2019), except for studies that examine these interventions as they relate to impaired naming at semantic versus phonological levels (Schuchard & Middleton, 2018a, 2018b). RP was more effective than ELess for improving later naming performance in a person with aphasia with a word retrieval deficit (Stage 1 mapping impairment), whereas a second person with aphasia with a Stage 2 mapping impairment benefited similarly from the two treatment approaches (Schuchard & Middleton, 2018b). Likewise, in a group study of 10 people with aphasia, RP was more effective than ELess at improving performance on items that elicited naming errors attributable to Stage 1 (e.g., semantic errors) and not Stage 2 (e.g., phonological errors) mapping failure (Schuchard & Middleton, 2018a). These findings are consistent with incremental learning via lexical access as an active MoA in retrieval and repetition-based naming treatments.

The spacing of repeated training trials was examined as a variable that may influence naming effort. Middleton et al. (2016, 2019) administered RP and ELess for both massed practice (items separated by one intervening trial) and spaced practice (items separated by multiple intervening trials). In both studies, when collapsed across RP and ELess conditions, spaced practice produced greater learning than massed practice. Middleton et al. (2016) suggested that during RP, spaced learning increases retrieval effort and, ultimately, long-term retention of gains—as is found in many types of learning (for a review, see Carpenter et al., 2012).

Ingredients that promote successful retrieval may influence outcomes in RP. Middleton et al. (2019), for example, noted that the one of four participants did not show an advantage of RP over ELess. This participant was the most severely impaired and produced more errors relative to other participants during RP training. Similarly, Middleton et al. (2015) found that ingredients that promoted successful naming were beneficial to retention. The RP advantage over ELess was maintained longer for cued compared to uncued RP (Middleton et al., 2015). Authors proposed that these findings support the hypothesis that RP benefits are tied to successful retrieval in addition to effort.

Additional training after an item has been learned may influence outcomes differently for RP and ELess. Friedman et al. (2017) examined "overlearning," specifically, how additional ELess (called study trials) or RP trials influenced retention after a target was learned (named twice on two consecutive initial test trials). At 1 and 4 months posttreatment, items that were overtested (RP) were retained better than items that were overstudied (ELess). When comparing overtested and overstudied items to items that were dropped from further training once learned, only overtested (RP) items benefited from additional training at 1 and 4 months posttreatment. This work suggests that continued ELess via repetition practice once a target is learned may not confer additional benefits to the language system while additional RP may.

Retrieval Practice and Errorful Learning

Only one study evaluated the comparative effectiveness of RP and EFul training (Fridriksson et al., 2005). When collapsing the total number of correctly named items across treatment probes for all participants, Fridriksson et al. (2005) found a statistically significant advantage for RP compared to EFul. In this review, Fridriksson et al. (2005) is the only RP study to have manipulated the "time" elapsed between repeated training trials as opposed to the "number" of subsequent training trials between repeated trials of the same target. Interstimulus intervals achieved by manipulating time are amenable to a concurrent second therapy task completed during spacing intervals. Fridriksson et al. (2005) found improved outcomes in naming and the concurrent writing treatment.

Discussion

This scoping review aimed to apply the RTSS to ELess, EFul, and RP for naming in aphasia to clarify the potential MoAs and central treatment ingredients. Within the discussion, we describe and consider gaps in these areas that were revealed through the scoping review process.

MoAs

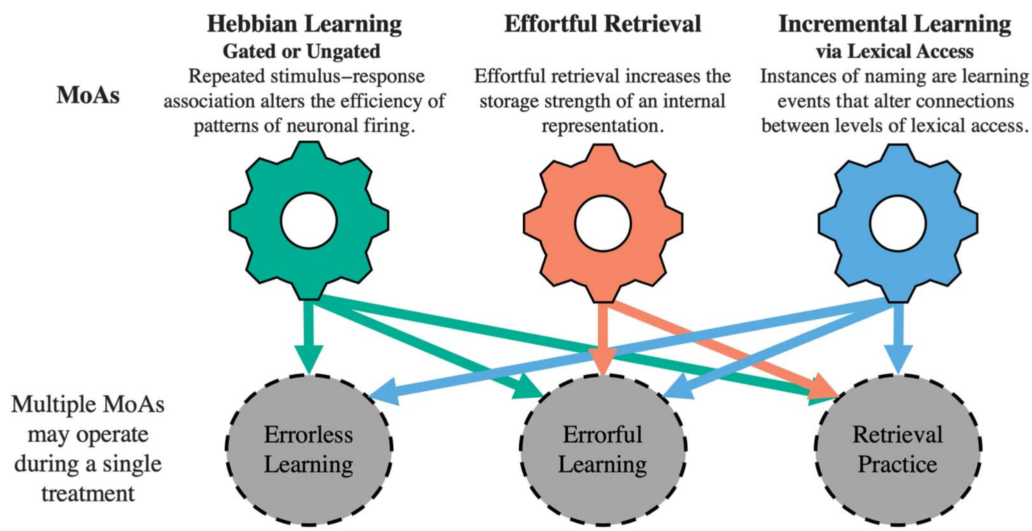
Four potential MoAs were identified across the studies, and 17 of the 19 studies identified an MoA for at least one of the compared interventions. There is no consensus as to which mechanism(s) of learning likely underlie ELess, EFul, and RP approaches. Interestingly, the results of the reviewed studies were not always consistent with the hypothesized MoAs. These discrepancies may call into question the proposed MoAs or be a result of methodological or statistical limitations.

