

A Review of Errorless Learning Strategies in Rehabilitation

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Neuroplasticity:

- Potential of the nervous system to be modified in response to stimulation and activation
- Experience-dependent
- Cortical reorganization

Evidence of Neuroplasticity in Humans

- Cortical reorganization following:
 - Exposure to sensory stimulation (somatosensory)
 - Practice (musicians; London Taxi drivers)
 - Missing or altered sensory input
 - Central lesions
 - Evidence of increased right hemisphere activity in rehabilitation (Crosson et al., Brier et al., 2006)

Recovery in Aphasia still difficult to predict

1. The literature on aphasia recovery and rehabilitation is replete with variability in findings regarding its neural substrates and characterized by disagreements regarding their underlying nature.

2. The variability is real, we need to understand it.

Review from: Crosson, B. (2007). Functional neuroimaging of impaired language: Aphasia. In Hillary & DeLuca (eds.) *Functional Neuroimaging in Clinical Populations*. New York: Guilford.

Neuroplasticity: Survivors of brain damage will engage in behaviors

- Rehabilitation or otherwise
- Adaptive or maladaptive
- Identify principles that will maximize the adaptive and compensatory, and minimize the maladaptive

Examine errorless learning strategies

- Language deficits in aphasia thought to benefit from errorless learning because of:
 - Hebbian based learning mechanism
 - Gains in language retrieval (face-name associations) demonstrated in memory impaired population

Errorless Learning Takes Flight

- Errorless learning was first described by Terrace (1963) in a study of animal behavior
- Terrace taught pigeons to discriminate between a red and a green key using errorless and errorful approaches

Errorless Learning Takes Flight

- The pigeons that received errorless learning discriminated between the keys more accurately than those that received errorful learning

Errorless strategies

- Constant Time Delay: fixed delay intervals between learning trials (Mattingly & Bott (1990). Teaching multiplication facts to students with learning problems. *Exceptional Children*. 56(5), 438-449)

Errorless strategies

- Method of Vanishing Cues: systematic increase & decrease of cues (Glisky, Schacter, & Tulving (1986b). Learning and retention of computer-related vocabulary in memory-impaired patients: method of vanishing cues. *Journal of Clinical and Experimental Neuropsychology*. 30, 899-910)

Errorless strategies

- Self-generated Errorless Learning: participant generated responses (Tailby, & Haslam (2003). An investigation of errorless learning in memory-impaired patients: improving the technique and clarifying theory. *Neuropsychologia*. 41, 1230-1240)

Errorless strategies

- Spaced Retrieval: increasing delay intervals between trials (Brush & Camp (1998b). Using spaced retrieval as an intervention during speech-language therapy. *Clinical Gerontologist*. 19(1), 51-64.)

Errorless Learning in Neuropsychology

- Errorless learning strategies have been applied to a variety of fields with success, including:
 - Learning
 - Memory
 - Aphasia

Learning

- Errorless learning has been found to produce greater learning outcomes than errorful learning in a variety of learning domains, including:
 1. Teaching sequencing to children with language learning deficits (Merzenich, Jenkins, Johnston, Schreiner, Miller, & Tallal (1996). Temporal processing deficits of language-learning impaired children ameliorated by training. *Science*. 271, 77-81)

Learning

- Teaching word lists to individuals with Schizophrenia (O'Carroll, Russell, Lawrie, & Johnstone (1999). Errorless learning and the cognitive rehabilitation of memory-impaired schizophrenic patients. *Psychological Medicine*. 29, 105-112)
- Teaching reading strategies to an individual with pure alexia, an acquired reading impairment (Sage, Hesketh, & Lambon Ralph (2005). Using errorless learning to treat letter-by-letter reading: contrasting word versus letter based therapy. *Neuropsychological Rehabilitation*. 15(5), 619-642)

Learning

- Teaching child compliance using an errorless type behavioral intervention (Ducharme (1996). Errorless compliance training. *Behavior Modification*. 20(3), 259-280.)
- Treating limb apraxia using an errorless type rehabilitation program (Jackson (1999). Dyspraxia: guidelines for intervention. *British Journal of Occupational Therapy*. 62(7), 321-326.)
- Teaching shapes to children with Mental Retardation (MR) (Sidman & Stoddard (1967). The effectiveness of fading in programming a simultaneous form discrimination for retarded children. *Journal of the Experimental Analysis of Behavior*. 10, 5-15.)

