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Therapists' use of motor learning strategies in children with and without Developmental Coordination Disorder
A qualitative approach to advance the understanding of teaching motor tasks

Ingrid van der Veer

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2023 | Faculty of Rehabilitation Sciences

Doctoral dissertation submitted to obtain the degree of
Doctor of Rehabilitation Sciences and Physiotherapy, to be defended by

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List of abbreviations

ABI	acquired brain injury
ADHD	attention deficits hyperactivity disorder
ASD	autism spectrum disorder
CO-OP	cognitive orientation to daily occupational performance
CP	cerebral palsy
DCD	developmental coordination disorder
EF	external focus of attention
IF	internal focus of attention
ITT	intention-to-treat
KP	knowledge of performance
KR	knowledge of results
MCL-model	motor learning component model
MLS	motor learning strategy
NTT	neuromotor task training
OCP	optimal challenge point
OT	occupational therapist
OPTIMAL-theory	optimizing performance through intrinsic motivation and attention for learning theory
PE	physical education
PPT	paediatric physical therapist
PT	physical therapist
RCT	randomized controlled trial
RoB	risk of bias
SLI	specific language impairments
TDC	typically developing children

Glossary for motor learning terminology

Analogy learning	Providing the learner with an analogy (metaphor) that integrates the complex structure of the to-be-learned task[1].
Blocked practice	Practicing the same motor tasks in a blocked order, without alternation with other motor tasks[2].
Constant practice	Practicing a motor task repetitively without variation during practice[3].
Dual-tasking	Using a secondary (mostly cognitive) task to draw the attention of the learner to, whereby short-memory capacity is likely not to be used for explicit knowledge of the primary task to-be-learned[4].
Errorless learning	Arranging the practice situation in such way that the learner makes no or few outcome errors[5].
Explicit motor learning	Learning which generates verbal knowledge of movement performance (e.g. facts and rules), involves cognitive stages within the learning process and is dependent on the working memory[6].
External focus of attention	An external focus of attention directs the learner's attention to the impact of the movement on the environment[7].
Guided discovery	Guiding the learner to the correct movement response with a sequence of questions[8].
Implicit motor learning	Learning which progresses with no or minimal increase in verbal knowledge of movement performance (e.g. facts and rules) and without

	awareness. Implicitly learned skills are (unconsciously) retrieved from implicit memory[6].
Information content	The amount of (detailed) information given in one instructions or feedback.
Internal focus of attention	An internal focus of attention directs the attention to the learner's body movements[7].
Knowledge of performance	Feedback providing the learner with information about its own body movements[9].
Knowledge of results	Feedback after the performance providing the learner with information about its success in meeting the environmental goal[9].
Motor imagery	Asking the learner to mentally execute the motor task without actually doing it[10].
Motor learning	A set of processes associated with practice or experience leading to relative permanent changes in motor behavior[11].
Observational learning	Watching another person performing a motor task, which provides the learner with a cognitive model of the movement performance[12].
Part practice	Practicing units of motor tasks, after breaking down a motor task into smaller units[13].
Random practice	Practicing various motor tasks in a random order[2].
Trial-and-error learning	The learner performs the task repeatedly and optimizes its performance with intrinsic and extrinsic feedback on its errors[14].
Variable practice	Practicing a motor task with increased variation during practice[3].
Whole practice	Practicing a motor task in its entirety[13].

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Chapter 1

General introduction

During an average day, children perform many motor tasks: at home (e.g. when getting dressed, or using cutlery when eating); at school (e.g. when writing, or during physical education classes); during organized sports; and during recreational activities (e.g. when playing with friends, or doing craft)[1,2]. Most children learn these motor tasks almost without much effort; however, children with an atypical development experience problems in learning such motor tasks[3–6]. But what is meant by motor learning? Motor learning can be described as a set of processes associated with practice or experience leading to relative permanent changes in motor behavior[7]. Having problems with learning motor tasks results in lower motor abilities, which has impact on a child's level of physical activity, their participation in daily-life, and their psychosocial development (e.g. perceived competence, and self-efficacy)[2,8–11]. This in turn impacts a child's development across the lifespan with consequences on physical health (e.g. cardiovascular diseases), mental health (e.g. depression), and social health (e.g. social exclusion)[2,8].

A specific population with mild-to-severe problems in motor learning are children with developmental coordination disorder (DCD)[3]. These children have difficulties automatizing motor tasks, and transferring learned motor tasks (i.e. performing the same motor tasks in other contexts), which impacts their participation in daily-life activities[3]. Frequently, these children are trained by physical and/or occupational therapists to improve their motor skill performances[12]. *International clinical practice recommendations on definition, diagnosis, assessment, intervention, and psychosocial aspects of DCD* (furtherly described as international DCD recommendations) advise therapists to use evidence-based activity- and participation-oriented interventions[12]. These interventions are based on theories of motor learning and motor control. The therapists use motor learning strategies (MLSs) derived from motor learning research to teach these children various motor tasks[13,14]. MLSs can be described as observable actions of a therapist that are adapted to child and task to enhance motor learning. These MLSs should be the result of clinical decision-making processes[15]. However, little is known about the use of MLSs in children with DCD. Furthermore, Zwicker and Harris[16] reflected on motor learning theories and strategies that could be used in paediatric clinical care, and concluded that they lack clarity, simplicity and generalizability, which challenges therapists to use them. A recent scoping review, that identified and described conceptual frameworks used to translate theoretical concepts of motor learning into clinical practice, supported this conclusion by showing that: (1) frameworks used different perspectives to frame the knowledge; (2) frameworks included different elements enhancing motor learning; and (3) terminology was used inconsistently[17]. So, there is a need for more clarity about how to teach motor tasks in clinical practice.

As such, the main focus of this doctoral thesis is to contribute to a better understanding of how therapists can use MLSs to teach children motor tasks, and children with DCD specifically. The first part of this introduction gives insight into relevant **components of motor learning**. Furthermore, it describes what is known in the existing literature about: how to promote implicit and explicit motor learning, and effectiveness of MLSs used in children. The second part focuses on what is known about **therapists' current use of MLSs** in paediatric clinical care. The third part elaborates on **children with DCD**: their motor learning difficulties, and associated problems. Furthermore, commonly used activity-oriented interventions, and effectiveness of MLSs used in children with DCD will be described. The introduction will end with the **aims and outline** of this thesis.

1.1 Motor learning component model

Motor learning literature includes many different aspects and inconsistent terminologies[16,17]. At the start of this PhD trajectory, we developed a so-called *motor learning component model* (MCL-model) to frame relevant components in motor learning from our perspectives. This model is based on the status quo of the literature and our clinical experiences as paediatric physical therapists, see Figure 1.1. The left side of the model represents the unique combination of characteristics of a child, task and environment, so-called **factors** (Component 1), that should guide therapists' choice for: promoting specific **types of motor learning processes** (Component 2), their use of **elements of MLSs** (Component 3), and/or **specific MLSs** (Component 4) (the right side of the model). The next paragraphs will elaborate on each of these components of the MCL-model.

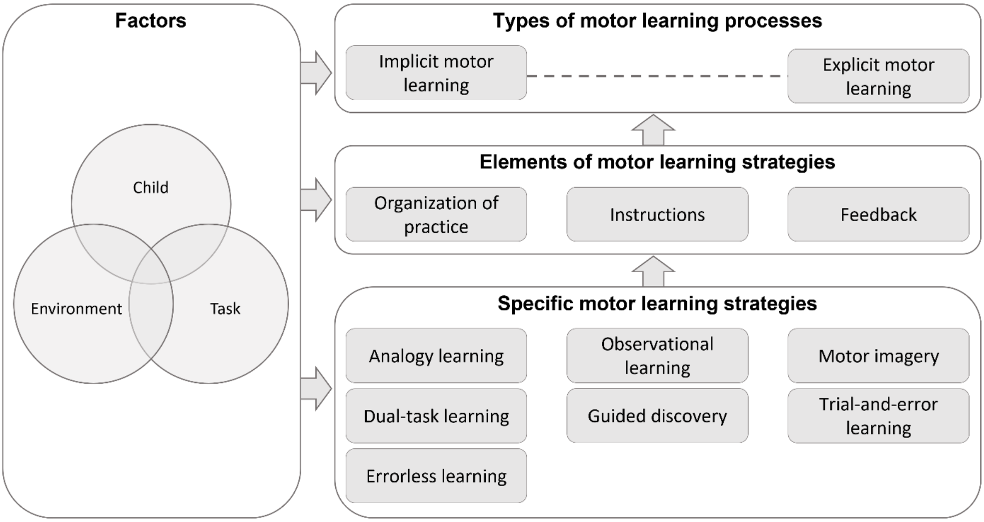

Figure 1.1. *The Motor Learning Component model (4 components)*

1.1.1 Child, task and environmental factors

According to the *Dynamic systems theory*, movement behaviour emerges from self-organization of characteristics (also known as constraints) of an individual, task, and environment, with no characteristic having logical priority[18–20]. Each individual has its own unique characteristics such as age, weight, cognitive abilities, and motivation[18,19,21]. Tasks are characterized by constraints like spatial and temporal demands, number and sequence of steps within a task, and number of body parts involved[18,19,22]. Environmental characteristics concern everything outside an individual; these characteristics can be physical (e.g. the surface, the type of ball used for practice, and weather conditions) or social (e.g. characteristics of parents, teachers, and friends). Physical environmental characteristics can function as affordances. An affordance creates a meaningful opportunity for action which is specific for an individual, for example, a chair affords sitting in older children but climbing in infants[1,18,19].

Development of movement patterns is considered to be nonlinear, meaning that, depending the conditions, small differences can generate large changes in motor behaviour. For instance, when increasing speed gradually while walking, a person can keep on walking for a period of time, however, at a certain point, a small increase in speed will change walking into running. Such parameters that change motor behaviour are called control parameters[18,19].

Within interventions, therapists can choose to promote specific types of motor learning processes based on the presence of certain characteristics within a child, task, and environment. To enhance these motor learning processes, therapists manipulate the interaction of characteristics of child, task, and environment by using various MLSs influencing control parameters or creating affordances[1,18,19].

1.1.2 Types of motor learning processes

Motor learning processes within individuals can occur implicitly or explicitly. From a clinical perspective, implicit motor learning is defined as: *learning which progresses with no or minimal increase in verbal knowledge of movement performance (e.g. facts and rules) and without awareness. Implicitly learned skills are (unconsciously) retrieved from implicit memory*[23]. Explicit motor learning is defined as: *learning which generates verbal knowledge of movement performance (e.g. facts and rules), involves cognitive stages within the learning process and is dependent on the working memory*[23]*.* Although, a theoretical distinction is made between both types of learning processes, they are considered both upper ends of a continuum (Figure 1.1). It is known that children's motor learning processes occur through multiple mechanisms, with each mechanism having different primary neural substrates and different levels of cognitive involvement resulting in either (more) implicit or (more) explicit motor learning on the continuum[24,25]. Therapists can manipulate elements of instructions, feedback and organization of practice, and/or use specific MLSs with the intention to activate one or more mechanisms to promote either (more) implicit or (more) explicit motor learning in children[24,25].

1.1.3 Elements of motor learning strategies

The MCL-model distinguishes three categories of elements of MLSs: (1) instructions; (2) feedback; and (3) organization of practice (Figure 1.1). **Instructions and feedback** are used to motivate a child or to provide a child with specific information about the task being practiced[26,27]. They are modelled in various ways, for instance, by its focus of attention, modality, frequency and timing[15,17,27,28]. The **focus of attention** can be externally or internally. An external focus of attention (EF) directs a child's attention to the impact of the movement on the environment (e.g. the therapist instructs to aim at the *basket* when throwing), while an internal focus of attention (IF) directs a child's attention to its body movements (e.g. the therapist instructs to extend the *elbow* while throwing)[29]. We consider knowledge of results (KR), feedback that informs a child about its success in meeting the environmental goal (e.g. the therapist tells *how many tennis balls were thrown into the basket*), and knowledge of performance (KP), feedback that informs a child about its own movements (e.g. the therapist gives feedback on the *arm movement*)[30], as subtypes of EF and IF, respectively, because both serve as a basis for error corrections in the next trial[29,30]. According to the constrained action hypothesis, it is suggested that an EF and IF each promote different types of motor learning processes[31]. Based on behavioural outcomes, an IF is expected to promote explicit motor learning, because a child's attention for its body movements is likely to interfere with the normal automatic control processes. Furthermore, it is assumed that it requires larger involvement of cognitive processes due to a greater reliance on conscious control processes[29,31]. An EF is expected to promote implicit motor learning, because a child's attention is directed to the impact of the movement on the environment, which is assumed not to interfere with the normal automatic control processes[29,31].

Modalities of instructions and feedback can be verbally, visually, tactilely, or auditory[32,33]. Most instructions and feedback are given verbally. Real-life or video demonstrations by therapists, experts or peers are examples of visual modalities. A tactile modality is used when therapists provide children manual guidance when performing motor tasks, for instance, when practicing forward rolls. Lastly, an example of auditory modality is when the therapist claps the hands to provide rhythm during the execution of the motor task (e.g. when hopping on a single leg). **Frequencies** of instructions and feedback can be reduced, faded, or continuously: reduced frequencies are used when instructions and feedback are given ones in every few practice trials; the frequency is fading when the number of instructions and feedback decreases when practice progresses; and continuous frequency is used when instructions and feedback are provided after every practice trial[30,32,34]. For **timing**, instructions and feedback can be initiated by a child, so-called self-controlled, or by a therapist[27].

The **organization of practice** comprises amongst others how exercises and materials are arranged during a practice situation[35]. Therapists can **manipulate task and context** to enhance motor learning, for instance, by changing materials to stimulate other movement patterns (e.g. changing the size of a ball to stimulate one-hand throwing instead of two-hands throwing)[1,36]. But therapists can also use MLSs to structure the organization of practice: **random or blocked practice**, **variable or constant practice**, and **part or whole practice** are known elements of MLSs[17,28]. Therapists use random practice schedules, when they practice various motor tasks in a random order. However, if they choose to practice the same motor task repeatedly without alternating it with other motor tasks, they use blocked practice schedules[37,38]. Variable practice is used when therapists increase variability during practice, for instance, when using multiple balls of different sizes, weights, and shapes while throwing and catching. In constant practice this variability is reduced, for instance, when therapists practice throwing and catching with the same ball over and over again[39]. Therapists use part practice when they break the motor task into smaller units, and practice these units separately. They use whole practice when they practice the motor task in its entirety[40].

For EF and IF it seems likely which types of motor learning processes they intent to promote. However, for the remaining elements of MLSs this remains unclear. Kleynen et al.[35] conducted a survey study with international experts to gain more insight into how MLSs could be used to promote implicit and explicit motor learning processes in adults in neurorehabilitation, however, no consensus was reached. So far, little is known about how the various elements of MLSs can be used to promote implicit and explicit motor learning processes in children.

1.1.4 Specific motor learning strategies

Literature recognizes specific motor learning strategies that could be used to teach motor tasks (Figure 1.1). These motor learning strategies prescribe how the elements of instructions, feedback and/or organization of practice should be modelled.

The strategies analogy learning, errorless learning and dual-task learning are expected to promote implicit motor learning. With **analogy learning**, a therapist uses a metaphor (e.g. jump like a frog) as instruction or feedback that integrates the complex structure of the to-be-learned task[41]. It is suggested that a metaphor relies very little on the manipulation of explicit information, reducing the involvement of cognitive processes and the working memory[41]. With **errorless learning**, a therapist arranges the practice situation in such way that outcome errors are limited[42]. This reduction of errors is assumed to diminish the need to consciously correct movements, which lowers the involvement of cognitive processes[42]. In **dual-task learning**, it is expected that the attention of the learner is drawn to a secondary (mostly cognitive) task whereby short-memory capacity cannot be used for explicit knowledge of the primary task to-be-learned, for example, a therapist lets the child count backwards from 100 to 0 while throwing beanbags at a target[43]. In a Delphi study, in which researchers sought consensus about the classification of seven well-known specific MLSs as promoting either (more) implicit or (more) explicit motor learning, international experts (with backgrounds in clinical care, education and research in predominantly adult motor learning) consented that these three strategies indeed intent to promote more implicit motor learning[23].

For the following four strategies mentioned in the MCL-model, it remains unclear which types of motor learning processes they promote[23]. With **observational learning**, the learner watches another person performing a motor task, which should provide the learner with a cognitive model of the movement performance. In case of learning complex motor tasks, it is needed to accompany the observation with verbal information to activate cognitive processes to build the internal model[44]. The observed person can be an expert or a peer. With **guided discovery**, a therapist guides the learner to the correct movement response with a sequence of questions like "what went wrong?", "what can you do differently?", and "why would you think that would help?"[45]. With **motor**

imagery, the learner is asked to mentally execute the motor task without actually doing it. It is demonstrated that this mental rehearsal also activates brain structures related to motor performance which facilitates the actual performance[46]. Finally, with **trial-and-error learning**, the learner performs the task repeatedly and optimizes its performance with intrinsic and extrinsic feedback on its errors[47].

1.1.5 Effectiveness of motor learning strategies used in children

In this section, a brief summary is given about the existing evidence regarding effectiveness of various MLSs in children. The systematic review of Van Abswoude et al.[48] investigated effectiveness of four **strategies that intent to promote implicit motor learning** (external focus learning, analogy learning, errorless learning, and dual-task learning), to teach functional motor tasks to typically and atypically developing primary school children. These strategies were compared to the explicit strategies internal focus learning or error-strewn learning. The methodological quality of the majority of the included studies was low, with fair internal validity (instead of high) and limited generalizability of the results. Most studies provided limited detailed descriptions of: the experimental and control conditions; the psychometric properties of the outcome measurements; sample size calculations; and the statistical evaluation. Furthermore, studies were difficult to compare due to heterogeneity in study characteristics like designs, populations, tasks, experimental and control interventions, outcome measures, and the timing of measurements. The effectiveness of dual-task learning appeared not to be investigated in children. The authors cautiously concluded, after performing a narrative synthesis, that implicit strategies are just as effective, or in some cases even more effective, compared to explicit strategies[48]. However, many studies found no differences between groups.

Simpson et al.[27] investigated effectiveness of **external focus learning and MLSs that enhance a child's motivation**, to teach functional motor tasks to typically and atypically developing children. In their systematic review, they included MLSs that fitted the *optimizing performance through intrinsic motivation and attention for learning (OPTIMAL) theory*[27]*.* The OPTIMAL theory conceptualizes how a learner's motivation and attention for a to-be-learned task influence motor learning[26]. The theory advocates to use an EF, and argues that motivation will be improved by giving a learner autonomy and enhancing his or her expectancies for success[26]. Examples of included MLSs that support a child's autonomy are: letting a child decide when and/or in which modality to receive feedback, and giving a child opportunity for choice (e.g. in which ball to use). Examples of included MLSs that enhance a child's expectancies are: positive feedback, or feedback on good instead of poor trials[27]. The study showed conflicting results for external focus learning. However, most studies reported beneficial effects for MLSs that enhanced expectancies and supported autonomy[27]. The authors did not assess methodological quality of the studies. Nonetheless, they stressed that most studies: did not include experimental and control conditions that reflected real-world settings; and provided no conceptual and methodological justification for included population(s).

Two systematic reviews investigated effectiveness of **frequencies of feedback** in typically developing children (TDC) and children with cerebral palsy (CP); reduced, faded, and continuous frequencies were used[32,49]. In the review of Schoenmaker et al.[32] 11 of 12 included studies had low(er) methodological quality, most concerns were raised about selection bias, attrition bias, and reporting bias. Furthermore, studies were difficult to compare because studies varied in: design, characteristics of the CP population, the practiced tasks, characteristics of provided feedback, and measured outcomes. For children with CP, both reviews found limited or contradicting evidence[32,49]. For TDC, it was concluded, based on a qualitative synthesis, that a reduced frequency might be more effective[32]. However, not all studies included a control group with a continuous frequency, and the study that compared a continuous with a faded frequency found no differences between groups. Therefore, this conclusion should be interpreted with caution.

Graser et al.[37] investigated effectiveness of **random practice compared to blocked practice** in TDC and children with acquired brain injury (ABI) in a systematic review. The methodological quality of the included studies was predominantly low, with all studies being at risk for selection and performance bias. Furthermore, all studies missed descriptions of the appropriate statistics, including how they controlled for confounding variables. The included studies were difficult to compare, mostly because of heterogeneity in designs, populations, and types of task. No studies investigated effectiveness of random or blocked practice in children with ABI. For TDC, the best evidence synthesis showed no or conflicting evidence[37].

In a final systematic review, Buszard et al.[36] investigated the influence of **scaling the equipment and play area** (e.g. field size) in children. The included studies were difficult to compare, because the authors included various outcome measures: psychological factors (e.g. engagement, and self-efficacy); biomechanical factors (e.g. quality of movement, and risk of injury); and performance (e.g. accuracy, and frequencies of match-playing skills like ball passing). The narrative syntheses indicated that children performed motor tasks better, and with more enjoyment, when equipment and play area were scaled[36]. However, only four studies actually measured the impact of scaling the equipment on learning, which resulted in conflicting evidence. The authors stressed that future research should include research contexts that match real-world settings more[36].

In summary, most systematic reviews found no or conflicting evidence. None of the reviews performed a meta-analysis, because the methodological quality of the studies was predominantly low and the included studies were too heterogenous to compare[27,32,36,37,48,49]. When comparing the quality assessments across the various systematic reviews, risk of bias was moderate to high for almost all sub domains: selection, performance, detection, and attrition bias. Furthermore, authors mentioned design, population, task, interventions (experimental and control), and outcome measure(s) as sources for heterogeneity in study characteristics. Almost all reviews discussed that child and task characteristics might moderate effectiveness of the MLSs, but that more research is necessary to gain insights into their modifying role. Some suggested characteristics were: task complexity, cognitive skills (e.g. information processing abilities), working memory capacity, trait anxiety, and age[27,32,37,48,49]. Furthermore, several authors stressed that the included experimental and control conditions in the studies did not match real-world settings, which hinders generalizability of the results[27,36,48]. Thus, existing literature provides insufficient insight into the effectiveness of MLSs used in children with and without motor disabilities. So, it remains unclear which evidence-based MLSs should be preferred to teach these children motor tasks.

1.2 Therapists' current use of motor learning strategies

Only two studies gained insights into therapists' current use of MLSs during treatment sessions in paediatric care. MacWilliam et al.[50] explored occupational therapists' use of MLSs in video-taped treatment sessions of children with ABI. They scored frequencies of individual MLSs observed with the 22-item version of the Motor Learning Strategy Rating Instrument, a standardized observation tool which comprises three categories with MLSs: (1) therapist verbalizations; (2) therapist actions; and (3) practice organization. Furthermore, they used qualitative analysis to explore how characteristics of a child, task and environment influenced therapists' clinical decision-making in choosing MLSs. Results showed that therapists used some MLSs more frequently than others, and that the use of analogy, mental practice and random practice were not observed at all. The qualitative analyses showed that therapists used MLSs to motivate and engage children for therapy, as a prerequisite for motor learning. Furthermore, therapists constantly adapted their use of MLSs throughout the treatment session to match a child's performance, abilities, and interests[50].

Niemeijer et al.[51] investigated whether frequencies of particular verbal MLSs of therapists were associated with the improvement of motor performance in children with DCD. The Motor Teaching Principle Taxonomy was used to register the type and frequency of verbal MLSs of the therapist in video-taped treatment sessions. The taxonomy includes 20 items divided into three categories: (1) instructions; (2) sharing knowledge; and (3) providing or asking feedback. The results showed that therapists provided more instructions in comparison to sharing knowledge and providing/asking feedback, with highest frequencies for: 'giving commands' and 'giving clues' as types of instruction; 'ask about movement execution of a task' as type of sharing knowledge; and 'tell positive results' as type of feedback[51].

A final study investigated physical therapists' perspectives on the construct of motor learning, and their use of it in clinical practice using semi-structured interviews[52]. The therapists had different levels of clinical expertise in using motor learning in various fields of practice (e.g. musculo-skeletal/orthopaedic care, and neurorehabilitation), only one of them had expertise in paediatric care. Therapists found motor teaching fundamental in their profession, and they emphasized the importance of it in their interventions. However, they experienced difficulties understanding the construct, which hindered them in using MLSs, resulting in intuitive use of MLSs in their clinical care. In general, therapists experienced low self-efficacy in teaching motor skills to individuals, but they expressed feeling more confident in using some MLSs compared to others. The therapists mentioned limited knowledge as the main barrier for implementing MLSs into their clinical care, and they stressed the need for more and/or better education[52]. It is to be expected that therapists in paediatric care also experience these difficulties, because motor learning theories and strategies that could be used in paediatric clinical care lack clarity, simplicity and generalizability as well[16]. Also, literature about the effectiveness of MLSs used in children is limited with predominantly conflicting results. To conclude, therapists need more insight into how they can, and should, use MLSs to teach motor tasks to children.

1.3 Children with Developmental Coordination Disorder (DCD)

1.3.1 Diagnosis

Children with DCD have specific problems in motor coordination and motor learning. The prevalence of these children is estimated at 5-6%, with boy-girl ratios varying from 2:1 to 7:1[12]. According to the DSM-5, DCD is defined by following four criteria:

I. The acquisition and execution of coordinated motor skills is substantially below the expected level for chronological age, given sufficient opportunity for age-appropriate motor skill learning;
II. The motor skills deficits significantly and persistently interfere with daily-life activities appropriate to chronological age, and impacts upon academic/school productivity, prevocational and vocational activities, leisure and play;

III. The motor skills deficits are not better accounted for by any other medical, neurodevelopmental, psychological, social condition, or cultural background;

IV. Onset of symptoms in childhood (although not always identified until adolescence or adulthood)[12].

DCD is frequently associated with comorbidities as attention deficits hyperactivity disorder (ADHD), autism spectrum disorder (ASD), specific language impairments (SLI), and ocular motility problems[12,53–56].

1.3.2 Problems in motor learning and associated problems

Wilson et al.[57] developed the *hybrid model of DCD*, a conceptual model which integrates knowledge from neuroscience and dynamic systems approaches, see Figure 1.2. It gives insight into relevant characteristics of child, task and environment in children with DCD, and their interaction. Children with DCD have poorly developed motor abilities, they have difficulties automatizing motor tasks. Furthermore, they experience problems with transferring motor tasks (i.e. applying the same motor task in other contexts)[3,57]. Because of altered brain structures and functions (e.g. atypical white matter network structures, and atypical activation of the mirror neuron system), children with DCD have underlying difficulties with predictive control and motor planning because of an internal model deficit[3,57,58]. Furthermore, they experience executive function difficulties, and disabilities in observational learning[3,57]. The problems in motor coordination and motor learning are more prominent when locomotor, manipulation, and stability tasks are more complex, for instance, when they include multiple steps, require more end-point precision, and/or need dual-tasking; and when tasks need to be performed in environments with background distractions, and/or uneven surface[3,57].

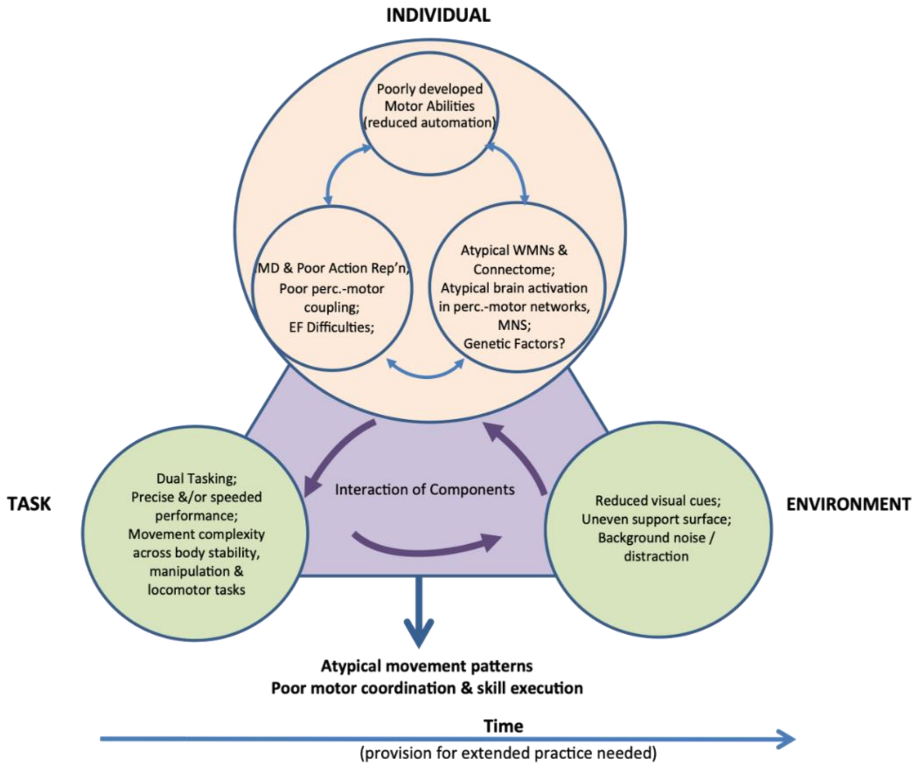

Figure 1.2. *The Hybrid model of DCD (Source: Wilson et al. 2017)*

IMD = internal modelling deficit; Rep'n = representation; perc. = perception; EF = executive function; WMNs = white matter network structures; MNS = mirror neuron system

As a consequence of their compromised motor abilities, children with DCD are at higher risk for lower physical fitness abilities, obesity, and internalizing problems (e.g. depression or anxiety)[10,59,60]. Furthermore, they frequently report lower levels of perceived athletic competence, self-perceptions and self-efficacy[61–63]. Children with DCD also experience social exclusion, bullying, and loneliness [63,64]. As a result of the motor and non-motor problems, children with DCD, and their parents, report lower levels of health-related quality of life[65]. Additionally, they participate less in daily-life activities[62–64,66–68]. At home, they experience problems in self-care tasks like getting dressed and using cutlery[66,68]. Specific school-based activities that are hampered are handwriting, self-management of learning, and physical education classes[63,68]. Lastly, these children are socially and physically less engaged in leisure, play, recreational activities, and organized sports[62,64,67,68].

1.3.3 Activity- and participation-oriented interventions

The international DCD recommendations advise physical and occupational therapists to use activity- or participation-oriented interventions in children with DCD because of their strong evidence[12,69,70]. Activity-oriented interventions are designed to improve performances of activities, while participation-oriented interventions are designed to improve participation in daily-life activities[12]. Two evidence-based activity-oriented interventions frequently used in clinical care are neuromotor task training (NTT) and cognitive orientation to daily occupational performance (CO-OP)[69,70]. Both NTT and CO-OP are child-centred interventions, and based on theories of motor learning and motor control[13,14]. Therapists practice meaningful activities, addressing a child's need(s), after performing a comprehensive analysis of the performance of these activities. CO-OP focuses mainly on learning cognitive strategies to facilitate the acquisition of motor skills, while NTT focuses more on manipulating task and environment to enhance motor learning[13,71]. In both interventions, therapists use MLSs derived from motor learning research[13,14]. For optimal motor teaching, therapists should carefully consider various child, task and environmental characteristics when deciding which MLSs to use[57].

1.3.4 Effectiveness of motor learning strategies used in children with DCD

Only few studies have investigated effectiveness of MLSs used to teach motor tasks to children with DCD. For instructions and feedback, effectiveness of the focus of attention (EF and IF) has been investigated in five studies[72–76]. Evidence appeared conflicting: two studies found beneficial effects favouring an EF[74,75], while three studies found no significant differences between the EF and IF groups[72,73,76]. Furthermore, one study investigated effectiveness of self-controlled feedback compared to instructor-controlled feedback in improving accuracy in an aiming task[77]. Results showed that the self-controlled group outperformed the instructor-controlled group on the retention test, but no group differences were found for acquisition[77]. For organization of practice, two studies investigated effectiveness of variable practice compared to constant practice using active video games to learn balance skills. Both studies found no significant differences between groups[78,79]. So, it remains unclear which MLSs should be preferred in children with DCD.

1.4 An overview of the identified knowledge gaps

In current literature, we identified three knowledge gaps that may hinder therapists in their use of MLSs when teaching motor tasks to children, and children with DCD specifically.

First, evidence about the effectiveness of MLSs used in typically and atypically developing children is limited, and even less is known about the effectiveness of MLSs used in children with DCD. Most authors stressed that effectiveness is likely to be modified by characteristics of a child and task being practiced, and that a better understanding is wanted into this modifying role. However, insufficient insight exists into which child and task characteristics might be relevant. Furthermore, some authors underpinned that the research context in which effectiveness of MLSs are investigated do not suit real-world settings. In clinical care, instructions and feedback are modelled by their focus of attention, modality, frequency and/or timing. Therefore, it can be assumed that a specific modality, frequency and/or timing might modify effectiveness of instructions and feedback with a certain focus of attention as well.

Second, literature suggests that the focus of attention, analogy learning, errorless learning, and dual-task learning can be used to promote specific types of motor learning processes. However, it remains unclear how other MLSs can be used to promote (more) implicit and (more) explicit motor learning processes in children, and children with DCD specifically.

Third, the hybrid model of DCD suggests that MLSs should be adapted to characteristics of a child, task, and environment. However, more insights need to be gained into how these characteristics can guide therapists' choice for specific types of motor learning processes and MLSs. Furthermore, too little is known about therapists' current use of MLSs in children with DCD, and whether they actually do adapt their use of MLSs to an individual child and task being practiced.

1.5 Aims and outline of this doctoral thesis

In summary, teaching motor tasks to children with motor disabilities is fundamental in the profession of physical and occupational therapists in paediatric clinical care. During interventions, therapists enhance (more) implicit and (more) explicit motor learning processes in children by using various elements of MLSs and specific MLSs adapted to the interaction of characteristics of a child, task and environment (Figure 1.1). However, we identified several knowledge gaps which may hinder therapists in their use of MLSs.

Therefore, the main aim of this thesis is to gain a better understanding on how therapists can use MLSs to teach motor tasks to children, and children with DCD specifically. Because previous research used mainly more quantitative approaches, we decided to combine literature with qualitive research designs to investigate explorative research questions addressing some of the knowledge gaps. We had four research objectives:

1. To systematically review the literature investigating effectiveness of instructions and feedback with EF applied with reduced frequency, with visual or auditory modality, and/or on request of the child.

2. To explore experts’ opinions on how MLSs can be used to promote implicit or explicit motor learning in children with and without DCD.
3. To explore therapists’ current use of instructions and feedback to teach motor tasks to children with DCD.
4. To explore therapists’ perspectives on how characteristics of the individual child and the task being practiced guide their use of MLSs when teaching motor tasks to children with DCD.

In **Chapter 2**, the results of a systematic literature review with best-evidence synthesis will be reported (Objective 1). **Chapter 3** will discuss the results of two questionnaires used to explore the perspectives of international experts on how MLSs can be used to promote (more) implicit and (more) explicit motor learning processes in children with and without DCD (Objective 2). The subsequent two chapters, Chapters 4 and 5, will describe therapists’ use of MLSs which we explored twofold: by videotaping treatment sessions of paediatric physical therapist teaching motor tasks to a child with DCD, and by conducting individual and focus group interviews with paediatric physical therapists. **Chapter 4** will report the results of the analyses of video-taped treatment sessions using a newly developed analysis plan. In this study we focused on therapists’ current use of instructions and feedback in teaching motor tasks to children with DCD (Objective 3). In the individual and focus group interviews we explored how characteristics of child and task guided therapists’ clinical decision making in choosing how to use instructions, feedback and organization of practice to teach motor tasks to children with DCD (Objective 4). The results of this study will be described in **Chapter 5**. A general discussion of these four studies will be described in **Chapter 6**.

1.6 References

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Chapter 2

How can instructions and feedback with external focus be shaped to enhance motor learning in children? A systematic review

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Abstract

Aim: This systematic review investigates the effectiveness of instructions and feedback with external focus applied with reduced frequency, self-controlled timing and/or in visual or auditory modality*, on the performance of functional gross motor tasks in children aged 2 to 18 with typical or atypical development.

Methods: Four databases (PubMed, Web of Science, Scopus, Embase) were systematically searched (last updated May 31st 2021). Inclusion criteria were: 1. children aged 2 to 18 years old; 2. Instructions/feedback with external focus applied with reduced frequency, self-controlled timing, and/or visual or auditory modality as intervention, to learn functional gross motor tasks; 3. Instructions/feedback with external focus applied with continuous frequency, instructor-controlled timing, and/or verbal modality as control; 4. performance measure as outcome; 5. (randomized) controlled studies. Article selection and risk of bias assessment (with the Cochrane risk of bias tools) was conducted by two reviewers independently. Due to heterogeneity in study characteristics and incompleteness of the reported data, a best-evidence synthesis was performed.

Results: Thirteen studies of low methodological quality were included, investigating effectiveness of reduced frequencies (n = 8), self-controlled timing (n = 5) and visual modality (n = 1) on motor performance of inexperienced typically (n = 348) and atypically (n = 195) developing children, for acquisition, retention and/or transfer. For accuracy, conflicting or no evidence was found for most comparisons, at most time points. However, there was moderate evidence that self-controlled feedback was most effective for retention, and limited evidence that visual analogy was most effective for retention and transfer.

Conclusion: More methodologically sound studies are needed to draw conclusions about the preferred frequency, timing or modality. However, we cautiously advise considering self-controlled feedback, and visual instructions.

* In the published paper, we used the term *form* for visual, verbal and auditory instructions and feedback. However, in the other papers included in this thesis, we used the term *modality* because it is a more commonly used term in motor learning literature to describe these types of instructions and feedback. Therefore, we used modality in this chapter as well.

Registration: Prospero CRD42021225723

Key words: motor learning; child; adolescent; instruction; feedback; external focus

2.1 Introduction

Children apply many different gross motor skills in a wide variety of contexts, such as physical education (PE) classes, sports and playtime[1]. These so-called functional skills are defined as motor skills used in sports or other daily life activities that entail relatively complex movement organization[2]. Most children learn these skills almost effortlessly. Their increasing gross motor competence results from the interaction between factors in child (e.g. age, executive functions, psychological characteristics, and motor skill level), task (e.g. rules of the game, type of task, and level of task complexity) and environment (e.g. opportunities for PE and sports)[1,3–5]. However, motor skills learning can be challenging for some children, due to neurological conditions[6,7] or neurodevelopmental disorders[8–11]. Motor learning can be defined as a set of processes associated with practice or experience leading to relatively permanent improvements in the capability for producing motor skills[12]. Instructors, like PE teachers, trainers, coaches, and occupational and physical therapists, apply motor learning on a daily basis[13–16]. They use various motor learning variables, such as instructions and feedback, which they adapt to the child and the task practised[15–19]. Their instructions and feedback are shaped by parameters, such as content (e.g. a specific focus of attention), frequency, modality (e.g. visual or verbal), and timing (self- or instructor-controlled)[18,20,21].

