

Motor Learning in Pediatric Therapy: Theory, Application and Evidence

A sampling of related articles published in peer-reviewed journals.

Note: This topical listing of the articles is arbitrary. Many articles overlap between these topics.

Topics

- **Specificity**
 - **Salience**
 - **Intensive**
 - **Variability / Difficulty**
 - **Transfer-Appropriate**
 - **Explicit vs. Implicit Learning**
 - **Implicit: Task and Environment – see Transfer-Appropriate**
 - **Explicit: Verbal/Visual instruction and feedback**
 - **External Focus**
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- **Applying Motor Learning Principles in Intervention**

Specificity – see also Intensive – see also Transfer-Appropriate

Moreau NG.; Winter Bodkin A; Bjornson K; Hobbs A; Soileau M; Lahask, K. (2016) Effectiveness of Rehabilitation Interventions to Improve Gait Speed in Children With Cerebral Palsy: Systematic Review and Meta-analysis. *Physical Therapy*, 96(12):1938-1954. Free Full Text <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5131187/>

Salience (activity-focused, goal-directed)

Apache RR. (2005) Activity-based intervention in motor skill development. *Percept Mot Skills*. 100(3 Pt 2):1011-20. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=16158688>

Lowing, K., Bexelius, A., & Brogren Carlberg, E. (2009). Activity focused and goal directed therapy for children with cerebral palsy-do goals make a difference? *Disabil Rehabil*, 31(22), 1808–1816. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=19479520>

McCain K, Shearin S. (2017) A Clinical Framework for Functional Recovery in a Person With Chronic Traumatic Brain Injury: A Case Study. *J Neurol Phys Ther*. 41(3):173-181 Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=28628551>

[Adult Acquired Brain Injury]

Mastos, M., Miller, K., Eliasson, A. C., & Imms, C. (2007). Goal-directed training: linking theories of treatment to clinical practice for improved functional activities in daily life. *Clin Rehabil*, 21(1), 47–55. Abstract <http://journals.sagepub.com/doi/abs/10.1177/0269215506073494>

Valvano, J. (2004). Activity-Focused Motor Interventions for Children with Neurological Conditions. *Phys Occup Ther Pediatr*, 24(1/2), 79–107. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=15268999> (Free Full Text Available to APTA members on PTNow <https://www.ptnow.org/ArticleSearch>)

Valvano J; Rapport MJ. (2006) Activity-focused motor interventions for infants and young children with neurological conditions. *Infants & Young Children: An Interdisciplinary Journal of Early Childhood Intervention*. 19(4): 292-307. Free Full Text https://depts.washington.edu/isei/iyv/valvano_19.4.pdf

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Intensive (Amount/Frequency)

Bleyenheuft, Y., Arnould, C., Brandao, M. B., Bleyenheuft, C., & Gordon, A. M. (2015). Hand and Arm Bimanual Intensive Therapy Including Lower Extremity (HABIT-ILE) in Children With Unilateral Spastic Cerebral Palsy: A Randomized Trial. *Neurorehabil Neural Repair*, 29(7), 645–657. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=25527487>

Bleyenheuft Y, Gordon AM. (2014) Hand-arm bimanual intensive therapy including lower extremities (HABIT-ILE) for children with cerebral palsy. *Phys Occup Ther Pediatr*. 34(4):390-403. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=25271469> (Free Full Text Available to APTA members on PTNow <https://www.ptnow.org/ArticleSearch>)

Brandão MB, Ferre C, Kuo HC, Rameckers EA, Bleyenheuft Y, Hung YC, Friel K, Gordon AM. (2014) Comparison of Structured Skill and Unstructured Practice During Intensive Bimanual Training in Children With Unilateral Spastic Cerebral Palsy. *Neurorehabil Neural Repair*. 28(5):452-61. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=24376067>

Dong VA, Fong KN, Chen YF, Tseng SS, Wong LM. (2017) 'Remind-to-move' treatment versus constraint-induced movement therapy for children with hemiplegic cerebral palsy: a randomized controlled trial. *Dev Med Child Neurol*. 59(2):160-167 Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=27503605>

Dumas HM, Fragala-Pinkham MA, Rosen EL, Folmar E. (2017) Physical Therapy Dosing: Frequency and Type of Intervention in Pediatric Postacute Hospital Care. *Pediatr Phys Ther*. 29(1):47-53. Free Full Text https://journals.lww.com/pedpt/fulltext/2017/01000/Physical_Therapy_Dosing_Frequency_and_Type_of.14.aspx