Memory

- Errorless learning strategies have been shown to be effective with individuals with memory impairments
- Through errorless learning, individuals with severe memory impairments have:
 - Acquired new information
 - Learned new skills
 - Formed new associations

Memory

- Etiologies of memory impairments studied included:

<ul style="list-style-type: none"> ■ Encephalitis ■ Korsakoff's syndrome ■ TBI ■ Stroke 	<ul style="list-style-type: none"> ■ Dementia ■ Hypoxic brain disease ■ Hydrocephalus ■ Alzheimer's disease
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Memory

- Errorless strategies have been used to instruct individuals with memory impairments in:
 - Word list learning
 - Face-name associations
 - Technological instruction
 - Novel information & associations

Word List Learning

- Observed errorless advantage for word list learning in individuals with memory impairments
(Wilson, Baddeley, Evans, & Shiel (1994). Errorless learning in the rehabilitation of memory impaired people. *Neuropsychological Rehabilitation*. 4(3), 307-326.; Hunkin, Squires, Parkin, & Tidy (1998). Are the benefits of errorless learning dependent on implicit memory? *Neuropsychologia*. 36(1), 25-36)
- Word list learning: learning and recalling lists of 5 words, such as "fly, story, house, bird, give"

Word List Learning

- Wilson et al. (1994) was first to study errorless learning in this population
- Errorless procedure of word list learning with cued recall:
 - Participants told NOT to guess
 - "I am thinking of a five letter word beginning with ST and the word is STORY. Write that down."

Word List Learning

- Wilson et al. (1994)
- Errorful procedure of word list learning:
 - "I am thinking of a five letter word beginning with ST. Guess what that might be."
 - Correct answer revealed after 25 seconds or 4 incorrect answers
 - If target word guessed, substitute word used to ensure at least one error

Word List Learning

- Wilson et al. (1994)
- Conclusions:
 - Participants benefited significantly more from errorless learning than errorful learning
 - Demonstrated in cued recall of word lists
 - Cued recall: recall task where cues are given
 - Errorless Advantage for word list learning in individuals with severe memory impairments

Word List Learning

- Hunkin, Squires, Parkin & Tidy (1998) confirmed Wilson et al.'s findings
- Both Wilson et al. (1994) and Hunkin and colleagues reported an errorless advantage for cued recall (with cues) of learned word lists
- Hunkin et al. also reported an errorless advantage for free recall (without cues)

Word List Learning

- Hunkin Squires, Parkin & Tidy (1998) also extended Wilson et al's (1994) findings by testing delayed recall
- Hunkin et al. found that the errorless advantage was maintained across a 48 hour delay
- However, there was a significant decrease in errorless performance accuracy

Face Name Associations

- Reported errorless advantage for face name association learning in individuals with memory impairments
 - Individual results vary
- A very functional task for individuals with memory impairments

Face Name Associations

- Some reported errorless advantage for Cued Recall (Kalla, Downes, & van den Broek (2001). The pre-exposure technique: enhancing the effects of errorless learning I the acquisition of face-name associations. *Neuropsychological Rehabilitation*. 11(1), 1-16.; Wilson et al., 1994)
- Some reported errorless advantage for Free Recall (Clare, Wilson, Breen, & Hodges (1999). Errorless learning of face-name associations in early Alzheimer's disease. *Neurocase*. 5, 37-46.)
- Some reported conflicting results—2 cases with errorless advantage and 1 case without errorless advantage (Evans et al. (2000). A comparison of "errorless" and "trial-and-error" learning methods for teaching individuals with acquired memory deficits. *Neuropsychological Rehabilitation*. 10(1), 67-101.)

Face Name Associations

- Possible methods to enhance errorless learning of face name associations:
 - Pre-Exposure technique: intervention in which one factor of a targeted association is presented in advance of the second factor
 - Used in combination with errorless learning strategy

Face Name Associations

Kalla et al. (2001)

Errorless learning of face name associations produced significantly better outcomes than errorful learning

Errorless learning combined with Pre-Exposure techniques produced better significantly outcomes than errorless learning alone

Technological Instruction

- Observed errorless advantage in instruction of technology-based skills to individuals with memory impairments
 - Individual results vary
- Technology-based skills include:
 - Word processing (Hunkin et al., 1998)
 - Programming electronic memory aid (Evans et al., 2000; Wilson et al., 1994)

Technological Instruction

- Hunkin, Squires, Aldrich, & Parkin (1998) taught instructed and alternative word processing skills using errorless strategies (Hunkin, Squires, Aldrich, & Parkin (1998). Errorless learning and the acquisition of word processing skills. *Neuropsychological Rehabilitation*. 8(4), 433-449.)