With implicit motor learning, a child learns without awareness and with no or minimal increase in verbal knowledge[22]. It is suggested that children benefit from this type of learning, because there is minimal involvement of the working memory[2,23,24]. Implicit motor learning can, for instance, be shaped by using an external focus of attention (EF)[23]. With an EF, the child's attention is directed to the impact of the movement on the environment[25]. On the contrary, with an internal focus of attention (IF) the attention is directed to its body movements[25]. According to the constrained action hypothesis, an IF promotes a larger involvement of cognitive processes due to a greater reliance on conscious control strategies. These strategies interfere with the normal automatic control processes of the motor system. An EF promotes these automatic control processes, therefore, enhancing motor learning more[26]. A recent systematic review investigated effectiveness of implicit learning strategies in functional motor skills learning in typically developing children (TDC)[23]. They concluded that the use of an EF appeared to be as, or even more, effective than an IF[23]. An EF was also more effective than an IF in motor learning for children with Mild Intellectual Disabilities (MID)[27] and Attention Deficit and Hyperactivity Disorder (ADHD)[28]. However, an IF appeared more effective in children with Autism Spectrum Disorder (ASD)[29]. In children with Developmental Coordination Disorder (DCD), no differences were found for retention and transfer between groups using an EF or an IF[30,31]. Although, the beneficial effects of the EF have not yet been shown for each population, the constrained action hypothesis promotes using an EF for teaching motor skills[26]. Therefore, this systematic review focuses instructions and feedback with EF.

When using an EF in practical settings, instructors have to decide how often (frequency), when (timing) and in what modality to provide their instructions and feedback[20]. Feedback can be provided after each trial (continuous frequency) or after a number of trials (reduced frequency)[32–34]. Based on the guidance hypothesis, a reduced frequency would be more beneficial for retention and transfer than a continuous frequency because it reduces the feedback dependency enhancing the processing of other sources of information, which results in more implicit learning[34]. In stroke patients, it is indicated that reduced frequency is preferred[35]. However, in (a)typically developing children, this remains unclear [32,33]. The timing of instructions and feedback can be determined by the instructor (instructor-controlled) or the child (self-controlled)[36]. Self-controlled timing advances a child's autonomy, which is essential to enhance intrinsic motivation according to the Self-Determination Theory[37]. As motivation is considered relevant in motor learning, self-controlled timing could be more effective[38]. Studies in children showed that self-controlled feedback may enhance motor learning more than instructor-controlled feedback[36]. Most instructions and feedback are provided verbally[23,32,36] but instructors also use visual, tactile, and auditory (e.g. sound beeps) modalities[14,17,19,20]. Currently, it remains unclear what frequency, modality and timing are to be preferred when using instructions and feedback with EF[14,32,36].

While previous reviews suggest that the effectiveness of EF may be moderated by child and task characteristics, like working memory capacity, motor skill level and type of task[23,36], we hypothesize that the effectiveness of EF may also be moderated by the instructors' chosen frequency, timing, and modality. Therefore, this systematic review investigates the effectiveness of instructions and feedback with EF applied with reduced frequency, in visual or auditory modalities, and/or on request of the child (I), compared to instructions and feedback with EF applied with continuous frequency, in verbal modality, and/or initiated by the instructor (C), on the performance of functional gross motor tasks (O) in children aged 2 to 18 with typical and atypical development (P).

2.2 Methods

A systematic review of randomized controlled trials (RCTs) and non-randomized controlled clinical trials (CCTs) was performed. The hypotheses were: 1. instructions and feedback with EF applied with reduced frequency will be more effective than those applied with continuous frequency; 2. self-controlled instructions and feedback with EF will be more effective than instructor-controlled instructions and feedback; and 3. visual or auditory instructions and feedback with EF will be more effective than verbal instructions and feedback. This systematic review is written according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses 2020 (PRISMA 2020)[39,40] and registered in the international prospective register of systematic reviews (PROSPERO) under registration number: CRD42021225723.

2.2.1 Inclusion and exclusion criteria

Inclusion and exclusion criteria were defined in line with the PICOT structure (Population, Intervention, Control, Outcome, Type of study).

Inclusion criteria were:

1. Population: Children with (a)typical development aged 2-18 years. Studies which included a combined population of adolescents and adults were included if there were sub-analyses with adolescents.

2. Intervention: Instructions or feedback with EF applied with reduced frequency, in visual or auditory modalities and/or with self-controlled timing, used to learn functional gross motor tasks. With instructions or feedback with EF the instructor directs the attention of the child to the effects of the movement on the environment (e.g. "Try to focus on the red markers and try to keep the markers at the same height" when balancing a stabilometer)[25]. With Knowledge of Results feedback (KR) the instructor informs the child about the effects of the movement on the environment (e.g. by indicating to what extent the ball deviated the target in direction and distance)[41]. This information serves as a basis for error corrections improving next performances[34]. Although in KR the child needs to process the obtained information more to determine how to act, both EF and KR focus on the effects of the movement on the environment. Therefore, we considered KR as a subtype of feedback with EF. An analogy, a metaphor that integrates the complex structure of the to-be-learned task[42], is considered an EF because a child aims to reproduce the metaphor[38]. Reduced frequencies can be applied in fixed frequency (feedback after a fixed number of trials) or faded frequency (reducing the frequency over time)[32,35].

3. Control: Instructions and feedback with EF applied with continuous frequency, in verbal modality and/or with instructor-controlled timing.

4. Outcome: A performance measure (e.g. accuracy or quality of movement) as primary outcome, used to assess acquisition and/or learning of functional gross motor tasks. Acquisition is measured during practice blocks or with a post-intervention test ("post-test"), and learning is measured with retention and/or transfer tests[43].

5. Type of study: Studies using a RCT or CCT without randomization design.
6. Publication type: Publications of original RCTs and CCTs.
7. Language: Studies written in English or Dutch.

Exclusion criteria were:

1. Population: Children with (a)typical development under the age of 2 years or adults.
2. Intervention: Instructions or feedback with an IF; intervention methods like Neuromotor Task Training, because they provide no insight into effectiveness of separate instructions or feedback; instructions and feedback used to learn laboratory, fine motor and static balance tasks, because they did not meet the definition of functional gross motor task[2].
3. Control: A tactile modality of instructions and feedback, because it directs the attention of the child to the body, therefore, promoting an IF.
4. Outcome: Outcome measures that assessed brain anatomy and functions as primary outcomes.
5. Type of study: Studies performed with designs other than RCT and non-randomized CCT.
6. Publication type: Conference proceedings/reports and books.
7. Language: Studies not written in English or Dutch.

2.2.2 Literature search

A systematic search was conducted in PubMed, Web of Science, Scopus and Embase. The search was last updated on the 31st of May 2021. Because instructions and feedback are also used when applying practice conditions, a broad search query was used to ensure that no relevant studies were missed. The search terms concerned four key topics: motor learning, instruction, feedback, and practice conditions. These topics were combined as motor learning AND (instruction OR feedback OR practice conditions). An explorative search to inventories relevant search terms showed that, in title and abstract, participants were often described in general (e.g. subjects). It also showed that various outcome measures were used to assess motor task performance (e.g. accuracy, speed, count, distance). To prevent studies being missed, search terms did not incorporate terms related to population or outcome. No date restrictions or filters were applied. See Appendix 2.1 file for the detailed search queries.

2.2.3 Study selection

The eligibility of the studies was assessed in two phases: on title and abstract (phase 1); on full text (phase 2). The selection criteria were applied in a fixed sequence (population, intervention, control, outcome, type of study, publication type and language) by two reviewers independently (IvdV and EV). If necessary, authors were contacted for full texts. After each phase, a consensus meeting discussed the results of the article selection. Full text versions were read in case of disagreement after phase 1 and an independent reviewer (ER) was consulted in case of disagreement after phase 2. References of the included studies and of the three systematic reviews concerning children's motor learning[23,32,36] were checked by one reviewer (IvdV) to ensure that all relevant studies had been included.

2.2.4 Data extraction

Data were extracted using a standardized sheet by one reviewer (IvdV or EV) and checked and complemented by the other. Corrections and additions were discussed between both reviewers; in the case of disagreement, an independent reviewer (ER) was consulted. Authors were not contacted for further details about studies.

For each study, the following data were extracted: 1. Characteristics of the study design: information regarding the group allocation of the participants (e.g. randomization procedure), blinding of participants, assessors, outcome measures and all relevant data for analyses; 2. Population characteristics: number of participants in total and per group, age range, mean age and standard deviations (SD), skill level (inexperienced or trained), and diagnosis, if given; 3. Intervention characteristics: details about instructions or feedback to the experimental and control group(s), the task, and the practice sessions (e.g. frequency, volume and duration); 4. Outcome and assessment time points: the primary and secondary outcome(s) to measure motor performance and type and timing of measurements in acquisition and test phase (pre-, post-, retention and/or transfer tests); 5. Results: summary statistics with measures of precision for each group, the data for differences between groups, and thresholds of minimal clinically important differences.

2.2.5 Methodological quality assessment

The revised Risk of Bias tool (RoB2), for randomized trials[44], and the Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I)[45], were used to assess methodological quality.

The RoB2 evaluates five major domains of biases: selection, performance, detection, attrition, and reporting biases. Signalling questions were answered to reach a domain-specific RoB judgement of 'low', 'some concerns' or 'high'. If not referred to a registered trial protocol, Questions 5.2 and 5.3 were answered based on the data-analysis section. Using the judgements of the five domains, an overall RoB judgement was made. If at least four domains were of some concern, the overall RoB was considered high.

The ROBINS-I evaluates seven major domains of biases: confounding, selection, classification, performance, detection, attrition, and reporting biases. As for the RoB2, signalling questions were used to reach a domain-specific RoB judgement of 'low', 'moderate', 'serious', 'critical' or 'no information'. If not referred to a registered trial protocol, Questions 7.1, 7.2 and 7.3 were answered based on the data-analysis section. Based on the domain-specific judgements, an overall RoB judgement was made.

Four reviewers (IvdV, EV, ER and KK) investigated RoB. Each study was assessed by two reviewers independently. A consensus meeting was organized with all reviewers and an epidemiologist (CB) to reach consensus.

2.2.6 Analyses

Results were described for study selection, study characteristics and methodological quality. The RoB judgments were visualized[46]. To answer the hypotheses, as a first step a meta-analysis was planned with studies comparable for study design, instructions and feedback, and task. Therefore, the instructions and feedback were coded according to each parameter (frequency, timing and modality). For frequency, the intervention was coded as reduced fixed or reduced faded frequency and the control as continuous frequency (Hypothesis 1). For timing, the intervention was coded as self-controlled and the control as instructor-controlled (Hypothesis 2). In studies investigating timing, the control group is either yoked (the children received feedback as their counterpart in the intervention group requested feedback) or instructor-controlled (the instructor determined when the child received feedback). Because of the chosen focus of this systematic review in the self-controlled aspect, we combined both yoked and instructor-controlled groups as control intervention. For modality, the intervention was coded as visual or auditory and the control as verbal (Hypothesis 3). Studies were grouped according to the type of comparison between coded intervention and control. Each task is defined by its own constraints, which are related to the context in which the task is performed[47]. Only studies with similar tasks could be combined in a meta-analysis. After subgrouping in subsequent steps according to (firstly) task and (secondly) population (TDC and per diagnosis), it was still not possible to pool data due to heterogeneity and to the incompleteness of the reported data. Therefore, a best-evidence synthesis was performed. The best-evidence synthesis table was structured according to the parameter of interest (frequency, timing, or modality) and subdivided into comparisons of coded interventions and controls, as described above. If studies included more than one group with reduced frequency, the frequency that was most comparable with other studies was used for analysis. Within comparisons, studies were ordered according to comparable tasks and population, mentioning studies of good methodological quality first to increase the prominence of the most trustworthy evidence. This study aimed to investigate whether the instructor-controlled parameters frequency, timing and modality moderate effectiveness of instructions and feedback in children. Subsequent analyses with sub groups were not performed for two reasons: 1. it was not possible to define relevant sub groups due to insufficient insights, and presented data in the included studies, into which child characteristics could be potentially relevant to moderate effectiveness[36]; and 2. the number of studies per potential comparison and methodological quality was too low. Results were described per outcome measure. The results of each study were rated as significant (favouring a specific frequency, timing or modality), inconsistent or not significant[48]. Then, the evidence for each comparison was rated according to the guidelines of van Tulder et al.[48]: strong (consistent findings among multiple high quality RCTs), moderate (consistent findings among multiple low quality RCTs and/or CCTs and/or one high quality RCT), limited (one low quality RCT and/or CCT), conflicting (inconsistent findings among multiple RCTs and/or CCTs), or no evidence from trials (no RCTs or CCTs). Consistency was defined as 75% of the studies assessing the same comparison showing results in the same direction.

2.3 Results

2.3.1 Study selection

The search resulted in 3813 unique hits. After screening title and abstract, 3521 hits were excluded. The reviewers agreed in 86% of the studies on inclusion or exclusion, 14% of the abstracts were discussed. The remaining 292 hits were screened on full text, eight of which met the inclusion criteria. The reviewers agreed in 93% of the studies on inclusion or exclusion, 7% of the articles were discussed. Reasons for exclusion were not meeting the criteria for: population (n = 150), intervention (n = 84), control (n = 1), type of study (n = 41), publication type (n = 7) or language (n = 1). Of the excluded studies, 24 investigated effectiveness of instructions and feedback with EF in children's functional gross motor learning in comparison with an IF and/or no instructions or feedback, without distinction in frequency, timing or modality between groups[27–30,49–68]. Of the studies that distinguished in frequency, timing or modality between groups, eight used an IF[69–76]. One study was excluded because its control group also used reduced instead of continuous frequency[77] (see Appendix 2.2 for an overview of the excluded studies that nearly met inclusion criteria). Additionally, five studies were found through the references check, resulting in a total of 13 included studies (Figure 2.1).

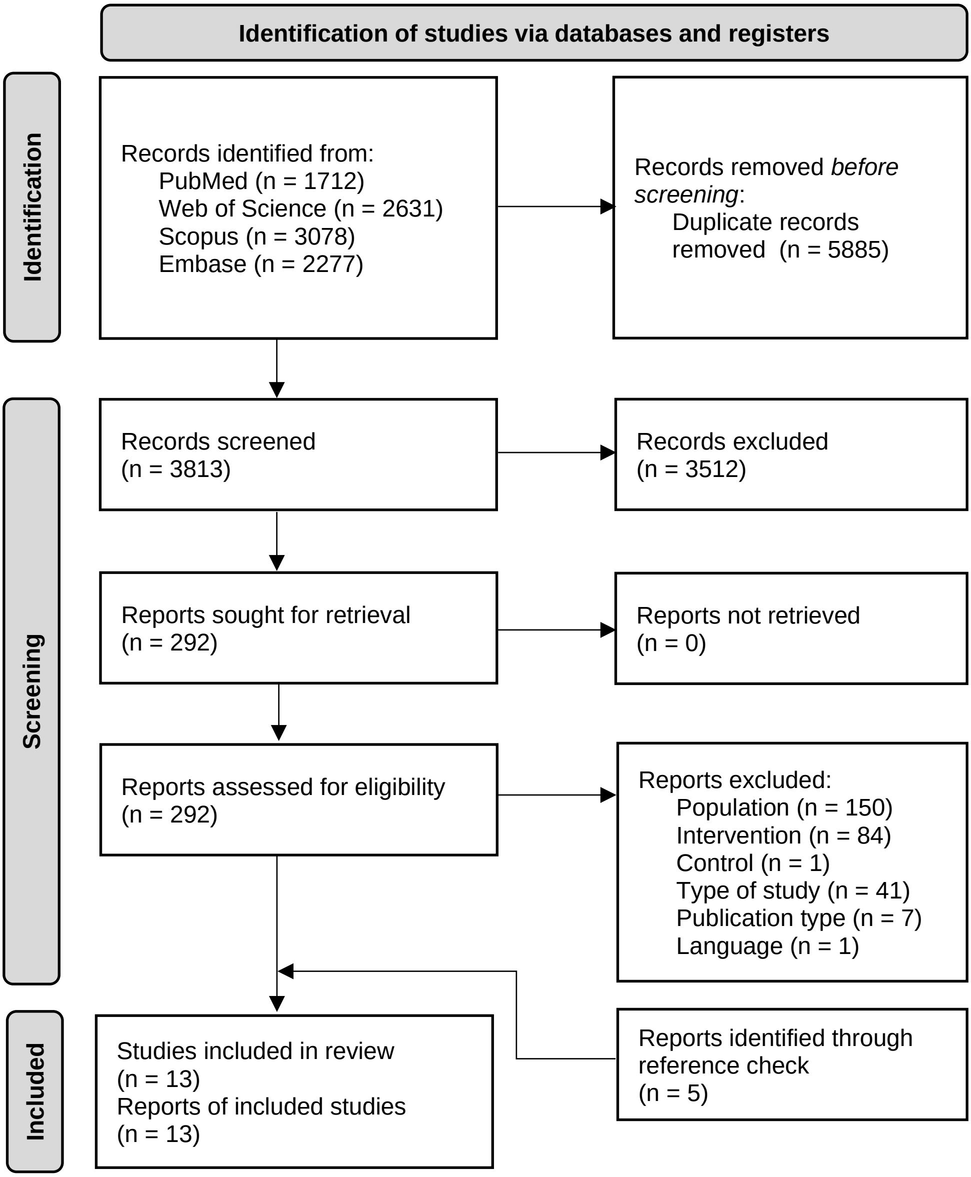

Figure 2.1. *Prisma flow diagram of the study selection*

n = number

2.3.2 Methodological quality

Twelve RCTs were assessed with the RoB2, all of which having an overall RoB judgement of high[41,78–88] (Figure 2.2a). Percentages of agreements between reviewers varied (Domain 1: 75%; Domain 2: 25%; Domain 3: 41%; Domain 4: 25%; Domain 5: 67%). Although studies mentioned randomized groups, none described the generation method used and whether allocation was concealed[41,78–88]. Only one study provided a demographic characteristics table[87]. Most studies were at high risk for performance bias, none of the studies reported using intention-to-treat (ITT) analysis and how they handled missing data[41,78–88]. Most studies were also at high risk for detection bias, only one study reported no missing data[88]. In six studies, the F statistics showed that there were missing data, but information on the amount, at which time point and in which group was lacking[78–80,83–85]. In most studies, outcome assessors were not blinded or it remained unclear whether they were blinded[41,78–86,88,89]. None referred to a registered trial protocol, raising concerns about possible reporting bias[41,78–88]. The study of Hemayattalab & Rostami (2010)[89] was the only non-randomized CCT included. It had an overall judgement of serious RoB due to a serious RoB in measurement of outcomes, while the remaining domains were at low RoB[89] (Figure 2.2b). Reviewers scored similar for all domains except Domain 6.

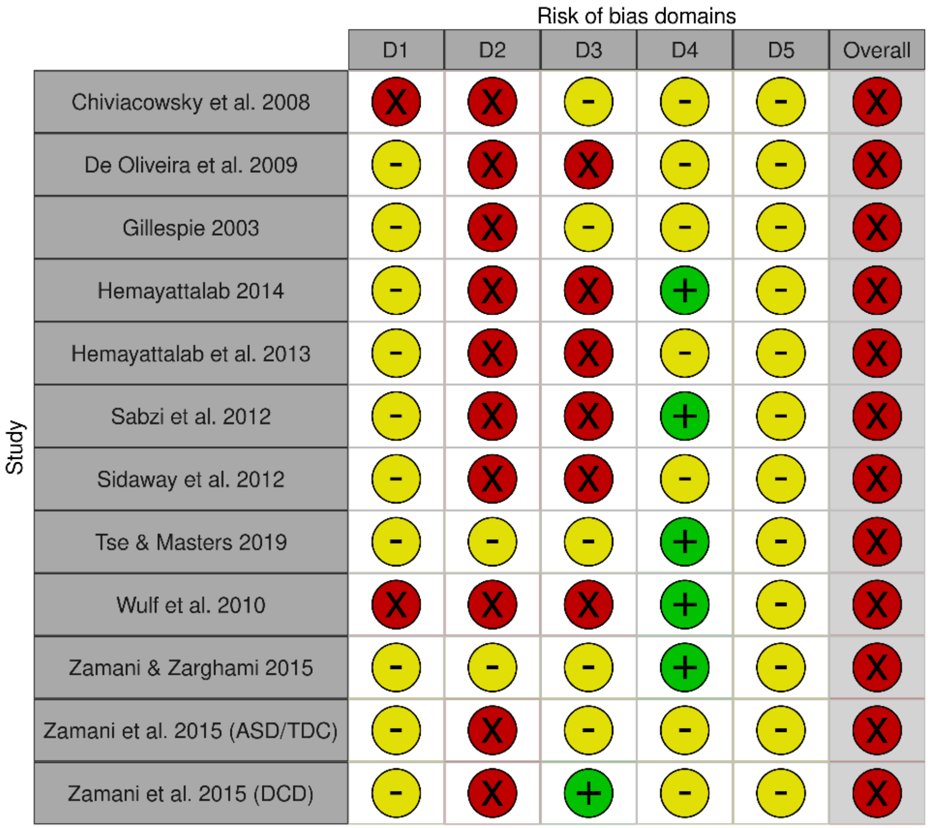

Figure 2.2a. *Methodological quality of the included studies assessed with RoB2*

D1 = selection bias; D2 = performance bias; D3 = detection bias; D4 = attrition bias; D5 = reporting bias; + = low risk; - = some concerns; X = high risk.

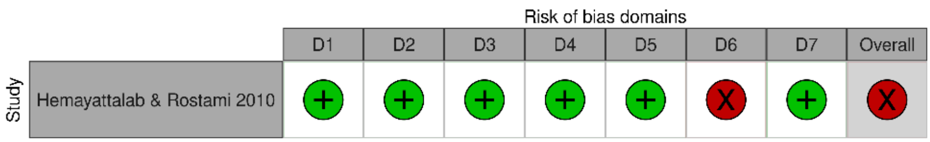

Figure 2.2b. *Methodological quality of the included study assessed with ROBINS-I*

D1 = bias due to confounding; D2 = selection bias; D3 = classification bias; D4 = bias due to deviation from intended interventions; D5 = bias due to missing data; D6 = bias in measurement of outcomes; D7 = reporting bias; + = low risk; X = high risk.

2.3.3 Study characteristics

Seven out of 13 studies included 348 inexperienced TDC[41,78–83], ages ranging from 6[81,82] to 13 years[83]. Seven studies included 195 inexperienced children with motor disabilities[81,84–89], ages ranging from 6[81,85,87] to 18 years[85]. Mean ages and SDs were not reported in five studies[80–82,88,89]. The children with motor disabilities comprised children with MID[86], DCD[88], ASD[81,87] or CP[84,85,89]. Overall, the studies involved small sample sizes, the number of participants per group ranging from 6[88] to 16[86], with six studies having samples of 10 or less[78,81,84,85,88,89]. All studies used object control tasks[41,78–89]; 12 throwing[41,78–85,87–89] and one golf-putting[86]. In 10 studies, participants practised only once[41,78–84,86,87], the number of trials ranging from 30[80] to 90[83,87]. Participants in the remaining studies practised five times with a total of 100 trials[85], or eight times with a total of 240 trials[88,89]. All groups showed within group improvements during practice in 12 out of 13 studies[41,78–85,87–89] (Table 2.1).

Table 2.1. *Study characteristics of the included studies*

Author(s), year	Population characteristics Type (n) Mean age in years (SD) Skill level	Study design	Intervention characteristics Groups (n) The provided instructions or feedback	Intervention characteristics Task	Intervention characteristics Practice	Measurements Outcome Covariables	Assessment time points	Results > significantly better than = no significant differences
Frequency								
Gillespie, 2003	Children with MID, IQ range 55-70 (n = 32) 10.8 (0.68) Inexperienced	RCT	<u>Groups</u> • 20% frequency: KR after every fifth trial[a] • 100% frequency: KR after every trial[a] <u>The provided feedback</u> the instructor informed the child about the accuracy score and the child was allowed to see where the ball had stopped	Golf-putting task	1 practice session of 10 blocks of 5 trials (total 50 trials)	<u>Outcome</u> Accuracy: score varied from 0-5 based on zones around the target (higher is better)	During acquisition Retention: • 24h • 1w	ANOVA analysis • <u>During acquisition:</u> No significant main effect for blocks Significant main effect for frequency 100% > 20* • <u>Retention 24h:</u> Significant main effect for frequency 20% > 100%* • <u>Retention 1w:</u> Significant main effect for frequency 20% > 100%*

Table 2.1 continued

Hemayattalab & Rostami, 2010	Children with CP, GMFCS 1 (n = 24) 7-15[b] Inexperienced	Non-rando-mized CCT	<u>Groups</u> • 50% frequency: KR on half of the trials (n = 8) • 100% frequency: KR after every trial (n = 8) • 0% frequency: no KR (n = 8) <u>The provided feedback</u> the instructor informed the child about the accuracy score	Dart throwing	8 practice sessions of 6 blocks of 5 trials, period not reported (total 240 trials)	<u>Outcome</u> Accuracy: registered in points based on zones around the target (higher is better)	Pre-test During acquisition Post-test Retention: 72h	Significant paired sample t-tests for pre-test / post-test for all groups, all groups improved accuracy ANOVA analysis with post-hoc Tukey HSD tests • <u>Post-test:</u> Significant main effect for frequency Post-hoc testing: 100% > 50%**, 100% > 0%** and 50% > 0%* • <u>Retention:</u> Significant main effect for frequency Post-hoc testing: 50% > 100%**, 50% = 0% (p = 0.093) and 100% = 0% (p = 0.146)

Table 2.1 continued

de Oliveira et al., 2009	TDC (n = 120) 11.8 (1.2) Inexperienced	RCT	<u>Groups</u> • Simple task + 25% frequency: KR after a quarter of the trials (n = 15) • Simple task + 50% frequency: KR after half of the trials (n = 15) • Simple task + 75% frequency: KR after three quarters of the trials (n = 15) • Simple task + 100% frequency: KR after every trial (n = 15) • Complex task + 25% frequency: KR after a quarter of the trials (n = 15) • Complex task + 50% frequency: KR after half of the trials (n = 15) • Complex task + 75% frequency: KR after three quarters of the trials (n = 15) • Complex + 100% frequency: KR	Bocha game throwing • Simple task: throw with backward-forward pendulum movement of the arm • Complex task: throw with same pendulum movement followed by an overhead circular movement of the arm	1 practice session of 9 blocks of 10 trials (total 90 trials)	<u>Outcome</u>[c] Accuracy: absolute error in cm (lower is better) Variability: variable error in cm (lower is better)	During acquisition Transfer: 0h	ANOVA analysis with post-hoc Tukey HSD tests Accuracy • <u>During acquisition:</u> Significant main effect for blocks, accuracy improved during practice Significant main effect for frequency Post-hoc testing: 25% > 50%, 75% and 100%* and 75% > 50%* • <u>Transfer:</u> Significant main effect for frequency Post-hoc testing: 25% > 50%* Variability • <u>During acquisition:</u> Significant main effect for blocks, variability decreased during practice Significant main effect for frequency Post-hoc testing: 25% > 50%, 75% and 100%* and 75% > 50% and 100%* • <u>Transfer:</u> Significant main effect for frequency Post-hoc testing: 25% > 50%, 75% and 100%*

			after every trial (n = 15) <u>The provided feedback</u> the child was allowed to see where the ball had stopped					
Sabzi et al., 2012	TDC (n = 40) 10.4 (1.0) Inexperienced	RCT	<u>Groups</u> • Reduced frequency: KR with faded frequency from 100% to 0% (n = 10) • 100% frequency: KR after every trial (n = 10) • Self-controlled: KR on request in 3 out of every 10 trials (n = 10) • Bandwidth: feedback when score is less than 50 out of 100 points (n = 10) <u>The provided feedback</u> the instructor informed the child about the results in terms of the direction and distance from the target centre	Throw with beanbag at target on the floor[d]	1 practice session of 6 blocks of 10 trials (total 60 trials)	<u>Outcome</u> Accuracy: score varied from 0-100 based on zones around the target (higher is better)	During acquisition Retention: 24h	ANOVA analysis with post-hoc Tukey HSD tests • <u>During acquisition:</u> Significant main effect for blocks, accuracy increased during practice No significant main effect for groups • <u>Retention:</u> Significant main effect for groups Post-hoc testing: 100% > reduced feedback, SC and bandwidth*

Table 2.1 continued

Sidaway et al., 2012	TDC (n = 48) 10.7 (0.6) Inexperienced	RCT	<u>Groups</u> • Simple task + 33% frequency: KR after every third trial[a] • Simple task + 100% frequency: KR after every trial[a] • Complex task + 33% frequency: KR after every third trial[a] • Complex task + 100% frequency: KR after every trial[a] <u>The provided feedback</u> the instructor informed the child about the accuracy score	Throw with beanbag at target on the floor • Simple task: throw while standing • Complex task: throw while walking	1 practice session of 6 blocks of 12 trials (total 72 trials)	<u>Outcome</u>[c] Accuracy: absolute error score varied from 0-3 based on zones around the target (lower is better) Variability: variable error based on the standard deviation about the mean score (lower is better)	During acquisition Post-test: in analysis referred to as retention 0h Retention: 1w Transfer: • 0h • 1w	ANOVA analysis[e] Accuracy • <u>During acquisition:</u> Significant main effect for blocks, accuracy increased during practice No significant main effect for frequency • <u>Retention 0h and 1w:</u> No significant main effect for frequency • <u>Transfer 0h and 1w:</u> No significant main effect for frequency Variability • <u>During acquisition:</u> Significant main effect for blocks, variability decreased during practice No significant main effect for frequency • <u>Retention 0h and 1w:</u> No significant main effect for frequency • <u>Transfer 0h and 1w:</u> No significant main effect for frequency

Table 2.1 continued

Wulf et al., 2010	TDC (n = 48) 10-12[b] Inexperienced	RCT	<u>Groups</u> • 33% frequency with EF: feedback after every third trial with focus on ball, target or shoes (n = 12) • 100% frequency with EF: feedback after every trial with focus on ball, target or shoes (n = 12) • 33% frequency with IF: feedback after every third trial with focus on the body (n = 12) • 100% frequency with IF: feedback after every trial with focus on the body (n = 12) <u>The provided feedback</u> • EF-feedback: example, *"The sneaker should point at the target; keep them apart"* • IF-feedback: example, *"The feet, hips, knees and shoulders*	Throw with soccer ball at target on the floor	1 practice session of 6 blocks of 5 trials (total 30 trials)	<u>Outcome</u>[c] Accuracy: score varied from 0-5 based on zones around the target (higher is better) Quality of movement: score varied from 0-8 (8 criteria, per criteria 1 point if performed correctly and 0 point if not) (higher is better)	During acquisition Post-test: in results referred to as retention 0h Retention: 24h Transfer: • 0h • 24h	ANOVA analysis[e] Accuracy • <u>During acquisition:</u> Significant main effect for blocks, accuracy increased during practice No significant main effect for frequency • <u>Retention:</u> No significant main effect for frequency • <u>Transfer:</u> No significant main effect for frequency Quality of movement • <u>During acquisition:</u> Significant main effect for blocks, quality of movement increased during practice No significant main effect for frequency • <u>Retention:</u> No significant main effect for frequency • <u>Transfer:</u> No significant main effect for frequency

			should be aimed at the target, feet shoulder-width apart"					
Zamani & Zarghami, 2015	TDC (n = 45) 6-8[b] Inexperienced	RCT	Groups • 50% frequency: KR after every second trial[a] • 100% frequency: KR after every trial[a] • 0% frequency: no KR[a] The provided feedback the instructor informed the child about the results in terms of the direction and distance from the target centre	Throw with beanbag at target on the floor[d]	1 practice session of 6 blocks of 10 trials (total 60 trials)	Outcome Accuracy: score varied from 0-100 based on zones around the target (higher is better)	Pre-test During acquisition Retention: 24h	ANOVA analysis with post-hoc Tukey HSD tests • During acquisition: Significant main effect for blocks, accuracy increased during practice Significant main effect for frequency Post-hoc testing: 100% > 50% **, 100% > 0%** and 50% > 0% ** • Retention: Significant main effect for frequency Post-hoc testing: 50% > 100**, 50% > 0%** and 100% > 0%**

Table 2.1 continued

Zamani et al., 2015	TDC (n = 21) Children with ASD (n = 21) 6-8[b] Inexperienced	RCT	<u>Groups</u> • 50% frequency: KR after every second trial (TDC: n = 7 / ASD: n = 7) • 100% frequency: KR after every trial (TDC: n = 7 / ASD: n = 7) • 0% frequency: no KR (TDC: n = 7 / ASD: n = 7) <u>The provided feedback</u> the instructor informed the child about the results in terms of the direction and distance from the target centre	Throw with beanbag at target on the floor[d]	1 practice session of 6 blocks of 10 trials (total 60 trials)	<u>Outcome</u> Accuracy: score varied from 0-100 based on zones around the target (higher is better)	Pre-test During acquisition Retention: 24h	ANOVA analysis with Tukey-Kramer tests TDC • <u>During acquisition:</u> Significant main effect for blocks, accuracy increased during practice Significant main effect for frequency Post-hoc testing: 100% > 50%**, 100% > 0%** and 50% > 0%** • <u>Retention:</u> Significant main effect for frequency Post-hoc testing: 50% > 100%**, 50% > 0%** and 100% > 0%** Children with ASD • <u>During acquisition:</u> Significant main effect for blocks, accuracy increased during practice Significant main effect for frequency Post-hoc testing: 100% > 50%**, 100% > 0%** and 50% > 0%** • <u>Retention:</u> Significant main effect for frequency Post-hoc testing: 100% > 50%**,

								100% > 0%** and 50% > 0%**
				Timing				
Chiviacowsky et al., 2008	TDC (n = 26) 10.0 (0.5) Inexperienced	RCT	<u>Groups</u> • Self-controlled: KR on request (n = 13) • Yoked: KR whenever counterpart requested feedback (n = 13) <u>The provided feedback</u> the instructor informed the child about the results in terms of the direction and distance from the target centre	Throw with beanbag at target on the floor	1 practice session of 6 blocks of 10 trials (total 60 trials)	<u>Outcome</u> Accuracy: score varied from 0-100 based on zones around the target (higher is better)	During acquisition Retention: 24h	ANOVA analysis • <u>Acquisition:</u> Significant main effect for blocks, accuracy increased during practice No significant main effect for timing • <u>Retention:</u> Significant main effect for timing SC > yoked*

Table 2.1 continued

Hemayattalab et al., 2013	Children with CP, GMFCS 1-3 (n = 24) 11.6 (1.5) Inexperienced	RCT	<u>Groups</u> • Self-controlled: KR on request (n = 10) • Yoked: KR whenever counterpart requested feedback (n = 10) <u>The provided feedback</u> the instructor informed the child about the results in terms of the direction and distance from the target centre	Throw with beanbag at target on the floor[d]	1 practice session of 10 blocks of 8 trials (total 80 trials)	<u>Outcome</u> Accuracy: score varied from 0-100 based on zones around the target (higher is better)	Pre-test During acquisition Post-test Retention: 24h Transfer: 24h	A graph showed that both groups improved accuracy during practice. However, this was not tested with paired sample t-tests pre-test / post-test MANOVA analysis <u>Post-test:</u> • No significant main effect for timing ($p = 0.473$) <u>Retention:</u> • Significant main effect for timing ($p = 0.003$) SC > yoked <u>Transfer:</u> • Significant main effect for timing ($p = 0.018$) SC > yoked

Table 2.1 continued

Hemayattalab et al., 2014	Children with CP, GMFCS 1 (n = 22) 12.26 (3.11) Inexperienced	RCT	<u>Groups</u> • Self-controlled: KR on request in maximum half of the trials (n = 8) • Instructor-controlled: KR when instructor wanted in half of the trials (n = 7) • Control: no KR (n = 7) <u>The provided feedback</u> the instructor informed the child about the accuracy score	Dart throwing	5 practice sessions of 4 blocks of 5 trials, period not reported (total 100 trials)	<u>Outcome</u> Accuracy: score varied from 0-100 based on zones around the target (higher is better)	During acquisition (mean scores practice session 1 and 5 used as pre- and post-test) Retention: 24h Transfer: 24h	ANOVA analysis with post-hoc Tukey HSD tests • <u>During acquisition:</u> Significant main effect for days, accuracy increased during practice No significant main effect for timing • <u>Retention:</u> Significant main effect for timing Post-hoc testing: SC = IC*, SC > control (p = 0.014) and IC = control* • <u>Transfer:</u> Significant main effect for timing Post-hoc testing: SC = IC*, SC > control* and IC = control (p > 0.05)

Table 2.1 continued

Sabzi et al., 2012	TDC (n = 40) 10.4 (1.0) Inexperienced	RCT	<u>Groups</u> • Reduced frequency: KR with faded frequency from 100% to 0% (n = 10) • 100% frequency: KR after every trial (n = 10) • Self-controlled: KR on request in 3 out of every 10 trials (n = 10) • Bandwidth: feedback when score is less than 50 out of 100 points (n = 10) <u>The provided feedback</u> the instructor informed the child about the results in terms of the direction and distance from the target centre	Throw with beanbag at target on the floor[d]	1 practice session of 6 blocks of 10 trials (total 60 trials)	<u>Outcome</u> Accuracy: score varied from 0-100 based on zones around the target (higher is better)	During acquisition Retention: 24h	Anova analysis with post-hoc Tukey HSD tests • <u>During acquisition:</u> Significant main effect for blocks, accuracy increased during practice No significant main effect for groups • <u>Retention:</u> Significant main effect for groups Post-hoc testing: 100% > reduced feedback, SC and bandwidth*

Table 2.1 continued

Zamani et al., 2015	Children with DCD and MID, IQ range 50-70 (n = 24) 9-11[b] Inexperienced	RCT	<u>Groups</u> • Self-controlled + 75% frequency: KR on request in 75% of the trials (n = 6) • Self-controlled + 50% frequency: KR on request in half of the trials (n = 6) • Instructor-controlled + 75% frequency: KR when instructor wanted in 75% of the trials (n = 6) • Instructor-controlled + 50% frequency: KR when instructor wanted in half of the trials (n = 6) <u>The provided feedback</u> the instructor informed the child about the results in terms of the direction and distance from the target centre	Throw with tennis ball at target[f] (unclear whether target is placed on floor or wall)	8 practice sessions of 6 blocks of 10 trials, period not reported (total 240 trials)	<u>Outcome</u> Accuracy: score varied from 0-100 based on zones around the target (higher is better)	Pre-test During acquisition Post-test Retention: timing unclear	Significant paired sample t-tests for pre-test / post-test for all groups, all groups improved accuracy Anova analysis with post-hoc Tukey HSD tests • <u>Post-test:</u> No significant main effect for timing • <u>Retention:</u> Significant main effect for timing SC > IC**

Table 2.1 continued

Modality								
Tse & Masters, 2019	Children with ASD and MID, IQ range 50–70 (n = 48) 10.10 (2.0) Inexperienced	RCT	<u>Groups</u> • Instruction with visual analogy (n = 12) • Instruction with verbal analogy (n = 12) • Explicit instruction: with IF on arm or hand (n = 12) • Control: no specific instruction (n=12) <u>The provided instructions</u> • Visual analogy: an illustration of a child putting a cookie in a cookie jar on a high shelf • Verbal analogy: *"Shoot the ball as if you are trying to put cookies into a cookie jar on a high shelf"* • Explicit instruction: *"Move the ball upward and release the ball when your strong arm becomes*	Basketball free throw	1 practice session of 6 blocks of 15 trials (total 90 trials)	<u>Outcome</u> Accuracy: score varied from 0-5 based on zones around the target (higher is better) <u>Covariables</u> Age IQ WMI SRS-2	During acquisition Retention: 24h Transfer: 24h	Pearson correlation • Covariables were not correlated to accuracy score ANOVA analysis with post-hoc tests with Bonferroni correction • <u>During acquisition:</u> Significant main effect for blocks Post-hoc testing: the 3 instruction groups improved performance during practice, while the control group did not Significant main effect for group Post-hoc testing: visual analogy > control**, verbal analogy > control** and explicit > control** • <u>Retention:</u> Significant main effect for group Post-hoc testing: visual analogy > verbal analogy** 95% CI = [1.57,9.77], visual analogy > explicit** 95% CI = [1.07,9.27], visual analogy > control** 95% CI =

vertical"; "When releasing the ball, your strong hand is facing downwards"	[5.65,13.85], verbal analogy > control* 95% CI = [-0.02,8.18], explicit > control* 95% CI = [0.48,8.68] and verbal analogy = explicit (p = 0.74) 95%CI [-4.60,3.60] • <u>Transfer:</u> Significant main effect for group Post-hoc testing: visual analogy > verbal analogy** 95% CI = [2.50,9.00], visual analogy > explicit** 95% CI = [1.41,7.92], visual analogy > control** 95% CI = [5.91,12.42], verbal analogy > control* 95% CI = [0.16,6.67], explicit > control* 95% CI = [1.25,7.75] and verbal analogy = explicit (p = 0.39) 95%CI [-4.34,2.17]

*n = number; SD = standard deviation; h = hour(s); w = week(s); RCT = randomized controlled trial; CCT = controlled clinical trial; KR = knowledge of results; EF = external focus; IF = internal focus; MID = mild intellectual disabilities; IQ = intelligent quotient; CP = cerebral palsy; GMFCS = gross motor functioning classification system; TDC = typically developing children; ASD = autistic spectrum disorder; DCD = developmental coordination disorder; SC = self-controlled; IC = instructor-controlled; CI = confidence interval; IQ = intelligence quotient; WMI = Working Memory Index; SRS-2 = social responsiveness scale, 2nd ed.; [a] number per group not reported; [b] only age range was reported; [c] primary and secondary outcome not specified; [d] according to protocol Chiviacowsky 2008; [e] not reported which post-hoc test used; [f] same target as Chiviacowsky 2008; * $p < 0.05$; ** $p \leq 0.001$.*

The effectiveness of feedback with EF applied in **reduced frequency** compared to **continuous frequency** was investigated in eight studies[78–83,86,89], six of which included TDC[78–83]. The remaining studies included children with ASD[81] or CP[89]. The reduced frequency was applied in three fixed frequencies of 20%[86], 33%[79,80] and 50%[81–83,89], and one faded frequency decreasing from 100% to 0% with an average of 62%[78]. All studies assessed accuracy[78–83,86,89], with two also measuring variability[79,83], and one quality of movement[80]. Acquisition was assessed in all studies [78–83,86,89], while retention tests were used in seven[78–82,86,89], in which timing varied from 24 hours[78,80–82,86] to 1 week[79,86]. Only three studies measured transfer[79,80,83], in which timing varied from immediately after practice (0 hours)[79,80,83] to 1 week[79] (Table 2.1).