Most of the reviewed papers aimed to compare the relative effectiveness of interventions rather than evaluate the proposed MoAs. Evaluating MoAs requires theoretically motivated, iterative research (Boyle et al., 2022) and can support designing and modifying treatments in ways faithful to the underlying MoAs. Schuchard and Middleton (2018a, 2018b) have begun to engage in this process when evaluating incremental learning via lexical access as a mechanism in ELess and RP. This work has implications for the selection of treatment ingredients based on a client's language deficits. Future research can move toward the evaluation of hypothesized MoAs. For example, work can evaluate whether Hebbian learning is gated by cognitive–linguistic skills during naming treatment for aphasia. Gated Hebbian learning can be supported or disputed by comparing outcomes under low- and high-error training conditions with a large sample of clients with and without cognitive–linguistic impairments in areas hypothesized to augment learning. Findings would establish whether cognitive–linguistic abilities should be considered when selecting ingredients that affect error rate.

Studies evaluating the MoAs of ELess, EFul, and RP may produce findings suggesting that MoAs coexist in a single intervention. Figure 3 illustrates which MoAs may operate concurrently during ELess, EFul, or RP. Hebbian learning, for instance, is a basic tenet of neuroplasticity and likely involved when internal representations are modified through repeated practice. Effortful retrieval may apply in any intervention involving retrieval of information from long-term memory, while incremental learning via lexical access may warrant consideration when treatments require participants to activate lexical representations. The classification of ELess, EFul, and RP into three distinct treatments with separable MoAs may limit consideration of how ingredients can be applied to align with multiple theoretical frameworks. Note that Figure 3 combines Hebbian and gated Hebbian learning into one MoA. As described previously, it has yet to be determined whether error-correcting mechanisms moderate Hebbian learning, a key area of future research.

Finally, the proposed MoAs may not be comprehensive. Implicit and explicit learning mechanisms have been more thoroughly evaluated in fields outside of aphasia. Implicit/explicit learning mechanisms may be relevant given that ELess is hypothesized to rely on implicit memory and, thus, be beneficial for those with declarative memory impairments (e.g., amnesia; Baddeley & Wilson, 1994; cf. Tailby & Haslam, 2003). It remains to be elucidated whether structural impairments to memory systems are associated with distinct learning profiles under ELess, EFul, and/or RP in aphasia. Given that memory is not a primary impairment in aphasia following acquired brain injury, implicit and explicit memory has not been probed

Figure 3. An illustration of which mechanisms of action (MoAs) may operate concurrently during a single intervention. Dividing errorless learning, errorful learning, and retrieval practice into three separable interventions may limit consideration of how MoAs coexist within a learning context.



in aphasia to determine their contribution to success in ELess and EFul contexts. While errors are at the forefront of the ELess and EFul comparison, there is no mechanistic rationale motivating error inflation during naming treatment for aphasia considering the subsequent impacts on relearning. Literature in other disciplines posits that during novel declarative learning tasks, errors act as future retrieval cues (Pyc & Rawson, 2012) or induce curiosity (Potts et al., 2019). However, it is unclear how these hypothesized mechanisms would relate to the retrieval of abstract, language-based representations (e.g., lemmas, Dell, 1986, or word forms, Caramazza, 1997) or operate within an impaired language system (e.g., error learning; Middleton & Schwartz, 2013).

Ingredients

Success and Effort

Success and effort are prominent within the MoAs proposed for ELess and RP learning that are manipulated via treatment ingredients including cues (e.g., Abel et al., 2005) and the spacing of repeated training trials of the same target (e.g., Middleton et al., 2016). Spacing retrieval during therapy is thought to establish conditions in which a memory trace is fading, and thus, retrieval is effortful while remaining successful. Learning improves when items were spaced compared to massed within and across sessions (Lacey et al., 2004; Middleton et al., 2016, 2019). Despite benefits for spaced over massed learning within single-training sessions, the spacing effect may diminish when training occurs over multiple sessions rather than within a single session (Middleton et al., 2019). A reduction in the spacing effect over multiple sessions is likely because both spaced and massed conditions benefit from the lag between training sessions. For language rehabilitation, which occurs over multiple sessions, distributed practice principles that take advantage of across-session spacing may be preferred. Recent work suggests that spacing training trials of the same target across sessions is more beneficial than spacing within a session (Schuchard et al., 2020). In that study, 7 days after training, naming accuracy was 21% higher for items named at a criterion of two (i.e., named accurately twice per session) across two sessions compared to items named at a criterion of four within one session. Given that effort and success are consistently identified as key aspects of ELess, EFul, and RP, future research can elucidate how clinicians can take advantage of various treatment ingredients including cues, within or across session spacing, and criterion of learning to achieve the desired level of effort and success for optimal learning.

Feedback

The notion that feedback is an important ingredient for naming interventions aligns with a recent meta-analysis that aimed to determine key components associated with successful naming interventions. Sze et al. (2021) found that feedback on the accuracy of a naming response was one of the most important factors for improved naming performance. From the perspective of proposed MoAs, EFul has been modeled as being gated by cognitive–linguistic skills including error detection (Lambon Ralph & Fillingham, 2007). Detection of errant behavior describes the recognition that an action conflicts with what is believed to be true and is considered a precursor for updating erroneous memory traces. Broadly, error detection is described as being either internally driven via self-monitoring or externally driven via the provision of feedback (Ohlsson, 1996; Postma, 2000). Self-monitoring abilities of naming may vary among people with aphasia (e.g., Schwartz et al., 2016) and depend on item difficulty, aphasia severity, and aphasia type (Nozari et al., 2011; Sampson & Faroqi-Shah, 2011). Fillingham et al. (2005a, 2005b, 2006) reported significant correlations between accuracy judgments on a naming test and ELess and EFul outcomes. However, the ability to detect feedback and use feedback to modify future performance has not been evaluated in aphasia, to our knowledge. External error monitoring via feedback may be particularly relevant when a person with aphasia is unable to self-monitor the accuracy of their responses.

