Critical Review: In Children with Childhood Apraxia of Speech (CAS), does Incorporating the Principles of Motor Learning Provide Therapeutic Benefits?

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Childhood Apraxia of Speech (CAS) is a developmental speech sound disorder that impacts the way speech movements are consistently and precisely executed. The Principles of Motor Learning (PML) have been shown in the literature to have positive effects on movements in limb apraxia and Apraxia of Speech (AOS). This critical review examines the current literature on PML in the therapeutic context of CAS. Four single-subject designs and one mixed design were included in the review. The evidence supports the use of PML in CAS therapy. However, the exact feature of PML that creates these benefits is still unknown. Further investigation is recommended to identify the effective components of the PML approach.

Introduction

Childhood Apraxia of Speech (CAS) is a developmental speech sound disorder in which children have motor programming and planning deficits. These deficits impact the way a child precisely and consistently produces speech (ASHA, 2007; Teverovsky, Ogonowski Bickel, & Feldman, 2009). This disorder occurs in 1 to 2 children per 1000 and accounts for 3.4-4.3% of all children referred with speech sound disorders (ASHA, 2007). Some of the typical speech features of children with CAS include inconsistent speech sound errors on both vowels and consonants, prosodic abnormalities, and coarticulation deficits (Maas, Gildersleeve-Neumann, Jakielski, & Stoeckel, 2014; Shriberg et al. 2003).

Motor learning can be defined as practice or experience that leads to relatively permanent changes of a movement parameter (Maas et al., 2008). These parameters include the movements required for speech production. Maas et al. (2008) explained the impact of PML on motor speech disorders after the nonspeech literature suggested there were improvements in motor learning as a result of these principles. PML can be divided into two categories: practice conditions and feedback conditions. The practice conditions relate to the individual's production of a target, including the amount, variation, distribution, schedule, attention, and target selection of therapeutic practice. The type, frequency, and timing are all considered in relation to feedback conditions, or the response that is provided by the clinician. These principles can be delivered to fit the two phases of learning: acquisition, and retention. The acquisition phase is utilized when the individual is practicing the movement and has not yet mastered it. The retention phase demonstrates completion of practice where the individual has a learned change in their ability to complete that movement. Each principle has two conditions for delivery, for example, high and low, or immediate and delayed. Appendix A provides a description of the principles and their delivery conditions in relation to the two phases of learning. Permanent changes are most notable when the PMLs from the retention phase are implemented after the individual has undergone an appropriate acquisition phase (Maas et al., 2008).

Typical therapy procedures targeting articulation and phonology often show little benefits for children with CAS, and because of the motoric nature of the diagnosis, the PML have been looked at to target the deficits. The principles from Maas et al.'s 2008 paper were researched in the context of AOS and other acquired motor speech disorders, which have different etiologies and trajectories from CAS. Therefore, transferring this knowledge of enhanced motor learning to CAS requires continued research. Multiple PMLs are hypothesized to increase speech production in children similar to the improvements noted in the literature for other motor speech disorders; these principles include practice schedule, practice variability, practice distribution, feedback type, feedback frequency, feedback timing, and attentional focus (Maas et al., 2008; Maas et al. 2014). A limited number of the principles have been individually assessed in the context of CAS, and the empirical knowledge on the effectiveness of grouping principles on therapy outcomes is limited as well. Expanding the understanding of the effectiveness of PMLs can help increase the effectiveness of therapy being administered by clinicians, and improve overall speech production of children with CAS.

Objectives

The primary objective of this paper is to critically appraise the current literature related to the therapeutic benefits of CAS intervention utilizing PML.

Methods

Search Strategy
Online databases including PubMed, Google Scholar, and CINAHL were searched using the following key terms: [(Childhood Apraxia of Speech) OR CAS] AND (Principles of Motor Learning) AND [(Intervention) OR Therapy]. Reference lists of relevant articles were also searched.

Selection Criteria
Search results yielded studies regarding both CAS and AOS or acquired Apraxia. For the purpose of this paper, only studies relating to CAS and published after 2010 were included.

Data Collection
Results of the literature search yielded five articles that met the previously mentioned selection criteria. These articles included four single-subject designs and one mixed design study.

Results

Single-Subject Designs
Single-subject designs allow for systematic manipulation of the variable(s) of interest within a study. The participants also act as their own controls, which is beneficial when studying a disorder with low prevalence rates, but may present challenges when generalizing to the population.