Effectiveness of **self-controlled feedback** compared to **instructor-controlled feedback** to improve accuracy in object control tasks was investigated in five studies[41,78,84,85,88]. TDC were included in two studies[41,78], while the others included children with DCD[88] or CP[84,85]. In four studies, the frequency of the self- and instructor-controlled feedback was the same[41,84,85,88], while in one frequencies were different, 30% in the self-controlled group and 100% in the instructor-controlled group[78]. All studies measured acquisition and retention[41,78,84,85,88]. In most studies, retention was measured after 24 hours[41,78,84,85], though in one the timing was unclear [88]. One-day transfer tests were used in two studies[84,85] (Table 2.1).

One study with children with ASD and MID investigated the effectiveness of **visual analogy** compared to **verbal analogy** for improving accuracy in basketball shooting on acquisition, retention (24 hours), and transfer (0 and 24 hours)[87] (Table 2.1).

2.3.4 Best-evidence synthesis

Regarding frequency of feedback (Hypothesis 1), three out of seven studies investigated the effectiveness of reduced fixed frequency in similar tasks[79,81,82]. However, one reported no summary statistics[79] and the other two had the same first author[81,82]. The remaining studies used non-comparable tasks[80,83,86,89]. Only one study examined the effectiveness of reduced faded frequency. As regards timing of feedback (Hypothesis 2), four out of five studies included similar tasks[41,78,84,88], but summary statistics were lacking in two of these[41,78]; the remainder included different populations[84,88], and only one investigated a visual modality of instruction (Hypothesis 3). Therefore, all studies were included in the best-evidence synthesis[41,78–89] (Table 2.2). Although each study described whether there were significant group differences, none mentioned thresholds for minimal clinically important differences[41,78–89].

The following paragraphs describe the results from the best-evidence synthesis for the parameters frequency, timing and modality. For frequency, results were reported for the outcomes accuracy, variability and quality of movement. Studies of timing and modality only assessed accuracy. For each parameter, results are ordered according to the following time points: 1. Acquisition measured during practice; 2. Acquisition measured with a post-test; 3. Retention; and 4. Transfer.

Table 2.2. *Best-evidence synthesis of instructions or feedback applied with a specific frequency, timing or modality*

Para-meter studied	Com-parison	Author	Task	Population	Evidence synthesis per study						Evidence synthesis summary			
					Acquisition		Retention		Transfer		Acquisition		Retention	Transfer
					During	Post	Timing	Effect	Timing	Effect	During	Post		
Accuracy														
Frequency	Reduced fixed vs continuous	Sidaway et al. 2012	Throw with beanbag	TDC	NS	NS	1w	NS	0h 1w	NS NS	X	X	X	-
		Zamani & Zarghami 2015	Throw with beanbag	TDC	C	NA	24h	R	NA	NA				
		Wulf et al. 2010	Throw with soccer ball	TDC	NA	NS	24h	NS	0h 24h	NS NS				
		De Oliveira et al. 2009	Throw with bocha ball	TDC	NS	NA	NA	NA	0h	NS				
		Zamani et al. 2015	Throw with beanbag	TDC	C	NA	24h	R	NA	NA				
			Throw with beanbag	Children with ASD	C	NA	24h	C	NA	NA				
		Hemayattalab & Rostami 2010	Dart throwing	Children with CP	NA	C	72h	R	NA	NA				
		Gillespie 2003[a]	Golf putting	Children with MID	C	NA	24h 1w	R R	NA	NA				
	Reduced faded vs continuous	Sabzi et al. 2012	Throw with beanbag	TDC	NS	NA	24h	C	NA	NA	-	NA	* C	NA

Table 2.2 continued

Timing	Self-controlled vs instructor-controlled (equal frequency in both groups)	Chiviacowsky et al. 2008	Throw with beanbag	TDC	NS	NA	24h	SC	NA	NA	X	-	** SC	X
		Hemayattalab et al. 2013	Throw with beanbag	Children with CP	NS	NA	24h	SC	24h	SC				
		Hemayattalab et al. 2014	Dart throwing	Children with CP	SC	NA	24h	NS	24h	NS				
		Zamani et al. 2015	Throw with tennis ball	Children with DCD and MID	NA	NS	NR	SC	NA	NA				
	Self-controlled 30% vs instructor-controlled 100% feedback	Sabzi et al. 2012	Throw with beanbag	TDC	NS	NA	24h	C	NA	NA	-	NA	* IC-100%	NA
Modality	Visual analogy vs verbal analogy	Tse & Masters 2019	Basketball free throw	Children with ASD and MID	NS	NA	24h	VisA	24h	VisA	-	NA	* VisA	* VisA

Table 2.2 continued

Variability														
Frequency	Reduced fixed vs continuous	Sidaway et al. 2012	Throw with beanbag	TDC	NS	NS	1w	NS	1w	NS	-	-	-	-
		De Oliveira et al. 2009	Throw with bocha ball	TDC	NS	NA	NA	NA	0h	NS				
Quality of movement														
Frequency	Reduced fixed vs continuous	Wulf et al. 2010	Throw with soccer ball	TDC	NA	NS	24h	NS	0h 24h	NS NS	NA	-	-	-

[a] = the groups did not improved performance during practice; h = hour(s); w = week(s); TDC = typically developing children; ASD = autistic spectrum disorder; CP = cerebral palsy; MID = mild intellectual disabilities; DCD = developmental coordination disorder; NA = not applicable; NR = not reported; C = significant, favouring continuous frequency; R = significant, favouring reduced frequency; SC = significant, favouring self-controlled feedback; IC-100% = significant, favouring instructor-controlled feedback after every trial; VisA = significant, favouring the visual analogy. Consistency was defined as 75% of the studies assessing the same comparison showing results in the same direction.

*Strength of the evidence according to the guidelines of van Tulder et al.: *** = Strong – consistent findings among multiple high quality RCTs; ** = Moderate – consistent findings among multiple low quality RCTs and/or CCTs and/or one high quality RCT; * = Limited – one low quality RCT and/or CCT; X = conflicting – inconsistent findings among multiple RCTs and/or CCTs; - = no evidence from trials – no RCTs or CCTs*

2.3.4.1 *Frequency*

The evidence whether reduced fixed frequency of feedback was more effective than continuous frequency (Hypothesis 1) in improving **accuracy** of object control tasks on acquisition was conflicting[79,80,82,83,86,89]. For *acquisition measured during practice*, continuous frequency appeared more effective in TDC[81,82] and in children with ASD[81] or MID[86]; however, two other studies with TDC found no significant group differences[79,83]. For *acquisition measured with a post-test*, the results of the studies varied with the population. No significant group differences were found in TDC[79,80], while continuous frequency appeared more effective in children with CP[89]. For *retention*, conflicting evidence was also found[79,80,82,83,86,89]: for TDC, two studies found no significant group differences[79,80], while two other studies indicated that reduced frequency was more effective[81,82]; for children with motor disabilities, results showed that children with CP[89] and MID[86] performed best with reduced frequency while children with ASD did best with continuous frequency[81]. For *transfer*, no evidence supported either frequency in TDC[79,80,83] (Table 2.2). Only one study compared reduced faded frequency to continuous frequency to improve **accuracy** in beanbag throwing in TDC[78]. For *acquisition measured during practice*, they found no significant group differences[78]. For *retention*, limited evidence was found favouring continuous frequency[78] (Table 2.2).

There was no evidence that reduced fixed or continuous frequency was more effective in reducing **variability** or improving **quality of movement** in throwing in TDC for *acquisition, retention and transfer*[79,80,83] (Table 2.2).

2.3.4.2 *Timing*

For **accuracy** in object control tasks, conflicting evidence was found on effectiveness of self-controlled versus instructor-controlled feedback (Hypothesis 2) with equal frequency for *acquisition measured during practice*[41,84,85]. Of the studies including children with CP[84,85], one showed that self-controlled timing was more effective[85], while another found no significant group differences[84]; no significant group differences were found in TDC[41]. Also, no significant group differences were found in children with DCD for *acquisition measured with a post-test*[88]. For *retention*, the self-controlled group performed best in three studies[41,84,88], including TDC[41], children with CP[84] and DCD[88]. A fourth study showed no significant group differences in children with CP[85], which resulted in only moderate evidence favouring self-controlled timing[41,84,85,88]. For *transfer*, the evidence was conflicting in children with CP: while one study showed that self-controlled timing was more effective, another found no significant group differences[84,85] (Table 2.2).

One study used different frequencies in the self- and instructor-controlled groups to improve **accuracy** in beanbag throwing in TDC[78]. For *acquisition measured during practice*, no evidence supported either timing. However, there was limited evidence that 100% instructor-controlled feedback was more effective than 30% self-controlled feedback for *retention*[78] (Table 2.2).

2.3.4.3 *Modality*

One study investigated the effectiveness of visual analogy compared to verbal analogy (Hypothesis 3) used to improve **accuracy** in basketball throwing in children with ASD and MID[87]. For *acquisition measured with a post-test*, no evidence supported either modality[87]. However, for *retention* limited evidence was found favouring a visual modality of instruction[87] (Table 2.2).

2.4 Discussion

The aim of this systematic review was to investigate the effectiveness of instructions and feedback with EF applied with reduced frequency, with self-controlled timing or in visual modality in the learning by (a)typically developing children of functional gross motor tasks. Although, the constrained action hypothesis suggested that an EF would be more effective, previous research investigating effectiveness of instructions or feedback with EF found conflicting results for children[23,36] and adults[43,90]. It was hypothesized that the frequency, timing and/or modality of instructions and feedback[20] influenced their effectiveness. The following paragraphs will discuss results by each hypothesis.

First, it was hypothesized that reduced frequency would be more effective than continuous frequency. However, the results of the best-evidence synthesis did not support this. For acquisition, conflicting evidence was found for accuracy, but studies found either no significant group differences[78–80,83] or significant differences favouring continuous frequency[81,82,86,89]. A possible reason why continuous frequency appeared more effective could be the short practice duration, as most studies included only one practice session[78–83,86] (Table 2.1). At the beginning of the learning process, feedback dependency is likely to be higher because more information (e.g. by means of more instructions and feedback) is needed to acquire new skills[12,34,91,92]. With inexperienced children, it is likely that some children remained in the early learning stage due to insufficient repetitions and, therefore, performed better with continuous frequency. In practical settings, children have longer training periods. Therefore, future studies adopting longer practice durations would be of more practical interest which will improve ecological validity as well. For retention, conflicting evidence was found for accuracy as well, however, four out of seven experiments found beneficial effects for reduced frequency[81,82,86,89] as expected[34]. From the remaining three studies, two found non-significant results[79,80]. For transfer, no evidence was found for accuracy[79,80,83]. However, these studies, also measuring variability and quality of movement, found non-significant results for acquisition and retention as well[79,80,83]. Only one study compared a faded reduced frequency to a continuous frequency in TDC using a one-day training protocol, resulting in limited evidence for continuous frequency for retention[78]. The interpretation of these results might be influenced due to methodological limitations, which will be elaborated later. This limited or conflicting evidence is in line with previous research. Systematic reviews investigating effectiveness of frequency of feedback to improve motor skills in TDC and children with CP found limited or contradicting evidence for children with CP[32,33]. They suggested that child characteristics and task complexity might moderate effectiveness, but foremost they recommended that more studies of methodologically sound quality including the investigation of relevant child characteristics are needed to draw conclusions[32,33]. For TDC, they concluded that reduced frequency might be more effective[33]. However, two studies investigating the effectiveness of reduced frequency in TDC and CP did not include a control group with a continuous frequency. Furthermore, the study that compared a continuous with a faded frequency found no differences between groups for TDC[33]. In summary, several individual studies in the best-evidence synthesis showed beneficial effects for reduced frequency for retention, and for continuous frequency for acquisition. However, overall results in this, and previous studies, were conflicting. Therefore, it was not possible to draw conclusions about the preferred frequency.

Secondly, it was hypothesized that self-controlled timing would be more effective than instructor-controlled timing. The results of the best-evidence synthesis confirmed this, with moderate evidence for retention when frequency of feedback was similar in both groups[41,84,85,88] (Table 2.2). On the contrary, when frequencies were dissimilar, the instructor-controlled group appeared more effective for retention[78]. This inconsistency may be due to the frequency of feedback, as the self-controlled group received less feedback than the instructor-controlled group during the one-day training protocol[78] (Table 2.1). For all other time points, either no or conflicting evidence was found. However, if results were conflicting, studies found either non-significant results or evidence favouring self-controlled timing as was expected by the Self-Determination Theory[41,84,85,88]. The non-significant results might be due to the low methodological quality of the included studies, which will be elaborated later. In this study, the yoked and instructor-controlled groups were combined as control. However, it can be argued that effectiveness can differ depending on the type of control group. Moreover, instructor-controlled feedback may be more supportive to the child than the yoked controlled feedback because of its timing; it is to be expected that the instructor estimates when the feedback would be most informative to the child, while in the yoked condition the moment of feedback is not related to the child's performances. It would be interesting to explore this assumption in future research. A systematic review investigating the effectiveness of autonomy support in children's functional skill motor learning yielded similar results[36]. It found that self-controlled feedback was more effective in several studies, but it was argued that child characteristics, like trait anxiety, cognitive skills and age, may have influenced effectiveness[36]. In the best-evidence synthesis, three out of four studies with equal frequency of feedback in both groups included children with either CP[84,85] or DCD[88]. These children are characterized by cognitive deficits, which might influence their abilities for autonomous functioning[6,37,93]. These characteristics, in addition to the methodological limitations, might explain why results are not as consistent as expected[37]. Although more evidence is needed to draw conclusions for all time points, the results from the best-evidence synthesis, supported by previous research, suggests that instructors should consider using self-controlled timing in children's motor learning.

Finally, it was hypothesized that children learnt functional gross motor skills best with a visual modality of instructions and feedback compared to a verbal modality. However, only one study investigated this specific comparison[87]. Post-hoc comparisons showed that children with ASD threw more accurately after a visual analogy[87]. Similar results were found in studies with healthy young adults and young adults with Down syndrome, where skill performance improved more after video[94,95] or instructor demonstration[96] than with verbal instructions with EF. Although evidence is limited, instructors might consider using pictures, videos or real live demonstrations as instructions or feedback to teach children motor skills.

This was the first study to systematically investigate the modifying role of frequency, timing and modality in instructions and feedback with EF on children's motor learning. A strength of this study was that it followed a registered protocol, comprising a selection process and RoB assessment performed by two reviewers independently, with an epidemiologist (CB) to be consulted in cases of disagreement. Furthermore, RoB was assessed by means of reference standards (the Cochrane RoB tools) and findings were analysed according to a prespecified plan. There was no need to contact authors of included studies for further details. There is a small possibility that we interpreted reported information slightly different than meant by the authors. This study included functional tasks which improved the ecological validity of this study.

Providing recommendations for instructors about the frequency, timing and modality of instructions and feedback with EF appeared challenging for three particular reasons. Firstly, drawing evidence-based conclusions was difficult because of the poor methodological quality of the studies[41,78–88] (Figure 2.2). In particular, blinding of outcome assessors, analysing according to ITT, and handling missing data properly require attention in future studies[97,98]. Furthermore, authors should report methods and results in more detail, essential for adequately determining the RoB[97,98]. It is possible that methodological quality appeared lower due to insufficient reporting of details. Additionally, the generally small sample sizes and the lack of reported thresholds of clinically meaningful differences also hindered interpretation. Inadequate sample sizes increase the risk of finding non-significant results or contrary conclusions with similar studies[99,100]. This might have influenced the number of non-significant results found in individual studies and, more specifically, the lack of evidence or the conflicting evidence in the best-evidence synthesis (Table 2.2)[99,101]. In particular, the results of the post-hoc comparisons should be interpreted cautiously[99]. Although some studies found significant differences, it remains unclear whether these differences are large enough to be relevant in practical settings[102,103]. More methodologically sound studies based on proper sample size calculations are needed to draw conclusions regarding the preferred frequency, timing and modality of instructions and feedback.

Secondly, it is suggested that child and task characteristic may moderate effectiveness[23,36]. However, more research is necessary to gain insights into which characteristics are relevant, and their moderating role. Accordingly, it was not possible to perform sub analyses in the best-evidence synthesis. For instructors, it is not only important to know how to shape their instructions and feedback, but also how to adapt their instructions and feedback to child and task[17,104]. Therefore, performing sub analyses on all potentially relevant variables such as typical/atypical development, age, cognitive or motivational factors, would be recommended for future research when more methodologically sound studies are available, including relevant data to make sub groups properly.

Thirdly, generalizability of the results was hampered because all included studies used object control tasks with inexperienced children, and measured accuracy. This overrepresentation of tasks, skill level and outcome is in line with previous research[23,36]. In therapy, PE classes and sports, children learn various tasks with different levels of complexity[105] and, depending the child's needs, instructors teach new tasks to novice children or optimize existing skills in experienced or trained children[8,106,107]. The *challenge point framework* conceptualizes the amount and specificity of information needed to learn skills, based on the level of task complexity, the skill level of the individual, and the interaction of level of complexity with skill level[91]. This framework, and other studies, suggest that instructors should adapt frequency, timing and modality of instructions and feedback to the individual and the task[17,23,36,91,104]. Child characteristics as skill level, cognitive functioning, motivation, and the presence of a diagnose are considered relevant[17,23,36,104]. However, more research is necessary to gain a better understanding of their moderating role. Therefore, future research should attempt to include a wider variety of tasks and/or child characteristics in their studies. This will improve ecological validity and generalizability of the studies as well. In order to guarantee comparability of studies, a framework that classifies tasks based on their characteristics could be helpful. Future research should give attention to developing such a framework. Potentially relevant characteristics are the number of degrees of freedom, cognitive demands, sequence of movement structure, spatial and temporal demands, and the context of tasks[2,47,92]. As for outcome, few studies assessed variability[79,83] or quality of movement[80], as well as accuracy. In practical settings, instructors often focus on improving functionality instead of normality[8,106,107]. From that point of view, accuracy is a relevant outcome, because it focuses on the result of the performance instead of on the optimal movement pattern. However, instructors can target various improvements, depending on the child's need. Therefore, for better ecological validity, more result-related outcomes (e.g. variability, number of successful attempts and distance) and movement pattern-related outcomes (e.g. quality of movement and kinematic variables) should be considered in future studies. Irrespective of the chosen outcome, researchers should use valid, reliable and responsive outcome measures.

2.5 Conclusion

Based on the results of this systematic review, instructors should consider using self-controlled feedback with EF to enhance children's motor learning (moderate evidence). Regarding a specific frequency or modality, no conclusions can be drawn yet. However, based on limited evidence, instructors could consider using visual instructions. Because specific child and task characteristics can also moderate the effectiveness of instructions and feedback[23,36,91], instructors should explore the optimal frequency, timing and modality for each child until more research provides us with a better understanding of their moderating role. Future research should put effort into developing a framework that classifies tasks based on their characteristics. Furthermore, it should aim to advance insights into the modifying role of frequency, timing and modality in instructions and feedback with EF with methodologically sound studies focusing on: 1. a variety of tasks; 2. populations with different skill levels, age ranges, and diagnoses; 3. various outcome measures; and 4. with longer practice duration.

2.6 References

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2.7 Appendix 2.1: Search queries for the individual databases

2.7.1 PubMed

(("motor learning"[TIAB] OR "procedural learning"[TIAB] OR "declarative learning"[TIAB]) AND (instruction[TIAB] OR instructions[TIAB] OR "internal focus"[TIAB] OR "external focus"[TIAB] OR "focus of attention"[TIAB] OR feedback[TIAB] OR feedback[Mesh] OR "Knowledge of Results (Psychology)"[Mesh]OR "knowledge of results"[TIAB] OR "knowledge of performance"[TIAB] OR "external feedback"[TIAB] OR "learning strategies"[TIAB] OR "learning strategy"[TIAB] OR analogy[TIAB] OR analogies[TIAB] OR "dual task"[TIAB] OR "observational learning"[TIAB] OR observational[TIAB] OR "motor imagery"[TIAB] OR "errorless learning"[TIAB] OR errorless[TIAB] OR "trial and error"[TIAB] OR "guided discovery"[TIAB] OR "differential learning"[TIAB] OR "action observation"[TIAB] OR "practice conditions"[TIAB] OR "random practice"[TIAB] OR "blocked practice"[TIAB] OR "variable practice"[TIAB] OR "repetitive practice"[TIAB] OR "whole practice"[TIAB] OR "part practice"[TIAB] OR "practice schedule"[TIAB] OR "self-controlled practice"[TIAB]))

2.7.2 Web of Science

TS=(("motor learning" OR "procedural learning" OR "declarative learning") AND (instruction OR instructions OR "internal focus" OR "external focus" OR "focus of attention" OR feedback OR "knowledge of results" OR "knowledge of performance" OR "external feedback" OR "learning strategies" OR "learning strategy" OR analogy OR analogies OR "dual task" OR "observational learning" OR observational OR "motor imagery" OR "errorless learning" OR errorless OR "trial and error" OR "guided discovery” OR "differential learning" OR "action observation" OR "practice conditions" OR "random practice" OR "blocked practice" OR "variable practice" OR "repetitive practice" OR "whole practice” OR "part practice" OR "practice schedule" OR "self-controlled practice"))

2.7.3 Scopus

TITLE-ABS-KEY (({motor learning} OR {procedural learning} OR {declarative learning}) AND (instruction OR instructions OR {internal focus} OR {external focus} OR {focus of attention} OR feedback OR {knowledge of results} OR {knowledge of performance} OR {external feedback} OR {learning strategies} OR {learning strategy} OR analogy OR analogies OR {dual task} OR {observational learning} OR observational OR {motor imagery} OR {errorless learning} OR errorless OR {trial and error} OR {guided discovery} OR {differential learning} OR {action observation} OR {practice conditions} OR {random practice} OR {blocked practice} OR {variable practice} OR {repetitive practice} OR {whole practice} OR {part practice} OR {practice schedule} OR {self-controlled practice}))

2.7.4 Embase

('motor learning'.ti,ab,kw. or exp motor learning/ or 'declarative learning'.ti,ab,kw. or 'procedural learning'.ti,ab,kw.) and (instruction or instructions or 'internal focus' or 'external focus' or 'focus of attention' or feedback or 'knowledge of results' or knowledge of performance' or 'external feedback' or 'learning strategies' or 'learning strategy' or analogy or analogies or 'dual task' or 'observational learning' or observational or 'motor imagery' or 'errorless learning' or errorless or "trial and error" or 'guided discovery' or 'differential learning' or 'action observation' or 'practice conditions' or 'random practice' or 'blocked practice' or 'variable practice' or 'repetitive practice' or 'practice schedule' or 'self-controlled practice' or 'whole practice' or 'part practice).ti,ab,kw.

2.8 Appendix 2.2: Excluded studies that nearly met inclusion criteria

2.8.1 Excluded because the instructions or feedback with an external focus were compared to instructions or feedback with an internal focus and/or no instructions or feedback

- Bahmani M, Babak M, Land WM, Howard JT, Diekfuss JA, Abdollahipour R. Children's motor imagery modality dominance modulates the role of attentional focus in motor skill learning. Hum Mov Sci. 2021;75: 102742.

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2.8.2 Excluded because the instructions or feedback were applied with reduced frequency, but with an internal focus

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Chapter 3

Experts' perspectives on how to promote implicit and explicit motor learning in children: a mixed-methods study

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Abstract

Background: Little is known about how motor learning strategies (MLSs) can promote implicit and explicit motor learning processes. This study aimed to explore experts' perspectives on therapists' use of MLSs to promote specific learning processes in children with and without developmental coordination disorder (DCD).

Methods: In this mixed-methods study, two consecutive digital questionnaires were used to ascertain the opinions of international experts. Questionnaire 2 explored the findings of Questionnaire 1 in greater depth. In order to reach a certain level of agreement about the classification of MLSs as promoting either (more) implicit or (more) explicit motor learning, 5-point Likert scales were used in addition to open-ended questions. The open-ended questions were analysed with a conventional analysis approach. Open coding was performed by two reviewers independently. Categories and themes were discussed within the research team, taking both questionnaires as one dataset.

Results: Twenty-nine experts from nine different countries with different backgrounds in research, education and/or clinical care completed the questionnaires. The results of the Likert scales showed large variation. Two themes emerged from the qualitative analyses: (1) experts found it difficult to *classify motor learning strategies* as promoting either implicit or explicit motor learning, and (2) experts stressed the *need for clinical decision making* when choosing MLSs.

Conclusion: Insufficient insight was gained into how MLSs could promote (more) implicit or (more) explicit motor learning in children in general, and in children with DCD specifically. But this study demonstrated the importance of clinical decision making to model and adapt MLSs to child, task and environment, with therapists' knowledge of MLSs being an important prerequisite. Research is needed to better understand the various learning mechanisms of children, and how MLSs can be used to manipulate these mechanisms.

Key words: implicit motor learning; explicit motor learning; instructions; feedback; clinical decision making; children; mixed-methods study.

Key messages

1. Insufficient insight exists about how motor learning strategies (MLSs) can be used to promote (more) implicit or (more) explicit motor learning in children.

2. This study exposed relevant knowledge gaps about: the constructs of implicit and explicit motor learning, the learning processes in children, and how these processes can be activated with specific MLSs.

3. The process of clinical decision making requires: knowledge about modelling and adapting MLSs, analysis to determine which MLS to use, and evaluation of the impact of the MLSs used on a child's performance of a motor task.

4. Experts suggested various child and task characteristics that might guide clinical decision making in children's motor learning, more research is needed to gain insight into how these characteristics should guide clinical decisions.

3.1 Introduction

Typically developing children acquire motor skills almost effortlessly by participating in home, school, and sports activities[1,2]. However, atypically developing children frequently need guidance by physical and/or occupational therapists to acquire motor tasks. A specific population having mild-to-severe problems in learning motor skills are children with developmental coordination disorder (DCD)[3]. As a consequence of their compromised motor abilities, these children are hampered in their participation in activities of daily life, and experience various social, emotional and psychological problems[4–6].

Children can learn motor skills implicitly or explicitly; see Table 3.1 for descriptions of implicit and explicit motor learning. By using specific motor learning strategies (MLSs), therapists intend to promote either (more) implicit or (more) explicit motor learning[7–9]. MLSs can be described as observable therapeutic actions, adapted to child and task, intended to advance motor learning, which should be the result of clinical decision making[10]. They can be categorized into: instructions, feedback, and organization of practice[7,11]. *Instructions* and *feedback* can enhance a child's motivation or give a child specific information about the task performance[12,13]. They are modelled by their focus of attention (e.g. external/internal focus), modality (e.g. visual or verbal), frequency, timing (e.g. therapist- or child-controlled), and information content (the amount of information in one instruction or feedback)[10]. Examples of MLSs that fit the category *organization of practice* are: scaling equipment, random or blocked practice, constant or variable practice, and part or whole practice (Table 3.1)[7,11].

When deciding which MLSs to use, therapists have to consider characteristics of child, task and environment[10,14]. Three think-aloud studies investigating physical therapists (PTs)' clinical decision-making processes in video-taped treatment sessions of children with cerebral palsy (CP), and adults with acquired brain injury (ABI) showed that therapists' actions resulted from their knowledge, observations and assessments[15–17]. Thus, knowledge about how to use various MLSs to promote implicit and explicit motor learning in children is an important requirement. However, scientific knowledge about this topic is limited.

In paediatric research, only three strategies that are expected to promote implicit motor learning have been studied: external focus learning, analogy learning, and errorless learning (Table 3.1)[9]. A fourth strategy also considered to promote implicit motor learning is dual-task learning (Table 3.1) but this has only been studied in adult populations[18]. In both studies, internal focus learning and error-strewn learning (Table 3.1) were used for the explicit motor learning groups[9,18]. According to the constrained action hypothesis, an internal focus promotes explicit motor learning because the attention for body movements requires larger involvement of cognitive processes due to greater reliance on conscious control processes, which interfere with normal automatic control processes. An external focus does not interfere with these automatic control processes, therefore, promoting implicit motor learning[19]. Analogy learning promotes implicit motor learning because a metaphor relies little on the manipulation of explicit information which reduces the involvement of cognitive processes and working memory[20]. Dual-task learning promotes implicit motor learning because the short-memory capacity cannot be used for explicit information of the primary task, as it is already used for the secondary task[21]. Errorless learning promotes implicit motor learning because the reduction of errors diminishes the need to consciously correct movement which reduces the involvement of cognitive processes and working memory. Whereas error-strewn learning promotes explicit motor learning because the errors increase the need to consciously correct movement[22]. An international expert panel with backgrounds in clinical care, education and research in motor learning also categorized errorless learning, analogy learning and dual-task learning as promoting implicit motor learning. However, in this Delphi study that intended to reach consensus about the classification of seven well-known learning strategies as promoting either (more) implicit or (more) explicit motor learning, no consensus was reached for trial-and-error learning, observational learning, movement imagery, and discovery learning (Table 3.1)[23]. In a second study, the authors asked a selection of international experts in their Delphi study how other MLSs could be used to promote implicit and explicit motor learning: answers were widely distributed and no consensus was reached[7]. Thus, for the majority of MLSs used in (paediatric) clinical care, it remains unclear whether they promote implicit or explicit motor learning.

Because previous studies merely reported the results of Likert scales[7,23], this study used a mixed-methods design with qualitative analyses in addition to Likert scales to advance the understanding of the findings. Furthermore, previous studies included experts in adult neurorehabilitation[7,23]. It was expected that experts in children's motor learning have different experiences and perspectives than experts in neurorehabilitation as: children and adults learn differently based on capacities to store and cognitively process information[24], and children frequently learn new motor tasks while adults mainly re-learn motor tasks. In order to gain a better understanding of how therapists can use MLSs to promote implicit and explicit motor learning in paediatric care, our study explored experts' perspectives on these. An international expert panel, with different backgrounds in clinical, educational and research aspects of motor learning in children with and without DCD, completed two questionnaires to share their opinions on how instructions, feedback and organization of practice could be used to promote specific types of motor learning processes in children, and in children with DCD specifically.

Table 3.1. *Descriptions of motor learning terminology commonly used in literature*

Term	**Description**
Types of motor learning processes	
Explicit and implicit motor learning[23]	Explicit motor learning processes involve cognitive stages, with involvement of working memory, generating verbal knowledge about the movements performed. Implicit motor learning processes progress without awareness, generating no or minimal verbal knowledge about the movements performed.
	Instructions and feedback
Analogy learning[20]	The learner is provided with an analogy (metaphor) that integrates the complex structure of the to-be-learned task.

Table 3.1 continued

Internal and external focus learning[19,25]	Internal focus learning: while learning, the learner's attention is directed to its own body movements. External focus learning: while learning, the learner's attention is directed to the impact of the movement on the environment.
Observational learning[23,26]	The learner observes a model performing a motor task, which provides the learner with a cognitive model of the key spatial and/or temporal features of the movement performance.
Organization of practice	
Dual-task learning[21]	A secondary (mostly cognitive) task is used to draw the learner's attention away from the primary task to-be-learned.
Errorless learning or error-strewn learning[22]	Errorless learning: a practice situation is arranged is such way that the learner makes no or few outcome errors. Error-strewn learning: a practice situation is arranged in such way that the learner makes more outcome errors.
Discovery learning[23]	Learning without guidance or feedback from another person.
Guided discovery[27]	The learner is guided to the correct movement response with a sequence of questions
Movement/motor imagery[23,28]	The learner mentally executes the motor task without physically performing the movements.
Random or blocked practice[29]	Random practice: motor tasks are practiced in a random order. Blocked practice: the same motor task is practiced in a blocked order, without alternation with other motor tasks.
Trial-and-error learning[30]	The learner performs a motor task repeatedly and optimizes its performance with intrinsic and extrinsic feedback on its errors.
Variable and constant practice[31]	Variable practice: a motor task is practiced with increased variation in spatial and temporal parameters. Constant practice: a motor task is practiced repetitively without variation in spatial and temporal parameters
Whole and part practice[32]	Whole practice: a motor task is practiced in its entirety. Part practice: a motor task is broken down into smaller units, and these units are practiced individually.

3.2 Methods

3.2.1 Design

In this mixed-methods study, opinions of international experts about the use of MLSs to teach motor tasks to children implicitly or explicitly were explored with two consecutive questionnaires, the second deepening the findings of the first one. This study intended to reach a certain level of agreement between experts, but because previous studies showed that this was challenging, a qualitative analyses of open-ended questions was included to advance the understanding of the findings[7,23,33]. This study was approved by the Medical Ethical Review Board of Maastricht University (2019-1342). All experts gave written consent for participation after receiving written information.

3.2.2 Participants

Ideally, experts met two of the following three criteria: (1) having performed scientific research on motor learning in children; (2) having given education on teaching motor skills to children; and (3) having more than 5 years of clinical experience as a caregiver in teaching motor skills to children.

3.2.3 Procedure

3.2.3.1 *Recruitment*

To obtain a wide range of expert perspectives on how therapists can model and adapt implicit and explicit motor learning, it was important to include a heterogeneous sample of experts[34]. Therefore, following criteria were applied in the recruitment: (1) experts from different practical areas in which motor learning approaches are used (e.g. rehabilitation and physical education); (2) experts with greater theoretical and clinical expertise in different types of child development, both typical and atypical; and (3) experts from various countries, to allow for cross-cultural differences. Experts were recruited from the board of the International Society for Research in DCD consisting of anchors of 15 different countries. Furthermore, experts were recruited in the professional network of the authors, comprising experts from the areas of rehabilitation and physical education. All experts received an information letter and consent form, and were invited to recommend other experts in their networks or to forward the information letter themselves. This snowball sampling strategy was used to increase the heterogeneity of the sample, and to gain access to a large number of relevant experts[34].

3.2.3.2 *Questionnaires*

The questionnaires were developed by the research team (IvdV, ER, CB, KK), with the support of two students from the postgraduate Master Pediatric Physical Therapy. The students already worked as PTs with atypically developing children, they both had clinical expertise in teaching motor task. The research team had

clinical, educational, and research expertise with motor learning in various types of children, including children with DCD, and methodological expertise in qualitative research. Because of the different nationalities of the experts, English and Dutch questionnaires were used. Questionnaire 1 used open-ended questions to explore experts' opinions on: (1) how MLSs could be used to enhance implicit and explicit motor learning in children in general; (2) whether the suggested MLSs were applicable in children with DCD; and (3) which of the suggested MLSs should be preferred in these children. Questionnaire 2 was accompanied with a summary of the results of Questionnaire 1 and deepened the findings from this, using open-ended and structured questions (Table 3.2). See Appendix 3.1 for the questions of both questionnaires.

Two Dutch experts, meeting all three inclusion criteria, pilot-tested Questionnaire 1 to assess: meaning and relevance of content; the preference for reformulating questions; and feasibility of the software used to send and complete the questionnaires[34]. The English version of this questionnaire was edited by an English translator. For Questionnaire 2, meaning and relevance of the content including preference for reformulating questions was discussed within the research team.