Feedback was found to vary in its informativeness. In psychology and education research, the provision of informative feedback has been found to lead to greater learning gains and long-term retention relative to corrective feedback (Bangert-Drowns et al., 1991; Gilman, 1969; Pashler et al., 2005). However, no study within this review evaluated how the “information” conveyed by feedback influenced learning via systematic evaluation. Furthermore, only one study (McKissock et al., 2007) systematically compared EFul interventions with and without feedback within the same study. Further exploration of feedback may reveal whether feedback is an active ingredient within ELess, EFul, and RP interventions for aphasia, what information feedback should contain, and which individuals may benefit from feedback.

Eight studies discussed the influence of EFul (often associated with negative feedback) on motivation, effort, and treatment preference (Abel et al., 2005; Choe et al., 2017; Conroy et al., 2009a, 2009b; Fillingham et al., 2005b, 2006; Lacey, 2010; McKissock & Ward, 2007). The consequences of negative feedback on motivation and effort have not been systematically evaluated in the context of ELess, EFul, and RP using quantitative or qualitative methods. Client motivation is a relevant factor to consider and has been found to influence learning in education and psychology (Bourgeois et al., 2016; Pintrich, 2003).

Linking Ingredients to MoAs

Currently, treatment ingredients are mapped onto specific treatment approaches (e.g., repetition-based approaches are classified as ELess). This classification likely stems from initial research studies, which aimed to determine whether error rate (ELess, EFul) and/or participant effort (ELess, RP) influenced learning. However, as the mechanistic underpinnings of these approaches as they related to naming in aphasia continue to develop, a more useful conceptualization may be linking treatment ingredients to proposed MoAs as is illustrated in Figure 4. Within this framework, clinicians are not bound by a specific treatment approach and can precisely apply treatment ingredients that engage desired MoAs.

Individual Impairment Profile

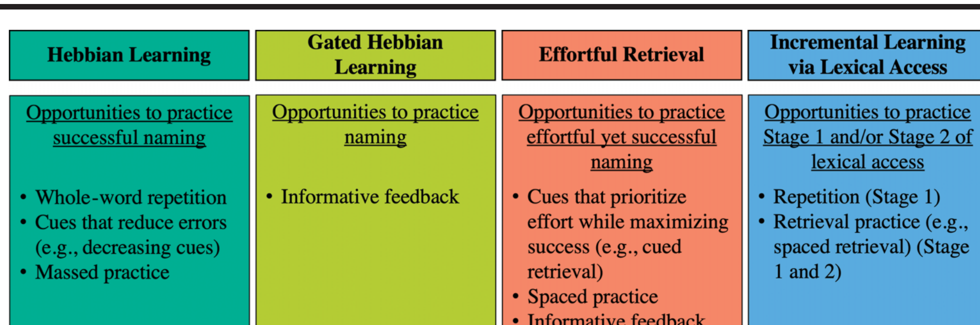
Eight studies considered the contribution of cognitive–linguistic skills to outcomes under ELess and EFul naming conditions with inconsistent findings, potentially calling into question gated Hebbian learning as an MoA (Choe et al., 2017; Conroy et al., 2009a, 2009b; Fillingham et al., 2005a, 2005b, 2006; Lacey, 2010; McKissock & Ward, 2007). Measures of cognition are known to map onto multiple cognitive constructs. Skills such as executive functioning may be more effective to evaluate with latent variable approaches (e.g., Miyake et al., 2000) and may provide additional insight into the role of specific cognitive constructs in EFul. Small sample sizes and differences in study ingredients may also contribute to inconsistent results highlighting the need for ongoing work. Lambon Ralph et al. (2010) combined data from four increasing cue studies and found that measures of attention, but not executive functioning, were associated with therapy gain immediately posttreatment and at follow-up. Interestingly, the lack of a relationship between executive skills and treatment response in the study of Lambon Ralph et al. is inconsistent with at least one of its constituent studies (Fillingham et al., 2006) potentially due to the methodological and/or statistical irregularities across the amalgamated studies. Cognitive skills such as working memory and attention may be relevant for RP in aphasia if these skills mediate retrieval difficulty but have not been evaluated (see Brewer & Unsworth, 2012; Dudukovic et al., 2009; Maddox & Balota, 2015; Maddox et al., 2011). If cognition is a key factor for ELess, EFul, or RP, future research can evaluate how to support cognition at the individual level.

Research comparing ELess and EFul has not consistently found a relationship between language impairment profile and treatment outcomes when evaluated (Fillingham et al., 2005a, 2005b, 2006). This may be because the mechanism underlying ELess and EFul is independent of language. Alternatively, it could mean that selected language measures are not sensitive to the kinds of impairments that interact with treatment type. Schuchard and Middleton (2018a, 2018b) have done work that suggests that RP and ELess may be more effective at treating naming impairments at the level of semantics or phonology, respectively. However, conclusions from this work are preliminary and may benefit from additional large-scale studies. The severity of naming impairment may also interact with treatment outcomes and may be further evaluated. Middleton et al. (2015) found that the benefits of RP are most strongly associated with trials in which retrieval is successful. Future research may evaluate whether individuals who make more errors respond differently to approaches or ingredients that promote successful retrieval.