Ballard, Robin, McCabe, and McDonald (2010) conducted a single-subject design with multiple baselines across 3 participants (7-10 years) that examined acquisition and retention of appropriate speech prosody following intervention incorporating 3 PML (knowledge of results, variable stimuli, and random distribution). Participants were siblings with an appropriately confirmed CAS diagnosis, typical language skills, and no prior therapy addressing speech. Standardized language tests were completed at baseline, as were experimental probes of 10 target words spoken in a carrier phrase with knowledge of performance feedback completed prior to, at each intervention session, and 4-weeks post intervention. Intervention involved four 60-minute sessions per week for 3 weeks, and involved giving knowledge of results feedback for 100-120 trials of syllable strings. These syllables were either a weak-strong (WS) or a strong-weak (SW) syllable pattern. Outcome measures included acoustic measures of vowel and syllable duration, as well as perceptual accuracy judgements. Acceptable inter- and intra-rater reliability was reported.

Appropriate statistical analyses revealed a difference in the duration of SW syllables compared to WS syllables post treatment for all children. Treatment effects were noted to generalize to untreated strings of the same level and a less complex level. Generalization to more complex strings was noted, but inconsistent. Retention was calculated after a four-week period, and long-term retention was not analyzed. The two older participants were able to maintain prosodic improvements post treatment, while the youngest participant produced all strings with equal stress.

Overall, this study provides highly suggestive evidence for the effectiveness of implementing the PML in CAS therapy.

Edeal and Gildersleeve-Neumann (2011) used a single-subject design to examine the relevance of production frequency (overall treatment intensity) to intervention in 2 males (6;2 and 3;4 years). Participants were well described, but inclusion and exclusion criteria were limited. An AB treatment design involved moderate (30-40) and high frequency (100-150) production phases. Intervention involved integral stimulation therapy, imitation, and clinician cueing, and was completed in 40 minutes sessions including 5-minute for administering probes to track generalization to untrained words. One child completed 3 sessions per week for 11 weeks and the other, 2 sessions per week for 5 weeks. Appropriate standardized tests and a play-based language sample were completed at baseline, and the probe measure was completed 2 weeks post intervention. Selection of appropriate therapy targets was well-described. The PML of blocked and random practice, distributed practice, variability of practice, feedback, and attention to rate were incorporated into both treatment conditions throughout the study and were not manipulated.

Appropriate statistical analyses revealed higher accuracy in the high frequency compared with moderate frequency treatment for both participants, with one participant showing more variable performance. At post testing, one child showed maintenance of gains for the high but not moderate probes whereas the other child showed the opposite effect.

Overall, this study provides highly suggestive evidence for the use of high intensity therapy for children with CAS.

Maas & Farinella (2012) used an alternating treatment single-subject design to compare the effects of random vs. blocked practice intervention in four monolingual English children with CAS. The participant information, including severity, age, and recruitment method, were clearly noted in this paper. Intervention involved two four-week phases, each with a two-week maintenance period for assessment of retention. Each session targeted both blocked and random practice, in randomized order. Intervention followed a Dynamic Temporal and Tactile Cueing (DTTC) approach. Speech targets were individually selected for each participant based on their error profile and comparable difficulty between the two conditions and their corresponding transfer items. Acceptable inter-rater reliability was reported.

Appropriate statistical analyses revealed inconsistent results with two children showing better improvements with blocked practice both with and without evident transfer effects, one child showing more improvement with random treatment with transfer effects, and the last child showing no treatment or transfer effects at all. Only one child showed consistency from practice schedule effects. Discussion of the relative difficulty of treatment sets was considered as a factor influencing the blocked practice advantage.

Overall, this study provides suggestive evidence that practice schedule does not have a consistent effect on therapy for CAS.

Maas, Butalla, & Farinella (2012) implemented a single-subject design to investigate the role of feedback frequency in the retention and transfer of speech production for four children with CAS. Participant's diagnosis severity, age, and recruitment information was included; it should be noted that three participants were also included in Maas & Farinella's 2012 paper looking at the effects of blocked vs random practice. Intervention involved two four-week phases, each with a two-week maintenance period for assessment of retention following a DTTC approach. High-frequency feedback (HFF) and low-frequency feedback (LFF) were targeted in each session. Targets were individually selected for each participant using appropriate criteria, while personal and functional relevance were not taken into account. Appropriate inter-rater reliability was noted.

The statistical analysis was appropriately conducted and revealed one child showing no improvement, two children favouring the LFF, and the remaining child favouring HFF. Transfer to untreated targets was limited for all participants, likely due to the similarity of treated and untreated targets.

Overall, this study provides suggestive evidence that feedback frequency does not have consistent effects on CAS therapy.

Mixed Design

Mixed design studies allow for comparisons of repeated measures between two or more groups of participants. PML can be tested individually and directly compared between groups with this design. This design provides a lower level of evidence than the single-subject design.

Namasivayam et al. (2015) completed a mixed design study to examine the effects of treatment intensity on articulation, functional communication, and speech intelligibility for 37 children (age 3;8-4;6) with CAS. The authors clearly indicated appropriate recruitment methods from a larger study and specific exclusion criteria. A pre/post treatment design was utilized to test the effects of low and high treatment intensity. Low intensity was noted as 1 session per week, and high intensity was 2 sessions per week. The Motor Speech Treatment Protocol (MSTP) was utilized for intervention following appropriate baseline assessments. Clinician recruitment and training was clearly noted. Inter-rater reliability was noted to be acceptable.