Technological Instruction

Hunkin, Squires, Aldrich, & Parkin (1998)

Reported improvement in both instructed and alternative word processing skills following errorless type intervention

Novel Information & Associations

Errorless advantage for teaching novel information and associations to individuals with memory impairments

- Errorless Learning was beneficial for learning novel definitions (Hayman, C., MacDonald, C., & Tulving, E. (1993). The role of repetition and associative interference in new semantic learning in amnesia: a case experiment. *Journal of Cognitive Neuroscience*. 5(4), 375-389)
- Errorless Learning was beneficial for learning novel information (Wilson et al., 1994)
- Errorless Learning was beneficial for learning novel word associations (Squires, E.J., Hunkin, N.M., & Parkin, A.J. (1997). Errorless learning of novel associations in amnesia. *Neuropsychologia*. 35(8), 1103-1111.)

Novel Information & Associations

Squires et al. (1997)

Remote word associations: "salad-cold"

Errorless advantage observed for cued recall not free recall

Conflicting evidence regarding delayed recall

Memory Conclusions

- Errorless learning strategies facilitated new learning in individuals with memory impairments
- Errorless strategies were beneficial for:
 - Word list learning
 - Face-name associations
 - Technological instruction
 - Novel information & associations

Memory Conclusions

- Factors that may affect errorless outcomes:
 - Type of recall task: cued vs. free recall
 - Type of instructional task
 - Severity of participant's memory impairments (Evans et al., 2000; Wilson et al., 1994)

Aphasia

- Researchers have begun to examine errorless learning in individuals with aphasia

Aphasia

- Errorless learning strategies have been used to instruct individuals with aphasia in:
 - Word finding treatment (anomia)
 - Word list learning

Word Finding

- Review of existing anomia treatments revealed: (Fillingham, Hodgson, Sage, & Lambon Ralph (2003). The application of errorless learning to aphasic disorders: a review of theory and practice. *Neuropsychological Rehabilitation*. 13(3), 337-363)
 - Most anomia treatments are errorful in nature
 - Some are error reducing in nature
 - Provision of orthographic or phonologic cues (Micelli, Anitirano, Capasso, & Caramazza (1996). The treatment of anomia resulting from output lexical damage: analysis of two cases. *Brain and Language*. 52(1), 150-174.)
 - Semantic Therapy: semantic analysis, not explicit retrieval (Micelli et al., 1996; Nickels & Best (1996). Therapy for naming disorders (Part 1): specifics, surprises and suggestions. *Aphasiology*. 10(2), 155-182.)

Word Finding

- Few anomia treatments are errorless in nature (error eliminating)
 - Picture-word matching (Marshall, Pound, White-Thompson, & Pring (1990). The use of picture/word matching tasks to assist word retrieval in aphasic patients. *Aphasiology*. 4(2), 167-184)
- Errorful and errorless strategies had equal likelihood to produce positive outcomes

Word Finding

- Most reported positive outcome using errorless learning for word finding
 - Frattali & Kang (2004). An errorless learning approach to treating dysnomia. *Brain and Language*. 91, 177-178;
 - McKissock & Ward (2007). Do errors matter? Errorless and errorful learning in anomic picture naming. *Neuropsychological Rehabilitation*. 17(3), 355-373;
 - Fillingham, Sage, Lambon Ralph (2005a-c). The treatment of anomia using errorless learning. *Neuropsychological Rehabilitation*. 16(2), 129-154.