Further Considerations

When evaluating treatment methods, it is important to consider the relative difficulty of implementing them within the standard clinical practice. Seven studies remarked on the challenges of managing cue hierarchies

Figure 4. Active ingredients as they may map onto proposed mechanisms of action (MoAs). Under each MoA, a broad active ingredient is listed and describes the types of naming opportunities that are hypothesized to confer change under each MoA. Underneath the broad active ingredients are ways in which these types of productions have been elicited and/or supported in the reviewed literature and are tools that clinicians may be able to utilize to engage a desired MoA.



or spaced retrieval intervals (Conroy et al., 2009a, 2009b; Fillingham et al., 2005a, 2005b, 2006; Fridriksson et al., 2005; McKissock & Ward, 2007). Implementation of evidence-based practices in the clinical environment is enhanced when approaches reduce barriers including those imposed by time, treatment complexity, and environmental constraints (Fucetola et al., 2005; Olswang & Prelock, 2015; Shrubsole et al., 2019). Given that treatment complexity has been identified as a potential barrier within some studies, it is important to engage stakeholders in subsequent studies and determine how to reduce complexity while maintaining faithful to key treatment ingredients.

Recently, the field of speech-language pathology is recognizing the importance of describing studies within a unified framework to improve treatment fidelity, allow clinicians to modify treatments based on individual impairment profiles, and help researchers address gaps in the literature (Basilakos et al., 2021; Boyle et al., 2022; Cherney et al., 2022; Fridriksson et al., 2022; Van Stan et al., 2021). The current scoping review demonstrates that it is feasible to apply the RTSS retrospectively to ELess, EFul, and RP and that it can be useful in clarifying related interventions. In ELess, EFul, and RP research, the RTSS may aid researchers in identifying whether ELess, EFul, and RP are distinct enough to be considered unique treatments. In a consensus study seeking to identify ingredients and MoAs in voice treatments, Van Stan et al. (2021) noted that equivalent outcomes in comparative effectiveness studies could be the result of comparing studies that consist of primarily the same active ingredients. It is possible that ELess, EFul, and RP share the same primary ingredient (e.g., opportunities to produce names for targets) with other ingredients being volitional in nature (e.g., targeting motivation or performance; see Whyte et al., 2019). However, because RP has shown advantages relative to ELess and EFul, RP is more likely to contain distinguishing ingredients.

While the RTSS supported the systematic evaluation of ingredients and MoAs in ELess, EFul, and RP, there were challenges in applying this framework to language rehabilitation. Within the RTSS, a distinction is made between ingredients that target a treatment group versus client volition (e.g., motivation, effort, and performance accuracy; Whyte et al., 2019). Treatment ingredients addressing effort or success are characterized in the RTSS as volitional, whereas in ELess, EFul, and RP for naming in aphasia, these ingredients are hypothesized to play a key role in altering internal language representations and, ultimately, the skill and habit of naming. Constructs of effort and success may play a distinct role when the target of treatment is an abstract mental representation. Additionally, the current review highlights the importance of (a) a precisely defined MoA (e.g., learning by practicing mapping from the word form to phonology) and (b) a means to capture multiple MoAs for a single target. Describing these findings using the RTSS is challenging given that the RTSS defines the MoA for treatments targeting skills and habits as “learning by doing” and provides guidance on applying one MoA to one target. Ongoing consideration of the application of the RTSS to language rehabilitation will further strengthen clinicians’ and researchers’ ability to uphold theory-driven language treatment.

Limitations

Given the variability of terms used to refer to interventions that manipulate success and error rate during naming treatment for aphasia, it is possible that some papers were not identified in the current review. Additionally, the reviewed studies were not written using the RTSS framework. Thus, MoAs and ingredients had to be extrapolated based on information provided by the original authors, which may not include aspects of treatment that the authors deemed evident.

Conclusions

Applying the RTSS to a systematic scoping review of ELess, EFul, and RP provides initial insights into hypothesized MoAs and ingredients that may produce change in naming. Gaps identified can drive future research that aims to (a) conduct iterative studies that aim to support or dispute MoAs through theory-driven comparative effectiveness research, (b) determine which ingredients are likely active and their relation to proposed MoAs, and (c) identify how individual-level factors can guide treatment selection and modification within the proposed theoretical frameworks. Ongoing efforts to determine the learning mechanisms responsible for creating durable change within the language system and ingredients that support these mechanisms may reduce variability in treatment response by enhancing a clinician’s ability to administer treatments in accordance with the underlying MoAs.

Data Availability Statement

The data collected in this scoping review are available from the corresponding author on reasonable request.

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References

Abel, S., Schultz, A., Radermacher, I., Willmes, K., & Huber, W. (2005). Decreasing and increasing cues in naming therapy for aphasia. *Aphasiology, 19*(9), 831–848. https://doi.org/10.1080/02687030500268902

Abel, S., Willmes, K., & Huber, W. (2007). Model-oriented naming therapy: Testing predictions of a connectionist model. *Aphasiology, 21*(5), 411–447. https://doi.org/10.1080/02687030701192687

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology, 8*(1), 19–32. https://doi.org/10.1080/1364557032000119616

Baddeley, A. (1993). A theory of rehabilitation without a model of learning is a vehicle without an engine: A comment on Caramazza and Hillis. *Neuropsychological Rehabilitation, 3*(3), 235–244. https://doi.org/10.1080/09602019308401438

Baddeley, A., & Wilson, B. A. (1994). When implicit learning fails: Amnesia and the problem of error elimination. *Neuropsychologia, 32*(1), 53–68. https://doi.org/10.1016/0028-3932(94)90068-X

Bangert-Drowns, R. L., Kulik, C.-L. C., Kulik, J. A., & Morgan, M. (1991). The instructional effect of feedback in test-like events. *Review of Educational Research, 61*(2), 213–238. https://doi.org/10.3102/00346543061002213

Basilakos, A., Hula, W. D., Johnson, L. P., Walker, G. M., Fridriksson, J., & Kiran, S. (2021). Defining the neurobiological mechanisms of action in aphasia therapies: Applying the rehabilitation treatment specification system framework to research and practice in aphasia. *Archives of Physical Medicine and Rehabilitation, 103*(3), 581–589. https://doi.org/10.1016/j.apmr.2021.10.017

Bjork, R. A. (1994). Memory and metamemory considerations in the training of human beings. In J. Metcalfe & A. Shimamura (Eds.), *Metacognition: Knowing about knowing* (pp. 185–205). MIT Press.