Appropriate statistical analysis indicated that lower intensity treatment did not yield significant changes in any of the three outcomes (articulation, intelligibility, or functional communication). High intensity treatment provided improvements in both articulation and functional communication. Improvements in speech intelligibility were not noted for participants in either treatment intensity group.

Overall, this study provides highly suggestive evidence for implementing higher intensity treatment for children with CAS.

Discussion

The impact of PML on CAS intervention is a valuable clinical question for speech-language pathologists. The most recent evidence is mixed regarding the efficacy of utilizing PML in intervention. The current review described five studies that collectively provide suggestive evidence of the therapeutic benefits associated with PML. Researchers are not unanimous on the most effective delivery model for PML, and there is currently a range of approaches that implement these principles. The condition that had the greatest impact on motor learning was treatment intensity, with more intense treatment favoured.

The small sample sizes result in limited conclusions and generalizations that can be drawn from the research.

One of the key premises of PML is the enhanced motor behaviours over time or retention of the behaviour. This was targeted in brief maintenance periods throughout these studies, and the lasting retention benefits were not studied. All children had confirmed CAS diagnoses, but other participant characteristics, such as age, severity, and comorbid diagnoses were not controlled for in the studies. This variability should lead clinicians to exert caution when generalizing to children outside of the research samples. The papers included in this review had variable outcome measures that they used to evaluate the efficacy of PMLs in intervention. This inconsistency makes it difficult for clinicians to draw overarching conclusions about the improvements on intervention, and easily discern when a specific principle will provide the most significant benefit. PMLs were used concurrently for treatment delivery, and therefore, it is difficult for clinicians to tease apart the benefits from the manipulated principle in comparison with the PMLs serving as the control.

PMLs can also be used to support arguments regarding effective service delivery models. For example, if the literature concludes that high intensity treatment is three sessions per week and this is required for the most significant benefits, then clinicians can advocate to see these clients accordingly. More research characterizing the precise delivery to maximize PML effectiveness will be beneficial for making appropriate amendments to the current service delivery model. This will maximize the efficiency of the system by providing service in a manner that will generate the greatest clinical results.

Future Research

Additional research is suggested to address the studies' limitations and improve evidence in the literature. When doing so, the following recommendations should be considered:

I. Utilize larger sample sizes to enhance validity and generalizability.
II. Evaluate the effectiveness of motor learning with thorough maintenance periods extending past four weeks.
III. Control for CAS severity and other comorbidities to determine the effects on the success of PML intervention.
IV. Create consistent research outcomes with control groups to compare manipulations against when researching the most effective PML delivery combination, and each PML in its own entity.

Clinical Implications

Children with CAS have three distinctive characteristics that differentiate their diagnosis from other speech sound disorders. The studies in this review indicate the increased therapeutic benefit of using PML to target the segmental, prosody, and coarticulation errors. Currently, the principles of high intensity, variable stimuli, random practice, and low frequency feedback have literature support regarding motor learning. Clinicians should also be cautious when only implementing one specific principle, given the current knowledge of interaction effects between the PML. The PML can be used to guide best practices for CAS intervention and modify current service delivery models to align with the most up to date literature.

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Appendix A: Principles of Motor Learning

Conditions	**Acquisition Phase** Support short-term Motor Performance (MP)	**Retention Phase** Support long-term Motor Learning (ML)
Practice Amount: Number of trials or treatment sessions	**Small** Low number of practice trials or sessions	**Large** High number of practice trials or sessions
Practice Distribution: How trials or sessions are practiced over time	**Massed** Practice in a small period of time	**Distributed** Practice over a longer period of time
Practice Variability: Number of targets practiced per session	**Constant** Practice of the same target in the same context	**Variable** Practice of different targets in different contexts
Practice Schedule: How targets are presented within a session	**Blocked** Targets practiced in separate, successive blocks or phases (e.g., AAA CCC)	**Random** Multiple targets practiced together (e.g., BAC CBA)
Target Complexity: Movements required for target production	**Simple** Easy, earlier acquired sounds and sequences (e.g., CV syllables)	**Complex** Difficult, later acquired sounds and sequences (e.g., CCV syllables)
Feedback Type: Response provided after target production	**Knowledge of Performance (KP)** Target specific e.g., how a sound was produced	**Knowledge of Results (KR)** Target accuracy e.g., whether a sound was correct of incorrect
Feedback Frequency: How often responses are provided after target production	**High** Feedback after every production attempt, accuracy not considered	**Low** Feedback after only some attempts, accuracy not considered
Feedback Timing: When feedback is given in relation to target production	**Immediate** Right after production	**Delayed** e.g., 5 seconds after production