Table 3.2. *Topics and types of question in the questionnaires*

Questionnaire 1		
Topic	**Sub-topic**	**Type of question**
Implicit and explicit motor learning	a) Description of implicit and explicit motor learning b) Preferred type of motor learning in children with DCD	Open-ended
Specific learning strategies (e.g. analogy learning, errorless learning, trial-and-error)	a) Strategies that promote implicit and explicit motor learning in children b) Applicability of the suggested strategies to children with DCD c) Preferred strategies in children with DCD	Open-ended
Instructions	a) Instructions that promote implicit and explicit motor learning in children b) Applicability of the suggested instructions to children with DCD c) Preferred instructions for children with DCD	Open-ended
Feedback	a) Feedback that promotes implicit and explicit motor learning in children b) Applicability of the suggested feedback to children with DCD c) Preferred feedback for children with DCD	Open-ended
Organization of practice	a) Practice conditions that promote implicit and explicit motor learning in children b) Applicability of the suggested practice conditions to children with DCD c) Preferred practice conditions for children with DCD	Open-ended
Questionnaire 2		
Topic	**Sub-topic**	**Type of question**
Implicit and explicit motor learning	a) Characteristics of implicit and explicit motor learning	5-point Likert scale

Table 3.2 continued

Specific learning strategies (e.g. analogy learning, errorless learning, trial-and-error)	a) Classification of the suggested (in Questionnaire 1) characteristics of specific learning strategies as promoting either (more) implicit or (more) explicit motor learning	5-point Likert scale
Instructions	a) Classification of the suggested (in Questionnaire 1) instructions as promoting either (more) implicit or (more) explicit motor learning	5-point Likert scale
Feedback	a) Classification of the suggested (in Questionnaire 1) feedback as promoting either (more) implicit or (more) explicit motor learning b) Generic feedback	a) 5-point Likert scale b) Open-ended
Organization of practice	a) Classification of the suggested (in Questionnaire 1) practice conditions as promoting either (more) implicit or (more) explicit motor learning b) Preference for random, blocked, or variable practice given the specific child characteristics suggested in Questionnaire 1 c) Other child or task characteristics that might guide the choice of random, blocked, or variable practice	a) 5-point Likert scale b) Multiple choice c) Open-ended
Child characteristics	a) Preference of implicit or explicit motor learning given the specific child characteristics suggested in Questionnaire 1 b) Other child characteristics that might guide the choice of implicit or explicit motor learning	a) 5-point Likert scale b) Open-ended
Task characteristics	a) Task characteristics that might guide the choice of implicit or explicit motor learning	Open-ended
Environmental characteristics	a) Environmental characteristics that promote either implicit or explicit motor learning b) Environmental characteristics that hinder either implicit or explicit motor learning	Open-ended

DCD = developmental coordination disorder

3.2.4 Data collection

Questionnaires were sent and completed electronically, using Qualtrics software (Qualtrics, Provo, UT, USA. https:/www.qualtrics.com). Up to three reminders were sent for each questionnaire to increase response rates.

Each expert received an unique code, with only one researcher (IvdV) having access to the key. To guarantee experts' privacy, all identifying information was removed from the files shared for data analyses. Data were stored separately from the key on the password-secured server of Hasselt University.

3.2.5 Data analyses

Demographic characteristics of experts (age, sex, country of work, work setting, and category of caregiver) were reported in frequencies.

The 5-point Likert scales were analysed by calculating frequencies and percentages. They were visualized in stack bar charts.

The open-ended questions were analyzed using ATLAS.ti Windows (version 8) (ATLAS.ti Scientific Software Development GmbH. https://atlasti.com). Analyses followed a conventional content analysis approach with three consecutive steps[35]: (1) open coding of the data using an inductive strategy (i.e. coding without predefined codes); (2) sorting open codes into categories; and (3) identifying themes by organizing and grouping categories into meaningful clusters[35,36]. During the analyses, memos were written with first impressions and thoughts[36]. The themes with associated categories were represented in a figure, and quotes were included in the text to support the themes and categories. The data was open coded independently by the two master's students, whom each received 15 hours of education to acquire analysing skills and to standardize analysis procedures. This education included: reading literature about analysing qualitative data and motor learning; and analysing two completed questionnaires with open-ended questions from another study investigating experts' perspectives on motor learning, on which they received extensive feedback. The first author (IvdV) reviewed and discussed the open codes with the students in multiple meetings until consensus was reached. In case of disagreement, another researcher (ER) was consulted. Multiple meetings were organized with the research team (IvdV, ER, CB, KK) to categorize the open codes and to identify themes. Although Questionnaire 1 was analysed separately to prepare the content of Questionnaire 2, for defining the final themes, data from both questionnaires were taken together.

3.3 Results

3.3.1 Process of recruitment and data collection

A total of 79 experts were invited to participate in this study, of whom 29 assented. Reasons for declining invitations were lack of time or not considering oneself an expert. The data from Questionnaire 1 were collected in January and February 2020, all experts receiving Questionnaire 1 having completed it. The data from Questionnaire 2 were collected from March to June 2020, with two experts not responding (Figure 3.1).

In Questionnaire 1, experts were asked how they would use MLSs to promote implicit and explicit motor learning. Results showed a large variation in suggested use of MLSs. Furthermore, some experts suggested specific MLSs as promoting implicit motor learning, while others suggested the same ones as promoting explicit motor learning. Questionnaire 2 aimed to reduce this variation by asking experts to classify all suggested MLSs on a 5-point Likert scale: implicit motor learning / more implicit than explicit motor learning / equally implicit and explicit motor learning / more explicit than implicit motor learning / explicit motor learning. Because experts frequently stated (in Questionnaire 1) that child, task and environmental factors should guide the choice of MLSs, this topic was comprehensively explored in Questionnaire 2 (Table 3.1). The results of Questionnaire 2 showed that variation in classification remained large. Qualitative analyses showed various reasons for this variation (Theme 1). We decided not to use a third questionnaire to deepen the findings furtherly, because it was expected that it would not have provided additional insights into how MLSs could promote either (more) implicit or (more) explicit motor learning.

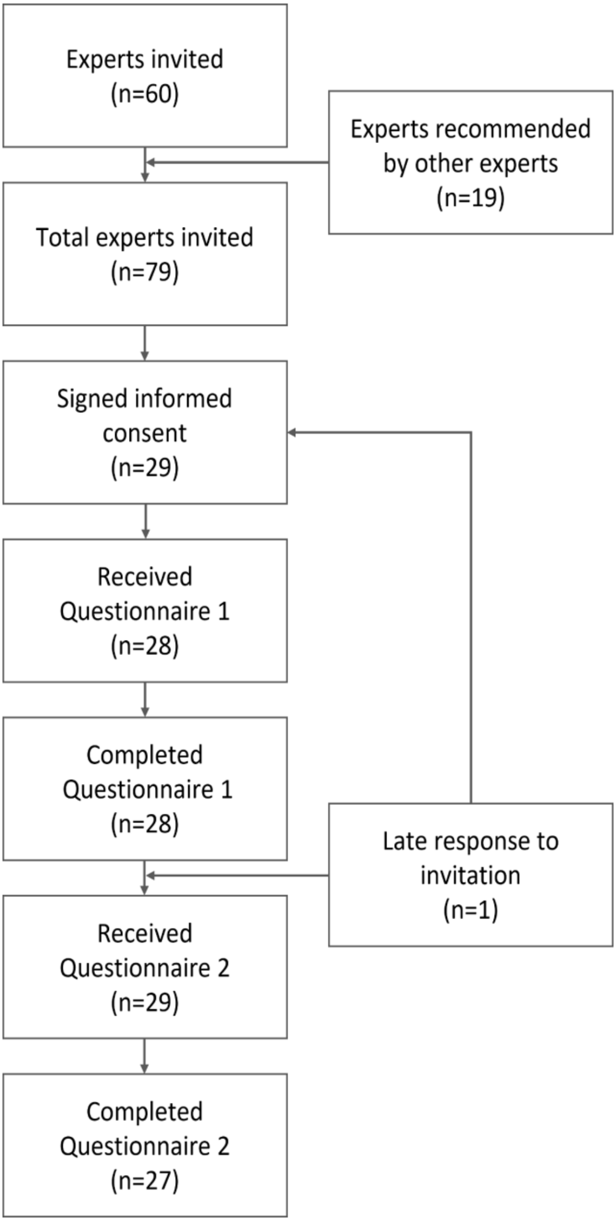

Figure 3.1. *Flow diagram of the recruitment and data collection*

n = number

3.3.2 Participants

A panel of 29 experts, working in nine different countries, having different backgrounds in work setting, participated in this study (Table 3.3). Twelve experts met all three inclusion criteria, 14 met two criteria, and three met only one.

Table 3.3. *Demographic characteristics of the expert panel*

Category	Subcategory	Absolute number
Age	30-39 years	6
	40-49 years	5
	50-59 years	14
	60-69 years	4
Sex	Male	9
	Female	20
Working country	Australia	3
	Belgium	8
	Canada	1
	Italy	1
	the Netherlands	9
	Spain	1
	Sweden	1
	United Kingdom	4
	USA	1
Number of experts that met following inclusion criteria	Caregiver/Educator/Researcher	12
	Caregiver/Educator	6
	Caregiver/Researcher	3
	Educator/Researcher	5
	Caregiver	1
	Educator	0
	Researcher	2
Types of caregiver	PPT	8
	OT	5
	PPT + OT	1
	Exercise therapist	2
	PE-teacher	1
	PPT + PE-teacher	2
	Rehabilitation physician	1
	Psychologist	2

PPT = paediatric physical therapist; OT = occupational therapist; PE = physical education

3.3.3 Findings of the 5-point Likert scales

Although, Questionnaire 2 attempted to reduce variation in classification by using 5-point Likert scales, extensive variation still remained (Figures 3.2a-c). For **instructions and feedback with result-oriented focus** (= external focus), the distribution of classification varied widely. However, for most **instructions and feedback with body-oriented focus** (= internal focus), and **focus on the sequence of steps**, the majority of experts (≥ 70%) classified them as promoting more explicit motor learning. Using minimal feedback promoted implicit motor learning, according to 77% of the experts.

For almost all MLSs within the category 'organization of practice', the distribution varied; with the classification 'promotes equally implicit and explicit motor learning' being scored most frequently.

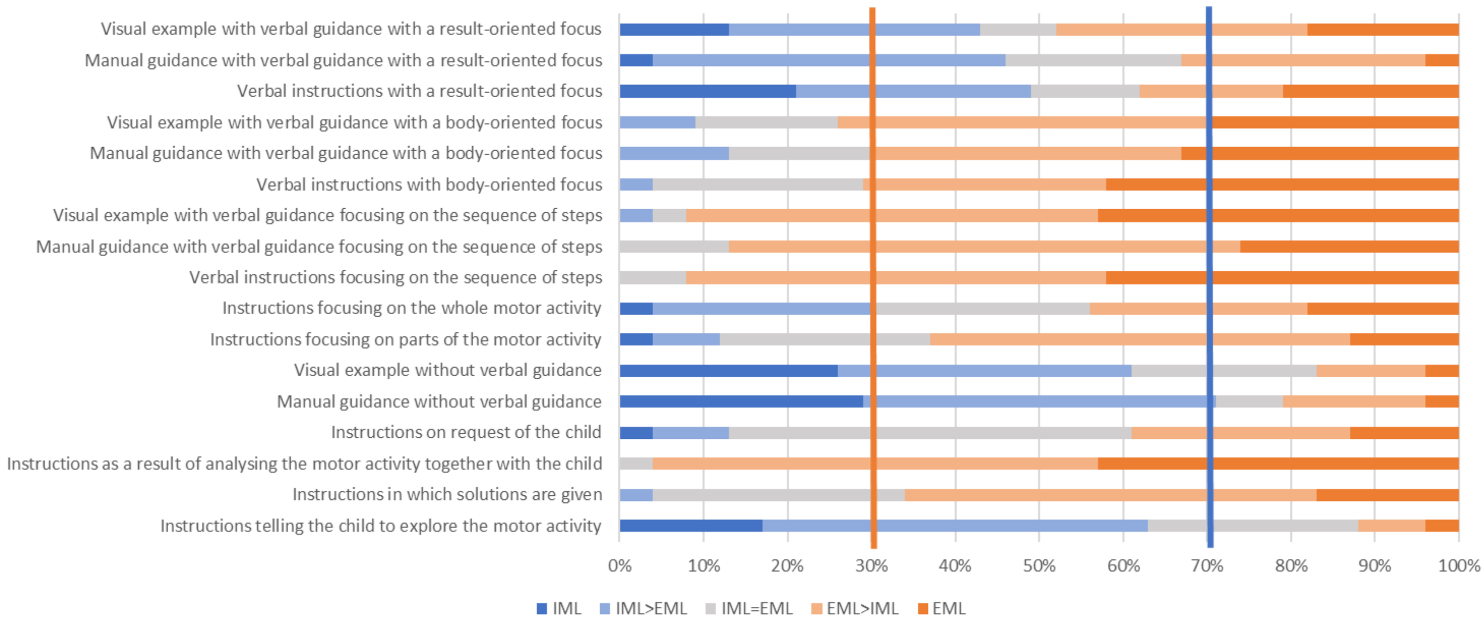

Figure 3.2a. *Motor learning strategies within the category instructions*

IML = promotes implicit motor learning; IML>EML = promotes rather implicit than explicit motor learning; IML=EML = promotes both implicit and explicit motor learning; EML>IML = promotes rather explicit than implicit motor learning; EML = promotes explicit motor learning; blue vertical line = 70% of the experts scored that it promotes more implicit motor learning; orange vertical line = 70% of the experts scored that it promotes more explicit motor learning.

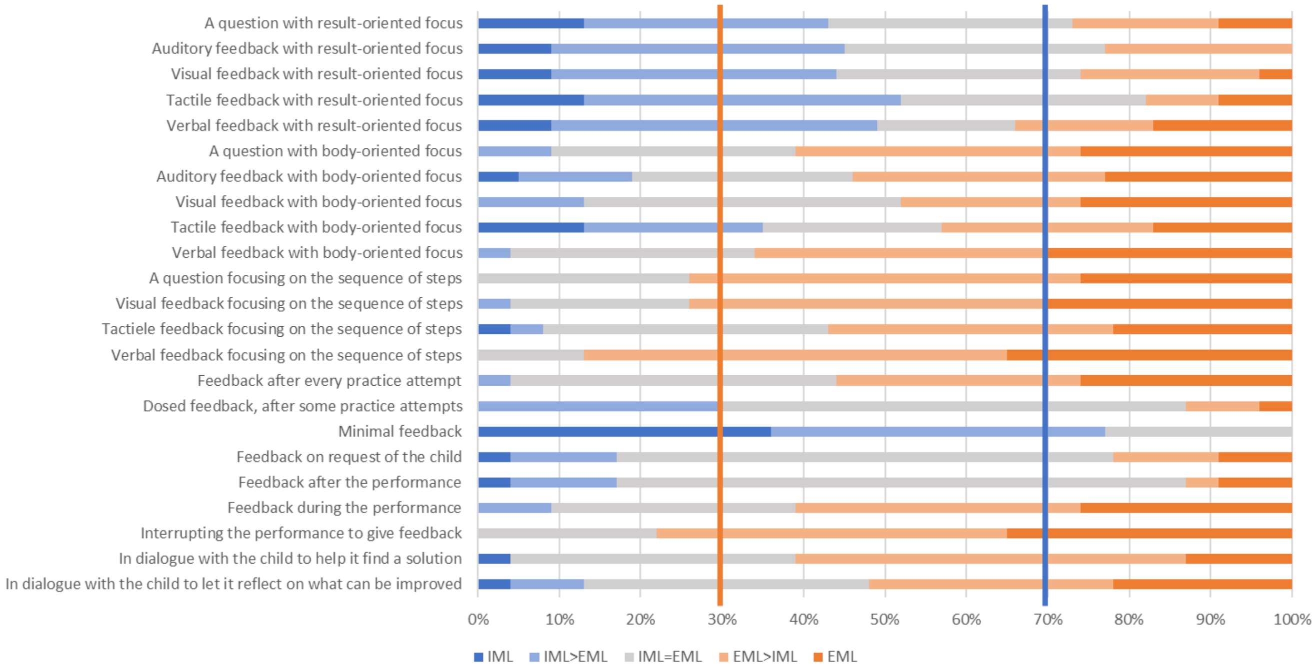

Figure 3.2b. *Motor learning strategies within the category feedback*

IML = promotes implicit motor learning; IML>EML = promotes rather implicit than explicit motor learning; IML=EML = promotes both implicit and explicit motor learning; EML>IML = promotes rather explicit than implicit motor learning; EML = promotes explicit motor learning; blue vertical line = 70% of the experts scored that it promotes more implicit motor learning; orange vertical line = 70% of the experts scored that it promotes more explicit motor learning.

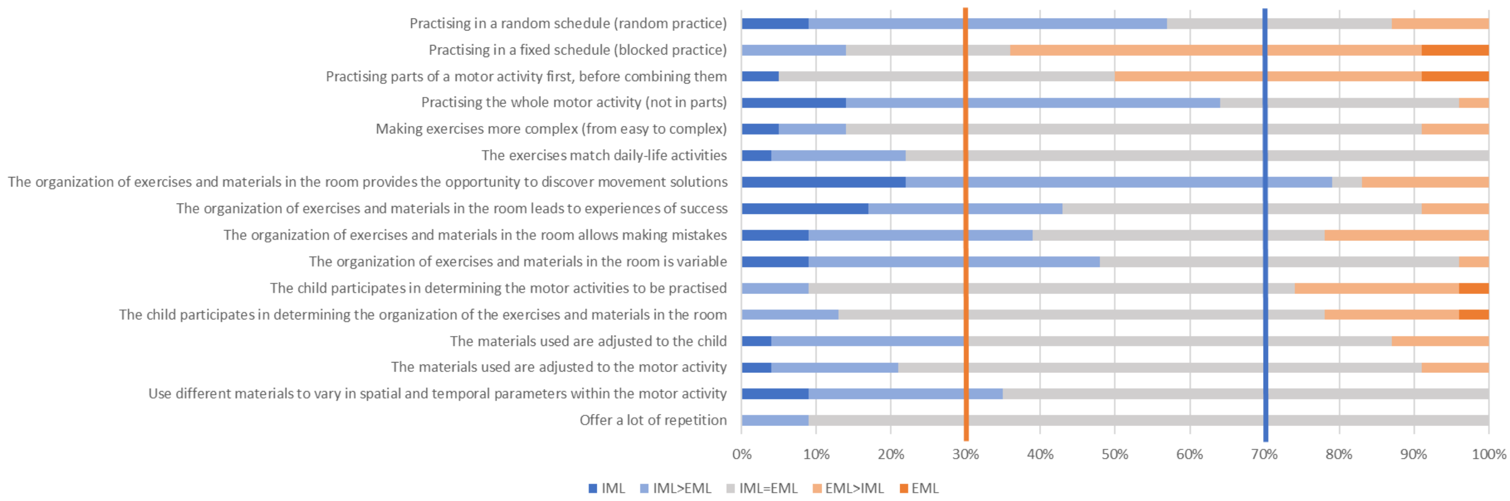

Figure 3.2c. *Motor learning strategies within the category organization of practice*

IML = promotes implicit motor learning; IML>EML = promotes rather implicit than explicit motor learning; IML=EML = promotes both implicit and explicit motor learning; EML>IML = promotes rather explicit than implicit motor learning; EML = promotes explicit motor learning; blue vertical line = 70% of the experts scored that it promotes more implicit motor learning; orange vertical line = 70% of the experts scored that it promotes more explicit motor learning.

3.3.4 Findings of the qualitative analyses

Analyses of both questionnaires taken together resulted into two themes: (1) classifying motor learning strategies; and (2) clinical decision making (Figure 3.3). Furthermore, experts provided great insight into modelling MLSs; see Appendix 3.2.

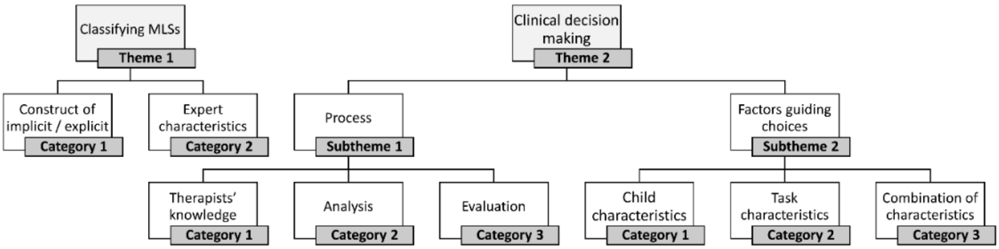

Figure 3.3. *Themes, subthemes and categories*

MLSs = motor learning strategies

3.3.4.1 *Theme 1: Classifying motor learning strategies*

This theme consisted of two categories (Figure 3.3).

The open-ended questions showed that classifying MLSs was difficult, for various reasons. For instance, one expert claimed that **constructs of implicit and explicit motor learning** (Category 1) are not that distinct, and that evidence is conflicting and limited:

"Research in implicit and explicit learning shows: (a) a diversity in perspective about what implicit and explicit exactly are; (b) many contrary results; and (c) in children with DCD only few strategies are investigated."

Moreover, some experts argued that the same MLSs could be used in both implicit and explicit ways:

"All strategies can be implicit and explicit: it depends on the instructions. For instance, in observational learning, if you say 'look carefully and copy exactly' then it is more explicit."

Furthermore, perspectives seemed to be influenced by **experts' own characteristics** (Category 2) like knowledge, experiences, preferences and beliefs, which may have contributed to the large variation found. For instance, one expert stated:

"I don't really know all that much about explicit motor learning."

3.3.4.2 *Theme 2: Clinical decision making*

This theme comprised two subthemes and six categories (Figure 3.3).

All experts felt that clinical decision making was needed to decide which MLSs to use when teaching motor tasks to children with and without DCD. With their answers they provided insight into **the process of clinical decision making** (Subtheme 1).

Some of the experts mentioned that **therapists' knowledge** (Category 1) could influence their use of MLSs, and that good knowledge is a prerequisite to enhance children's motor learning:

“Knowledge/skill of a therapist; if it is inadequate, a child can learn the wrong strategy [to perform a motor task]*”*

However, few experts underpinned that little scientific evidence was available about motor learning in children with DCD:

"We don't yet know enough about how children with DCD actually 'learn' to be clear about the value of different approaches."

Some experts stressed that an important first step in this clinical decision-making process was to perform a comprehensive **analysis** (Category 2):

“DCD means that children experience problems in learning motor activities. It contains various subgroups: children with execution problems, but also children with problems in motor planning, or just disuse (not enough movement experience). The solution is to perform a good analysis, and then choose what fits the child, task and context.”

Lastly, few experts stated that it was important **to evaluate** (Category 3) whether the MLSs used had the expected result, and that therapists should adapt MLSs until they found out which worked best for a child:

"DCD is a heterogeneous disorder and a broad approach should be taken in the first instance. That approach can then be adapted until finding a strategy that works best for the child."

In addition to the process of clinical decision making, experts provided insight into **factors guiding therapists’ choice of MLSs** (Subtheme 2).

Various individual **child characteristics** (Category 1) were suggested in both questionnaires (Figure 3.4). However, perspectives on how these characteristics might guide clinical decisions in children in general, and with DCD specifically, varied. In children with DCD, experts commented more frequently that special attention was required for experiences of success, and for stimulating the child’s problem-solving capacities:

“Evidence is growing that these children [with DCD] *can learn, but that they need more time and experience. In order to motivate them and keep them going,*

enjoyment is very important: they should experience success! That is the most important task of the therapist."

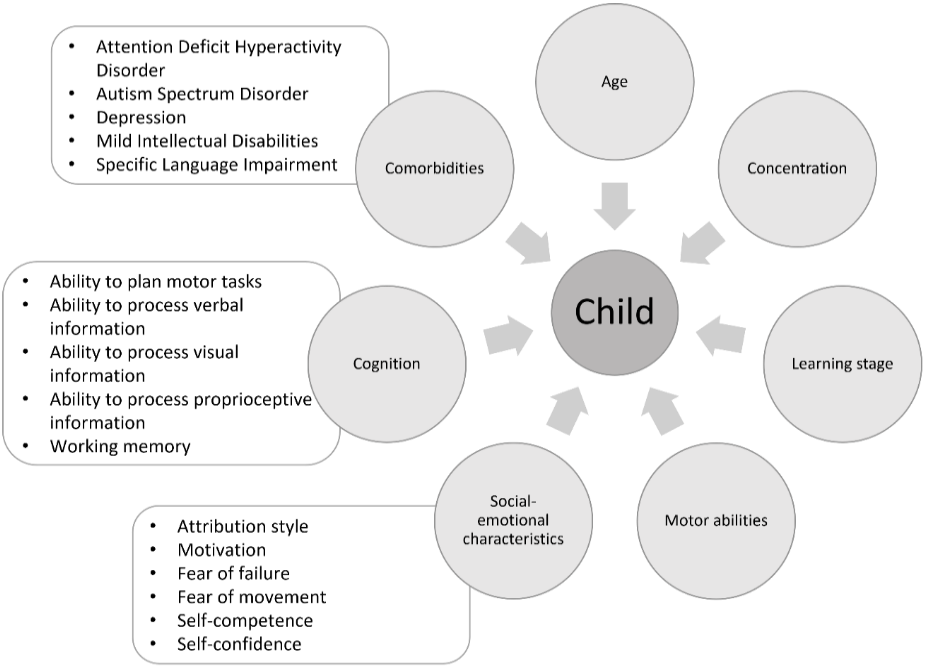

Figure 3.4. *Categories of child characteristics that might guide clinical decisions*

The categories 'social-emotional characteristics', 'cognition', and 'comorbidities' comprise multiple child characteristics

The experts also mentioned various **task characteristics** (Category 2) that might guide clinical decision making. If tasks required higher technical demands (e.g. when using equipment), more complex coordination between body parts, multiple steps in a specific sequence, and specific rules (e.g. when playing sports), the majority of the experts suggested that explicit motor learning might be more beneficial but that the choice for promoting this type of motor learning process still depended on the child's characteristics. Other task-specific characteristics mentioned were timing, precision, speed, and dual tasking.

Although experts suggested various child and task characteristics that could guide therapists' choices, they stressed that the **combination of characteristics of child, task and environment** (Category 3), and their interaction was most important:

"It is over-simplifying things to suggest that a particular task is better taught in a certain way e.g. using implicit or explicit teaching strategies. The answer depends on a combination of factors relating to task, child and environment. For example, teaching a child to learn to ride a bicycle - implicit motor learning might suit a child with the confidence to 'have a go' but not an anxious child, who is scared of falling."

3.4 Discussion

This mixed-methods study aimed to explore international experts' perspectives on the use of MLSs to promote implicit and explicit motor learning in children with and without DCD. It resulted into two main findings: (1) insufficient insight was gained into what extend MLSs promoted (more) implicit or (more) explicit motor learning; and (2) experts stressed the importance of adapting MLSs to characteristics of child and task, and the need for clinical decision making to do so.

3.4.1 Classifying MLSs

We expected that experts' opinions could help diminish the knowledge gap in how various MLSs could be used to promote either implicit or explicit motor learning in children. However, variation in opinions appeared large, for instance, regarding the focus of attention. According to the constrained action hypothesis, an internal focus promotes explicit motor learning because it requires larger involvement of cognitive processes[19]. Because of this larger involvement of cognitive processes, it is to be expected that a focus on sequence of steps would also promote explicit motor learning. The results showed that most experts classified the majority of the suggested MLSs with focus on body movements and sequence of steps as promoting more explicit motor learning. However, an interesting finding was that experts' opinions varied on whether an external focus promoted implicit motor learning, as was suggested by the constrained action hypothesis[19]. It might be possible that the used modality (verbal, visual, manual, or audible) was taken into consideration when classifying the suggested MLSs.

Two other findings may also have contributed to the variation found: experts' knowledge and experiences, and the unclarity regarding the constructs of implicit and explicit motor learning. First, some experts stated to have limited knowledge about specific types of motor learning, and/or specific MLSs. Others mentioned that their clinical experiences contradicted their knowledge gained from motor learning literature. Furthermore, the answers of Questionnaire 1 demonstrated that experts focused on some MLSs within the full range of MLSs (e.g. only focusing on frequencies of feedback). Because of the explorative character of the research question, this study included experts with different backgrounds to obtain a wide range of perspectives[34]. However, this choice made reaching a certain level of agreement challenging. In order to better understand how experts' knowledge and experiences influenced their perspectives, and to what extend this contributed to the variation found, further research is needed.

Second, some experts suggested that the constructs of implicit and explicit motor learning are still unclear. In scientific literature, different implicit and explicit motor learning paradigms are used. A frequently used paradigm from an experimental perspective is a serial reaction time task (e.g. finger tapping task), investigating the cognitive process of spatial sequence learning[37,38]. In explicit learning conditions, learners are informed about the presence of a sequence in the task, while in implicit learnings conditions learners are unaware of this sequence. Other used paradigms from a more clinical/sports perspectives are the MLSs mentioned in the introduction (external/internal focus learning, errorless/error-strewn learning, dual task learning, and analogy learning). These paradigms aim to promote or reduce the accumulation of explicit knowledge during learning[9]. With these different paradigms, defining and operationalizing implicit and explicit motor learning when conducting research and applying them in clinical settings is essential, and should have special attention. Furthermore, several experts stated that both types of motor learning (implicit and explicit) can co-occur, and that it remains unclear if the used MLS actually activated the intended type of motor learning process within a child. Previous research showed that there indeed are multiple co-occurring motor learning mechanisms that contribute to motor learning. Each mechanism has its own primary neurological substrate, including: (1) prefrontal cortex; (2) basal ganglia; (3) motor cortex and spinal cord; and/or (4) cerebellum[8]. Implicit and explicit motor learning occurs through different neurological substrates. The relative contribution of each mechanism can be manipulated by using specific MLSs leading to (more) implicit and/or (more) explicit motor learning. The authors stressed the need for further research to understand how the various mechanisms interact[8]. Several studies investigating the role of working memory capacity on children's motor learning have hypothesized that working memory capacity would predict the degree of internal focus learning, because explicit motor learning involves working memory[39–42]. However, none of the studies with typically developing children, children with DCD or children with low motor abilities found evidence supporting this hypothesis, confirming that learning mechanisms in children are not yet fully understood[39–41].

3.4.2 Clinical decision making

Experts agreed that good knowledge about the use of MLSs is required to enhance motor learning in children. Furthermore, some stressed that a comprehensive analysis is needed to determine which MLSs to use. Importance of knowledge and analysis in clinical decision making is supported by previous studies investigating PTs' processes of clinical decision-making in the rehabilitation of children with CP and adults with ABI[15–17]. An interview study exploring PTs' perspectives on the construct of motor learning, and experiences in motor-learning-based practice, showed that they need more knowledge of this topic[43]. It is to be expected that paediatric therapists will also have a need for more knowledge, because motor learning theories used in paediatric populations also lack clarity and simplicity[44].

Several child and task characteristics that might guide clinical decisions were identified (Figure 3.4). It concerned generic characteristics applicable to all types of populations and tasks, with some of these characteristics being more prominent in children with DCD (e.g. problems with motivation and motor planning). It appeared that experts' opinions on how these characteristics might guide clinical decision making varied. In particular, they stressed that the interaction of child, task and environment is most relevant, which is in line with the *hybrid model of DCD* that advocates that the MLSs used for children with DCD should be adapted to the same interaction[14]. More research is needed to better understand how characteristics of child and task, and their interaction, should guide clinical decisions.

3.4.3 Strengths and limitations

Previous research investigating effectiveness of MLSs promoting implicit or explicit motor learning in adults and children in clinical settings focused on a few MLSs (errorless/error-strewn learning, dual-task learning, analogy learning, and external/internal focus learning)[9,18]. Other research that intended to classify a broad range of MLSs as either (more) implicit or (more) explicit motor learning resulted in a wide distribution of answers and no consensus for MLSs other than the few mentioned above[7,23]. The additive value, and strength, of this study was that it used a mixed-methods design[33], because previous studies using quantitative approaches provided insufficient insight into how MLSs could be used to promote a specific type of motor learning.

Another strength was that all participating experts had expertise with children, and that we included a heterogeneous expert panel with different backgrounds in work settings (clinicians, educators, and researchers) and practical areas (different types of clinical care with different types of children with motor disabilities; and physical education), enriching the data available for the qualitative part of this study[34].

There were also some limitations to this study. Firstly, relatively few of the invited experts decided to participate (29 of 79). Some experts provided a reason for declining invitation (lack of time, or not considering themselves an expert), but not all invited experts did. Secondly, only the Dutch-language Questionnaire 1 was pilot-tested with members of the target population. Because the software used to send and complete the questionnaires appeared feasible for Questionnaire 1, the meaning and relevance of content of Questionnaire 2, and the preference for reformulating questions, were discussed only within the research team.

3.4.4 Recommendations for future research

Future research should focus on understanding how the various motor learning mechanisms in children work, interact, and may be manipulated to promote (more) implicit or (more) explicit motor learning. Furthermore, more insight needs to be gained into how the identified characteristics of child and task, and their interaction, can guide clinical decision making, for instance, by conducting vignette studies focusing on examining judgements and decision-making processes[45].

3.4.5 Conclusions

Although, variation in answers led to insufficient insight into how MLSs can be used to promote (more) implicit or (more) explicit motor learning, this study exposed important knowledge gaps about: the constructs of implicit and explicit motor learning, the learning processes in children, and how these processes can be activated with specific MLSs. This study demonstrated the importance of clinical decision making in order to make conscious choices in modelling and adapting the various MLSs to the interaction of child, task and environment. This requires therapists to: have adequate knowledge about MLSs and motor learning processes, perform comprehensive analysis to determine which MLSs to use, and to evaluate the impact of the MLSs used on the child's performance of a motor task. The exposed knowledge gaps, and identified child and task characteristics can be used by researchers to generate hypotheses for future research.

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3.7 Appendix 3.1: Questionnaires

Table 3.4. *Questionnaire 1*

Questionnaire 1	
Topic	**Implicit and explicit motor learning**
Question 1	What does implicit motor learning mean to you? Please, describe as specific as possible.
Question 2	What does explicit motor learning mean to you? Please, describe as specific as possible.
Question 3	In your opinion, what are the differences between implicit and explicit motor learning? Please, explain your answer.
Question 4	Which form of motor learning (implicit or explicit) do you prefer to apply when learning children in general motor activities? Please, explain your answer.
Question 5	Which form of motor learning (implicit or explicit) do you prefer to apply when learning children with DCD motor activities? Please, explain your answer.
Topic	**Specific learning strategies**
Question 6	In your opinion, which learning strategies enhance implicit motor learning in children? Please, explain your answer and describe how you would apply the learning strategies.
Question 7	In your opinion, which learning strategies enhance explicit motor learning in children? Please, explain your answer.
Question 8	In your opinion, which of these learning strategies are applicable to children with DCD? Please, explain your answer.
Question 9	In your opinion, which learning strategy/strategies do you prefer to use in children with DCD? Please, explain your answer.
Topic	**Instructions**
Question 10	In your opinion, how can the therapist shape his/her instruction to enhance implicit motor learning in children in general? Please, explain your answer.
Question 11	Do you think this is also applicable for children with DCD? Please, explain your answer.
Question 12	In your opinion, how can the therapist shape his/her instruction to enhance explicit motor learning in children in general? Please, explain your answer.

Table 3.4 continued

Question 13	Do you think this is also applicable to children with DCD? Please, explain your answer.
Question 14	In your opinion, how should the therapist optimally shape the instructions in children with DCD? Please, explain your answer as specific as possible.
Topic	**Feedback**
Question 15	In your opinion, how can the therapist shape his/her feedback to enhance implicit motor learning in children in general? Please, explain your answer.
Question 16	Do you think this is also applicable for children with DCD? Please, explain your answer.
Question 17	In your opinion, how can the therapist shape his/her feedback to enhance explicit motor learning in children in general? Please, explain your answer.
Question 18	Do you think this is also applicable for children with DCD? Please, explain your answer.
Question 19	In your opinion, how should the therapist optimally shape his/her feedback on children with DCD? Please, explain your answer as specific as possible.
Topic	**Organization of practice**
Question 20	How can the therapist organize the practice conditions to enhance implicit motor learning in children in general? Please, explain your answer.
Question 21	In your opinion, is this also applicable for children with DCD? Please, explain your answer.
Question 22	How could the therapist organize the practice conditions to enhance explicit motor learning in children in general? Please, explain your answer.
Question 23	In your opinion, is this also applicable for children with DCD? Please, explain your answer.
Question 24	In your opinion, how should the therapist organize the practice conditions for children with DCD? Please, explain your answer as specific as possible.
Topic	**Demographic characteristics**
Question 26	What is your age?

Table 3.4 continued

Question 27	What is your gender? – Male / Female / Do not want to say
Question 28	What is your nationality?
Question 29	In which country do you work?
Question 30	Are you currently working in: ● the clinical field as a caregiver applying motor learning in children ● research concerning motor learning in children ● education concerning motor learning in children
Question 31	Have you worked in: ● the clinical field as a caregiver applying motor learning in children ● research concerning motor learning in children ● education concerning motor learning in children
Question 32	If currently working in the clinical field or have worked in the clinical field, what kind of caregiver are/were you: ● Paediatric physical therapist ● Occupational therapist ● Physical education teacher ● Other; please specify ● I am not working as a caregiver
Question 33	State the number of years of working experience in the following domains: ● In the clinical field as a caregiver applying motor learning in children in general ● In the clinical field as a caregiver applying motor learning in children with DCD ● In research concerning motor learning in children in general ● In research concerning motor learning in children with DCD ● In education concerning motor learning in children in general ● In education concerning motor learning in children with DCD

Table 3.5. *Questionnaire 2*

Questionnaire 2	
Topic	**Implicit and explicit motor learning**
Question 1	***Question:*** We ask you to score the, in Questionnaire 1 cited, characteristics on a 5-point scale, to indicate more/or less focus on implicit or explicit motor learning. You do not have to think about a specific activity; the response should fit multiple activities. ***Likert-scale:*** implicit motor learning / rather implicit than explicit motor learning / belongs to both implicit and explicit motor learning / rather explicit than implicit motor learning / explicit motor learning ***Cited characteristics:*** • The child is conscious of the learning process • The child is unconscious of the learning process • The child is able to generate verbal knowledge about the learned motor activity • The child is unable to generate verbal knowledge about the learned motor activity • The focus of instruction, clue or feedback is result oriented • The focus of instruction, clue or feedback is body oriented • The focus of instruction, clue or feedback is oriented on execution sequence • Without instructions • Minimal dependence on working memory • Great dependence on working memory • Let the child explore the performance of the motor activity, without verbal guidance during or after the performance • Let the child explore the execution of the motor activity, with verbal guidance during or after the performance

Table 3.5. continued

Topic	Child, task and environmental characteristics
Question 2	***Question:*** In the following question we state the child factors that were mentioned in Questionnaire 1. We ask you to score each child factor on a 5-point scale, to indicate whether the child factor relates more or less on implicit or explicit motor learning. ***Likert-scale:*** implicit motor learning / rather implicit than explicit motor learning / belongs to both implicit and explicit motor learning / rather explicit than implicit motor learning / explicit motor learning ***Cited child characteristics:*** • Young age / Older age • Strong cognitive capacities / Normal cognitive capacities / Weak cognitive capacities • Normal functioning working memory / Less functioning working memory • Cognitive stage of motor learning / Associative stage of motor learning / Autonomous stage of motor learning • Strong verbal capacities / Normal verbal capacities / Less verbal capacities • No motor impairments (-1SD to +1SD around the average) / Motor impairments (in between -2SD and -1SD below average) / Severe motor impairments (lower than -2SD below average) • Normal motivation / Decreased motivation • Normal experience of competence • Normal sensory feedback mechanism (e.g proprioception) / Decreased sensory feedback mechanism (e.g proprioception)
Question 3	Which other child factors should be considered relevant related to implicit or explicit motor learning? Please, explain your answer.
Question 4	Which comorbidities are relevant in decision-making for implicit or explicit motor learning, in DCD? Please, explain your answer.
Question 5	Which learning style of a child with DCD fits better to implicit motor learning? Please, explain your answer.
Question 6	Which learning style of a child with DCD fits better to explicit motor learning? Please, explain your answer.
Question 7	Which tasks, based on specific task factors, have a preference for implicit motor learning? Please, explain your answer.
Question 8	Which tasks, based on specific task factors, have a preference for explicit motor learning? Please, explain your answer.
Question 9	Name (preferably 3) specific environmental factors which are, in your opinion, promoting (positive) or hindering (negative) implicit motor learning.