Bjork, R. A., & Bjork, E. L. (1992). A new theory of disuse and an old theory of stimulus fluctuation. In A. Healy, S. Kosslyn, & R. Shiffrin (Eds.), *Learning processes to cognitive processes: Essays in honor of William K. Estes* (Vol. 2, pp. 35–67). Erlbaum.

Bourgeois, A., Chelazzi, L., & Vuilleumier, P. (2016). How motivation and reward learning modulate selective attention. In *Progress in brain research* (Vol. 229, pp. 325–342). Elsevier. https://doi.org/10.1016/bs.pbr.2016.06.004

Boyle, M., Gordon, J. K., Harnish, S. M., Kiran, S., Martin, N., Rose, M. L., & Salis, C. (2022). Evaluating cognitive–linguistic approaches to interventions for aphasia within the rehabilitation treatment specification system. *Archives of Physical Medicine and Rehabilitation, 103*(3), 590–598. https://doi.org/10.1016/j.apmr.2021.07.816

Brewer, G. A., & Unsworth, N. (2012). Individual differences in the effects of retrieval from long-term memory. *Journal of Memory and Language, 66*(3), 407–415. https://doi.org/10.1016/j.jml.2011.12.009

Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cognitive Neuropsychology, 14*(1), 177–208. https://doi.org/10.1080/026432997381664

Carpenter, S. K., Cepeda, N. J., Rohrer, D., Kang, S. H. K., & Pashler, H. (2012). Using spacing to enhance diverse forms of learning: Review of recent research and implications for instruction. *Educational Psychology Review, 24*(3), 369–378. https://doi.org/10.1007/s10648-012-9205-z

Cherney, L. R., DeDe, G., Hoover, E. L., Murray, L., Obermeyer, J., & Pompon, R. H. (2022). Applying the rehabilitation treatment specification system to functional communication treatment approaches for aphasia. *Archives of Physical Medicine and Rehabilitation, 103*(3), 599–609. https://doi.org/10.1016/j.apmr.2021.10.016

Chiaravalloti, N. D., & DeLuca, J. (2002). Self-generation as a means of maximizing learning in multiple sclerosis: An application of the generation effect. *Archives of Physical Medicine and Rehabilitation, 83*(8), 1070–1079. https://doi.org/10.1053/apmr.2002.33729

Choe, Y., Foster, T., Asselin, A., LeVander, M., & Baird, J. (2017). Cognitive-linguistic effort in multidisciplinary stroke rehabilitation: Decreasing vs. increasing cues for word retrieval. *Neuropsychological Rehabilitation, 27*(3), 318–348. https://doi.org/10.1080/09602011.2015.1078820

Clare, L., & Jones, R. S. P. (2008). Errorless learning in the rehabilitation of memory impairment: A critical review. *Neuropsychology Review, 18*(1), 1–23. https://doi.org/10.1007/s11065-008-9051-4

Conroy, P. (2008). *Exploring errorless therapies for verb naming in aphasia* [Dissertation]. University of Manchester.

Conroy, P., Sage, K., & Lambon Ralph, M. A. (2009a). Errorless and errorful therapy for verb and noun naming in aphasia. *Aphasiology, 23*(11), 1311–1337. https://doi.org/10.1080/02687030902756439

Conroy, P., Sage, K., & Lambon Ralph, M. A. (2009b). The effects of decreasing and increasing cue therapy on improving naming speed and accuracy for verbs and nouns in aphasia. *Aphasiology, 23*(6), 707–730. https://doi.org/10.1080/02687030802165574

Covidence systematic review software. (n.d.). *Veritas Health Innovation*. http://www.covidence.org

de Lima, M. F. R., Cavendish, B. A., de Deus, J. S., & Buratto, L. G. (2020). Retrieval practice in memory- and language-impaired populations: A systematic review. *Archives of Clinical Neuropsychology, 35*(7), 1078–1093. https://doi.org/10.1093/arclin/acaa035

Dell, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review, 93*(3), 283–321. https://doi.org/10.1037/0033-295X.93.3.283

Dell, G. S., Schwartz, M. F., Martin, N., Saffran, E. M., & Gagnon, D. A. (1997). Lexical access in aphasic and nonaphasic speakers. *Psychological Review, 104*(4), 801–838. https://doi.org/10.1037/0033-295X.104.4.801

Dudukovic, N. M., DuBrow, S., & Wagner, A. D. (2009). Attention during memory retrieval enhances future remembering. *Memory & Cognition, 37*(7), 953–961. https://doi.org/10.3758/MC.37.7.953

Fillingham, J., Hodgson, C., Sage, K., & Lambon Ralph, M. A. (2003). The application of errorless learning to aphasic disorders: A review of theory and practice. *Neuropsychological Rehabilitation, 13*(3), 337–363. https://doi.org/10.1080/09602010343000020

Fillingham, J., Sage, K., & Lambon Ralph, M. (2005a). Further explorations and an overview of errorless and errorful therapy for aphasic word-finding difficulties: The number of naming attempts during therapy affects outcome. *Aphasiology, 19*(7), 597–614. https://doi.org/10.1080/02687030544000272

Fillingham, J., Sage, K., & Lambon Ralph, M. (2005b). Treatment of anomia using errorless versus errorful learning: Are frontal executive skills and feedback important? *International*