Gordon AM (2011) To constrain or not to constrain, and other stories of intensive upper extremity training for children with unilateral cerebral palsy. *Dev Med Child Neurol*. Sep;53 Suppl 4:56-61. Free Full Text <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1469-8749.2011.04066.x>

Heathcock JC, Baranet K, Ferrante R, Hendershot S. (2015) Daily Intervention for Young Children With Cerebral Palsy in GMFCS Level V: A Case Series. *Pediatr Phys Ther*. 27(3):285-92. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/25974119>

Hoare, B. J., & Greaves, S. (2017). Unimanual versus bimanual therapy in children with unilateral cerebral palsy: Same, same, but different. *Journal of Pediatric Rehabilitation Medicine*. 10(1),47–59. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/28339410>

Palisano RJ, Murr S. (2009) *Phys Occup Ther Pediatr*. Intensity of therapy services: what are the considerations? 29(2):107-12. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/19401925> (Free Full Text Available to APTA members on PTNow <https://www.ptnow.org/ArticleSearch>)

Palisano RJ, Begnoche DM, Chiarello LA, Bartlett DJ, McCoy SW, Chang HJ. (2012) Amount and focus of physical therapy and occupational therapy for young children with cerebral palsy. *Phys Occup Ther Pediatr*. 32(4):368-82. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=22954372> (Free Full Text Available to APTA members on PTNow <https://www.ptnow.org/ArticleSearch>)

Variability (Contextual interference)

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Difficulty

Kantak SS, Zahedi N, McGrath R. (2017) Complex Skill Training Transfers to Improved Performance and Control of Simpler Tasks After Stroke. *Phys Ther.* 97(7):718-728. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/28444320>

Prado MT, Fernani DC, da Silva TD, Smorenburg AR, de Abreu LC, and de Mello Monteiro CB. (2017). Motor learning paradigm and contextual interference in manual computer tasks in individuals with cerebral palsy. *Research in Developmental Disabilities.* 64:56-63. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=28351764>

Transfer-Appropriate and Implicit Learning: Task and Environment (context-based, task-oriented)

Ahl LE, Johansson E, Granat T, Carlberg EB. (2005) Functional therapy for children with cerebral palsy: an ecological approach. *Dev Med Child Neurol.* 47(9):613-9. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/16138669>

Darrah J, Law MC, Pollock N, Wilson B, Russell DJ, Walter SD, Rosenbaum P, Galuppi B. (2011) Context therapy: a new intervention approach for children with cerebral palsy. *Dev Med Child Neurol.* 53(7):615-20. Free Full Text <http://onlinelibrary.wiley.com/doi/10.1111/j.1469-8749.2011.03959.x/full>

Hubbard IJ, Parsons MW, Neilson C, Carey LM. (2009) Task-specific training: evidence for and translation to clinical practice. *Occup. Ther. Int.* 16(3-4):175-189

Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=19504501>

Seek Freaks <https://www.seekfreaks.com/index.php/2016/06/16/article-review-child-focused-vs-context-focused-intervention/>

Ketelaar, M., Vermeer, A., Hart, H., van Petegem-van Beek, E., & Helders, P. J. (2001). Effects of a functional therapy program on motor abilities of children with cerebral palsy. *Phys Ther,* 81(9):1534-1545. Free Full Text <https://academic.oup.com/ptj/article/81/9/1534/2857660>

Kruijssen-Terpstra AJ, Ketelaar, Verschuren O, Gorter JW, Vos RC, Verheijden J, et al. (2016) Efficacy of three therapy approaches in preschool children with cerebral palsy: a randomized controlled trial. *Dev Med Child Neurol.* 58(7): 758-766. Free Full Text <https://onlinelibrary.wiley.com/doi/full/10.1111/dmcn.12966>

Law M, Darrah J, Pollock N, Wilson B, Russell, DJ, Walter SD, Rosenbaum P, Galuppi B. (2011) Focus on function: a cluster, randomized controlled trial comparing child- versus context-focused intervention for young children with cerebral palsy. *Developmental Medicine & Child Neurology.* 53(7):621-629

Free Full Text <http://onlinelibrary.wiley.com/doi/10.1111/j.1469-8749.2011.03962.x/full>

Miyahara M, Hillier SL, Pridham L, Nakagawa S. (2017) Task-oriented interventions for children with developmental co-ordination disorder. *Cochrane Database Syst Rev.* Jul 31;7:CD010914. Abstract

<https://www.ncbi.nlm.nih.gov/pubmed/28758189>

Polatajko HJ, & Cantin N. (2005). Developmental coordination disorder (dyspraxia): An overview of the state of the art. *Seminars in Pediatric Neurology,* 12, 250-258. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/16780296>