Table 3.5. continued

Question 10	Name (preferably 3) specific environmental factors which are, in your opinion, promoting (positive) or hindering (negative) explicit motor learning.
Topic	**Instructions**
Question 11	***Question:*** To get a complete view of all aspects relevant for an implicit or explicit instruction, we summed up the cited aspects that you have addressed in Questionnaire 1. We ask you to rate these aspects on a 5-point scale to indicate whether it fits more or less in implicit or explicit motor learning. ***Likert-scale:*** implicit motor learning / rather implicit than explicit motor learning / belongs to both implicit and explicit motor learning / rather explicit than implicit motor learning / explicit motor learning ***Cited instructions:*** • Verbal instruction with a body-oriented focus • Verbal instruction with a result-oriented focus • Verbal instruction focused on execution sequence • Manual guidance without verbal instruction • Manual guidance with verbal guidance with a body-oriented focus • Manual guidance with verbal guidance with a result-oriented focus • Manual guidance with verbal guidance focused on execution sequence • A visual example without verbal guidance • A visual example with verbal guidance with a body-oriented focus • A visual example with verbal guidance with a result-oriented focus • A visual example with verbal guidance focused on execution sequence • Instruction regarding the complete motor activity • Instruction regarding parts of the motor activity • Instruction to repeat the motor activity • Instruction to explore the motor activity • Instruction in which solutions are given • Using dialogue to analyse the motor activity, together with the child, to realise an instruction • Instruction on request of the child

Table 3.5. continued

Topic	**Feedback**
Question 12	***Question:*** To get a complete view of all aspects relevant to provide feedback in an implicit or explicit way, we summed up the cited aspects that you have addressed in Questionnaire 1. We ask you to rate these aspects on a 5-point scale to indicate whether it fits more or less in implicit or explicit motor learning. ***Likert-scale:*** implicit motor learning / rather implicit than explicit motor learning / belongs to both implicit and explicit motor learning / rather explicit than implicit motor learning / explicit motor learning ***Cited feedback:*** • Verbal feedback with a body-oriented focus • Verbal feedback with a result-oriented focus • Verbal feedback focused on the execution sequence • Visual feedback with a body-oriented focus • Visual feedback with a result-oriented focus • Visual feedback focused on the execution sequence • Tactile feedback with a body-oriented focus • Tactile feedback with a result-oriented focus • Tactile feedback focused on the execution sequence • Auditory feedback with a body-oriented focus • Auditory feedback with a result-oriented focus • Minimal feedback • Dosed feedback, after some practice attempts • Feedback after every practice attempt • Feedback at the end of the performance of the motor activity • Feedback during the performance of the motor activity • Interrupt the performance of the motor activity to give feedback • Feedback on request of the child • A question with a result-oriented focus • A question with a body-oriented focus • A question focused on the execution sequence • In dialogue with the child to help the child to find a solution • In dialogue with the child to let the child reflect on what can be improved
Question 13	What is general feedback, in your opinion? Please, explain your answer in 3 examples.

Table 3.5. continued

Topic	Specific learning strategies
Question 14	***Question:*** Your answers emphasized that how a learning strategy is used determines whether a learning strategy is implicit or explicit. In the following list you can read the, in Questionnaire 1, cited prerequisites of learning strategies. We ask you to rate with a 5-point scale in which degree the prerequisites belong to either implicit or explicit motor learning. ***Likert-scale:*** implicit motor learning / rather implicit than explicit motor learning / belongs to both implicit and explicit motor learning / rather explicit than implicit motor learning / explicit motor learning ***Cited prerequisites of learning strategies:*** • A lot of verbal guidance • Minimal verbal guidance • Without instruction • Let the child discover by doing (without analysis and/or reflection) • Analysing the body oriented performance of the motor activity together with the child • Analysing the result of the motor activity together with the child • Analysing the motor activity to clarify the execution sequence together with the child • Let the child reflect on the body oriented performance of the motor activity • Let the child reflect on the result of the motor activity • Let the child reflect on the execution sequence of the motor activity • Not reflecting on errors in the performance of the motor activity • The focus of the learning strategy is on the errors made with regard to a body oriented performance • The focus of the learning strategy is on the errors made with regard to the result • The focus of the learning strategy is on the errors made with regard to the execution sequence • The focus of the learning strategy is on the result of the motor activity • The focus of the learning strategy is on the body-oriented performance of the motor activity • The focus of the learning strategy is on the execution sequence • Bringing solutions regarding the execution sequence of the motor activity • Bringing solutions regarding the body oriented performance of the motor activity • Bringing solutions regarding the result of the motor activity

Table 3.5. continued

Topic	Organization of practice
Question 15	***Question:*** In the following list you can read the cited characteristics of practice conditions you mentioned in Questionnaire 1. We ask you to rate with a 5-point scale in which degree the characteristics belong to either an implicit or an explicit practice condition. ***Likert-scale:*** implicit motor learning / rather implicit than explicit motor learning / belongs to both implicit and explicit motor learning / rather explicit than implicit motor learning / explicit motor learning ***Cited practice conditions:*** • Practice in a random schedule (random practice) • Practice in a fixed schedule (blocked practice) • First practising the parts of an motor activity before combining them • Practising the whole motor activity (not in parts) • At the beginning of the practising accent on the execution sequence before using more variation • Making exercises more complex (from easy to complex) • The exercises match daily life activities • The organization of exercises and materials in the room provides the opportunity to discover a movement solution • The organization of exercises and materials in the room leads to experience of success • The organization of exercises and materials in the room allows making mistakes • The organization of exercises and materials in the room is variable • The child participates in determining the practiced motor activities • The child participates in determining the organisation of the exercises and materials in the room • The material selection is adjusted to the child • The material selection is adjusted to the motor activity • Use different materials to vary in spatial and temporal parameters within a motor activity • Within a motor activity, variety needs to be induced to load spatial and temporal parameters • Offer a lot of repetition

Table 3.5. continued

Question 16	***Question:*** Please, give your preference for random, blocked or variable practice in the following statements. ***Multiple choice:*** random practice / blocked practice / variable practice ***Statements:*** • Has a preference to achieve learning results in the short term • Has a preference to achieve better learning results in the longer term • Has a preference to have a better transfer of the learned motor activity to another context • Has a preference in a cognitive stage of motor learning • Has a preference in an associative stage of motor learning • Has a preference in an autonomous stage of motor learning • Has a preference to refine the motor activity performance • Has a preference in children who learn more slowly compared to typically developing children • Has a preference in children who have more need of experience of success
Question 17	Which other child and/or task factors are playing a role in the choice for the practice schedule (random or blocked practice)? Please, explain your answer.

3.8 Appendix 3.2: Modelling motor learning strategies

The experts gave many suggestions for modelling: (1) teaching styles; (2) instructions and feedback, (3) organization of practice; and (4) specific learning strategies.

3.8.1 Teaching styles

In general, two types of teaching styles were distinguished: indirect and direct. An indirect style uses questions to guide a child to the correct movement solution by letting the child: analyse the motor task; think about movement solutions; and/or reflect on its own performance. When the organization of practice (e.g. organization of materials in space) challenges a child to search for movement solutions, this is also an indirect style. A direct style uses explicit instructions about the movement solution (e.g. how to perform the motor task).

3.8.2 Instructions and feedback

According to the experts, the aim of instructions and feedback could be to motivate a child by emphasizing successes, complimenting their perseverance, and encouraging them. They considered motivation important for motor learning:

“General feedback, such as ‘well done’, might be very motivational for a child. It can help with persistence in a difficult or effortful task. It can help the child make their best effort and try their hardest.”

But instructions and feedback also could be used to provide a child with specific information about the task. For instance, with an indirect teaching style:

"Give concrete feedback during or after the performance, like, ‘I saw you doing this… Can you try to do it higher/lower/harder/softer’, ‘What are other possibilities? Try it and then we will compare what worked best.’”

Experts elaborated on how instructions and feedback could be modelled, identifying five different parameters: (1) focus of attention; (2) modality; (3) information content; (4) frequency; and (5) timing. See Table 3.6 for a description of how these parameters can be modelled. Additionally, the use of an analogy (i.e. a metaphor that integrates the complex structure of the to-be-learned task) was frequently suggested as a specific type of instruction.

Table 3.6. *Parameters of instructions and feedback and of organization of practice*

Instructions and feedback	
Parameter	**How the parameter could be modelled**
Focus of attention	The focus of attention of instructions and feedback could be external (on the impact of the result on the environment), internal (on body movements), or focused on strategy (e.g. sequence of steps and/or rules of game). Underlying this, instructions and feedback could focus on positive aspects of the performance (e.g. what went well) or negative aspects (e.g. what went wrong). Note: knowledge of results is considered a subtype of external focus, because both provide information about the results of the movement on the environment as basis for error corrections in the next trial. Knowledge of performance is considered a subtype of internal focus, because both provide information about the movement performance as basis for error corrections in the next trial.
Modality	The modality of the instructions and feedback could be verbal, visual (e.g. demonstration, video, or photo), tactile (e.g. manual guidance of the movement), or auditory (e.g. providing rhythm by clapping hands).
Information content	This varies from short instructions and feedback with little detailed content to extensive instructions and feedback with very detailed content.
Frequency	The frequency varies from no instructions and feedback to continuous feedback (after every trial).
Timing	The timing of instructions and feedback can be determined by the child (self-controlled instructions and feedback) or by the therapist. When determined by the therapist, feedback can be provided during (concurrent) or after the performance.

Table 3.6 continued

Organization of practice	
Parameter	**How the parameter could be shaped**
Arrangement of the practice situation	When arranging the practice situation, the following have to be considered: the location (e.g. indoors/outdoors, size of room); the materials to use (e.g. scaling equipment); the positioning of the materials in space; and whether to practise individually or in a group.
Level of difficulty of the tasks trained	The level of difficulty concerns the individual exercises, but also the increase of level of difficulty between exercises. The latter varies from very easy to very difficult. The increase of level of difficulty between exercises varies from minimal to maximal.
Part or whole practice	Tasks can be practised in parts, focusing on sub-steps within a task, or as a whole.
Practice order	Tasks can be practised in a random or blocked order. With random practice, various tasks will be alternated in a random order. With blocked practice, the same task is practised repeatedly.
Variable or constant practice	Tasks can be practised with high variability in material, spatial and temporal demands (variable practice) or with no variability (constant practice).

3.8.3 Organization of practice

In addition to instructions and feedback, experts elaborated on how the aim targeted with the organization of practice could be to support the learning process for new tasks, or to stimulate transfer of learned tasks to daily-life contexts. When learning new tasks, the focus should be on learning the sequence of steps and/or specific spatial and/or temporal demands of that task:

"Start with practising small steps, using tailored materials in blocked practice. After a while, you can use more variation. And then, you can combine it with a second small step."

When stimulating transfer to daily-life contexts, the focus shifts towards applying tasks in contexts similar to real life, and learning to better anticipate the dynamical contexts of tasks:

"Tying shoelaces in a clinic is not the same task as tying shoelaces when running out to the playground to be with other children."

Whatever the focus (learning new tasks, or stimulating transfer), experts felt that the organization of practice should increase time on task and experiences of success, which they considered especially relevant for children with DCD. A few suggested that they would give children a voice in arranging the practice situation and that they would use a theme that met the child's interest. In addition to these more generic principles, five parameters were identified that could be used to shape the organization of practice: (1) arrangement of the practice situation; (2) level of difficulty of the tasks trained; (3) part or whole practice; (4) practice order; and (5) variable or constant practice (Table 3.6).

3.8.4 Specific learning strategies

Experts suggested various specific learning strategies potentially promoting children's motor learning. They could all be linked to the teaching style (e.g. guided discovery uses an indirect style), instructions and feedback (e.g. analogy learning uses metaphors as instruction), or organization of practice (e.g. with errorless learning, the arrangement of the practice situation leaves little or no room for errors).

Chapter 4

Therapists’ use of instructions and feedback in motor learning interventions in children with Developmental Coordination Disorder: a video observation study

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Abstract

Aim: this qualitative study explored therapists' use of instructions and feedback when teaching motor tasks to children with developmental coordination disorder (DCD) as a first step in developing practical recommendations.

Methods: a conventional content analysis approach was used to analyse video-taped treatment sessions of physical therapists using a newly developed analysis plan. Inductive coding was used to code purposively selected video segments. The codes were sorted into categories to identify key themes. Analyses were performed independently by two researchers until data saturation was reached.

Results: ten video-taped sessions were analysed and 61 segments coded. Three key themes were identified: (1) *therapists' intention with the instructions and feedback* was to motivate or to provide information; (2) the preferred *therapists' teaching style* was either direct or indirect; and (3) *parameters to shape specific instructions and feedback* were focus, modality, information content, timing and frequency.

Conclusion: This is one of the first studies that explored therapists' use of instructions and feedback in children with DCD. Therapists used numerous instructions and feedback with different information content, often shaped by multiple focuses of attention and/or modalities to motivate children or to provide specific information about task performance. Although therapists adapted instructions and feedback to child and task, future research should explore how specific characteristics of child and task can guide therapists' use of instructions and feedback.

Keywords: motor learning; instruction; feedback; children; Developmental Coordination Disorder; motor skills disorder; video observations

4.1 Introduction

Teaching motor skills is a fundamental part of the professions of occupational and physical therapists[1–3]. A think-aloud study in which physical therapists (PTs) reflected while watching videos of their own treatment sessions with patients with acquired brain injury (ABI) showed that they used a great variety of motor learning strategies to teach motor skills, which they constantly adapted to the individual situation[2]. In an interview study, PTs acknowledged the importance of using motor learning strategies, but they experienced teaching motor skills as a complex construct which they largely addressed intuitively[1]. Moreover, they emphasized that more insight was needed in translating theory into clinical practice to improve implementation of motor learning strategies[1]. Interview studies exploring how therapists perceive and experience using motor learning strategies to teach children motor skills are currently lacking. However, one study explored occupational therapists' (OTs) use of motor learning strategies in video-taped treatment sessions of children with ABI[3]. Results showed that therapists used various motor learning strategies which they adapted to child, task and environmental characteristics[3]. Published research shows that theories of motor learning lack the clarity and simplicity needed for application in paediatric practice[4]. To support implementation of motor learning theories into clinical settings, several theoretical frameworks with diverse approaches, addressing different motor learning strategies, have been described[5–8]. All consider instructions and feedback to be important[5–8]. As such, practical recommendations on how to use instructions and feedback may enhance teaching motor skills.

Children with developmental coordination disorder (DCD) experience severe problems with motor coordination and learning, impairing their participation in daily life[9,10]. In order to improve daily functioning, OTs and/or (paediatric) physical therapists (PPTs) use activity- or participation-oriented interventions to teach motor skill to children with DCD implicitly and/or explicitly[11]. With implicit motor learning processes, children learn motor skills without awareness and without no or minimal increase in verbal knowledge about the movement performance, whereas with explicit motor learning processes the learning process involves cognitive processes and verbal knowledge is generated about the movement performance[12]. Evidence-based activity- and participation oriented interventions[13], such as Neuromotor Task Training (NTT) or Cognitive Orientation to daily Occupational Performance (CO-OP), are underpinned by theories of motor learning and motor control[11,14,15]. Both approaches are child-centred, and based on the theoretical foundation that motor performance is the result of interactions between characteristics of child, task, and environment as described by the Dynamic Systems Theory[14–18]. Furthermore, motor learning strategies derived from motor learning research are addressed to enhance motor performance by manipulating the interaction of child, task and environment[14,15,19]. A pilot video-observation study in children with DCD showed that PPTs used a variety of instructions and feedback to improve motor performance[20]. However, little is known about the effectiveness of instructions and feedback in children with DCD. Only the effectiveness of the focus of attention has been investigated, and results from this were inconclusive[21–25]. In these studies, two types of focuses were distinguished: (1) an external focus (EF), directing the attention of the child to the impact of the movement on the environment; and (2) an internal focus (IF), directing the attention of the child to its body movements[26]. Two studies found beneficial effects favouring EF[23,24], while three studies found no significant differences between EF and IF[21,22,25]. As instructions and feedback are shaped by their content (e.g. a specific focus of attention) and modality (e.g. visual, tactile, auditory or verbal), and applied with a chosen frequency and timing (e.g. determined by therapist or child)[27], more insight is needed into how instructions and feedback can and should be shaped for children with DCD.

In summary, therapists experience teaching motor skills as challenging, and some practical recommendations on the use of instructions and feedback may enhance their teaching skills[1,4,6]. Although therapists constantly adapt instructions and feedback to the child, task, and environment[2,3], this seems to be based largely on intuition[1]. In interventions with children with DCD, teaching motor skills is additionally hindered because of limited knowledge of the effectiveness of instructions and feedback in such children. As a first step in developing practical recommendations on the use of instructions and feedback with these children, more insight is needed into therapists' current use of their instructions and feedback. The aim of this study was therefore to explore how therapists use instructions and feedback during video-taped treatment sessions with children with DCD aged 5 to 12 years. Existing tools to analyse video-taped sessions score the frequencies of a set of predefined items[3,27,28], providing insufficient insight into the full spectrum of therapists' use of instructions and feedback. Furthermore, these existing tools do not provide insight into how therapists act if their instructions and feedback do not seem to meet their expectations of immediate improvement in the motor task being practiced. Accordingly, the researchers developed a new and comprehensive analysis plan to explore and analyse these sessions in four consecutive steps: (1) splitting the video into smaller segments; (2) writing comments to each segment; (3) selecting segments for in-depth analysis; and (4) coding the selected segments.

4.2 Methods

4.2.1 Design

This qualitative study used a conventional content analysis approach to analyse video-taped treatment sessions and subsequent interviews with PPTs to explore therapists' use of motor learning strategies in the treatment of children with DCD. This article describes the results of analyses of treatment sessions, which focused on therapists' use of instructions and feedback. In order to prevent the observations being unduly influenced by the interview, sessions were recorded at least one week before the interview. The study was approved by the Medical Ethical Review Board of Maastricht University (2019-1338) for Dutch participants, and Hasselt University (CME2019/060) for Flemish participants.

4.2.2. Procedure

A convenience sampling strategy was used to recruit therapists[29]. A flyer was distributed within two regional networks of PPTs in the southern Netherlands (RVFK and network Den Bosch), within the University of Hasselt's network for PT clinical internships, and at educational activities for therapists (e.g. symposia). A heterogeneous sample was required to obtain rich data[29]. Therefore, therapists with different backgrounds in terms of experience in treating children with DCD and work settings (e.g. primary and secondary care) were selected. Therapists completed a short questionnaire to supply their demographic characteristics (age, work setting, graduation year, and years of experience in treating children with DCD). The Flemish data and copies of the Dutch data were stored, coded and secured, on the server of the University of Hasselt. Only one researcher (IvdV) had access to the code-key, the others having access to the coded videos and documents. Before the recording of the treatment sessions, therapists contacted children receiving their care (and their parents) to inform them about the study. After receiving written and oral information, therapists and parents gave written consent for participation, with children assenting orally.

The therapists were asked to videotape themselves during a regular treatment session in which they taught the child motor skills, with both child and therapist visible and audible. Each video was recorded with the therapist's own video camera or telephone, tripod-mounted or held by the parent. Each therapist provided one video, accompanied with information about the treatment goal(s) of that session.

Data were collected until no new meaningful information was to be gained[29,30]. An additional two more sessions were analysed to confirm that data saturation had been reached[29]. Based on a previous video-observation study exploring OTs' use of motor learning variables in children with ABI, it was expected that 8-10 videos would be sufficient[3].

4.2.3. Participants

Dutch and Flemish PTs, with at least one year of experience in treating children with DCD, could participate if they were able to video-tape their treatment sessions with a child (aged 5-12 years) with (probable) DCD. The child should preferably have been diagnosed with DCD: however, in the Netherlands, the mean age of receiving a diagnosis of DCD is 7.02 years (SD 1.79) and the process of diagnosis takes an average of 2.79 years (SD 2.13)[31]. Therefore, children with probable DCD were included if the criteria for DCD according to the international recommendations were met: (I) scoring ≤ 16th percentile of the Movement Assessment Battery for Children 2nd edition (Movement-ABC-2NL); (II) suspected of having DCD according to the Developmental Coordination Disorder Questionnaire (DCDQ); (III) no other condition that could account for the motor skills deficits was reported by the therapist; (IV) there had been an early onset of symptoms, as reported by the therapist[11].

4.2.4. A video-based analysis plan

Three members of the research group (IvdV, NvdW, ER) developed a plan to analyse video-taped treatment sessions, which allowed for reviewing the sessions at two levels[32]: (1) the treatment session as whole; and (2) in-depth analysis of specific segments using an inductive coding strategy[30,33]. See Appendix 4.1 for more information about the development of the plan.

Analyses were conducted in two phases: Phase 1 comprised of three steps and Phase 2 of one step. To promote internal validity of the investigation, all steps within the analyses were performed independently by two researchers. Phase 1 was performed by Researchers 1 (IvdV or NvdW) and 2 (MG): afterwards, differences were discussed to advance the understanding of the data. In Phase 2, segments were coded by Researcher 3, who had no prior knowledge of the video (IvdV or NvdW). The open coding was checked and complemented by Researcher 1, and subsequently discussed by both researchers. If these could not reach consensus, an independent researcher (ER) was consulted. Throughout the analysis process, notes were made of first impressions and thoughts. Frequent meetings were organized to continuously reflect on the process and results of the analyses with the whole research group, comprising researchers with methodological and/or clinical expertise.

Within the analyses of Phase 1, three consecutive steps were conducted. In **Step 1,** videos were split into relevant smaller segments. We assumed that the instructions and feedback provided by therapists would be related to each other. Thus, in order to better understand therapists' use of instructions and feedback, each segment had to contain: the instructions; the task performance; and the therapists' reactions to that performance (e.g. feedback). In **Step 2,** each segment was provided with comments about its content, firstly, whether it concerned practicing tasks or other activities (e.g. organizing practice situations) and, secondly, if it concerned practicing tasks, (a) the task practiced, (b) the motor learning strategies applied, (c) the amount of therapists' actions to enhance motor learning, and (d) whether the segment contained unique information when compared with other segments of that video. Further, each segment received a label regarding the type(s) of motor learning used. The label was based on: (1) the used focus of attention (e.g. EF), because an EF promotes implicit motor learning, and an IF explicit motor learning[34]; and (2) the amount of information given, because the amount of information that needs to be processed relates to the involvement of the working memory[7]. Following labels were used: (1) implicit motor learning (IML); (2) more implicit than explicit motor learning (IML>EML); (3) more explicit than implicit motor learning (EML>IML); or (4) explicit motor learning (EML). If the segment showed the child practicing without active guidance or showed other activities, the segment received one of the following labels: (5) no motor learning (NML); or (6) Others (Table 4.1 describes these labels). Finally, in **Step 3**, some segments were selected for further analysis. The selection process focused on segments that provided rich data or showed unique elements of motor learning. Because instructions and feedback are adapted to the child and task[2,3,16], and are shaped differently depending the type of motor learning[7], it was important to select segments with different tasks and labels. In Phase 2, **Step 4**, all observable actions of the therapist that might enhance the motor learning process of the child in the selected segments were coded, using an inductive strategy. See Appendix 4.1 for more detailed descriptions of the steps.

__Table 4.1.__ Description of labels assigned to video segments

Label	Description
IML	The therapist used an implicit motor learning approach to teach the child a motor task.
IML>EML	The therapist used a combination of implicit and explicit motor learning approaches to teach the child a motor task. However, the approach was more implicit than explicit.
EML>IML	The therapist used a combination of implicit and explicit motor learning approaches to teach the child a motor task. However, the approach was more explicit than implicit.
EML	The therapist used an explicit motor learning approach to teach the child a motor task.
NML	The child practiced a task. However, the therapist's approach used little or no motor learning variables.
Others	No tasks were practiced. Other activities like social talking or organizing the practice situation occurred.

IML = implicit motor learning; EML = explicit motor learning; NML = no motor learning

4.2.5. Data analysis

Median age (with range), and frequencies of gender, and nationality were presented for the therapists and children separately. For therapists, range of years of experiences in treating children with DCD were presented as well. An overview of the tasks practiced in the segments selected for coding was provided. The processes of recruitment and of data collection were described.

A conventional content analysis approach, using ATLAS.ti version 8, was used for qualitative analyses[33]. Videos were analysed independently from interviews. For Phase 1, following results were described: (1) the total length in minutes of the analysed treatment sessions and selected segments; (2) the number of segments in total and selected for coding; (3) the distribution of the labels assigned to the segments. The coding procedure in Phase 2 involved an iterative process of coding and recoding. In multiple meetings with the research group, codes were sorted into categories based on how different codes were related and linked to each other. Subsequently, themes were formulated by organizing and grouping categories into meaningful clusters[30,33].

4.3. Results

4.3.1 Process of recruitment and data collection

In the Netherlands, 23 PPTs requested more information after receiving the flyer via the regional networks (n = 10) or a symposium (n = 13). Ten therapists were interested in participating. However, three had no opportunity of video-taping a treatment session, leaving seven Dutch participants. In Belgium, 18 PTs requested more information after receiving the flyer via the University of Hasselt's clinical internship network (n = 16) or via one of the four symposia (n = 2). Eight therapists were interested in participating. However, three had no opportunity of video-taping a treatment session, leaving five Flemish participants. One therapist recorded task performances without instructions and feedback, so that video was excluded, leaving 11 videos available for analyses. Data saturation appeared reached after analysing eight videos. The analyses of two extra videos resulted in no new meaningful information, confirming saturation.

4.3.2 Participants

All 10 therapists were women, with a median age of 52 years (range 26-63). Six worked in a primary health care facility, three others in a secondary health care facility; the remaining therapist worked in both. Experience of treating children with DCD ranged from 4 to 40 years. The median age of the 10 children was 6.5 years (range 5-9), with six being boys. Several gross and fine motor tasks were practiced, with eight children practicing more than one task during their treatment session. Table 4.2 provides an overview of the tasks practiced in the segments selected for coding.

Table 4.2. *The tasks practiced in the segments selected for coding*

Gross motor tasks (number of children practicing that task)	Fine motor tasks (number of children practicing that task)
Catching and throwing beanbags or balls (3)	Putting iron Perler beads on pegboard (1)
Climbing various inclined wall bars (2)	Folding Origami paper (1)
Forward rolls (1)	Tying shoe laces (1)
Balancing on various objects (3)	Writing words or letter-like patterns (2)
Rope skipping (2)	
Single leg hop (1)	
Jumping with both feet: • Standing long jump: with and without obstacle (2) • Sequential jumping in different directions (4) • Jumping from height (1) • Bench jumps (1)	

4.3.3 Findings of the analyses of the treatment sessions

In Phase 1, 10 video-taped sessions with a total length of 243.04 minutes (mean = 24.30, range = 11.20-30.40) were analysed, resulting in 223 individual segments with the following labels: *IML* = 48, *IML>EML* = 34, *EML>IML* = 38, *EML* = 20, *NML* = 26 and *Others* = 57. Sixty-one segments with a total length of 89.52 minutes (mean = 8.95, range = 3.04-14.33) were selected for coding in Phase 2. The labels were distributed as follows: *IML* = 20, *IML>EML* = 14, *EML>IML* = 20 and *EML* = 7.

The analyses of Phase 2 resulted in three themes providing insight into therapists' use of instructions and feedback: (1) *therapists' intention with the instructions and feedback*; (2) *therapists' teaching style*; and (3) *parameters to shape specific instructions and feedback*. The following paragraphs will elaborate on the separate themes.

4.3.3.1 *Theme 1: therapists' intention with the instructions and feedback*

With their instructions and feedback, therapists' intended **to motivate the child** or **to provide the child with specific information** about the task performance. To motivate the child, all therapists used verbal and non-verbal encouragement before, during, and/or after the execution of the task. Most encouragements were verbal comments after the performance, like *"Well done!"* or *"Good job!"*, sometimes accompanied by non-verbal actions like *thumbs up* or *high fives*. Additionally, some therapists promised the child a reward or gave pep talks before the start of the performance. For instance, one therapist *promised the child stickers for each forward roll made*, while other therapists encouraged the child by saying *"Try again, I have seen that you can do it"* or *"You already did a great job".* During task performances, therapists gave children confidence by *holding the child's hand as support* when the task seemed challenging, for instance while walking a balance beam or jumping from height. Additionally, they made comments like *"Wow!"* or *"Go on!"* to motivate them.

Throughout treatment sessions, the majority of therapists used many different types of instructions and feedback to provide the child with specific information about task performance (further described as **specific** instructions and feedback). Therapists' approaches varied more when the child encountered complex challenges in task performance. For example, one therapist attempted to teach a 9-year-old child rope skipping but the child did not know how to position the handles of the skipping rope. To improve this, the therapist *demonstrated how to position the handles.* When the child kept struggling, she *told the child that the end of the handles should point to the wall,* and eventually she even *placed the handles in the child's hands, positioned the hands and said that thumbs should point outwards*. In general, it was observed that therapists used instructions more than specific feedback. After the performance, they often complimented the child without providing insight into what went well. In case of errors in execution, therapists frequently repeated the initial instructions or altered the modality of the instructions, for instance by *changing verbal instructions into a demonstration* or by *adding tactile guidance to the verbal instructions*. Theme 3 further elaborates on how these specific instructions and feedback were shaped.

4.3.3.2 *Theme 2: therapists' teaching style*

Most therapists used a combination of (1) asking the child questions to guide it to the correct motor performance and/or movement solution; and (2) instructing the child what to do to improve the task performance. Although therapists frequently used both, they tended to prefer one. So that two types of teaching styles could be recognized: the indirect and the direct styles. Therapists using the **indirect teaching style** asked the child many questions to enhance motor learning. For instance, one therapist wanted to improve catching in a 7-year-old child. Before performing the task, the therapist discussed the Goal-Plan-Do-Check strategy with the child (Missiuna et al., 2001). She drew attention to specific points of interest with questions like *"What do you need to do with your hands?"* or *"Do you remember what was important?"* She also simulated situations by asking *"What do your arms need to do if the beanbag ends up here?"* while holding the beanbag in the air in different positions. Furthermore, she attempted to increase insight by asking questions like *"Do you think that the beanbag will go faster or slower when I will stand further away?"*. After the performance, she asked questions like *"What was the reason why you missed two? What did you forget?"* or *"How did it go?"* Therapists using the **direct teaching style** informed the child directly what to do, and/or what went well or wrong when providing feedback. For example, one therapist aimed to improve the standing long jump in a 5-year-old child. The therapist *demonstrated the jump while telling the child exactly what to do with his feet, knees, hips and arms.* Subsequently, the therapist *performed the jump simultaneously with the child, while giving short cues* like *"Bent knees!"* and *"Push!".*

4.3.3.3 *Theme 3: parameters to shape specific instructions and feedback*

Five different relevant parameters were identified: (1) focus of attention; (2) modality; (3) information content; (4) timing; and (5) frequency. Each specific instruction or feedback was shaped by its focus and modality. For **focus of attention,** EF was observed most. Other observed focuses were IF and focus on the strategy needed to perform the task (e.g. the sequence of subsidiary steps). Knowledge of Results (information about the learner's success in meeting the environmental goal) and Knowledge of Performance (information about the learner's own movements) were considered subtypes of EF and IF respectively, because both provide information about the results or the movement performance as basis for error corrections in the next trial [35]. Analogies were classified as EF, because the child was attempting to reproduce a metaphor (Wulf & Lewthwaite, 2016). As for **modality**, most instructions and feedback were provided verbally. Therapists also used visual and, occasionally, tactile modalities. Specifically, for more complex tasks (e.g. writing, rope skipping, forward rolls, and tying shoe laces), therapists combined several focuses and/or modalities in their instructions and feedback. For instance, one child had an incorrect pencil grip while writing. The therapist *demonstrated the correct pencil grip while emphasizing that the pencil had to stay in contact with the hand* (visual and verbal modalities with IF). To improve forward rolls, the therapist *demonstrated the subsidiary steps while asking questions to the child about what to do with specific body parts in each step* (visual and verbal modalities, with IF and focus on strategy). During the performance, the therapist *manually guided the movement and told the child to put their hands on the green dots* (tactile and verbal modalities with both IF and EF). More examples can be found in the modality-focus matrix in Table 4.3.

Table 4.3. *Modality-focus matrix*

	External focus	Internal focus	Strategy focus	Combined focus
Verbal	• Before writing, the therapist said "The pencil has to stay in its bed during writing" (meaning in contact with the hand). • Before jumping, the therapist said "Jump softly without making a sound". During the performance the therapist cued "As a mouse". • After performance, the therapist said "You have caught two beanbags". • While tying shoe laces, the therapist asked "Can you make both loops equal?"	• Before the performance, the therapist said "Pick up the Perler bead between two fingers". • While walking a balance beam, the therapist said "Watch your feet". • After jumping, the therapist said "You did not bend your knees far enough". • After jumping, the therapist asked the child "Did you landed on your feet?".	• Verbal instructions with focus on strategy were always combined with a demonstration or the use of icons. • After putting Perler beads on a pegboard, the therapist said "Turn the pegboard when you change direction - that makes it easier". • The child climbed inclined wall bars but could not climb down. The therapist asked "How are you going to handle it?" Subsequently the therapist asked questions like "What can you do next?"	• Before jumping, the therapist said "Bend your knees and jump over the bar" (IF and EF). • While performing bench jumps, the therapist guided the child by saying "Hop on, hop off" and "Push with your feet" (EF and IF). • While descending a climbing wall with grips, the therapist said "Look where to put your foot", and asked questions like "What colour grip is best to go to?" (IF and focus on strategy).

Table 4.3 continued

Visual	• The therapist demonstrated a bench jump. • While hopping a pattern between cones on one leg, the therapist pointed in the direction the child had to go.	• While writing letter-like patterns, the therapist pointed at the child’s wrist to draw attention to its position.	• Visual instructions and feedback with focus on strategy were always combined with verbal guidance.	• Visual instructions and feedback with multiple focuses were always combined with verbal guidance.
Tactile	• Not possible: when the therapist touches the child, the attention is always drawn to the body. Therefore, the combination of tactile instructions and feedback with a merely EF is not possible.	• Before single leg hopping, the therapist positioned the child’s non-jumping leg. • The child stepped over an obstacle while walking a balance beam. The therapist corrected balance by grasping the child’s hand when it lost balance.	• Not possible: when the therapist touches the child, the attention is always drawn to the body. Therefore, the combination of a tactile form with a focus only on strategy is not possible.	• Tactile instructions and feedback with IF and focus on strategy were always combined with verbal guidance

Table 4.3 continued

Combined	• The therapist demonstrated folding origami paper while saying "Fold the paper over the line" (visual and verbal). • The therapist demonstrated jumping while saying "Jump to the red dot" (visual and verbal). • The child failed to make an extra knot after tying shoe laces. The therapist demonstrated what to do, while verbally accentuating the crossing of the laces the child should make (visual and verbal).	• The therapist demonstrated rope skipping while drawing attention to the positioning of the handles by saying "Watch how I hold the handles in my hands" (visual and verbal) • The therapist positioned the handles of the skipping rope in the child's hands and said "Your thumbs should point outwards" (tactile and verbal). • While writing letter-like movement patterns, the therapist manually guided the movement of the wrist while saying "Extend your wrist" (tactile and verbal).	• Before rope skipping, the therapist talked with the child about the strategy, using pictures of Goal-Plan-Do-Check (visual and verbal). • The therapist demonstrated tying shoe laces, while verbally guiding the sequence using an analogy of a rabbit and a tree (verbal and visual). • The child experienced problems jumping backwards. After performance, the therapist demonstrated the jump while saying "Jump – stop" repeatedly (visual and verbal). • After catching, the therapist demonstrated two positions in which the child had stood while catching, and asked "What position worked best?" (visual and verbal).	• Before jumping, the therapist demonstrated the jump and said what to do with the body and where to jump to (verbal and visual – IF and EF). • While folding origami paper, the therapist guided the child by: 1. saying in which direction to fold; 2. pointing at the corners; 3. drawing attention to icons of the separate steps; and 4. asking questions as "What would you do next?" (verbal and visual - EF and focus on strategy). • While forward rolling, the therapist manually guided the bending of the head while saying "Bend your head" and subsequently pushed the buttock to advance the roll (tactile and verbal - IF and focus on strategy).

IF = internal focus; EF = external focus

The third parameter identified was the **information content** of individual instructions and feedback, which varied from minimal to very extensive. For instance, some therapists used short instructions with minimal information, like *"Throw 10 times"* or *"Bend your knees"* (in jumping), while others used more extensive instructions by saying *"Bend your knees, hips and trunk in preparation for the jump. Swing your arms backwards and then forwards while pushing off with your feet".* The fourth identified parameter was the **timing** of instructions and feedback. It was observed that instructions and feedback were provided frequently on therapists' initiative. Occasionally, however, the therapist asked whether the child wanted instructions or feedback. For instance, one therapist asked *"Shall I explain it* [tying shoe laces] *from the beginning?"* So, in some cases, the timing of instructions and feedback was determined together with the child. The fifth identified parameter was **frequency**. It was observed that therapists' reactions to the child's execution of the task did not always comprise specific feedback. Therapists more often gave compliments, repeated initial instructions, and/or provided new instructions with another specific element of interest as well. Furthermore, if the various segments selected per therapists were compared, it was observed that some therapists provided little specific instructions and feedback and others did more, suggesting that the frequency varied.

4.4 Discussion

This qualitative study aimed to explore therapists' use of instructions and feedback when teaching motor tasks to children with DCD. The video-taped treatment sessions showed that therapists used a lot of encouragement. Furthermore, they used numerous specific implicit and/or explicit instructions and feedback to enhance children's motor learning. They preferred either a direct or indirect style in which instructions and feedback were shaped by the parameters focus of attention, modality, information content, timing and frequency.

Therapists' intentions with instructions and feedback were to motivate children to learn or to provide them with information about the performance of the task (Theme 1). Motivation is considered important in motor learning[8,36]: according to the Self-Determination Theory (SDT), intrinsic motivation will be advanced by promoting competence and autonomy[37]. Encouragements can improve the child's feeling of competence[36,37], while providing the child with choice enhances autonomy[8,36,37]. The therapist can let the child choose *when* or in *what modality* the child wants to receive instructions or feedback[36,38,39]. Published research has demonstrated that both motor performance and the child's perceived competence showed greater improvements when children decided *when* they wanted these so-called self-controlled instructions and feedback[36,38–40]. Because most children with DCD have lower levels of perceived athletic competence and self-esteem[41,42], motivational and self-controlled instructions and feedback are considered relevant. In this study, all therapists observed used encouragements but only two occasionally asked whether the child would like to have instructions, and none asked whether the child preferred a specific modality. With specific instructions and feedback, it was observed that therapists used relatively little feedback to provide the child with information about the movement performance and/or results of the task, somewhat surprisingly, given that specific feedback is considered fundamental to enhance motor learning in evidence-based interventions for children with DCD[14,15,19]. Furthermore, a meta-analysis in educational learning investigating effectiveness of feedback on several outcome measures, including physical performance, showed that feedback with information about performance and process was more effective than feedback without that information[43]. Besides the informational purpose of specific feedback, it can improve competence as well. Studies have shown that children who received feedback after good trials showed greater improvements in motor task performances, and were more motivated, than children who received feedback after poor trials[36]. Because of the reported beneficial effects of self-controlled conditions and specific feedback, it would be interesting to further explore what choices therapists make in using feedback to teach motor skills to children with DCD.