Word Finding

Contrasting errorless and errorful strategies:

- Equivalent treatment gains of treatment effects for errorless and errorful strategies (Fillingham, Sage, Lambon Ralph, 2005a-c; McKissock & Ward, 2007)
- Equivalent maintenance for errorless and errorful strategies (Fillingham, Sage, Lambon Ralph, 2005a-c)

Word Finding

- Influence of feedback:
 - Errorless learning equivalent to errorful learning *with or without* feedback (Fillingham et al., 2005)
 - Errorless learning equivalent to errorful learning *with* feedback (McKissock & Ward, 2007)

Word Finding

- Potential Advantages of errorless learning
 - Some participants preferred errorless learning over errorful (Fillingham, Sage, & Lambon Ralph, 2005a-c)
 - Some errorless methods could be used for home practice (McKissock & Ward, 2007)

Word List Learning

- Reported errorless advantage for spaced retrieval treatment of word list learning in individuals with aphasia (Fridriksson, Holland, Beeson, & Morrow (2005). Spaced retrieval treatment of anomia. *Aphasiology*. 19(2), 99-109)
- Spaced retrieval: error reducing technique
 - Recall of learned information over progressively longer periods of time

Word List Learning

- Spaced retrieval produced better outcomes than traditional cueing hierarchy (Fridriksson et al, 2005)
 - Better recall accuracy across sessions
 - Fewer sessions required to master objectives
 - Pattern of acquisition of information was inconsistent

Treatment of Aphasia and Related Disorders: Subproject 3: Contrasting Treatment for Sentence Production Deficits

- Lynn M. Maher, PI
- Leslie J. Gonzalez Rothi, Co-PI
- NIH: NIDCD P05

Compare errorless learning procedures to errorful learning procedures in treatment of sentence production

- Response to TX
- Differences in learning between the errorless and errorful learning
- Impact of each approach on measures of sentence production

Within Subject Experimental Design

- Each subject serves as own control
- Multiple baselines pre-TX and throughout TX
- Control measure also probed with same frequency as TX probes
- Untreated sentences to measure generalization
- C-statistic to measure change in slope of line over variability of baseline performance
- Group comparisons on treatment response measure
- Group effect sizes

Impact of Error on Treatment of Sentence Production in Non-Fluent aphasia. (Maher et al., in preparation)

- Compared two types of treatment for agrammatism: Mapping TX (Byng, 1988; Schwartz, 1994) to "Traditional" (Shewan and Bandur, 1986) under two delivery methods: Errorless (constant time delay) versus errorful (trial and error with cueing hierarchy) in 2 X 2 crossover design
- 25 participants; all single L CVA with chronic nonfluent aphasia and difficulty with comprehension and production of reversible sentences
- No difference between groups for age, education and MPO
- Crossover design: each subject received two versions of the treatment

Baseline and Probe measures

- 3 sets of 5 pictured reversible verbs: both directions and in both active and passive syntax
 - 1 set TX 1
 - 1set TX 2
 - 1 set untreated
 - Daily probes: total 60 sentences (treatment response measure)
 - Control task (individualized)
- TX:
 - 8 sessions active sentences
 - 8 sessions passive sentences
 - 4 sessions "Mixed"

Impact of Error on Treatment of Sentence Production in Non-Fluent aphasia. (Maher et al., in preparation)

Results:

TX Order	% gain in accuracy
1	33.42
2	20.18

Significant order effect: $p = .03$

Treatment Type	% gain in accuracy	Effect size
Errorless Traditional	40.11	1.42
Errorless Mapping	31.05	1.08
Errorful Traditional	20.07	1.35
Errorful Mapping	20.24	.90

Trend ($p = .09$) for significant difference between groups

Impact of Error on Treatment of Sentence Production in Non-Fluent aphasia. (Maher et al., in preparation)

After controlling for TX order, errorless TXs yielded significantly greater gains ($p = .05$) on sentence production than the errorful TXs.

Type of TX (Traditional or Mapping) was not significant ($p = .26$)

All four TXs yielded large effect sizes (d)

Impact of Error on Treatment of Sentence Production in Non-Fluent aphasia. (Maher et al., in preparation)

In this case, the errorless strategy did seem to have an advantage for generating active and passive reversible sentences, although all groups demonstrated progress

Individual differences: individual preferences

Summary

- Errorless strategies were advantageous for learning across a variety of fields
- Errorless strategies were advantageous for memory rehabilitation
- Benefit of errorless strategies for aphasia rehabilitation is not yet well defined

Summary

- Errorless word finding strategies produced results equivalent to errorful strategies
 - Some pragmatic advantages of errorless strategies
- Error reducing (spaced retrieval) word list learning strategy produced better results than errorful

Summary

- Errorless sentence production strategies produced larger effect sizes than errorful sentence production strategies

Summary

- Further research is needed to clarify the effects of errorless learning in aphasia rehabilitation
- Errorless learning strategies are a viable alternative to more commonly used errorful techniques
- Consider implementing errorless techniques in rehabilitation practice