Polatajko HJ, Mandich AD, Miller LT, & Macnab JJ. (2001). Cognitive Orientation to Daily Occupational Performance (CO-OP): part II -- the evidence. *Physical & Occupational Therapy in Pediatrics,* 20(2/3), 83-106. Abstract

<https://www.ncbi.nlm.nih.gov/pubmed/11345514>

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Toovey, R., Bernie, C., Harvey, A. R., McGinley, J. L., & Spittle, A. J. (2017). Task-specific gross motor skills training for ambulant children with cerebral palsy: a systematic review. *BMJ Paediatrics Open*, Vol 1(Issue 1). Free Full Text <http://bmjpaedsopen.bmj.com/content/1/1/e000078>

Van der Putten A. (2005) Children with profound intellectual and multiple disabilities: the effects of functional movement activities. *Clin Rehabil* 19(6):613-620. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=16180596>

Implicit versus Explicit Learning

Gentile, A. M. (1998) Movement Science: Implicit and Explicit Processes during Acquisition of Functional Skills. *Scandinavian Journal of Occupational Therapy*. 5(1):7-16. Abstract <https://www.tandfonline.com/doi/abs/10.3109/11038129809035723?journalCode=iocc20>

Kleynen M, Braun SM, Rasquin SMC, Bleijlevens MHC, Lexis MAS, Halfens J, Beurskens A. J. (2015). Multidisciplinary views on applying explicit and implicit motor learning in practice: An international survey. *PLoS ONE*, 10(8), 1–15. Free Full Text <https://doi.org/10.1371/journal.pone.0135522>

Steenbergen, B., van der Kamp, J., Verneau, M., Jongbloed-Pereboom, M., & Masters, R. S. (2010). Implicit and explicit learning: applications from basic research to sports for individuals with impaired movement dynamics. *Disabil Rehabil*. 32(18):1509–1516. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=20575752>

van der Kamp, J., Steenbergen, B., & Masters, R. S. W. (2017). Explicit and implicit motor learning in children with unilateral cerebral palsy. *Disability and Rehabilitation*.0(0):1–8. Published online: 30 Jul 2017. Free Full Text <https://www.tandfonline.com/doi/full/10.1080/09638288.2017.1360403>

Implicit: Task and Environment (context-based) – see Transfer-Appropriate

Explicit: Verbal/visual instruction and feedback, motor imagery

Bishop JC, Kelly LE, Hull M. (2018) Knowledge of performance feedback among boys with ADHD. *Res Dev Disabil*. Mar;74:31-40. doi: 10.1016/j.ridd.2017.12.003.Epub 2018 Jan 19. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=29360046>

Burtner PA, Leinwand R, Sullivan KJ, Goh HT, Kantak SS. (2014) Motor learning in children with hemiplegic cerebral palsy: feedback effects on skill acquisition. *Dev Med Child Neurol*. 56(3):259-66. Free Full Text <https://onlinelibrary.wiley.com/doi/full/10.1111/dmcn.12364>

Hemayattalab R, Rostami LR.(2010) Effects of frequency of feedback on the learning of motor skill in individuals with cerebral palsy. *Res Dev Disabil*. 31(1):212-7 Abstract <https://www.ncbi.nlm.nih.gov/pubmed/19864110>

Thorpe, D, E., & Valvano, J, (2002), The effects of knowledge of performance and cognitive strategies on motor skill learning in children with cerebral palsy. *Pédiatrie Physical Therapy*. 14(1)2-15. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=17053676>

Sharif MR, Hemayattalab R, Sayyah M, Hemayattalab A, Bazazan S. (2015) Effects of physical and mental practice on motor learning in individuals with cerebral palsy. *Journal of Developmental and Physical Disabilities*, 27(4):479-487. Free Full Text

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https://www.researchgate.net/publication/276178037_Effects_of_Physical_and_Mental_Practice_on_Motor_Learning_in_Individuals_with_Cerebral_Palsy

External Focus

Chiviawsky S, Wulf G, Ávila LT. (2013) An external focus of attention enhances motor learning in children with intellectual disabilities. *Journal of Intellectual Disability Research*. 57(7):627-634. Free Full Text
https://faculty.unlv.edu/wpmu/gwulf/files/2014/05/Chiviawsky_Wulf_%C3%81vila_AF_intellectual_disabilities_JIDR_2013.pdf