The therapists used either a more direct or a more indirect teaching style to enhance motor learning in children with DCD (Theme 2). The international DCD guideline[11] recommend evidence-based interventions such as CO-OP and NTT[13]. CO-OP strongly promotes an indirect teaching style: the therapist questions the child in order to enhance its problem-solving abilities to develop alternative solutions for the current movement problem[14]. In NTT, both direct instructions and feedback and indirect questioning are used to enhance motor learning[28]. In physical education (PE), the Spectrum of Teaching Styles (STS) is a commonly used framework[44]. This describes 11 styles that PE teachers can use to teach children motor skills. It assumes that teachers will shift between styles to adapt to child characteristics (e.g. motivation, cooperation and cognitive skills) and to the task being practiced[44]. As both therapists and PE teachers teach children motor skills by adapting instructions and feedback to child and task, it would be interesting to explore which teaching styles of the STS would be preferred in children with DCD, and how these styles relate to CO-OP and NTT.

Therapists shaped their instructions and feedback using various focuses of attention and modalities, with different information content, timing and frequency (Theme 3). While labelling the video segments, the combined labels (IML>EML and EML>IML) were used most frequently (n = 72). However, in general more implicit (IML and IML>EML) (n = 82) than explicit (EML and EML>IML) (n = 58) labels were assigned to the segments. For focus of attention, literature showed inconclusive results on the effectiveness of EF versus IF in children with DCD and in typically developing children, so further study is warranted[21–25,45]. As it is suggested that the effectiveness depends on the child's characteristics[22,25,45], it would be interesting to explore therapists' arguments for choosing a specific focus of attention. Each instance of instruction or feedback was shaped by its focus of attention and modality. In complex tasks specifically, therapists combined multiple focuses and modalities, seemingly in line with research findings suggesting that the type and amount of information needed to learn new skills depends on the level of difficulty of the task[5,46]. Furthermore, it was observed that therapists changed focus of attention and/or modality when the child encountered complex challenges in performing a task. These findings support previous research showing that characteristics of the individual and of the task influence therapists' use of motor learning strategies[3,7], which is considered important in interventions with children with DCD[16]. However, more research is necessary to gain a better understanding of how child and task characteristics guide or should guide therapists' use of the instructions and feedback.

Few studies assessed therapists' use of motor learning strategies in children[3,20]. This study expands previous studies since use of instructions and feedback was explored more comprehensively. A strength of this study was that it used video-taped observations which provided the opportunity to review them repeatedly from different points of view[32]. Because existing observation tools score frequencies of predefined items, they provided insufficient insight into the full spectrum of instructions and feedback used, and into whether therapists adapted instructions and feedback[27,28]. Therefore, we developed this new comprehensive video-based analysis plan to investigate more exploratory research questions. Frequent discussions within the research group throughout the analysis process advanced the understanding of: (1) how instructions and feedback were shaped; (2) the implementation of implicit and explicit motor learning approaches; (3) interactions between instructions and feedback; and (4) the adaptation of motor learning strategies to child and task. With these insights, we were able to answer our research question. In order to investigate future research questions that explore whether characteristics of therapist, child, and/or task influence therapists' use of instructions and feedback, it might be useful if the results of our study can serve as a basis for an analysis plan developing predefined codes within the population of interest. So, when a mixed-methods design is used, there is an opportunity to calculate frequencies if preferred.

This study also has some limitations. Firstly, the therapists selected which treatment session was video-taped and shared. It is possible that they chose to videotape and share a session in which they felt more competent in their use of motor learning strategies. Secondly, there is a possibility that the behaviour of the therapist and/or child was influenced by the knowledge that they were recorded. In order to reduce this influence, the treatment session was video-taped by the parent or unmanned with the camera tripod-mounted, because the presence of an unknown person (e.g. researcher) increases the risk for behavioural changes [47].

4.5 Conclusions

As a first step in developing practical recommendations on the use of instructions and feedback to enhance motor learning in children with DCD, this study explored their current use in video-taped treatment sessions. Therapists motivated the child to learn and used numerous specific instructions and feedback in a direct or indirect manner to provide the child with information to enhance task performance. In this study, it was observed that therapists used the parameters focus of attention, modality, information content, timing and frequency to shape instructions and feedback. They often combined multiple focuses and/or modalities, especially in more complex tasks. Furthermore, they changed focus of attention, modality and information content frequently when a child encountered challenges in performing a task. It was observed that therapists used relatively little self-controlled timing, and more specific instructions than feedback. Therefore, as a next step, interviews will gain more insights into therapists' clinical decision-making process regarding their use of instructions and feedback, and how characteristics of child, task, and themselves will influence their choices. Future research should also focus on exploring whether the used instructions and feedback met the therapists expectations of immediate improvement of the performance using a think aloud procedure, and investigating effectiveness and success rates of instructions and feedback in children with DCD in a quantitative study. This study showed that instructions and feedback were frequently shaped by multiple focuses and modalities, which researchers should take into consideration when designing future studies.

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4.8 Appendix 4.1: The video-based analyses plan

4.8.1 The development of the plan

Three members of the research group (IvdV, NvdW, ER) developed a plan to analyse video-taped treatment sessions which allowed for reviewing them at two levels[1]: (1) the treatment session as a whole and (2) in-depth analysis of specific segments using an inductive coding strategy[2,3]. The plan was developed based on previous motor learning research, the extensive clinical expertise of the developers, and on pilot analyses of four videos with different therapists treating a child with DCD or probable DCD. After each video, discussion refined the protocol. Because the first three therapists used a random practice order, a fourth video with blocked practice order was purposively selected, to better define the step of *splitting the video into relevant segments*.

4.8.2 The analysis procedure

The analyses were conducted in two phases: Phase 1 comprised Steps 1 to 3 and Phase 2 Step 4, to be elaborated in following paragraphs. To promote internal validity of the investigation, all steps within the analyses were performed independently by two researchers. Phase 1 (Steps 1 to 3) was performed by Researchers 1 (IvdV or NvdW) and 2 (MG); afterwards, the differences were discussed to advance the understanding of the data. Phase 2 (Step 4) was performed by Researcher 3, who had no prior knowledge of the video (IvdV or NvdW). The open coding was checked and complemented by Researcher 1, and subsequently discussed by both researchers. If these could not reach consensus, an independent researcher (ER) was consulted. Throughout the analysis process, notes were made of first impressions and thoughts. Furthermore, frequent meetings were organized to continuously reflect with the whole research group, comprising researchers with methodological and/or clinical expertise.

4.8.3 Step 1: Splitting the video into relevant segments

As preparation for the in-depth analysis, the video was split into smaller segments. Assuming that instructions and feedback provided by therapists would be related to each other, in order to better understand their use of instructions and feedback, each segment had to contain the instructions, the task performance and the therapists' reactions to that performance (e.g. feedback or compliments). We noted that therapists often repeated instructions or gave instructions with a new focus instead of providing feedback. Therefore, we agreed that segments should overlap, because in one segment these instructions were the reaction to the task performance, while in the following segment they became the instructions prior to the next task performance.

4.8.4 Step 2: Describing and labelling segments

Each segment was provided with comments regarding the content, firstly, whether it concerned practicing tasks or other activities (e.g. social talks or organizing practice situations) and, secondly, if it concerned practicing tasks, (a) the task practiced, and whether that task pertained treatment goals or not (b) the motor learning strategies applied, (c) the amount of therapists' actions to enhance motor learning (in terms of little, somewhat or a lot), and (d) whether the segment contained unique information when compared with other segments of that video. Each segment was assigned a label identifying the type of motor learning approach (implicit or explicit, or a combination of both). Based on the applied focus of attention (e.g. EF, IF, or on strategy), and the amount of information given, the following labels were assigned: (1) *Implicit motor learning (IML)*; (2) *More implicit than explicit motor learning (IML>EML)*; (3) *More explicit than implicit motor learning (EML>IML)*; (4) *Explicit motor learning (EML)*. It appeared that therapists also practiced tasks that were not actual treatment goals. They practiced these tasks to maintain previously acquired tasks, to reward the child for good practice, or to improve the child's confidence or motivation. In these situations, the therapists applied little motor learning. Therefore, these segments were labelled *no motor learning (NML)*. If the segment showed other activities, it received the label *Others*.

4.8.5 Step 3: Selecting segments

Some of the segments in which motor learning was applied were selected for further analysis. The selection process focused on segments that provided rich data or showed unique elements of motor learning. Because instructions and feedback are adapted to the child and task[4–6], and are shaped differently depending the type of motor learning[7,8], it was important to select segments with different tasks and labels. The number of segments selected per video varied: if multiple tasks were practiced, and/or the therapist used many different instructions and feedback, more segments were selected. As data-collection advanced, segments were more deliberately selected, focusing on unique information.

4.8.6 Step 4: Open coding of selected segments

Within the segments, all observable actions of the therapist that might enhance motor learning were coded, using an inductive strategy.

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Chapter 5

How do paediatric physical therapists teach motor skills to children with Developmental Coordination Disorder? An interview study

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Abstract

Background: When teaching motor skills, paediatric physical therapists (PPTs) use various motor learning strategies (MLSs), adapting these to suit the individual child and the task being practised. Knowledge about the clinical decision-making process of PPTs in choosing and adapting MLSs when treating children with Developmental Coordination Disorder (DCD) is currently lacking. Therefore, this qualitative study aimed to explore PPTs' use of MLSs when teaching motor skills to children with DCD.

Methods: Semi-structured individual and group interviews were conducted with PPTs with a wide range of experience in treating children with DCD. A conventional content analysis approach was used where all transcripts were open-coded by two reviewers independently. Categories and themes were discussed within the research group. Data were collected until saturation was reached.

Results: Twenty-six PPTs (median age: 49 years; range: 26-66) participated in 12 individual interviews and two focus-group interviews. Six themes were identified: (1) PPTs *treated* children in a *tailor-made* way; (2) PPTs*' teaching style* was either more indirect or direct; (3) PPTs used various strategies to improve children's *motivation*; (4) PPTs had reached the *optimal level of practice* when children were challenged; (5) PPTs gave special attention to *automatization and transfer* during treatment; and (6) PPTs considered *task complexity* when choosing MLSs, which appeared determined by task constraints, environmental demands, child and therapist characteristics.

Conclusion: PPTs' clinical decision-making processes in choosing MLSs appeared strongly influenced by therapist characteristics like knowledge and experience, resulting in large variation in the use of MLSs and teaching styles to enhance motivation, automatization, and transfer. This study indicates the importance of the level of education on using MLSs to teach children motor skills, and clinical decision-making. Future research should focus on implementing this knowledge into daily practice.

Keywords: motor learning, motor learning strategies, children, Developmental Coordination Disorder, clinical decision-making, interviews, focus groups.

5.1 Introduction

Teaching motor skills is fundamental in therapeutic interventions for children with motor disabilities[1]. Paediatric physical therapists (PPTs) aim to improve children's motor skills by using motor learning strategies (MLSs). MLSs can be described as observable actions of a PPT enhancing motor learning[2]. In general, three categories of MLSs can be distinguished: (1) instructions; (2) feedback; and (3) organization of practice[3]. PPTs use various instructions and feedback shaped by their focus, form, frequency, timing, and information content to motivate children or to provide specific information about task performance[2]. Organization of practice concerns how they arrange exercises and materials during treatment sessions. For instance, they use random or blocked practice to increase or decrease variation between tasks[4], or variable or constant practice to increase or decrease variation within tasks[5]. PPTs can manipulate task and environment to enhance motor learning as well, for instance, by decreasing distance to the target to improve throwing beanbags into a basket[6]. See Appendix 5.1 for (more) descriptions of MLSs commonly described in literature.

PPTs' use of MLS is the result of a clinical decision-making process[2]. The theoretical 'hybrid model of Developmental Coordination Disorder (DCD)' by Wilson et al.[7] advances insights into how child, task and environmental characteristics interact. It advocates that MLSs should be adapted to the unique combination of characteristics to address the specific needs and capacities of the individual child, for example, therapists simplify cognitive load by adopting less stringent task rules or using observational instructions[7]. Previous studies exploring physical and occupational therapists' use of MLSs in video-taped treatment sessions of adults or children with acquired brain injury (ABI) confirmed that they adapted their MLSs during treatment sessions[8,9]. A think-aloud procedure with physical therapists (PTs) watching video-taped treatment sessions of themselves treating adults with ABI showed that the chosen MLS came from therapists' knowledge, observations and assessments[8]. However, in another study, investigating PTs' perspectives on the construct of motor learning, PTs stated that they had difficulty understanding the theoretical construct of motor learning, and that their knowledge was limited, steering them towards an intuitive use of MLSs[10]. Thus, PPTs need more insights into how they can choose MLSs based on the characteristics of a child, a task, and an environment.

A population with mild-to-severe problems in motor coordination and motor learning is a population with children with DCD[11]. They experience difficulties with acquiring, automatizing, and transferring motor skills (e.g. applying skills in different contexts) while having underlying deficits in predictive control, lower abilities in observational learning, and problems in motor planning[7,12]. Their coordination and learning problems are more prominent when task complexity increases, for instance when the task has multiple steps, requires more precision, and/or needs dual-tasking[7,12]. As a consequence of their compromised motor abilities, these children frequently experience bullying[11], lower levels of perceived athletic competence[13], and higher levels of internalizing symptoms (e.g. depression or anxiety)[14], all resulting in lower participation levels and lower perceived health-related quality of life[11,15].

To improve their daily motor skills, children with DCD often receive physical therapy. According to the international recommendations on the definition, diagnosis, assessment, intervention and psycho-social aspects of DCD, PPTs are advised to use evidence-based activity- or participation-oriented interventions, like Neuromotor Task Training (NTT) and Cognitive Orientation to daily Occupational Performance (CO-OP)[16]. These child-centred interventions are based on theories of motor learning, and MLSs derived from motor learning research are used to manipulate the interaction between child, task and environment to improve motor skills[17,18]. However, a limited amount is known about the effectiveness of individual MLSs used in children with DCD. For instructions and feedback, only the effectiveness of the focus of attention (i.e. external or internal focus) has been investigated resulting in conflicting evidence [12]. For organization of practice, two studies showed no difference in the effectiveness of variable versus constant practice[19,20].

In summary, in activity- or participation-oriented interventions the use of MLSs is considered fundamental for teaching children with DCD motor tasks. However, a limited amount is known about their effectiveness, and also about which MLSs to choose, based on characteristics of the individual child, the tasks practised, and the environment. As a first step in developing recommendations for PPTs on the use of MLSs in children with DCD, PPTs were observed and interviewed to explore their use of MLSs. These observations provided insights into PPTs' use of instructions and feedback to teach motor skills to children with

DCD (5-12 years). This qualitative interview study aims to explore how the individual child and the task being practised guide PPTs' use of MLSs when teaching motor skills to these children.

5.2 Materials and method

5.2.1 Design

In this qualitative study, semi-structured individual and focus-group interviews were conducted to explore how PPTs adapt MLSs to suit children, and how the task being practised influenced their choices. The PPTs participating in the individual interviews were also observed during their therapy sessions to gain additional insights into their use of instructions and feedback. By combining interviews with observations, richer data were obtained about PPTs' use of MLSs because they could elaborate on their thoughts and choices during the interviews[21]. The results of the observations will be published elsewhere.

The study was approved by the Medical Ethical Review Board of Maastricht University (2019-1338) for Dutch participants, and Hasselt University (CME2019/060) for Flemish participants. All PPTs gave written consent for participation after receiving written and oral information.

5.2.2 Participants

Dutch and Flemish PPTs could participate if they had at least one year of experience in treating children with DCD. For the individual interviews, they were asked to videotape one of their own treatment sessions up to one week before. For the focus groups, the PPTs needed to be willing to share their experiences with colleagues.

5.2.3 Procedure

5.2.3.1 *Recruitment*

PPTs were recruited between January 2020 and June 2021 in Belgium and the Netherlands, using a convenience sampling strategy[22]. A flyer was distributed within the network for PT clinical internships of Hasselt University, within two regional networks of PPTs in the southern Netherlands (Limburg and Den Bosch networks), and at several educational activities for physical and occupational therapists (e.g. symposia) in both countries. In order to collect a wide range of PPTs' perspectives, a heterogeneous sample matching the following criteria was required[22]: (1) PPTs with different backgrounds in terms of work settings (e.g. private physical therapy practice, and rehabilitation centre); and (2) variation in years of experience in treating children with DCD. The PPTs supplied their demographic characteristics (age, work setting, graduation year, and years of experience in treating children with DCD) by completing a short questionnaire.

5.2.3.2 *Individual interviews*

Individual interviews were conducted to gain insight into the individual reasons of PPTs about their choices in MLSs used to teach motor tasks to children with DCD[21,23]. The framework described by Kallio et al.[24] was used to develop the interview guide. A preliminary semi-structured interview guide was developed by the authors who had clinical, educational, and research expertise in both motor learning and children with DCD. The interview guide started with introductory questions to get acquainted and to elicit information about PPTs' experiences in treating children with DCD. Subsequently, more specific questions explored therapists' use of MLSs with these children (Table 5.1). The interview guide contained suggestions for the interviewer for open-ended follow-up questions, prompts and probes which the interviewer could use to elaborate initial answers[24]. The preliminary interview guide was tested with pilot interviews to assess coverage and relevance of content, and to identify possible needs for reformulating questions and optimising the interview procedure[24]. After three pilot interviews with members of the target population, the interview guide was finalised (see Appendix 5.2). The data from the pilot interviews were discarded.

The first author (IvdV) and four master's students conducted the interviews. Six students each received 35 hours of education to make them familiar with the interview guide and procedure, and to teach them in interview skills such as using prompts and probes. Education included: reading literature about interviewing, and about the topics motor learning and DCD; listening to and discussing the pilot interviews; and performing two interviews by themselves on which they received extensive feedback. Two of the six students experienced difficulties in mastering the interview skills, leaving four to conduct the interviews. The interviewers were encouraged to use the interview guide flexibly to maintain the flow of the interview[24]. Because previous interviews showed that it was difficult for PTs to express exactly what their ideas were regarding their use of MLSs in a specific situation with a particular child[8,10], the PPTs recorded one treatment session in which they taught motor skills to a child (aged 5-12 years) with (probable) DCD. Preferably, the child was diagnosed with DCD. However, because the mean age of receiving a diagnosis of DCD in the Netherlands is 7.02 years (SD 1.79), and the process of diagnosis takes an average of 2.79 years (SD 2.13 years)[25], PPTs were able to video-tape a treatment session of a child with probable DCD if the child met all four DSM-5 criteria for DCD. Interviewers watched the videos in preparation for the interviews and, during these, referred to situations observed to encourage therapists to elaborate on their thoughts and choices.

The audiotaped interviews lasted approximately one hour. The interviews were held in the PPTs' own workplace so that they could support their answers with demonstrations. However, due to Covid-19 restrictions, five of 12 individual interviews were conducted online with Skype or Google Meet[26].

Table 5.1. *Main topics of the individual and focus-group interview guides*

Individual interviews	Focus group 1	Focus group 2
PPTs' use of instructions, feedback and organisation of practice	PPTs' use of MLSs in various tasks	PPTs' adaptation of MLSs to child characteristics
PPTs' use of implicit and explicit motor learning approaches	The information content of instructions and feedback	PPTs' use of MLSs in various tasks
The adaptation of MLSs to child, task and environmental characteristics	Environmental factors guiding therapists' use of MLSs	The interaction of child, task and environment
	The trade-off between the child's experiences of success and failure in the intervention	
	The use of variation in the intervention (e.g. random practice)	
	PPTs' adaptation of MLSs to the child's learning stage	

MLSs = Motor Learning Strategies

5.2.3.3 *Focus-group interviews*

Two focus-group interviews were planned: the first one after 10 individual interviews, and the second after the final individual interview. None of the participating PPTs had participated in the individual interviews. The focus groups were conducted in addition to the individual interviews to enhance data richness[21,23]. The focus-group interviews: (1) deepened topics mentioned in the individual interviews; (2) clarified and elaborated on different points of view about the use of MLSs; and/or (3) determined that insights obtained from the individual interviews were shared by a larger group of therapists[21,23]. The findings of the interview analyses prior to the focus-group interviews determined the main topics of these (Table 5.1). The topics of Focus group 1 emerged from the analyses of the first 10 individual interviews. The topics of Focus group 2 were modified after analysing Focus group 1 and more individual interviews. The structure of the focus-group interview guides was similar to that of the individual one: (1) an introductory question to get acquainted with each other; and (2) specific questions addressing the main topics. The focus-group interview guides (see Appendix 5.3) were discussed and fine-tuned within the research team (IvdV, KK, ER, CB) to ensure the relevance and completeness of their content[21].

To moderate group discussions, the interviewer (IvdV) asked follow-up questions, used prompts and probes, and invited participants to share their thoughts. Furthermore, an assistant made notes, managed time, and ensured that all topics were discussed[21]. Each focus group had 6 to 10 participants, and was organized in a venue proposed by the participants[21]. The audiotaped focus-group interviews lasted approximately two hours.

5.2.4 Data collection

Data collection started with individual interviews. An iterative process of data collection and analysis was used to sharpen the focus of the interviews as data collection progressed[27]. As a consequence, the interviews conducted after Focus group 1 focused more on how therapists adapted their MLSs to characteristics of child, task and environment. Focus group 2 was organized when data saturation in the individual interviews seemed reached. This was the case when two consecutive individual interviews identified no new themes, and provided no new meaningful information to better understand the identified themes[22,28]. A previous interview study exploring how PTs perceive motor learning in their practice reached saturation after 12 individual interviews [10] and therefore it was expected that 12-15 individual and two focus-group interviews would be sufficient.

All research documents were coded, after removing identifying information to guarantee participants' privacy. Only one researcher (IvdV) had access to the code-key. The Flemish data and copies of the Dutch data were stored on the secured server of Hasselt University.

5.2.5 Data analyses

Median age (with range), gender and nationality, and range of years of experience in treating children with DCD were reported.

The qualitative analyses used a conventional content analysis approach[29], using ATLAS.ti Windows (version 22.0.6.0)[30]. Each individual and focus-group interview was transcribed verbatim without the identifying information. The analyses followed six steps: (1) listening to the audio-tape, and reading the complete transcript, to obtain a sense of the whole; (2) line-by-line reading of the transcript, while making notes about first impressions and thoughts; (3) highlighting relevant text fragments; (4) coding these fragments using an inductive coding strategy (i.e. coding without predefined codes); (5) sorting open codes into categories; and (6) identifying themes by organizing and grouping categories into meaningful clusters[29,31].

Steps 1 to 4 were conducted by two reviewers independently. The first six individual interviews, and both focus-group interviews, were analysed by the first author (IvdV), together with a master's student. Three students each received 25 hours of education to acquire analysing skills and to standardize the procedure. Education included: reading literature and watching YouTube videos about analysing qualitative data; and analysing two transcripts according to the described procedure, on which they received extensive feedback. The remaining six individual interviews were analysed by two students, and checked by the first author. Differences were discussed between both reviewers until consensus was reached. In case of disagreement, differences were discussed with the other reviewers. For Steps 5 and 6, multiple meetings were organized with the research group (IvdV, KK, ER, CB), comprising researchers with clinical and methodological expertise.

5.3 Results

5.3.1 Process of recruitment and data collection

After receiving the flyer, 41 PPTs and two groups of PPTs (that meet four times a year for peer-review to optimise functioning in clinical practice) requested more information about the study. Of the PPTs interested in participating in the individual interviews, six had no opportunity to videotape a treatment session, which resulted in 12 PPTs and two groups participating in the interviews (Figure 5.1).

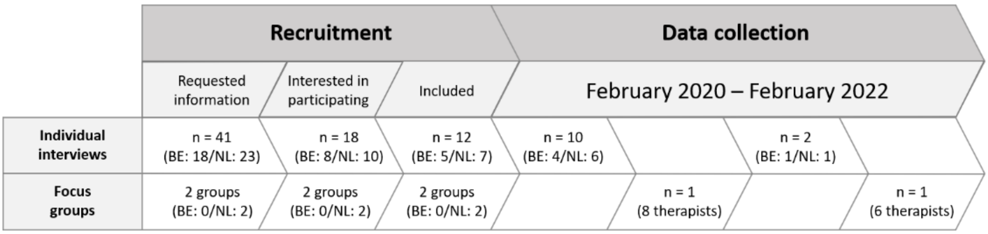

Figure 5.1. *Flow of the recruitment and data collection*

n = number; BE = Belgium; NL = the Netherlands

After 10 individual interviews, Focus group 1 was organized with eight PPTs to elaborate on six topics gained from findings of the individual interviews (Table 5.1). Another two individual interviews resulted in no new themes, and provided no new meaningful information for a better understanding of the identified themes. Focus group 2 with six PPTs confirmed saturation (Figure 5.1).

5.3.2 Participants

The PPTs had a median age of 49 years (range 26-66), with experience in treating children with DCD ranging from 4 to 40 years. Twenty-three of them worked in a private physical therapy practice, of which six combined this with working in a rehabilitation centre as well. The remaining three PPTs worked in rehabilitation centres (Table 5.2).

Table 5.2. *Characteristics of the participants*

	Individual interviews n = 12	**Focus group 1 n = 8**	**Focus group 2 n = 6**
Age: median in years (range)	49.5 (26-63)	51.5 (26-61)	47.5 (42-66)
Sex: f/m	12/0	7/1	6/0
Experiences in treating children with (probable) DCD: range in years	4-40	4-39	7-20
Work setting: P/RC/C	7/3/2	5/0/3	5/0/1

n = number; f = female; m = male; BE = Belgium; NL = the Netherlands; P = private physical therapy practice; RC = rehabilitation centre; C = combination of private physical therapy practice and rehabilitation centre.

5.3.3 Findings of the interview analyses

Most PPTs experienced challenges expressing their thoughts and choices during the interview. They supported their answers with many examples on using instructions, feedback and organization of practice in specific cases. Concepts, such as implicit and explicit motor learning, and specific learning strategies, like errorless learning and analogy learning (Appendix 5.1), were not explicitly known by the majority of the PPTs. However, examples showed that in fact they all used these in their daily practice. The only exception was motor imagery, which was not used at all. After the interview, most PPTs mentioned that they found the reflection on their actions valuable in optimising their use of MLSs. Six themes emerged from the analysis, providing insights into how PPTs adapted MLSs to suit child and task during treatment sessions of children with DCD. These were: (1) Tailor-made treatment; (2) Therapists' teaching style; (3) Motivation; (4) Optimal level of practice; (5) Automatization and transfer; and (6) Task complexity (Table 5.3). The following paragraphs will elaborate on these separate themes.

Table 5.3. *Themes, categories and quotes*

Themes	Categories	Quotes
Tailor-made treatment	Interaction of child, task and environment	*"I think, that in the early stage of the treatment period, child characteristics guide my choices most. Throughout the treatment period, environmental characteristics get more important."*
	Intuition	*"I think that I use that* [questions to provide feedback] *not that often, but that is not a conscious choice"*
	The search for "what works"	*"Some children prefer stories, while others learn more from pictures. So, you try and experience what works best."*
	PPT characteristics	*"I think, that I do that a lot automatically* [using visual cues]*, especially, because we also work a lot with children with autism." "So, it is second nature."*
	Child and task characteristics guiding PPTs' choice	*"In children with also autism I use less verbal language, but mostly demonstrations"*

Table 5.3 continued

Therapists' teaching style	Indirect/direct style	*"I want children to find their own movement solution." "In my opinion, it* [the solution] *sticks longer."*
	PPT characteristics	*"Now, it think it mostly because it suits me* [explicit instructions]*."*
	Child characteristics	*"I want them to think about other movement strategies. Specifically, because children with DCD have rigid strategies, and you want them to try other strategies than the one that is not successful."*
Motivation	Motivation as a prerequisite for learning	*"If they* [children with DCD] *fail to often, then I will lose them* [they will not practice anymore]*."*
	Child characteristics	*"They* [children with DCD] *are very often insecure about themselves, it is not necessarily fear, mostly they have low self-esteem. Or at least they think: I cannot do that."*
	Strategies to improve motivation	*"I will give them* [children with DCD] *confidence by saying 'if I say that you can do it, you can do it'." "So, I give them faith, but you have to make sure that the level of difficulty of the exercises provides them with experiences of success."*
Optimal level of practice	Experiences of success and failure	*"I do that* [leaving room for mistakes]*, to learn from mistakes."*
	Learning stages	*"If the child is in the associative learning stage, and I want to reach the autonomous stage, I will use dual tasks"*
Automatization and transfer	Specific learning disabilities of children with DCD	*"Every context is unique to them* [children with DCD]*, that is difficult for them."*
	Strategies to enhance automatization	*"Of course it is very important that everybody does it in the same way, otherwise the child gets confused."*
	Strategies to enhance transfer	*With respect to using a child's own materials: "At the end, I want them* [children with DCD] *to ty their own shoe, and not only a shoe in front of them on a table."*

Table 5.3 continued

Task complexity	Task constraints	*"Tying shoe laces has a fixed sequence of steps, while ball skills are more context dependent."*
	Environmental demands	*"Writing in a busy class room or in a one-to-one situation."*
	Children experience tasks as difficult to learn	*"Well, the experienced level of complexity of the task* [riding a bike] *will be different for the one than the other: a child with balance problems will experience riding a bike as more complex."*
	PPTs experience tasks as difficult to teach	*"In practicing ball skills it is easy to vary: catcher and thrower stand still, one of them can move, and both can move. But when practicing writing, I found it more difficult to vary."*

PPT = paediatric physical therapist; DCD = developmental coordination disorder

5.3.3.1 *Theme 1: Tailor-made treatment*

This theme consisted of five categories: (1) interaction of child, task and environment; (2) intuition; (3) the search for "what works"; (4) PPT characteristics; and (5) child and task characteristics guiding PPTs' choices (Table 5.3).

All PPTs provided tailor-made treatments to children with DCD. They pointed out that the **interaction of child, task and environment** most guided their use of MLSs:

"If I look at a child and I see that it is anxious, then that determines how I build my track with exercises. However, if I have a parent that is scared that the child will fall, and reacts negatively every time I let the child jump [of a height]*, then that will also influence my choices. Furthermore, if a child gets demotivated due to failure, I will change the task. So, I think there is not one* [characteristic that is most relevant in making choices]*."*

But they also acknowledged choosing MLSs mainly through **intuition**:

"It is when you ask all those questions that I start thinking about it. Because normally you just do things."

Several PPTs described how, in some cases, it was **a search to discover which MLSs worked best**. Their main reason for trying different MLSs was that children were experiencing difficulty mastering tasks with one MLS:

"I experienced with this child [the child of the videotape treatment session]*, that he did not showed improvement. Therefore, I decided to tell him exactly what I expected of him* [in the motor performance]*."*

After elaborating on the clinical decision-making process in the interviews, it appeared that not only did the interaction of child, task and environment guide PPTs' choices, but that this process was influenced by **PPT characteristics** as well. Characteristics such as knowledge, preferences, experiences, character, and/or beliefs affected their choice of MLSs. For instance, one PPT stressed the importance of pedagogical aspects within the learning environment, describing how she addressed this during treatment:

"I find it really important what the pedagogical context is for a child. So, does a child feel safe within the treatment and does it have autonomy? I find this important because it supports the child's development."

Several **child characteristics** were mentioned when PPTs elaborated on their choice for MLSs. However, variation in preferred MLSs for specific child characteristics was large. Some of the child characteristics will be discussed in more detail in the next themes. Following child characteristics were mentioned frequently: (1) deficits in executive functions (Theme 2); (2) level of motivation (Theme 3); (3) level of perceived competence (Theme 3); (4) presence of movement anxiety (Theme 3); (5) learning stage (Theme 4); (6) presence of comorbidity (e.g. autism spectrum disorder); and (7) age. Cognition, behavioural aspects like resistance, and verbal capacities were mentioned by some therapists. For **task characteristics**, their complexity seemed an important guiding characteristic (Theme 6).

5.3.3.2 *Theme 2: Therapists' teaching style*

This theme consisted of three categories: (1) indirect/direct style; (2) PPT characteristics; and (3) child characteristics (Table 5.3).

In general, two types of teaching styles could be recognized: **indirect and direct styles**. A greater part of the PPTs preferred an indirect style, using questions and/or manipulations of task and environment to guide children with DCD to the correct movement solution. However, some of them preferred a direct style, instructing children exactly what to do. For instance, one PPT talked about how she used demonstrations with extensive verbal guidance to improve jumping skills:

"For example, I demonstrate jumping while also guiding very verbally." "I give that guidance, so that he takes over from me, and starts guiding himself, first out loud and eventually in his head."

Reasons for preferring an indirect or direct style differed. Some were related to **PPT characteristics**: (1) it suited them because it is the style they prefer themselves or it matches their character; and (2) they had learned by experience or education that a certain style works best. For example, several PPTs argued that they preferred asking questions because they believed that children learn more when discovering their own movement solution:

"I prefer asking questions rather than giving feedback, because I think that it [the movement solution] *sticks better when the child comes up with it itself."*

Other reasons were related to **child characteristics**. Some PPTs suggested that children needed to be of a certain age and stage of cognition to process the explicit instructions used in a direct style. Furthermore, all PPTs agreed that children with DCD experience problems in executive functions (e.g. motor planning, finding movement solutions, and reflecting on their own actions). For some of them, that is why they use an indirect teaching style, so that such children learn these cognitive skills by themselves. However, for others, this justified a direct teaching style, because they believed these children to be insufficiently capable of learning these cognitive skills:

"I do not use that [guiding with questions] *in children with DCD, I do it with my other children, but not with them because they cannot reflect on their motor disabilities."*

5.3.3.3 *Theme 3: Motivation*

This theme consisted of three categories: (1) motivation as a prerequisite for learning; (2) child characteristics; and (3) strategies to improve motivation (Table 5.3).

All PPTs explained how a child's motivation guided their use of MLSs. A general assumption was that demotivated children will learn less. Several PPTs stressed the importance of **motivation as a prerequisite for learning**:

"Because success makes happy and positive, and, with positive experiences, learning improves, right? That is [scientifically] *demonstrated."*

Furthermore, PPTs talked about how various **child characteristics** impacted a child's motivation according to their opinion. They underpinned the problems in automatization and transfer (Theme 4), and the lower levels of perceived competence of children with DCD as main reasons for these children not being motivated to practice, and getting frustrated when experiencing tasks as being too difficult:

"If it is really difficult, and it goes wrong every time, I don't think they [children with DCD] *will practice."*

Other reasons mentioned were movement anxiety and behavioural aspects like resistance when children were experiencing a bad day or were fatigued.

The PPTs suggested various strategies to improve children's motivation (Table 5.4). For instance, one PPT talked about using themes to improve motivation:

"The boy had no motivation, because he was playing when he had to come to me. I asked what he was doing, and he told me he was making a marble run. So, we drew marble runs when practicing writing readiness skills."

Table 5.4. *Strategies to enhance children's motivation*

Strategies to enhance motivation
Giving frequent compliments and/or small rewards (e.g. stickers) enhancing self-confidence
Alternating "learning tasks" with "fun tasks" rewarding good practice to enhance self-confidence
Involving other children (e.g. friends) during treatment to increase enjoyment, and enhancing self-confidence
Decreasing the level of difficulty of the exercise to increase experiences of success
Increasing the level of difficulty between exercises more gradually, increasing experiences of success
Using fewer verbal instructions and feedback, and more visual cues or manipulations of task and environment, decreasing the focus on errors
Providing choice (e.g. in materials or exercises) to enhance autonomy
Working with themes that suit children's interests, increasing enjoyment
Changing teaching approaches (e.g. using more fantasy or competition), increasing enjoyment

5.3.3.4 *Theme 4: Optimal level of practice*

This theme consisted of two categories: (1) experiences of success and failure; and (2) learning stages (Table 5.3).

The majority of the PPTs emphasized that the optimal practice level is when children are challenged, but most trials are still successful. They argued that if tasks are too easy or too difficult, children will not learn and will become demotivated. They talked about the relevance of **experiences of success and failure**. Most PPTs underlined the importance of success in children with DCD:

"You make sure that the child still can perform the exercises, and that the challenge is there. But I think that, in these children, it is even more important that they get positive experiences."

However, several PPTs also talked about how errors enhanced learning:

"Sometimes, you have to do something wrong to know how you should actually do it."

One of the child characteristics frequently considered when estimating the optimal practice level was the child's **learning stage** (e.g. cognitive stage). However, perspectives on the use of MLSs within learning stages differed. In the early stage of learning, some therapists said they used more explicit instructions and feedback, while others strongly preferred using manipulation of tasks and environment without instructions and feedback. In one focus group, PPTs discussed the use of variation in the early stage of learning. Some of them reduced variation during practice to accelerate learning, while others deliberately introduced variation because of the varying contexts found in daily life. In reaction to a PPT that elaborated on how she used various types of ball to stimulate a child's anticipation abilities in throwing, another PPTs said:

"I practice the basics of the skill [throwing] *to make a child familiar with it, and start varying in a later stage."*

As learning progressed, PPTs agreed more on increasing variation and using dual tasks to enhance transfer (Theme 4). However, some PPTs said they still used explicit instructions and feedback as well to optimize performance, while others did not use these in the later stages.

5.3.3.5 *Theme 5: Automatization and transfer*

This theme consisted of three categories: (1) specific learning disabilities of children with DCD; (2) strategies to enhance automatization; and (3) strategies to enhance transfer (Table 5.3).

Most PPTs referred to the problems with automatization and transfer of skills as the **specific learning disabilities of children with DCD**. One PPT said:

"Automaticity takes much more time, so it is really important to give therapy in the best way in order to automatize [skills] *as optimally as possible."*

The same PPT stressed that children with DCD have to keep practising tasks, as otherwise they forget how to perform them.

The PPTs suggested various **strategies to enhance automatization**. They stressed the importance of instructing parents and teachers to practise in daily life, and underpinned using the same wording in instructions and feedback:

"They [parents and teachers] *should use the same wording as I do, because otherwise they* [children with DCD] *will never automatize."*

Furthermore, they suggested to practice tasks in similar ways throughout the various treatment sessions, and to decrease instructions and feedback when learning progresses to increase time for repetitions. They felt that with motivated children it was easier to achieve greater time on task.