Journal of Language & Communication Disorders, 40(4), 505–523. https://doi.org/10.1080/13682820500138572

Fillingham, J., Sage, K., & Lambon Ralph, M. A. (2006). The treatment of anomia using errorless learning. *Neuropsychological Rehabilitation, 16*(2), 129–154. https://doi.org/10.1080/09602010443000254

Foerde, K., & Shohamy, D. (2011). Feedback timing modulates brain systems for learning in humans. *The Journal of Neuroscience, 31*(37), 13157–13167. https://doi.org/10.1523/JNEUROSCI.2701-11.2011

Fridriksson, J., Basilakos, A., Boyle, M., Cherney, L. R., DeDe, G., Gordon, J. K., Harnish, S. M., Hoover, E. L., Hula, W. D., Pompon, R. H., Johnson, L. P., Kiran, S., Murray, L. L., Rose, M. L., Obermeyer, J., Salis, C., Walker, G. M., & Martin, N. (2022). Demystifying the complexity of aphasia treatment: Application of the rehabilitation treatment specification systemx. *Archives of Physical Medicine and Rehabilitation, 103*(3), 574–580. https://doi.org/10.1016/j.apmr.2021.08.025

Fridriksson, J., Holland, A. L., Beeson, P., & Morrow, L. (2005). Spaced retrieval treatment of anomia. *Aphasiology, 19*(2), 99–109. https://doi.org/10.1080/02687030444000660

Friedman, R. B., Sullivan, K. L., Snider, S. F., Luta, G., & Jones, K. T. (2017). Leveraging the test effect to improve maintenance of the gains achieved through cognitive rehabilitation. *Neuropsychology, 31*(2), 220–228. https://doi.org/10.1037/neu0000318

Fucetola, R., Tucker, F., Blank, K., & Corbetta, M. (2005). A process for translating evidence-based aphasia treatment into clinical practice. *Aphasiology, 19*(3–5), 411–422. https://doi.org/10.1080/02687030444000859

Gilman, D. A. (1969). Comparison of several feedback methods for correcting errors by computer-assisted instruction. *Journal of Educational Psychology, 60*(6, Pt. 1), 503–508. https://doi.org/10.1037/h0028501

Glisky, E. L., Schacter, D. L., & Tulving, E. (1986). Computer learning by memory-impaired patients: Acquisition and retention of complex knowledge. *Neuropsychologia, 24*(3), 313–328. https://doi.org/10.1016/0028-3932(86)90017-5

Hart, T., Tsaousides, T., Zanca, J. M., Whyte, J., Packel, A., Ferraro, M., & Dijkers, M. P. (2014). Toward a theory-driven classification of rehabilitation treatments. *Archives of Physical Medicine and Rehabilitation, 95*(1), S33–S44.e2. https://doi.org/10.1016/j.apmr.2013.05.032

Hart, T., Whyte, J., Dijkers, M., Packel, A., Turkstra, L., Zanca, J., Ferraro, M., Chen, C., & Van Stan, J. (2018). *Manual for rehabilitation treatment specification*. https://acrm.org/acrm-communities/rehabilitation-treatment-specification/manual-for-rehabilitation-treatment-specification/

Hebb, D. O. (1949). *Organization of Behavior*. Wiley.

Karpicke, J. D. (2017). Retrieval-based learning: A decade of progress. In J. Byrne (Ed.), *Learning and memory: A comprehensive reference* (2nd ed., pp. 487–514). Academic Press. https://doi.org/10.1016/B978-0-12-809324-5.21055-9

Kearney, E., Shellikeri, S., Martino, R., & Yunusova, Y. (2019). Augmented visual feedback-aided interventions for motor rehabilitation in Parkinson's disease: A systematic review. *Disability and Rehabilitation, 41*(9), 995–1011. https://doi.org/10.1080/09638288.2017.1419292

Komatsu, S.-I., Mimura, M., Kato, M., Wakamatsu, N., & Kashima, H. (2000). Errorless and effortful processes involved in the learning of face-name associations by patients with alcoholic Korsakoff's syndrome. *Neuropsychological Rehabilitation, 10*(2), 113–132. https://doi.org/10.1080/096020100389200

Kornell, N., Hays, M. J., & Bjork, R. A. (2009). Unsuccessful retrieval attempts enhance subsequent learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35*(4), 989–998. https://doi.org/10.1037/a0015729

Lacey, E. (2010). *Generalization and maintenance in aphasia rehabilitation* [Dissertation]. Georgetown University.

Lacey, E., Glezer, L., Lott, S., & Friedman, R. (2004). The role of effort in errorless and errorful learning. *Brain and Language, 91*(1), 189–190. https://doi.org/10.1016/j.bandl.2004.06.097

Lambon Ralph, M. A., & Fillingham, J. K. (2007). The importance of memory and executive function in aphasia: Evidence from the treatment of anomia using errorless and errorful learning. In A. S. Meyer, L. R. Wheeldon, & A. Krott (Eds.), *Advances in behavioural brain science. Automaticity and control in language processing* (pp. 193–216). Psychology Press.