Applying Motor Learning Principles in Intervention – General/Other

Bar-Haim S, Harries N, Nammourah I, Oraibi S, Malhees W, Loepky J, et al. (2010). Effectiveness of motor learning coaching in children with cerebral palsy: a randomized controlled trial. *Clin Rehabil*, 24(11), 1009–1020. Abstract
<https://www.ncbi.nlm.nih.gov/pubmed/20576667>

Goodgold-Edwards, S. A. (1984). Motor learning as it relates to development of skilled motor behavior: A review of the literature. *Physical and Occupational Therapy in Pediatrics*, 4(4), 5-18. Abstract
https://www.tandfonline.com/doi/abs/10.1080/J006v04n04_02

Goodgold-Edwards SA, Cermak SA. (1990) Integrating motor control and motor learning concepts with neuropsychological perspectives on apraxia and developmental dyspraxia. *Am J Occup Ther*. 44(5):431-9. Abstract
<https://www.ncbi.nlm.nih.gov/pubmed/?term=1693811> (Full Text Available to APTA members on PTNow
<https://www.ptnow.org/ArticleSearch>)

Jarus, T. (1994). Motor learning and occupational therapy: The organization of practice. *American Journal of Occupational Therapy* 48, 810-816. Free Full Text
<https://pdfs.semanticscholar.org/7091/0902a7ee4e7c6b51c0544e9f219678f2affd.pdf>

Kamath T, Pfeifer M, Banerjee-Guenette P, Hunter T, Ito J, Salbach NM, Wright V, Levac D. (2012) Reliability of the motor learning strategy rating instrument for children and youth with acquired brain injury. *Phys Occup Ther Pediatr*. 32(3):288-305. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/22574628> Obtain Full Text
<https://www.tandfonline.com/doi/full/10.3109/01942638.2012.672551>

Lesensky S, & Kaplan LR. (2000) Occupational therapy and motor learning: Putting theory into practice. *OT Practice*. 5(September):13-16. [Full Text Available to AOTA members: <https://www.aota.org/Publications-News/otp/Annual-Indexes.aspx>]

Levac D, DeMatteo C. (2009) Bridging the gap between theory and practice: dynamic systems theory as a framework for understanding and promoting recovery of function in children and youth with acquired brain injuries. *Physiother Theory Pract*. 25(8):544-54. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/19925262> (Full Text Available to APTA members on PTNow <https://www.ptnow.org/ArticleSearch>)

Levac D, Missiuna C, Wishart L, Dematteo C, & Wright V. (2011). Documenting the Content of Physical Therapy for Children With Acquired Brain Injury: Development and validation of the motor learning strategy instrument. *Phys Ther*. 91(5):689–699. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=21415229> Free Full Text:
<https://academic.oup.com/ptj/article/91/5/689/2735738>

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Levac D, Missiuna C, Wishart L, DeMatteo C, Wright V. (2013) The motor learning strategy instrument: interrater reliability within usual and virtual reality physical therapy interventions. *Pediatr Phys Ther.* 25(1):53-60. Free Full Text https://journals.lww.com/pedpt/fulltext/2013/25010/The_Motor_Learning_Strategy_Instrument_.15.aspx

Levac D, Wishart L, Missiuna C, Wright V. (2009) The application of motor learning strategies within functionally based interventions for children with neuromotor conditions. *Pediatric Physical Therapy* 21(4):345-355. Free Full Text https://journals.lww.com/pedpt/fulltext/2009/02140/The_Application_of_Motor_Learning_Strategies.8.aspx

Muratori LM, Lamberg EM, Quinn L, & Duff SV. (2013) Applying principles of motor learning and control to upper extremity rehabilitation. *Journal of Hand Therapy.* 26(2), 94–103. Free Full Text <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3773509/>

Niemeijer AS, Smits-Engelsman BC, & Schoemaker MM. (2007) Neuromotor task training for children with developmental coordination disorder: a controlled trial. *Dev Med Child Neurol,* 49(6), 406–411. Free Full Text <https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1469-8749.2007.00406.x>

Shishov N, Melzer I, & Bar-Haim S. (2017). Parameters and Measures in Assessment of Motor Learning in Neurorehabilitation; A Systematic Review of the Literature. *Frontiers in Human Neuroscience,* 11(82). Free Full Text <https://www.frontiersin.org/articles/10.3389/fnhum.2017.00082/full>

Zwicker JG, Harris SR. (2009) A reflection on motor learning theory in pediatric occupational therapy practice. 76(1) 29-37. Abstract <https://www.ncbi.nlm.nih.gov/pubmed/?term=19341020> (Full Text Available to APTA members on PTNow <https://www.ptnow.org/ArticleSearch>)