PPTs also talked about their **strategies to enhance transfer**. For instance, they varied spatial and temporal constraints during practice (e.g. by continuously changing throwing direction and/or speed to improve the child's catching abilities) to enhance anticipating to variable contexts in daily life:

"When they [children with DCD] *know the movement pattern, than you should start changing to try to simulate other situations* [from daily life]*."*

Other suggested strategies were: (1) simulating daily context by using dual tasks, or inviting other children to participate during treatment; (2) practising tasks that fit the child's needs; and (3) using regular tools from children's daily life (e.g. the child's own bike).

5.3.3.6 *Theme 6: Task complexity*

This theme consisted of four categories: (1) task constraints; (2) environmental demands; (3) children experience tasks as difficult to learn; and (4) PPTs experience tasks as difficult to teach (Table 5.3).

Most PPTs compared two types of tasks while elaborating on how tasks guide their use of MLSs. Frequently used examples were writing, cycling, rope skipping, and tying shoe laces. These tasks were compared to throwing, catching, running, and climbing. Because PPTs found it difficult to explain exactly how these tasks differed, this topic was extensively discussed in both focus groups. The overarching theme seemed to be task complexity, with four variables determining this identified: (1) task constraints; (2) environmental demands; (3) child and (4) therapist characteristics.

The PPTs mentioned following **task constraints** making tasks more complex: (1) multiple sequential steps; (2) dual tasking; (3) specific timing requirements; (4) bimanual coordination with both hands having different functions; and (5) the requirement to follow rules, for instance, in games. For instance, one PPT said:

"Eating is a bimanual skill, the hands must support each other, while doing opposite tasks" "I think that is what makes eating complex."

They also pointed out that **environmental demands** could increase complexity, for example riding a bike in traffic is much more complex then riding a bike on an empty schoolyard:

"The child could ride a bike inside very well, but he refused to ride outside." "Riding a bike depends on the person or the environment."

Some PPTs noted that **children may experience specific tasks as more difficult** to learn:

"I find it [rope skipping] *not difficult to teach, but I find it difficult to learn for the child* [with DCD]*."*

Finally, some **PPTs experienced tasks as more difficult to teach**, which seemed to be related to their knowledge and experience:

"I find skipping [as locomotion] *very difficult to teach to a child, probably one of the most difficult tasks."*

PPTs' opinions on how tasks guided their use of MLSs varied. In both focus groups, they discussed how they used MLSs to improve performances of complex tasks (e.g. cycling or rope skipping). MLSs varied from explicit instructions, in which the child was told step by step how to ride a bicycle, to implicit strategies with manipulations of task and environment without using instructions and feedback, for example by letting the child ride the bicycle of a hill to increase speed.

5.4 Discussion

This qualitative study explored how PPTs adapted MLSs, based on characteristics of a child with DCD, and the task practised. One of the main findings was that PPTs intuitively choose MLSs, and that their clinical decision-making process was not only guided by child and task, but also by their own characteristics (Themes 1 and 6). Another finding was that PPTs used indirect or direct teaching styles, and that they had different justifications for choosing a specific style in children with DCD (Theme 2). Lastly, some general key elements for motor learning in children with DCD emerged when PPTs elaborated on how child characteristics influenced their choices: (1) motivation (Theme 3); (2) optimal level of practice (Theme 4); (3) sufficient time spent on task (Theme 5); and (4) stimulating transfer (Theme 5).

5.4.1 Factors guiding PPTs' process of clinical decision making

5.4.1.1 *PPT characteristics*

Most PPTs experienced difficulties putting their thoughts into words about which characteristics led their clinical decision-making. They stressed that the interaction of child, task, and environment guided their choices, as suggested by the 'hybrid model of DCD'[7]. However, the results of this study showed that PPTs choose MLSs intuitively, and that their clinical decision-making process was influenced by their own characteristics like knowledge, preferences, and beliefs as well. These findings are in line with a previous interview study that explored PTs' perspectives on the construct of motor learning and their experiences of its implementation in clinical practice[10]. PTs stated that their use of MLSs was guided by intuition, and that their limited knowledge was an important barrier to implementation[10]. The importance of knowledge has also been demonstrated in several think-aloud studies investigating PTs' clinical decision-making processes in rehabilitation, showing that knowledge from prior clinical experience, education, scientific research, and mentors or colleagues influenced their clinical decision-making[8,32,33]. For optimal clinical decision making, PPTs require knowledge about: the use of MLSs to teach motor tasks (including adapting MLSs to child and task); the learning disabilities and associated problems of children with DCD; and basic knowledge about child development. The results of this study indicate the importance of the level of education on these topics. Specifically, PPTs' knowledge about implicit and explicit motor learning approaches appeared limited. A need for more education has also been stressed by previous research[8,10].

5.4.1.2 *Child characteristics*

PPTs elaborated on how specific characteristics of a child guided their use of MLSs. Various child characteristics were identified. However, because of large variation in suggested characteristics and preferred MLSs, more research is required to gain insights into how the identified characteristics can guide PPTs' decisions. One child characteristic that PPTs frequently mentioned guiding their choice of an indirect or direct teaching style was the presence of deficits in executive functions. As a result of deficits in inhibitory control, working memory, and attention, children with DCD have problems in planning and organizing activities of daily life[7,12]. Based on their assumption whether executive functions could be trained or not, some PPTs preferred an indirect teaching style, while others preferred a direct style. Research shows that executive functions in children can be improved by training[34,35]. Advancing critical and creative thinking, and problem-solving in movement situations encourages the development of executive functions[36]. Using questions that require children to think about movement solutions and then debriefing them about their actions is a frequently used strategy. Another is to place children in movement situations that challenge them to think about movement solutions[36]. Both strategies were used by the PPTs with indirect teaching styles. Because executive functions are important in many daily life activities (e.g. in learning at school, and in social interactions), and can be trained, PPTs can adopt an indirect teaching style to enhance the development of these executive functions when teaching motor tasks[36,37]. PPTs choices based on the characteristics learning stage, the presence of learning disabilities, level of motivation, and level of perceived competence will be discussed in the section 'Key elements in motor learning'.

5.4.1.3 *Task complexity*

Task complexity was identified as the most important task characteristic guiding PPTs' choice for MLSs. It appeared a complex construct described by four variables: (1) task constraints; (2) environmental demands; (3) child characteristics; and (4) therapist characteristics. The 'challenge point framework' conceptualizes complexity as a result of the combination of child, task and environment to which the PPTs should adapt their MLSs, which is in line with the results of our study[38]. The framework distinguishes two types of difficulties: the nominal task difficulty is defined by the task constraints, and is considered to reflect a constant amount of difficulty; the functional task difficulty is determined by the experiences of the individual (e.g. novices experience tasks as more difficult than individuals who have already performed those tasks) and environment (e.g. throwing outside in windy circumstances is more challenging than throwing indoors)[38]. This study also demonstrated that PPTs can experience teaching specific motor tasks as more or less difficult based on their knowledge and experiences.

PPTs' opinions on which MLSs to use in complex tasks (e.g. riding a bike, tying shoe laces, and writing) differed: some used specific instructions focusing on the planning of these motor tasks, while others chose to provoke the correct movements by manipulating task and context. According to the international DCD recommendations, evidence-based methods like CO-OP and NTT can be used to teach motor tasks to children with DCD: CO-OP focuses mostly on motor planning, while NTT focuses on manipulating task and context[16–18]. Some therapists explained that they chose specific MLSs because they were trained in CO-OP or NTT. However, other reasons for choosing to focus on motor planning in complex tasks were given as well, demonstrating that PPTs own characteristics influenced their choices: (1) PPTs did not know how to manipulate complex tasks and its context; (2) it suited their own preference in learning; and (3) they believed that children needed to learn motor planning to advance learning in daily life.

5.4.2 Key elements for motor learning

In the treatment of children with DCD, PPTs gave specific attention for children's motivation (Key element 1), the optimal practice level (Key element 2), adequacy of time on tasks (Key element 3), and transfer (Key element 4). The key elements motivation and the optimal practice level were related: if the practice level was too difficult or too easy, motivation decreased and learning was hampered. PPTs considered the child's learning stage when estimating the optimal practice level but their opinions on the use of explicit instructions and feedback in the early learning stage differed: some argued that children needed explicit information to learn tasks that they had not yet mastered, while others said that they reduced the amount of explicit information given because children with DCD experience difficulties with processing large amounts of information. Studies investigating effectiveness of explicit and implicit instructions and feedback used to teach functional motor skills to inexperienced children with DCD found conflicting evidence[39–41]. Systematic reviews investigating the effectiveness of these types of instructions and feedback in children with and without motor disabilities also found conflicting results[42,43]. Thus, both explicit and implicit instructions might be used.

PPTs stressed that attention to motivation is specifically needed in children with DCD, because most children experience problems in learning motor tasks and have lower levels of perceived competence. Research confirms that both characteristics are prominent in children with DCD[12,13]. The role of motivation in enhancing motor learning is conceptualized in the 'Optimizing Performance through Intrinsic Motivation and Attention for Learning' (OPTIMAL) theory[44]. According to this, motivation will be improved by giving autonomy to children, and by enhancing their self-confidence[44]. The findings of the current study showed a large variation between PPTs in strategies used for improving motivation (Table 5.3). All of them used positive encouragements and experiences of success to enhance self-confidence, in line with the OPTIMAL theory. Only a few enhanced autonomy by giving children choice. Furthermore, some stressed the importance of enjoyment to increase motivation. A systematic review investigating effectiveness of MLSs related to the OPTIMAL theory that enhanced children's motivation showed that, in most included studies, motor performance improved more when MLSs that enhanced motivation were used compared to MLSs that did not[43]. However, no such studies were performed in children with DCD. Furthermore, the authors reported that: (1) most investigated MLSs focused on feedback; (2) not all MLSs investigated had good ecological validity; and (3) effectiveness seemed modified by child characteristics like motor abilities, and the task practised. They recommended that future studies should explore how MLSs enhancing motivation could be integrated into children's motor learning[43]. The suggested MLSs in this study could be informative for researchers investigating effectiveness of MLSs.

PPTs considered the key elements adequacy of time on tasks and transfer important during treatment, because of the specific learning disabilities of children with DCD, and their consequences on the level of participation. Again, the MLSs suggested to improve time spent on task and transfer varied widely between PPTs. Most PPTs highlighted the importance of instructing parents and teachers to practise in the child's daily context, which is in line with the international DCD recommendations[16]. These recommendations also stress to practice meaningful activities fitting children's needs, and to consider practising in small groups[16]. Both were mentioned by PPTs as strategies to enhance transfer. Furthermore, PPTs frequently mentioned using variation in practice to enhance transfer, specifically as learning progressed. Studies in children with DCD showed no differences in the effectiveness of variable versus constant practice on immediate transfer tests after Wii Fit training[19,20]. However, a systematic review including a meta-analysis concluded that effectiveness of variable practice in predominantly healthy young adults seemed promising, but that the included studies were at a high risk of bias, had small sample sizes and were difficult to compare due to large amounts of heterogeneity[5]. The authors also mentioned that variable practice can increase enjoyment, and that it suits real-world contexts better[5]. Both arguments were also raised by therapists in our study.

5.4.3 Strengths and limitations

This study is the first to explore PPTs' thoughts on how to adapt MLSs during treatment in children. The design had several strengths. Firstly, individual interviews were combined with focus-group interviews, which advanced the understanding of themes like task complexity. Furthermore, it showed that the pre-identified themes were shared by a larger group of PPTs[23]. Secondly, despite the rather small sample size, a heterogeneous group of PPTs was included with wide range of experience in treating children with DCD in different settings (Table 5.2) which enlarged the various perspectives. Thirdly, video-taped treatment sessions facilitated the interviews because PPTs could elaborate their thoughts more easily by referring to their own treatment session. Fourthly, all transcripts were coded by two reviewers, and the themes discussed within the research team (which comprised researchers with clinical and methodological expertise).

There were also some limitations. Recruitment was challenging for several reasons: (1) PPTs found participation too time-consuming; (2) for a period of time, they had no opportunity to videotape treatment sessions because they were not allowed to treat children due to Covid-19; and (3) Covid-19 safety regulations necessitated remote participation by PPTs in individual and focus-group interviews. Further, despite intensive recruitment efforts, a Flemish focus group could not be included. Also, only one male PPT was included in this study, which seemed a logical consequence of less males working as PPTs. In the Netherlands, only 6% of the PPTs registered in the quality system of the Dutch association of PTs was male[45]. Our research aim was to explore therapists' use of MLSs, we did not focus on differences between subgroups of PPTs. Despite the recruitment challenges, we had been able to include a heterogeneous sample of PPTs, and reached saturation. Lastly, all PPTs treated children with other diagnoses (e.g. cerebral palsy or intellectual disabilities) with whom they also used MLSs. Therefore, there is a small chance that some of the experiences shared were influenced by experiences with other types of children.

5.4.4 Recommendations for future research

This study indicates the importance of the level of education on: using MLSs to teach children motor tasks (including adapting MLSs to child and task), the learning disabilities and associated problems in children with DCD, and child development. Future research should focus on implementing this knowledge into daily practice, for instance, by developing an online module about the use of MLSs with a focus on clinical decision-making. Previous research has shown that an evidence-based online DCD module tailored to PTs' needs, with information about identifying, assessing and treating children with DCD, appeared relevant, applicable and useful[46]. Furthermore, it enhanced PTs' self-reported knowledge and skills, and supported evidence-based practice[47]. In order to implement knowledge effectively, systematic approaches like the knowledge translation framework should be used[48].

5.4.5 Conclusions

In conclusion, this study has advanced insight into PPTs' use of MLSs in children with DCD. PPTs assumed that only the interaction of child, task, and environment guided their clinical decision-making, but in reality it appeared that this process was strongly influenced by their own characteristics, namely their knowledge, experiences and beliefs. These characteristics also influenced the clinical decision-making process of choosing specific teaching styles. Because of deficits in executive functions, an indirect teaching style might have been more effective but this was not always chosen[35,36]. Furthermore, the variation in MLSs used to enhance the child's motivation, automatization and transfer appeared large, with some choices the result of limited knowledge. The findings of this study might be of interest for treatment decisions in other populations with and without motor disabilities because the identified child characteristics are generic and the process of clinical decision-making is comparable.

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5.7 Appendix 5.1: Motor learning strategies commonly described in literature

Table 5.5. *Motor learning strategies commonly described in literature*

Types of motor learning	
Implicit and explicit motor learning	Implicit motor learning: learning which progresses with no or minimal increase in verbal knowledge of movement performance (e.g. facts and rules) and without awareness. Implicitly learned skills are (unconsciously) retrieved from implicit memory[1].
	Explicit motor learning: learning which generates verbal knowledge of movement performance (e.g. facts and rules), involves cognitive stages within the learning process and is dependent on the working memory[1].
Instructions and feedback	
External and internal focus of attention	External focus: an external focus of attention directs the learner's attention to the impact of the movement on the environment[2].
	Internal focus: an internal focus of attention directs the attention to the learner's body movements[2].
Knowledge of performance	Feedback providing the learner with information about its own body movements[3].
Knowledge of results	Feedback after the performance providing the learner with information about its success in meeting the environmental goal[3].
Observation learning	Watching a model performing a motor task, which provides the learner with a cognitive model of the movement performance[4].
Analogy learning	Providing the learner with an analogy (metaphor) that integrates the complex structure of the to-be-learned task[5].

Table 5.5 continued

Organization of practice	
Random and blocked practice	Random practice: practicing various motor tasks in a random order[6].
	Blocked practice: practicing the same motor tasks in a blocked order, without alternation with other motor tasks[6].
Variable and constant practice	Variable practice: practicing a motor task with increased variation during practice[7].
	Constant practice: practicing a motor task repetitively without variation during practice[7].
Whole and part practice	Whole practice: practicing a motor task in its entirety[8].
	Part practice: practicing units of motor tasks, after breaking down a motor task into smaller units[8].
Dual-task learning	Using a secondary (mostly cognitive) task to draw the attention of the learner to, whereby short-memory capacity cannot be used for explicit knowledge of the primary task to-be-learned[9].
Errorless learning	Arranging the practice situation in such way that the learner makes no or few outcome errors[10].
Guided discovery	Guiding the learner to the correct movement response with a sequence of questions[11].
Motor imagery	Asking the learner to mentally execute the motor task without actually doing it[12].
Trial-and-error learning	The learner performs the task repeatedly and optimizes its performance with intrinsic and extrinsic feedback on its errors[13].

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5.8 Appendix 5.2: Interview guide for the individual interviews

(Translated to English, interviews were conducted in Dutch)

Table 5.6. *Interview guide for the individual interviews*

Instructions for the interviewer
• Welcome the therapist, and introduce yourself. • Mention explicitly that the aim is to gain insights into therapists' use of motor learning strategies (MLSs) to teach motor skills to children with Developmental Coordination Disorder (DCD), and that you are interested in therapists' experiences without judging their answers or actions. • Mention that all information shared during the interview will be in confidence and that privacy will be respected. The therapist can interrupt or end the interview whenever he or she wants as described in the information letter and consent form. • Use the interview guide flexibly. Feel free to switch between topics if the conversation gives rise to it. • Ask open-ended follow-up questions to invite the therapist to elaborate on their answers. Suggestions are included in this interview guide. • Invite the therapist to use lots of examples, or to simulate situations, to support their answers. • Refer to the video-taped treatment session of the therapist to encourage the therapist to elaborate on answers or specific examples observed. • Use prompts and probes to encourage the therapist to elaborate on their answers. • Start the two recording devices.

Table 5.6 continued

Topic list			
Topic	**Introduction**	**Main questions**	**Follow-up questions and/or topics**
Topic 1: Therapists' experiences in treating children with DCD and teaching (a)typical developing children motor skills	These questions are to get acquainted, and to get insights into your experiences.	Which experiences do you have in *treating* children with DCD?	• The experiences with the various needs that children with DCD have • The experiences with different types of children with DCD, e.g. with and without comorbidity
		Which experiences do you have in *teaching* children with or without DCD motor skills?	• The therapists' opinion on the relevance of motor teaching in children (with DCD) • Non-therapeutic experiences in using MLSs, e.g. as sports trainer
Topic 2: Therapists' use of MLSs to teach children with DCD motor skills	In treating children with DCD, we try to teach new motor skills or to optimize acquired motor skills to these children. I would like to get some insights into the various MLSs you use in your treatment sessions.	How do you shape your MLSs when teaching children with DCD motor skills?	• The use of instructions and feedback • The organization of practice • The use of specific learning strategies • When do you choose to use [mentioned MLS]? • Can you give an example of using [mentioned MLS] in clinical practice? • On the video-taped treatment session I saw you using/doing/telling/showing [the action of the therapist], can you share your thoughts about why you did this?

Table 5.6 continued

Topic 3: Therapists' use of implicit and explicit motor learning approaches	In literature, motor learning approaches distinguishes implicit and explicit motor learning approaches. I would like to get more insights into your use of these approaches.	Are you familiar with the terms implicit and explicit motor learning?	• When "yes": Can you give a description of both implicit and explicit motor learning? • When "no", give a description: Do you recognize using implicit and explicit motor learning approaches as you heard the description? • Can you give an example on how you shaped implicit/explicit motor learning during a treatment session of a child with DCD?
		Which advantages and/or disadvantages do you experience using implicit and explicit motor learning approaches in children with DCD?	• Why do you experience this as a (dis)advantage? • Do you prefer an implicit or explicit motor learning approach in children with DCD and can you explain why?

Table 5.6 continued

Topic 4: The adaptation of MLSs to suit child, task and environmental characteristics	For each child we use different MLSs. Even within a child, we use different MLSs within or between treatment sessions. I would like to get more insights into which variables guide your choices when teaching motor skills to children with DCD.	Which child, task and environmental characteristics do you map during your therapeutic examination of children with DCD?	• Question specific child, task and environmental characteristics • Why are you interested in [mentioned characteristic]? • Do you map the same characteristics for each child with DCD? Why yes/no?
		How do these characteristics guide your choices in the use of MLSs?	• Why does [mentioned characteristic] guide your choices? • Can you give an example on how you acted differently in case of [mentioned characteristic]? • On the video-taped treatment session I saw you using/doing/telling/showing [the action of the therapist], can you share your thoughts about why you did this in this specific situation?
		During treatment sessions it can occur that you start using other MLSs, for instance, because results are not as you expected. Which characteristics are leading in this adaptation?	• Can you explain how [mentioned characteristics] changed your use of MLS? • How did you acted initially and what did change? Why? • On the video-taped treatment session I saw you changing from [the action of the therapist] to [the action of the therapist], can you share your thoughts about why you did this?

Table 5.6 continued

	You adapt the use of MLSs to each child individually. Can you explain why?	• Why is adapting MLSs to each individual child important for you? • Which characteristic is leading in guiding your choices?
Closing question before thanking the therapist	Do you have something to add to everything already discussed, for instance, a specific example of your daily practice that you find really illustrative for you as a therapist?	

5.9 Appendix 5.3: interview guide for the focus-group interviews

(Translated to English, interviews were conducted in Dutch)

Table 5.7. *Interview guide for the focus-groups interviews*

Instructions for the interviewer
• Welcome the therapists, and introduce yourself. • Mention explicitly that the aim is to gain insights into therapists' use of motor learning strategies (MLSs) to teach motor skills to children with Developmental Coordination Disorder (DCD) without reaching consensus, and that you are interested in the therapists' experiences without judging their answers or actions. • Ask the therapists to respect the opinions of each other without judging. • Mention that all information shared during the interview will be in confidence and that privacy will be respected. • Use the interview guide flexibly. Feel free to switch between topics if the conversation gives rise to this. • Ask open-ended follow-up questions to invite the therapists to elaborate on answers. Suggestions are included in this interview guide. • Invite the therapists to use lots of examples, or to simulate situations, to support the answers. • Use prompts and probes to encourage the therapists to elaborate on answers. • Start the recording devices.

Topic list focus group 1			
Topic	**Introduction**	**Main questions**	**Follow-up questions**
Introduction	I would like to start with a question to get acquainted with each other. Please introduce yourself and answer the following question.	What materials do you favour using in treatment sessions?	

Table 5.7 continued

Topic 1: Therapists' use of MLSs in various tasks	During your treatments, you practise various tasks with children. I would like to get more insight into how you use your MLSs in these tasks.	Which tasks do you practise a lot with children with DCD?	• How do you use your MLSs when practising [the task mentioned]? • What task characteristic determines which MLSs you use? • Do you always practise tasks the same way? Why or why not?
Topic 2: The information content of instructions and feedback	In the individual interviews, some therapists mentioned using short instructions and feedback, while others used more extensive ones with more details to teach children with DCD skills. I would like to hear how you address this.	How much detail do you give in your instructions and feedback?	• Why do you provide your instructions and feedback in that way? • Is the amount of detail always the same in your instructions and feedback? Why or why not? • Can you give an example?
Topic 3: Environmental factors guiding therapists' use of MLSs	In the individual interviews, therapists talked about how the environment of the child (e.g. parent, school) influences motor learning but they talked less about how this influences their use of MLSs.	How do environmental factors influence your use of MLSs?	• Which MLSs do you use when [mentioned environmental factor] is present? • Do you always use the same MLSs in case of [mentioned environmental factor]? Why or why not?

Table 5.7 continued

Topic 4: The trade-off between the child's experiences of success and failure in the intervention	In the individual interviews, some therapists talked about the importance of success experiences, while others mentioned that errors are needed to learn.	How do you use errors during practice?	• Can you elaborate on your thoughts? • What are your thoughts on success experiences? • Is it the same for all children?
Topic 5: The use of variation in the intervention (e.g. random practice)	In the individual interviews, therapists talked about how they gradually increased steps between exercises, and how they decreased or increased complexity within tasks. However, they talked less about the use of variation between or within tasks. For instance, random/blocked practice, and constant/ variable practice.	How do you use variation during practice?	• Why do you use it in that way? • Can you give an example on how you used variation during practice?

Table 5.7 continued

Topic 6: Therapists' adaptation of MLSs to the child's learning stage	In the individual interviews, the therapist elaborated on how the learning stage of a child (e.g. cognitive stage) influenced their use of MLSs.	How do you adapt your use of MLSs to the learning stage of a child?	• Why do you adapt in this way? • Can you give an example? • Do you always use the same MLSs in learning stages? Why or why not?
Closing question before thanking the therapists		Do you have something to add to everything already discussed, for instance, a specific example of your daily practice that you find really illustrative for you as a therapist?	
Topic list focus group 2			
Topic	**Introduction**	**Main questions**	**Follow-up questions**
Introduction	I would like to start with a question to get acquainted with each other. Please introduce yourself and answer following question.	Children with DCD have specific needs they wanted to practise: which needs do you like most?	

Table 5.7 continued

Topic 1: Therapists' adaptation of MLSs to child characteristics	In previous interviews, therapists talked about how characteristics of the child guided their use of MLSs. I would like to explore that topic with you.	Which child characteristic do you take into consideration when determining what MLSs to use?	• How does [mentioned child characteristic] influence your use of MLSs? • Do you always practise the same when [mentioned child characteristic] is present? • Can you give an example?
Topic 2: Therapists' use of MLSs in various tasks	In previous interviews, therapists talked about how they used MLSs in specific tasks. I would like to explore that topic with you.	Which task characteristic do you take into consideration when determining what MLSs to use?	• What make tasks more or less complex? • How does [mentioned task characteristic] influence your use of MLSs? • Can you give an example?
Topic 3: The interaction of child, task and environment	In previous interviews, therapists mentioned that the interaction of child, task and environment influenced their choice in MLSs.	What are your perspectives on that?	• Which characteristics within the child (or task, or environment) are most prominent in your choices? • Can you elaborate on your thoughts?
Closing question before thanking the participant		Do you have something to add to everything already discussed, for instance, a specific example of your daily practice that you find really illustrative for you as a therapist?	

Chapter 6

General discussion

The overall aim of this thesis was to gain a better understanding on how therapists can use motor learning strategies (MLSs) to teach motor tasks to children with motor disabilities, with a focus on children with developmental coordination disorder (DCD). Because motor learning literature includes many components and inconsistent terminologies, we developed the *motor learning component model* (MCL-model) to frame relevant components that were also topics of interest in our studies, see Figure 6.1. We refer to the general introduction (Chapter 1) for a detailed description of this model. The first component, so-called **factors**, represent the characteristics of a child, task and environment that should guide therapists' clinical decisions in choosing: which **types of motor learning processes** to promote (Component 2); and what **elements of MLSs** (Component 3), or **specific MLSs** (Component 4) to use. The results of our qualitative studies (Chapters 3 to 5) suggested that a fifth component can be added to the model: therapists' **teaching styles**, which can be either (more) direct or (more) indirect. Indirect styles use questions to guide a child to the correct movement solution, by letting a child: analyse motor tasks; think about movement solutions; and/or reflect on its own performance. Furthermore, when the organization of practice challenges a child to search for movement solutions, an indirect style is used as well. Direct styles use concrete instructions and feedback about the movement solution, for instance, by telling a child exactly what to do with knees and arms while jumping. Both styles are considered upper ends of a continuum.

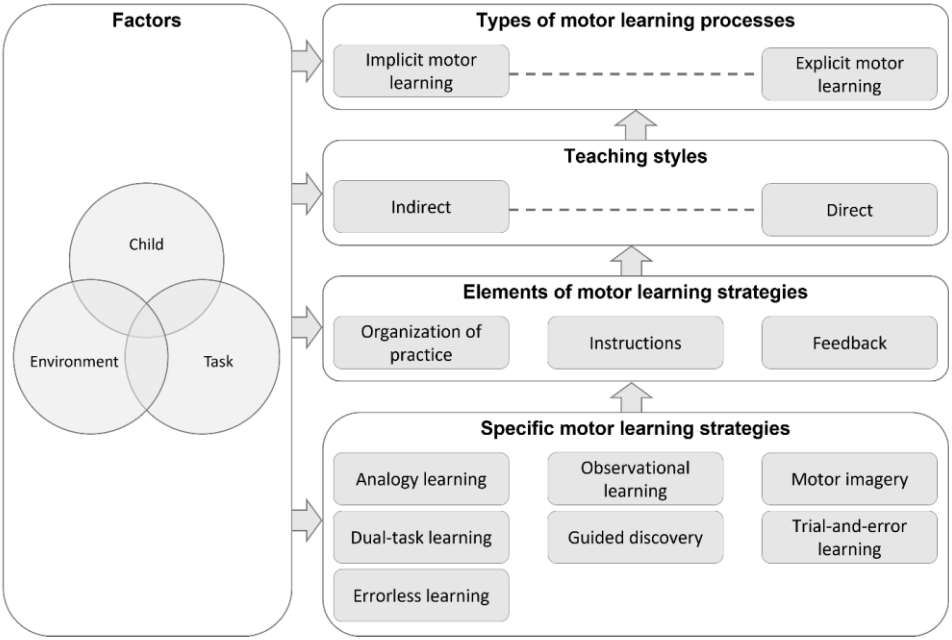

Figure 6.1. *The Motor Learning Component model with five components*

Based on reviewing literature about motor learning (Chapter 1), we identified three knowledge gaps in current literature that may hinder therapists in using MLSs to teach motor tasks to children. Firstly, the evidence about the effectiveness of MLSs used in children with and without DCD is limited, and little is known about the modifying role of: characteristics of child and task; and specific frequencies, modalities and timing of instructions and feedback. Secondly, it remains unclear how MLSs can be used to promote implicit and explicit motor learning processes in children with and without DCD. Thirdly, little is known about therapists' current use of MLSs in the treatment of children with DCD, and how characteristics of child and task should guide their choice for MLS.

In order to contribute to a better understanding on therapists' use of MLSs, we conducted four studies, each focusing on one or multiple components of the MLC-model. **Study 1** systematically reviewed the literature to investigate effectiveness of instructions and feedback with external focus (EF) applied with reduced frequency, with visual or auditory modality, and/or on request of a child to teach functional gross motor tasks to children with and without DCD (Chapter 2). **Study 2** used questionnaires to explore international experts' opinions on how MLSs could be used to promote implicit and explicit motor learning processes in children with and without DCD (Chapter 3). **Study 3 and 4** explored paediatric physical therapists' (PPTs) current use of MLSs to teach motor tasks to children with DCD using video-recordings of treatment sessions (Chapter 4), and individual and focus-group interviews (Chapter 5).

6.1 An overview of the main findings

With our studies, we gained important insights into: (1) the limitations of the available scientific literature in motor learning; (2) the need for clinical decision making; and (3) the clinical choices to make.

6.1.1 Limitations of the available scientific literature in motor learning

To gain more insight into effectiveness of MLSs and modifying variables, we conducted a systematic review (Chapter 2) and consulted experts (Chapter 3). The results of both studies raised awareness for two important limitations of current literature: (1) the methodological quality of studies investigating effectiveness of MLSs used in children; and (2) the limited amount of knowledge available.

6.1.1.1 *The methodological quality of studies investigating effectiveness of MLSs used in children*

The best-evidence synthesis of our systematic review investigating effectiveness of instructions and feedback with EF applied with specific frequencies, modalities, and/or timing showed moderate evidence for child-controlled timing of feedback on retention, also in children with DCD. The beneficial effects of this self-controlled timing in typically and atypically developing children was also demonstrated in a previous systematic[1]. Experts in our international survey study also mentioned that therapists should use self-controlled conditions in children, and children with DCD specifically. Self-controlled conditions support a child's autonomy, which improves intrinsic motivation for learning according to the *self-determination theory*[2]. Limited evidence was found for visual modality on retention and transfer, and continuous frequency when compared to faded frequency on retention.

However, for most comparisons, the summary synthesis showed no or conflicting evidence. This might be a consequence of the low methodological quality of the included studies. The assessment with the Cochrane risk of bias tools showed highest risks for performance and detection bias. None of the authors reported if they used intention-to-treat (ITT) analyses and how they handled missing data. During the process of conducting randomized controlled trials (RCTs), there is a chance for missing data and non-adherence of participants to the protocol. With ITT analysis, all participants retained in the group to which allocated[3,4]. This type of analysis is preferred because it resembles actual situations in clinical care, and provides most accurate estimations of effect[3,4]. Additionally, all studies included small subgroup samples increasing risk for finding non-significant results or contrary conclusions with similar studies[5,6]. Other systematic reviews investigating effectiveness of MLSs used in children also demonstrated small sample sizes and low methodological quality for the majority of the included studies, with moderate to high risk of bias for multiple types of bias: selection, performance, detection, and/or attrition bias[1,7–10].

In summary, the low methodological quality of studies investigating effectiveness of MLSs in children is a major limitation in the current literature and needs attention in future research.

6.1.1.2 *The limited amount of knowledge available*

Another limitation emphasized by experts is the limited amount of knowledge available about: (1) effectiveness of MLSs used in children with DCD; and (2) the construct of implicit and explicit motor learning, and children's motor learning processes.

Firstly, only few studies investigated effectiveness of MLSs in children with DCD focusing on: external/internal focus of attention; variable/constant practice; and self-controlled feedback[11–19]. Some experts mentioned that this limited evidence hindered them in answering questions about which MLSs should be preferred in children with DCD.

Secondly, some experts underpinned that the construct of implicit and explicit motor learning is still unclear, and that both types of motor learning processes can co-occur. In scientific literature, different implicit and explicit motor learning paradigms are used. Frequently used paradigms from an experimental perspective, use serial reaction time tasks (e.g. finger tapping task) to investigate the cognitive process of spatial sequence learning[20,21]. In explicit learning conditions, learners are informed about the presence of a sequence in the task, while in implicit learnings conditions learners are unaware of this sequence. However, from a more clinical/sports perspective, the MLSs mentioned in the introduction (external/internal focus learning, errorless/error-strewn learning, dual task learning/explicit instructions, and analogy/internal focus learning) are more commonly used paradigms. These paradigms aim to promote or reduce the accumulation of explicit knowledge during learning[7]. With these different paradigms, defining and operationalizing implicit and explicit motor learning should have special attention when conducting research and using them in clinical settings.

Previous research also showed that there are multiple co-occurring motor learning mechanisms contributing to the learning process of an individual, with each mechanism having its own primary neurological substrate, including: prefrontal cortex; basal ganglia; motor cortex and spinal cord; and/or cerebellum[22,23]. Therapists' use of instructions, feedback, organization of practice, and specific MLSs activates various neurological substrates with different levels of cognitive processes involved, resulting in either more implicit or more explicit motor learning (Figure 6.1). However, more research is needed to better understand how various mechanisms interact[22,23].

Some experts also mentioned that too little is known about whether MLSs stimulate motor learning processes as expected. Studies investigating the role of working memory capacity on children's motor learning hypothesized that working memory capacity would predict the degree of internal focus (IF) learning[15,24,25]. An IF directs the attention of the child to its body movements, which is assumed to have larger involvement of working memory then an EF which directs the attention of the child to the impact of the movement on the environment[26]. However, none of these studies with typically developing children, children with DCD, or children with low motor abilities found evidence supporting this hypothesis, which confirms that learning mechanisms in children are not yet fully understood[15,24,25]. These insufficient insights into the construct of implicit and explicit motor learning, and children's learning processes, might have contributed why poor insight was gained into how MLSs can be used to promote implicit and explicit motor learning processes.

6.1.2 The need for clinical decision making

Our qualitative studies with experts and PPTs demonstrated the need for clinical decision making when teaching motor tasks to children with and without DCD (Chapters 3 to 5). Also, the conflicting results of our systematic review imply that the chosen frequency, modality, and timing of instructions and feedback might be child and/or task dependent (Chapter 2), supporting the relevance of clinical decision making. The results of this thesis suggest that clinical decision making is a cyclic process which requires adequate knowledge about motor learning and the population of interest.

According to experts and therapists, providing tailored treatment to children with DCD requires clinical decision making. This is in line with the hybrid model of DCD that suggests that therapists should consider the interaction of characteristics of a child, task and environment when making treatment decisions[27]. Furthermore, it seems in line with literature, in which authors of systematic reviews investigating effectiveness of MLSs argued that effectiveness might be moderated by characteristics of child and task, implying that tailored use of MLSs should be preferred[1,7–9,28]. Experts stressed the importance of having adequate knowledge about motor learning and the population of interest for clinical decision making, which is supported by studies that investigated clinical decision-making processes of therapists[29–31], and research describing processes and models of clinical decision making in health care[32,33]. Interviews with PPTs showed that their knowledge is limited on motor learning terminology like implicit and explicit motor learning, and specific motor learning strategies like analogy learning and motor imagery (Chapter 5). Furthermore, their choice for MLS was mainly based on intuition, driven by their knowledge, experiences, beliefs, preferences and character. These results are in line with a previous interview study exploring PTs' perspectives on the construct of motor learning, and their use of MLSs in daily clinical care[34].

Experts stressed that an analysis of a child's situation, including tasks and contexts, is needed to make adequate choices for MLSs (Chapter 3). Furthermore, they mentioned that it is important for therapists to evaluate if the used MLSs reached their expectations of immediate improvement of the motor performance to determine whether adjustments are needed. Following definition of clinical decision making comprises these three processes as well: *clinical decision making is a contextual, continuous, and evolving process, where data are gathered, interpreted, and evaluated in order to select an evidence-based choice of action*[35]. These processes are the foundation of various clinical decision-making models used in health care[32,33,36]. These models are guided by hypotheses which are: (1) generated by **analysing** information provided by the patient, observations and/or assessments; (2) tested by **applying** specific manipulations in assessment or intervention; and (3) adjusted by **evaluating** the actions and reactions of the patient[32,33,36].

PPTs in our study mentioned that in some cases they explored various MLSs to discover which MLSs worked best, specifically, when they had observed that children were having trouble mastering tasks. This was also observed when analysing the video-taped treatment sessions (Chapter 4). So, both studies indicated that processes of analyses and evaluation were likely to be used to guide PPTs' clinical decisions.

Both observations and interviews showed large variation in PPTs' use of MLSs. The same variation was seen in a think-aloud study exploring PTs' use of MLSs in adults with central neurological disorders, and another study exploring occupational therapists' use of MLSs in video-taped treatment sessions of children with acquired brain injury (ABI)[29,37]. This variation is most likely a consequence of the therapists acting on intuition in combination with therapist' choices in adaptations of MLSs to individual children. To better understand this variation, more research is needed.

6.1.3 The clinical choices to make

Therapists have to make multiple choices when modelling and adapting MLSs during their treatment sessions. These choices concern: (1) when and how to adapt MLSs to characteristics of child and task; and (2) how to model MLSs to comply generic principles in motor teaching.

6.1.3.1 *When and how to adapt MLSs to characteristics of child and task*

In the first survey completed by experts, various child and task characteristics, such as age, cognitive abilities, skill level and task complexity, were mentioned that experts considered relevant in guiding therapists' choice for MLSs (Chapter 3). Experts' perspectives varied broadly, when we explored in a subsequent questionnaire how these and other characteristics should influence the choice for MLSs. During the interviews, PPTs also elaborated on how characteristics of child and task influenced their use of MLSs (Chapter 5). Again, suggestions on how to adapt MLSs varied. When comparing both studies, we can conclude that both experts and PPTs mentioned the same characteristics, which strengthens the relevance of these characteristics in clinical decision making.

Seven types of child characteristics were identified (with some types comprising multiple characteristics), see Figure 6.2. Literature confirms that in children with DCD comorbidities, social-emotional problems, and cognitive deficits are frequently present[11,38–44].