Lambon Ralph, M. A., Snell, C., Fillingham, J. K., Conroy, P., & Sage, K. (2010). Predicting the outcome of anomia therapy for people with aphasia post CVA: Both language and cognitive status are key predictors. *Neuropsychological Rehabilitation, 20*(2), 289–305. https://doi.org/10.1080/09602010903237875

Maas, E., Robin, D. A., Austermann Hula, S. N., Freedman, S. E., Wulf, G., Ballard, K. J., & Schmidt, R. A. (2008). Principles of motor learning in treatment of motor speech disorders. *American Journal of Speech-Language Pathology, 17*(3), 277–298. https://doi.org/10.1044/1058-0360(2008/025)

Maddox, G. B., & Balota, D. A. (2015). Retrieval practice and spacing effects in young and older adults: An examination of the benefits of desirable difficulty. *Memory & Cognition, 43*(5), 760–774. https://doi.org/10.3758/s13421-014-0499-6

Maddox, G. B., Balota, D. A., Coane, J. H., & Duchek, J. M. (2011). The role of forgetting rate in producing a benefit of expanded over equal spaced retrieval in young and older adults. *Psychology and Aging, 26*(3), 661–670. https://doi.org/10.1037/a0022942

Maier, M., Ballester, B. R., & Verschure, P. F. M. J. (2019). Principles of neurorehabilitation after stroke based on motor learning and brain plasticity mechanisms. *Frontiers in Systems Neuroscience, 13,* 74. https://doi.org/10.3389/fnsys.2019.00074

McClelland, J. L., Thomas, A. G., McCandliss, B. D., & Fiez, J. A. (1999). Understanding failures of learning: Hebbian learning, competition for representational space, and some preliminary experimental data. In *Progress in brain research* (Vol. 121, pp. 75–80). Elsevier.

McKissock, S., & Ward, J. (2007). Do errors matter? Errorless and errorful learning in anomic picture naming. *Neuropsychological Rehabilitation, 17*(3), 355–373. https://doi.org/10.1080/09602010600892113

Middleton, E. L., Rawson, K. A., & Verkuilen, J. (2019). Retrieval practice and spacing effects in multi-session treatment of naming impairment in aphasia. *Cortex, 119,* 386–400. https://doi.org/10.1016/j.cortex.2019.07.003

Middleton, E. L., Schuchard, J., & Rawson, K. A. (2020). A review of the application of distributed practice principles to naming treatment in aphasia. *Topics in Language Disorders, 40*(1), 36–53. https://doi.org/10.1097/TLD.0000000000000202

Middleton, E. L., & Schwartz, M. F. (2012). Errorless learning in cognitive rehabilitation: A critical review. *Neuropsychological Rehabilitation, 22*(2), 138–168. https://doi.org/10.1080/09602011.2011.639619

Middleton, E. L., & Schwartz, M. F. (2013). Learning to fail in aphasia: An investigation of error learning in naming. *Journal of Speech, Language, and Hearing Research, 56*(4), 1287–1297. https://doi.org/10.1044/1092-4388(2012/12-0220)

Middleton, E. L., Schwartz, M. F., Rawson, K. A., & Garvey, K. (2015). Test-enhanced learning versus errorless learning in aphasia rehabilitation: Testing competing psychological principles. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41*(4), 1253–1261. https://doi.org/10.1037/xlm0000091

Middleton, E. L., Schwartz, M. F., Rawson, K. A., Traut, H., & Verkuilen, J. (2016). Towards a theory of learning for naming rehabilitation: Retrieval practice and spacing effects. *Journal of Speech, Language, and Hearing Research, 59*(5), 1111–1122. https://doi.org/10.1044/2016_JSLHR-L-15-0303

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology, 18*(1), 143. https://doi.org/10.1186/s12874-018-0611-x

Nozari, N., Dell, G. S., & Schwartz, M. F. (2011). Is comprehension necessary for error detection? A conflict-based account of monitoring in speech production. *Cognitive Psychology, 63*(1), 1–33. https://doi.org/10.1016/j.cogpsych.2011.05.001

Nozari, N., Kittredge, A. K., Dell, G. S., & Schwartz, M. F. (2010). Naming and repetition in aphasia: Steps, routes, and frequency effects. *Journal of Memory and Language, 63*(4), 541–559. https://doi.org/10.1016/j.jml.2010.08.001

Ohlsson, S. (1996). Learning from performance errors. *Psychological Review, 103*(2), 241–262. https://doi.org/10.1037/0033-295X.103.2.241

Olswang, L. B., & Prelock, P. A. (2015). Bridging the gap between research and practice: Implementation science. *Journal of Speech, Language, and Hearing Research, 58*(6), S1818–S1826. https://doi.org/10.1044/2015_JSLHR-L-14-0305

Ownsworth, T., Fleming, J., Tate, R., Beadle, E., Griffin, J., Kendall, M., Schmidt, J., Lane-Brown, A., Chevignard, M., & Shum, D. H. K. (2017). Do people with severe traumatic brain injury benefit from making errors? A randomized controlled trial of error-based and errorless learning. *Neurorehabilitation and Neural Repair, 31*(12), 1072–1082. https://doi.org/10.1177/1545968317740635

Pashler, H., Cepeda, N. J., Wixted, J. T., & Rohrer, D. (2005). When does feedback facilitate learning of words? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*(1), 3–8. https://doi.org/10.1037/0278-7393.31.1.3

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology, 95*(4), 667–686. https://doi.org/10.1037/0022-0663.95.4.667

Postma, A. (2000). Detection of errors during speech production: A review of speech monitoring models. *Cognition, 77*(2), 97–132. https://doi.org/10.1016/S0010-0277(00)00090-1

Potts, R., Davies, G., & Shanks, D. R. (2019). The benefit of generating errors during learning: What is the locus of the effect? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 45*(6), 1023–1041. https://doi.org/10.1037/xlm0000637

Pyc, M. A., & Rawson, K. A. (2012). Why is test–restudy practice beneficial for memory? An evaluation of the mediator shift hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*(3), 737–746. https://doi.org/10.1037/a0026166

Rawson, K. A., & Dunlosky, J. (2011). Optimizing schedules of retrieval practice for durable and efficient learning: How much is enough? *Journal of Experimental Psychology: General, 140*(3), 283–302. https://doi.org/10.1037/a0023956

Robertson, I. H., & Murre, J. M. J. (1999). Rehabilitation of brain damage: Brain plasticity and principles of guided recovery. *Psychological Bulletin, 125*(5), 544–575. https://doi.org/10.1037/0033-2909.125.5.544

Rohatgi, A. (2020). *WebPlotDigitizer (4.5)*. https://automeris.io/WebPlotDigitizer/

Rowland, C. A. (2014). The effect of testing versus restudy on retention: A meta-analytic review of the testing effect. *Psychological Bulletin, 140*(6), 1432–1463. https://doi.org/10.1037/a0037559

Sampson, M., & Faroqi-Shah, Y. (2011). Investigation of self-monitoring in fluent aphasia with jargon. *Aphasiology, 25*(4), 505–528. https://doi.org/10.1080/02687038.2010.523471

Schuchard, J., & Middleton, E. L. (2018a). The roles of retrieval practice versus errorless learning in strengthening lexical access in aphasia. *Journal of Speech, Language, and Hearing Research, 61*(7), 1700–1717. https://doi.org/10.1044/2018_JSLHR-L-17-0352

Schuchard, J., & Middleton, E. L. (2018b). Word repetition and retrieval practice effects in aphasia: Evidence for use-dependent learning in lexical access. *Cognitive Neuropsychology, 35*(5–6), 271–287. https://doi.org/10.1080/02643294.2018.1461615

Schuchard, J., Rawson, K. A., & Middleton, E. L. (2020). Effects of distributed practice and criterion level on word retrieval in aphasia. *Cognition, 198,* 104213–104216. https://doi.org/10.1016/j.cognition.2020.104216

Schwartz, M. F., Dell, G., Martin, N., Gahl, S., & Sobel, P. (2006). A case-series test of the interactive two-step model of lexical access: Evidence from picture naming. *Journal of Memory and Language, 54*(2), 228–264. https://doi.org/10.1016/j.jml.2005.10.001

Schwartz, M. F., Middleton, E. L., Brecher, A., Gagliardi, M., & Garvey, K. (2016). Does naming accuracy improve through self-monitoring of errors? *Neuropsychologia, 84,* 272–281. https://doi.org/10.1016/j.neuropsychologia.2016.01.027

Shrubsole, K., Worrall, L., Power, E., & O'Connor, D. A. (2019). Barriers and facilitators to meeting aphasia guideline recommendations: What factors influence speech pathologists' practice? *Disability and Rehabilitation, 41*(13), 1596–1607. https://doi.org/10.1080/09638288.2018.1432706

Stark, J. A. (2005). Analysing the language therapy process: The implicit role of learning and memory. *Aphasiology, 19*(10–11), 1074–1089. https://doi.org/10.1080/02687030544000263

Sumowski, J. F., Chiaravalloti, N., & DeLuca, J. (2010). Retrieval practice improves memory in multiple sclerosis: Clinical application of the testing effect. *Neuropsychology, 24*(2), 267–272. https://doi.org/10.1037/a0017533

Sumowski, J. F., Coyne, J., Cohen, A., & DeLuca, J. (2014). Retrieval practice improves memory in survivors of severe traumatic brain injury. *Archives of Physical Medicine and Rehabilitation, 95*(2), 397–400. https://doi.org/10.1016/j.apmr.2013.10.021

Sze, W. P., Hameau, S., Warren, J., & Best, W. (2021). Identifying the components of a successful spoken naming therapy: A meta-analysis of word-finding interventions for adults with aphasia. *Aphasiology, 35*(1), 33–72. https://doi.org/10.1080/02687038.2020.1781419

Tailby, R., & Haslam, C. (2003). An investigation of errorless learning in memory-impaired patients: Improving the technique and clarifying theory. *Neuropsychologia, 41*(9), 1230–1240. https://doi.org/10.1016/S0028-3932(03)00036-8

Thomas, R., Hariharan, A., & Rao, T. S. (2012). The effects of increasing and decreasing cue therapy on improving naming abilities in a Malayalam speaking person with aphasia.

Strength for Today and Bright Hope for Tomorrow, 12, 400–412.

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., Moher, D., Peters, M. D. J., Horsley, T., Weeks, L., Hempel, S., Akl, E. A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M. G., Garritty, C., . . . Straus, S. E. (2018). PRISMA extension for scoping reviews (PRISMA-SCR): Checklist and explanation. *Annals of Internal Medicine, 169*(7), 467–473. https://doi.org/10.7326/M18-0850

Vallila-Rohter, S. (2017). Considering learning ability in language rehabilitation plans. *Perspectives of the ASHA Special Interest Groups, 2*(2), 23–30. https://doi.org/10.1044/persp2.SIG2.23

Van Stan, J. H., Whyte, J., Duffy, J. R., Barkmeier-Kraemer, J., Doyle, P., Gherson, S., Kelchner, L., Muise, J., Petty, B., Roy, N., Stemple, J., Thibeault, S., & Tolejano, C. J. (2021). Voice therapy according to the rehabilitation treatment specification system: Expert consensus ingredients and targets. *American Journal of Speech-Language Pathology, 30*(5), 2169–2201. https://doi.org/10.1044/2021_AJSLP-21-00076

Whyte, J., Dijkers, M. P., Hart, T., Van Stan, J. H., Packel, A., Turkstra, L. S., Zanca, J. M., Chen, C., & Ferraro, M. (2019). The importance of voluntary behavior in rehabilitation treatment and outcomes. *Archives of Physical Medicine and Rehabilitation, 100*(1), 156–163. https://doi.org/10.1016/j.apmr.2018.09.111