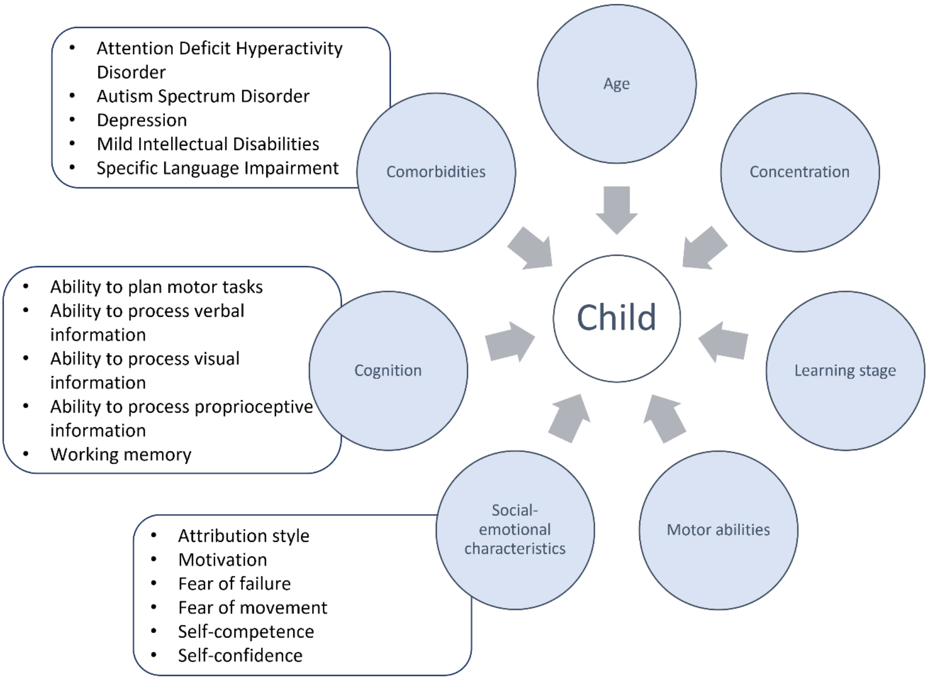

Figure 6.2. *Types of child characteristics that may guide therapists' use of MLSs.*

The types 'social-emotional characteristics', 'cognition' and 'comorbidities' comprise multiple characteristics.

How the suggested child characteristics should influence the choice for MLSs remains unclear, because both experts and PPTs made many suggestions with large variation. However, for one characteristic, the presence of **deficits in executive functions**, they were more aligned. Most children with DCD have poor motor planning and organization skills due to deficits in executive functions like reduced working memory capacity, inhibitory control, and attention[11]. Experts strongly preferred indirect teaching styles using questions or manipulations of task and context to guide the child to the correct movement performance. On the contrary, PPTs' opinions differed: some preferred more indirect teaching styles, while others would use more direct styles. Their preference was based on their assumption whether executive functions could be trained or not. Research shows that these functions can be trained by providing movement situations and questions that advance critical and creative thinking, and problem-solving[45–47]. Therefore, indirect teaching styles are likely to be preferred in children with DCD having problems with motor planning and organization of daily life activities.

As a task characteristic, **task complexity** was frequently mentioned. Experts suggested to use MLSs that promote explicit motor learning when tasks are more complex, for instance, when requiring higher technical demands, complex coordination between body parts, multiple sequential steps, and specific rules (e.g. like in sports). PPTs found it more difficult to put thoughts into words when describing how characteristics of tasks influenced their choice for MLS, but task complexity also seemed the most relevant characteristic. However, their opinions on which MLSs to use in more complex tasks varied. The analyses of the video-taped treatment sessions supported this variation, but in general, PPTs showed using more detailed explicit instructions and feedback when tasks were more complex (Chapter 4). The *challenge point framework* from Guadagnoli et al.[48] conceptualizes that task complexity is the result of: (1) the nominal task difficulty, which is the level of difficulty of a task defined by its constraints (e.g. multiple sequential steps); and (2) the functional task difficulty, which is an experienced level of difficulty by the learner depending on the learner's skill level, and the demands of the environmental context (e.g. surface). For instance, riding a bike is a complex task because it comprises multiple sequential steps with complex coordination between upper and lower limbs. However, cycling is even more complex when the learner is inexperienced and/or when cycling has to be performed in traffic. The framework suggests that the level of difficulty of the practiced task influences the amount of information a learner can process. For instance, if a task is very difficult, the task itself requires attention leaving less room for processing a large amount of additional information. This framework suggests that therapists' use of MLSs should be adapted to the level of difficulty of the task, but it provides little insight into how to use MLSs exactly[48].

In summary, MLSs should be adapted to characteristics of child and task. We identified seven types of child characteristics and task complexity as potentially relevant in guiding therapists choices. However, how these characteristics should guide therapists' use of MLSs remains unclear and requires more research.

6.1.3.2 *How to model MLSs to meet generic principles of motor teaching*

Therapists also have to decide how to model MLSs to provide tailored treatments. The results of the studies with experts (Chapter 3) and PPTs (Chapters 4 and 5) emerged into five generic principles that should be met when teaching motor tasks to children, see Figure 6.3. However, because of large variation in the suggested MLSs, it remains unclear which MLSs should be preferred for the individual generic principles.

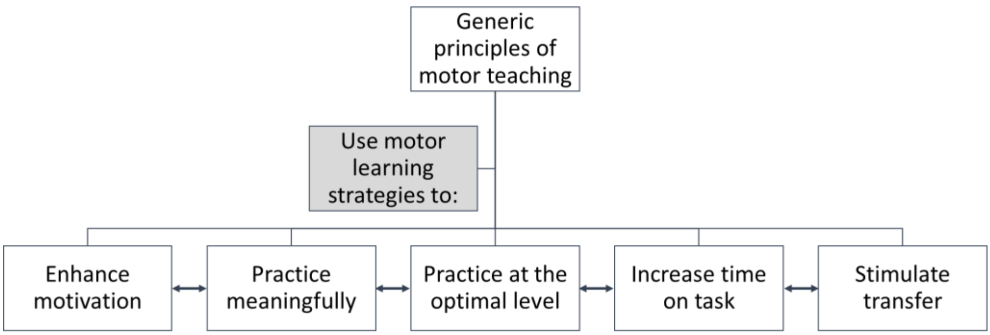

Figure 6.3. *Five generic principles of motor teaching*

Principle 1, both therapists and experts frequently stressed the importance of **enhancing motivation** in children with DCD (Chapters 3 and 5). The experts and therapists underpinned that the motivation of these children is often decreased as a consequence of frustration experienced during the learning process, their fears of failure and movement, and/or their lower levels of self-competence and self-confidence. They agreed that in case of decreased motivation, motivation should be increased first as a prerequisite for motor learning, which suits the *Optimizing Performance through Intrinsic Motivation and Attention for Learning (OPTIMAL) theory*. This theory conceptualizes how motivation and attention for the task are both needed for optimal motor learning[49]. Experts and therapists stated that children with DCD need many experiences of success to stay motivated. Additionally, PPTs gave many suggestions for improving motivation, also seen on the video-taped treatment sessions (Chapter 4). However, variation in used and preferred MLSs was large. The suggested MLSs focused on: enhancing children's self-confidence (e.g. by giving positive feedback); increasing enjoyment (e.g. by working with themes that suit children's interest); increasing experiences of success (e.g. by decreasing the level of difficulty of the exercises); and/or advancing autonomy (e.g. by giving children choice in what materials to use or using self-controlled timing of instructions and feedback). We had expected that many PPTs used self-controlled conditions, because it is known from the *self-determination theory* and *OPTIMAL theory* that supporting children's autonomy advances intrinsic motivation for learning[2,49]. However, the observations and interviews showed that only few of them actually used self-controlled conditions. A systematic review investigating effectiveness of MLSs that enhanced children's motivation showed that enhancing autonomy and improving self-confidence by enhancing the child's expectancies for success improved motor performance[1]. They argued that effectiveness is likely to be moderated by characteristics of child and task, but they recommend more research: to gain insight into how these characteristics influence effectiveness, and to examine how the investigated MLSs can be used in clinical and physical educational settings[1]. So, improving motivation in essential in motor learning. However, which MLSs should be preferred to enhance motivation remains unclear.

Principle 2, PPTs emphasized that **practice should be meaningful**. They referred to the problems in automatizing and transferring skills (i.e. using learned skill in other contexts) in children with DCD, and their lower levels of motivation when elaborating on why to practice meaningfully. Several PPTs stressed the importance of practicing tasks that fit a child's need(s), which was also emphasized by experts (unpublished data). Both experts and PPTs, also underpinned that practice is more meaningful when the arrangement of the practice situation matches children's daily-life contexts. The international DCD recommendations for intervention also advise to practice meaningful tasks that fit a child's needs[50].

Principle 3, in the interviews, PPTs stated that an **optimal level of practice** is when children are challenged, but still experience success. They felt that an optimal level of practice strongly influenced the learning process and motivation of a child: when tasks are too difficult, children will learn less and have fewer experiences of success which in turn decreases their motivation; when tasks are too easy, children will also learn less and will get bored loosing motivation as well. The aforementioned *challenge point framework* supports the relevance of an optimal level of practice[48]. The framework conceptualizes that there is an *optimal challenge point* (OCP) for each learner, see Figure 6.4. The figure shows that inexperienced learners (novice) have different performance curves (solid lines) than trained learners (expert): novices perform easy tasks very well, but their performance decreases quickly when the level of difficulty increases a little; experts perform most tasks with different levels of difficulty very well, and performance only decreases when tasks are very difficult. Furthermore, it shows that each individual has its own potential learning benefit (dashed line), which differs based on the learner's skill level (demonstrated in the figure as novice and expert). Learners will benefit less from learning when tasks are too easy or too difficult, indicating that therapists should carefully consider the level of difficulty of the practiced tasks to practice at the OCP.

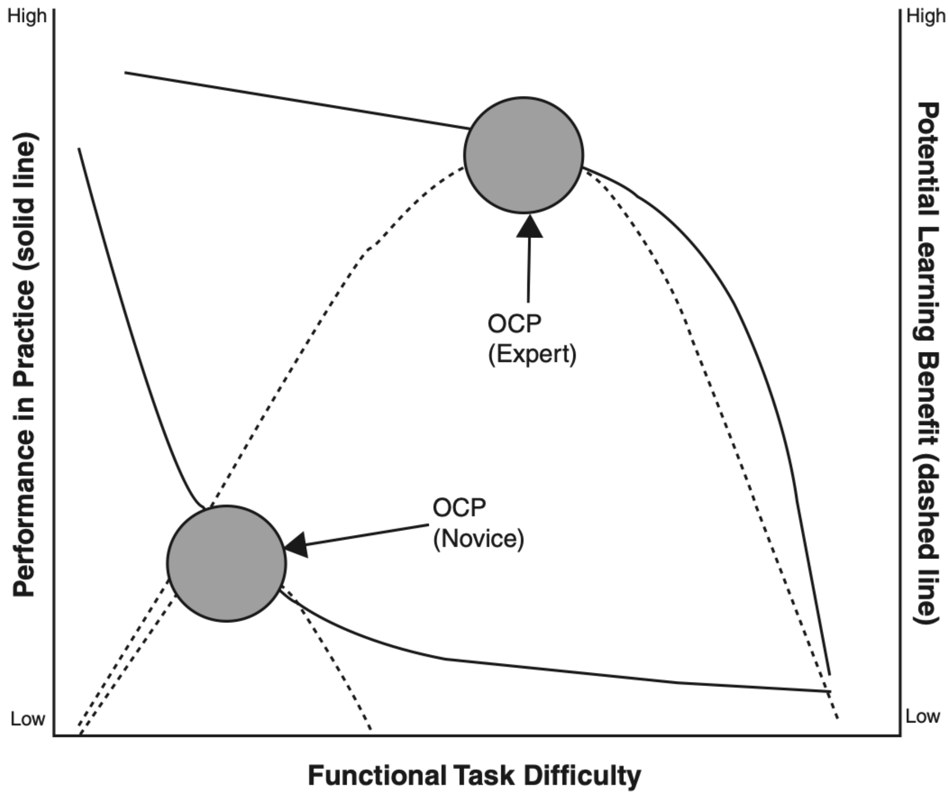

Figure 6.4. *The relationship between learning curves, performance curves, and the optimal challenge point (OCP) related to two performers of different skill levels (source: Guadagnoli et al. 2004)*

Principle 4, both experts and PPTs stressed that children with DCD need greater **time on task** because of their problems with automatizing motor taks. Research also advised to use extended periods, or higher volumes, of practice in these children because of their motor learning difficulties[51,52]. PPTs felt that it was easier to achieve greater time on task with motivated children. They mentioned increasing repetition time by decreasing the frequency of instructions and feedback when learning progressed. Additionally, experts suggested that the arrangement of the practice situation should enhance repetitions to increase time on task.

Lastly, Principle 5, the importance of **stimulating transfer** of the learned tasks to daily-life context in children with DCD was frequently mentioned by experts and PPTs. Research supports that children with DCD experience difficulties in transferring motor skills to other contexts[11,27]. Both experts and therapists mentioned the importance of practicing meaningful tasks in daily-life contexts, using regular tools from children's daily life, like the child's own bike. Both also suggested the use of variable practice, which therapists explicitly mentioned in the context of stimulating transfer. However, studies investigating effectiveness of variable practice in children with DCD showed no significant group differences between variable and constant practice in retention and transfer[13,14]. Also, a systematic review with meta-analysis investigating effectiveness increasing variation during practice in (mostly young) adults concluded that results were inconclusive, most likely as a consequence of methodological issues like low sample sizes, and high risk of bias in general according to the authors[53]. So, more insight needs to be gained into the effectiveness of variable practice in children in relation to transferring motor tasks.

Although more research is needed to gain insight into how MLSs could be used best to meet these generic principles of motor teaching, we did gain relevant insights into the **numerous ways to model MLSs**. These are outlined in Figure 6.5. The results from our expert study (Chapter 3) and PPTs studies (Chapters 4 and 5) showed that therapists have to consider: (1) their teaching styles (direct or indirect); (2) the intentions they have with the instructions, feedback and organization of practice; and (3) how to model the parameters of these. The intentions of instructions, feedback and organization of practice closely relate to the generic principles we described in this section. In our systematic review we included four different parameters based on literature (Chapter 2). These parameters were also recognized in the many suggested MLSs by experts and therapists. Furthermore, we identified a fifth parameter in these studies: the information content, which concerned the amount of detailed information given in one instruction or feedback. The parameters for organization of practice emerged from the analyses of both the questionnaires completed by the experts, and the interviews with the PPTs. Because research showed that terminology is used inconsistently[54,55], the identified parameters may provide a framework to discuss and model MLSs more unambiguously.

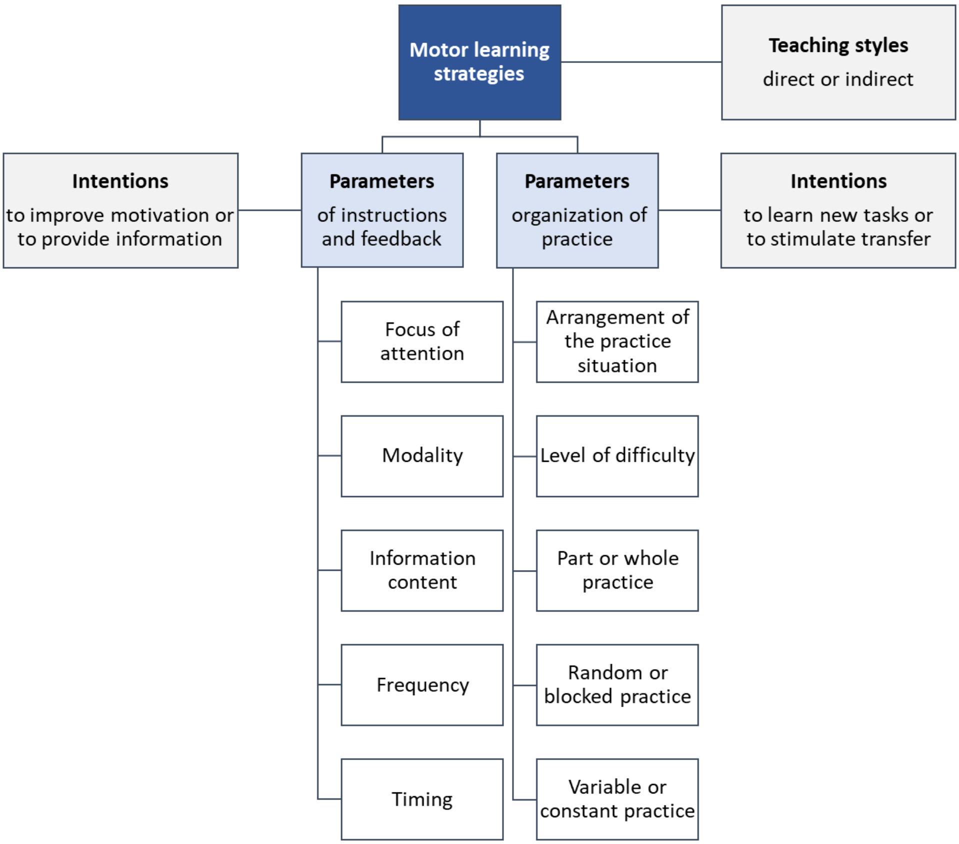

Figure 6.5. *Teaching styles, intentions and parameters of instructions, feedback and organization of practice*

In summary, therapists have to decide how to model MLSs to meet five generic principles of motor teaching: enhance motivation, practice meaningfully, practice at the optimal level, increase time on task, and stimulate transfer (Figure 6.3). When modelling MLSs, therapists should consider: teaching styles, intentions, and parameters of instructions, feedback, and organization of practice (Figure 6.5). The results showed large variation in used MLSs, more insights need to be gained into how MLSs could be modelled best to meet the generic motor teaching principles in individual children.

6.2 Methodological considerations and reflections

All chapters of the individual studies (Chapters 2 to 5) include methodological considerations and reflections. In this general discussion, we want to reflect on our choice for a qualitative approach for this PhD, and the chosen study designs.

6.2.1 A qualitative approach

As a PPT with many years of experience in teaching motor tasks to children with various motor disabilities, I felt the need for better knowledge and more tools to provide the best evidence-based tailored treatment for each child. As a teacher at the Master Pediatric Physical Therapy, I experienced that many colleagues had the same need, and that it was challenging to translate research results into clinical settings. Therefore, as a clinical epidemiologist, bridging the gap between science and clinical practice is what motivates me.

Because therapists are expected to provide tailored treatments when teaching motor tasks to individual children with and without DCD[27,55,56], it is important to provide them with knowledge about how to do so. This need for knowledge was also stressed in an interview study exploring PTs' use of MLSs in adult clinical care[34]. However, systematic reviews of quantitative studies investigating effectiveness of various MLSs in children did not provide us with adequate knowledge[1,7–9,28]. Also, previous research provided insufficient insight into how MLSs could be used to promote implicit or explicit motor learning processes[57,58]. Therefore, we wanted to contribute to a better understanding of how therapists can use MLSs to teach motor tasks to children with and without DCD. The use of a qualitative approach was the logical first step.

Because of the exploratory character of this thesis, we combined perspectives gained from literature, experts, and therapists about different components from the MLC-model (Figure 6.1)[59]. Because of the overlap in components between the individual studies, it was expected that all perspectives together would provide us with a better understanding on how to use MLSs when teaching motor tasks[59]. The results of this thesis showed that our main findings (see overview of the main findings) emerged from the combined data from literature, experts and therapists.

6.2.2 The used designs

We carefully considered the designs for the individual studies. Effectiveness of instructions and feedback with EF was investigated using a systematic review (Chapter 2). Experts' perspectives were explored with surveys (Chapter 3), and therapists' use of MLSs with observations and interviews (Chapters 4 and 5).

Although, previous systematic reviews investigating effectiveness of MLSs found mainly no or conflicting evidence, we did perform a **systematic review** because none of these studies included instructions and feedback that were modelled by multiple parameters as main topic of interest[1,7,8,28].

Experts' opinions were explored to gain insight into the use of MLSs to promote implicit and explicit motor learning processes in children, and children with DCD specifically, because previous research provided little insights[7,57,58]. Out of the different methodological designs regarding qualitative research we chose a Delphi study, because we wanted to come to a certain level of agreement on the mentioned MLSs by the international experts[60,61]. However, the answers to the open-ended questions of Questionnaire 1 showed large variation in perspectives. We attempted to reduce this variation in Questionnaire 2, by asking experts to score all MLSs suggested in Questionnaire 1 on a 5-point Likert scale (implicit motor learning / more implicit than explicit motor learning / equally implicit and explicit motor learning / more explicit than implicit motor learning / explicit motor learning). But variation remained large. Because of statements of experts about the limitations of current literature (see an overview of the main findings), and their own level of knowledge (for instance, some experts stated that they did not know much about explicit motor learning, or that their clinical experiences contradicted literature), we decided not to send a third questionnaire because it was expected that consensus could not be reached. Instead, we used a mixed-methods design and included qualitative analyses of the open-ended questions using a conventional content analysis approach[62]. This resulted in valuable insights about important knowledge gaps, and clinical decision making.

We explored **PPTs' use of MLSs** in children with DCD as a third relevant information source. Here, our interest was to gain insight into the individual reasons of PPTs about their choices in MLSs when teaching motor tasks to children with DCD, in combinations with their actual use in clinical practice. Therefore, we combined observations of individual treatment sessions with individual interviews with PPTs on that topic. We considered to use think-aloud procedures[63–65]. However, we decided that a more relevant first step would be to explore this topic using separate observations and interviews to enlarge the breadth and depth of the data[59,66]. Our focus of the analyses of the video-taped treatment sessions was to gain insight into all types of instructions and feedback used, how instructions and feedback inter-played, and whether PPTs adapted MLSs. Therefore, it was needed to develop a new and comprehensive analysis plan (Chapter 4), because existing observation tools score frequencies of a set of predefined MLSs[37,56,67], and knowing frequencies of some MLSs would have had little value in this explorative stage of our research aim. The newly developed analysis plan appeared suitable for our explorative research question.

In a next step of exploring PPTs' use of MLSs, we performed focus groups after conducting the first 10 individual interviews; to deepen topics, to explore different points of view, and to determine whether the obtained insights were shared by a larger group of PPTs[59,68]. With these focus groups, we deepened their perspectives about how characteristics of child and task guided their choice for

MLSs. We explored different points of view about the role of success and failure in a child's learning process, and the use of explicit instructions in various stages of motor learning advancing our understanding of therapists' use of MLSs. Furthermore, the focus groups showed that previous gained perspectives were shared by a larger group of PPTs.

The main findings of this thesis (see an overview of the main findings) showed that the data from the observations and interviews were both complementary and affirmatively, which provided many insight about modelling MLSs, generic principles of motor teaching, clinical decision making, and potentially relevant child and task characteristics guiding choices.

6.3 Recommendations for professionals, researchers, and educators

6.3.1 Recommendations for professionals teaching motor tasks to children

Although our research focused on PPTs, the results are not only relevant for them, but also for occupational therapists in paediatric clinical care, physical education teachers, and trainers in organized sports for children with and without motor disabilities. Therapists, teachers and trainers will be furtherly referred to as instructors in the next paragraphs.

Instructors should be aware that their choices for MLSs are predominantly influenced by their own knowledge, experiences, preferences and beliefs (Chapter 5); and only to a limited extent by characteristics of child and task, as would be preferred[27,34,56]. As such, we recommend that they invest in gaining adequate knowledge about all relevant components in motor learning (Figure 6.1). For instance, by taking specific courses in motor teaching, reading relevant scientific literature, discussing cases with colleagues, and/or letting themselves being mentored by more experienced colleagues[31]. Furthermore, to advance clinical decision-making skills, we advise instructors to use various types of reflection as a tool to become more aware of their own use of MLSs and motives about their choices regarding motor learning components[69]. Reflection includes: reflecting whether the used MLS improved immediate motor performance as expected; reflecting after treatment to affirm or modify the plan of care; and, occasionally, reflecting on how prior experiences influences their professional practice and clinical decision making[69]. To advance instructors' insight into their use of instructions, feedback and organization of practice in specific cases, we developed two observation tools based on the results shown in Figure 6.5. See Appendix 6.1 for the tools. These observation tools can be scored in video-taped or real-life observations by themselves or colleagues, which provides instructors with information to reflect on, or to discuss with colleagues. We have used these tools in various educational activities (a 3-day motor learning course we developed, a postgraduate education for physical and occupational therapists, and workshops on symposia for therapists), and received the feedback that it were easy and valuable tools that provided great insight.

The results of this thesis showed five relevant generic principles of motor teaching (Figure 6.3) that we advise instructors to meet when teaching motor tasks. Although, more insight is needed into how MLSs could best be modelled for each principle, we recommend instructors to carefully consider teaching styles, intentions with MLSs, and how to model parameters of instructions, feedback, and organization of practice to provide tailored treatments (Figure 6.5). Characteristics of a child and task complexity should be considered when deciding how to model and use MLSs. Seven types of child characteristics were identified (Figure 6.2), but further research is needed to gain more insight into how these characteristics should guide clinical decisions. However, we do advise instructors to gain an idea of these characteristics in their analyses, because this might help them in making more informed choices, and to reflect on these choices.

The observations showed that PPTs used relatively little feedback to provide a child with specific information about their task performance (Chapter 4). They frequently repeated initial instructions, gave new instructions with another focus, or used encouragements and positive feedback (e.g. "well done!"). However, literature showed that feedback with specific information is considered very valuable for a child's learning process[70–72]. Therefore, we recommend instructors to use this type of feedback.

We also recommend them to use self-controlled conditions because it is an evidence-based strategy to enhance a child's motivation for motor learning[2]. The results of our systematic review showed moderate effectiveness for self-controlled feedback (Chapter 2). The systematic review of Simpson et al.[1] also demonstrated beneficial effects for various self-controlled conditions in instructions, feedback and organization of practice. The use of these conditions was also suggested by experts (Chapter 3). Although, some PPTs talked about their use of self-controlled conditions in the interviews, the analyses of the video-taped treatment sessions revealed that they used them very little in instructions and feedback (Chapters 4 and 5). Instructors can apply self-controlled conditions by: providing a child choice in *when* or with *which modality* to receive instructions and feedback; or by giving it choice in the organization of practice (e.g. by letting a child choose which materials to use, or giving it a voice in the level of difficulty of the exercises).

A final recommendation is to consider using indirect teaching styles in children with deficits in executive functions, like children with DCD[11,38]. The interviews showed that several PPTs did not prefer this teaching style because of the problems with executive functions (Chapter 5). However, research showed that executive functions can be trained by advancing critical and creative thinking, and problem-solving[45–47]. Furthermore, improving these functions is expected to advance the use of executive functions in many daily life activities (e.g. in learning at school, and in social interactions)[47,73]. Instructors can arrange practice situations in such ways that a child is stimulated to solve a movement problem, for instance, by making an exercise very challenging or by using obstacles which hinder certain routes in exercise tracks. Furthermore, they can use questions to stimulate a child's problem-solving and reflection capacities, for instance, by asking "what went well/wrong?", "what can you do differently?", and "how can you solve this problem?".

6.3.2 Recommendations for researchers in the field of motor learning

6.3.2.1 *To optimize designs of future studies investigating effectiveness of motor learning strategies*

More insight is needed into the effectiveness of MLSs used to teach functional motor tasks to children with motor disabilities, and children with DCD specifically. However, exploring how to optimize the designs of studies investigating effectiveness of MLSs would be an important first step, because our systematic review (Chapter 2) and other systematic reviews investigating effectiveness of MLSs in typically and atypically developing children showed that methodological quality of the included studies is predominantly low on several aspects[1,7–10]. In general, the results of our systematic review showed that blinding of outcome assessors, using adequate outcome measures with good psychometric properties, analysing according to intention-to-treat, and handling missing data properly require attention in future studies[3,4]. Furthermore, more adequate sample sizes should be included to decrease the risk of finding non-significant results or contrary conclusions with similar studies. Also, authors should report thresholds for clinically and statistically relevant effects to advance interpretation[5,6,74].

We advise researchers to start with performing pilot/feasibility studies of (randomized) controlled trials[75–77], or (single/multiple) case studies[78,79] to investigate important aspects of feasibility before designing and conducting a final RCT on effectiveness. Those studies could have more different aims, such as: (1) the feasibility of the comparison of the experimental and control intervention itself; (2) the to be included study populations; (3) potential (primary) outcome measures, process measures, measurement procedures, and sample sizes.

Foremost, we recommend to explore how experimental (and control) interventions could best be modelled for research purposes to decrease the gap between interventions applied in research and clinical setting. According to the hybrid model of DCD, the results of our studies, and previous studies investigating therapists' use of MLSs, motor learning inventions should be tailored to the interaction of characteristics of a child, task and environment[27,29,34,37]. Also, previous systematic reviews investigating effectiveness of MLSs argued that effectiveness is likely to be moderated by characteristics of child and task, indicating that tailored treatment may be more effective[1,7–9,28]. Thus, it seems more relevant to include experimental and control interventions in future studies that are tailored; in which instructors can adapt MLSs during the intervention. Most studies included in our systematic review, and previous systematic reviews used one-day practice protocols[7,9]. We recommend using longer practice duration to provide children with motor disabilities with sufficient time on task. Specifically, in children with DCD because of their difficulties in automatizing motor tasks[11,38,51,52]. We encourage researchers to use mixed-methods designs to evaluate process and effect, both qualitatively and quantitively, to gain more insight into how tailored interventions could best be modelled[75,77–79].

Secondly, characteristics of a child should guide clinical decisions. We recommend researchers to explore which characteristics are potentially relevant to define the included population(s) of children, and relevant sub groups. Furthermore, the interviews demonstrated that PPTs' clinical decision making was influenced by their own knowledge and experiences. Therefore, it is to be expected that characteristics of therapists (e.g. more experienced versus inexperienced) might influence effectiveness of tailored interventions. As such, it would also be of interest to explore which characteristics are potentially relevant to define the included instructors, and relevant sub groups.

Lastly, our systematic review showed that the included studies only used effect outcome measures like accuracy and quality of movement. This skewness in outcome measures was also discussed in other systematic reviews investigating effectiveness of MLSs[1,7]. Research advises to use evidence-based activity- and participation-oriented interventions in children with motor disabilities, also in children with DCD[50,80,81]. The main focus of these interventions is to: improve performances of motor tasks that suit children's needs; and their participation in daily life[50,80,81]. So, measuring children's level of participation, and their perspectives on their improvements of motor tasks may be more relevant outcome measures. Furthermore, in order to gain comprehensive insights into effectiveness of interventions, we advise to evaluate both effect and process[77]. Differences found in effect may be influenced by various factors as: differences within the population characteristics; how the data was collected; the quality of the provided intervention(s); the used procedure and measurements in measuring effect; and chance. Process measures can provide understanding and insight into why differences in effects were found, and how various factors inter-played[77,82,83].

In summary, we recommend optimizing designs for scientific studies with the aim of investigating effectiveness of MLSs. One important point of attention is the methodological quality, for which we advise to follow the CONSORT statement for quantitative studies[3,4]. A second point of attention would be the included intervention(s), in relation with the population and outcome measures. Our studies showed that tailored interventions are likely to be more effective. Therefore, we encourage researchers to explore the use of tailored interventions in their studies. Because these types of interventions are not yet common in research, it is even more important to include process and effect outcome measures which will be assessed with relevant measurements with sound psychometric properties[77]. Since characteristics of instructor, child and task influence clinical decision making, we advise researchers to carefully consider which characteristics of instructor, child and task to include in their study. Current studies used RCT designs, which resulted in no or conflicting evidence when compared in systematic reviews[1,7–9,28]. For the purpose of exploring how studies could best be designed, we recommend to use pilot/feasibility studies, and/or (single/multiple) case designs [75–79].

6.3.2.2 *To deepen the understanding of therapists' use of motor learning strategies*

The results of this thesis raised new research questions to furtherly advance the understanding of therapists' use of MLSs. Experts stressed the importance of evaluating whether the used MLSs resulted in the immediate improvement as expected (Chapter 3). However, the observations and interviews provided little insights into how therapists evaluated their actions (Chapters 4 and 5). In future research, it would be interesting to explore therapists' thoughts about the immediate improvement on the motor task being practiced and how this would influence their actions. In addition to the therapists' perspectives, children's perspectives about how they experience the used MLSs are very important as well[77]. The video-taped treatment sessions showed interactions between therapist and child, analysing this interaction was not possible without knowing their thoughts. Therefore, we recommend researchers to explore both therapists' and children's perspectives in future research considering think-aloud procedures with subsequent interviews[63–65].

In the interviews, therapists stressed the importance of instructing parents and teachers to increase time on task and transfer of the learned task to daily-life settings (Chapter 5). We did not explore this topic in depth, because if was beyond the scope of our research question. Instructing parents and teachers is also recommended in the international DCD recommendations[50]. Therefore, exploring perspectives from parents, teachers, and other relevant stakeholders about therapists' actions to stimulate motor learning processes in daily-life contexts could also be relevant to advance the understanding on how therapists can/should use MLSs[77].

Furthermore, various child characteristics (Figure 6.2) and task complexity were identified as potentially relevant in guiding therapists' clinical decision making. We suggest to explore how these characteristic can guide therapists' clinical decision making considering vignette studies[84].

Our qualitative studies (Chapters 3 to 5) showed that many elements of instructions, feedback, and organization of practice can be used to meet five generic motor teaching principles (Figures 6.3 and 6.5). However, it remained unclear which MLSs could best be used to fulfil these principles, which would also be a relevant topic for future research to advance the understanding of using MLSs in motor teaching.

Lastly, we investigated PPTs' use of MLSs in activity- and participation-oriented interventions in Dutch and Flemish PPTs (Chapters 4 and 5). Some of the PPTs mentioned using interventions like neuromotor task training (NTT) and cognitive orientation to daily occupational performance (CO-OP), but we did not ask explicitly whether PPTs adopted specific types of interventions. Research showed that various types of evidence-based activity- and participation-oriented interventions can be used (e.g. NTT, CO-OP, task specific training, goal-directed training)[80,81]. Previous studies also demonstrated that translating scientific knowledge about motor learning into clinical practice is challenging[34,54,55,85]. It is to be expected that there can be cross-cultural differences in PPTs' use of MLSs based, for instance, on their educational program and level of experience with specific types of activity- and participation-oriented interventions. Therefore, it would be interesting to explore PPTs' use of MLSs in other countries as well.

6.3.2.3 *To implement insights gained from our studies into therapists' clinical care*

Experts stated that knowledge is an important prerequisite in teaching children motor tasks, and that therapists' clinical decision-making process should be guided by the interaction of child, task and environment (Chapter 3). However, our interview study showed that PPTs' clinical decision-making process was mainly guided by their own beliefs, preferences and level of knowledge (Chapter 5). The interviews also showed that terminology in motor learning (e.g. explicit/implicit motor learning; and specific motor learning strategies) was not known by the majority of PPTs. Previous studies using interviews or surveys to investigate the level of implementation of motor learning in PTs' daily care of various (mostly adult) patients identified limited knowledge as an important barrier[34,85]. Although there are still several knowledge gaps to overcome, it is important to implement the present knowledge because it is expected to optimize therapists' use of MLSs when teaching motor tasks to children with and without DCD.

Previous research showed that a tailored evidence-based DCD module with information about identifying, assessing and treating children with DCD was perceived relevant, applicable and useful by PTs[86]. Further evaluation showed that the online module enhanced their self-reported knowledge and skills, and supported evidence-based practice[87]. However, before developing and implementing intervention strategies like online modules, an important first step would be to inventories and prioritize barriers and facilitators that therapists experience when teaching motor tasks to children[88–91].

6.3.3 Recommendations for educators in the field of motor learning

The results of our studies stressed the importance of the level of education on motor learning and clinical decision making (Chapters 3 and 5). Experts emphasized the importance of adequate knowledge about using MLSs when teaching children with and without DCD motor tasks. The interviews with PPTs showed that various terms used in motor learning literature were not known by the majority of them. Furthermore, our study, and a previous interview study exploring PTs' use of MLSs in daily practice, showed that they adapt MLSs intuitively and that limited knowledge was an important barrier hindering their clinical decision making in adapting MLSs to the learner[34].

In our opinion, education in motor teaching should include knowledge about: the various components in motor learning (Figure 6.1); generic principles of motor teaching (Figure 6.3); how to model MLSs (Figure 6.5); the evidence of effectiveness of MLSs; how to promote specific types of motor learning processes; how to adapt MLSs to child, task and environment; and clinical decision making. We recommend educators to consider these topics to implement in their courses. Because there are still several knowledge gaps present, we advise educators to highlight that instructors should evaluate the child's action and/or reaction to the used MLSs, and that they adapt their MLSs when a child does not show the improvement that suit their expectations.

Research showed that motor learning theories and strategies used in (paediatric) clinical care lack clarity, simplicity and generalizability, and that terminology is used inconsistently[54,55]. This is confirmed by the interviewed PTs, that also underpinned the need for more clinical context in educational activities[34]. Therefore, we recommend to embed the theoretical theories and strategies in clinical context by providing examples of MLSs used in clinical settings and using case-based learning including clinical decision making (preferably with the learners' own cases). Research has shown that case-based learning deepened the learning process of health-care professionals, by advancing critical thinking and generalizability to other cases[92]. Furthermore, we recommend educators to embed various reflection skills in their educational courses[69]. The PPTs that participated in our study all felt that the reflection on their actions during the interviews was valuable in optimising their use of MLSs, and that they should do this more often. In order to provide therapists with the best knowledge to optimize their use of MLSs, we advise educators to systematically evaluate whether their educational courses matches participants' needs.

6.4 Conclusion

The results of this thesis showed that clinical decision making is fundamental when using MLSs to teach motor tasks to children with and without DCD, and that having adequate knowledge about all components of motor learning (Figure 6.1), and the population of learners (e.g. children with DCD) is an important prerequisite. Therapists should be aware that their clinical decision-making processes are influenced by their knowledge, experiences, preferences and beliefs, and only to a limited extent by characteristics of a child and task. At the start of this PhD, we felt that knowing how to promote implicit and explicit motor learning processes in children would be important to advance the understanding of how to use MLSs to teach motor tasks. However, advancing insights showed that it is more relevant to know how to model MLSs; to have options to adapt MLSs when the immediate improvement does not seem to meet therapists' expectations and to discover which MLSs suit a child best. In order to optimize clinical decision-making processes, future research should provide us with more insights into: how the identified characteristics of child (Figure 6.2) and task complexity can guide therapists' choices; and evidence about effectiveness of tailored use of MLSs in children with motor disabilities, including children with DCD.

When teaching motor tasks, it is important to have attention for five generic motor teaching principles: (1) enhance motivation; (2) practice meaningfully; (3) practice at the optimal level; (4) increase time on task; and (5) stimulate transfer (Figure 6.3). MLSs should be adapted to an individual child to meet these principles, various suggestions were made in this thesis. To provide tailored treatments, we recommend to carefully consider: teaching styles; intentions with the MLSs; and how to model the various parameters of instructions and feedback and organization of practice (Figure 6.5).

The findings of this thesis provide insights and tools for all types of instructors (e.g. PPTs, occupational therapists, physical education teachers, and trainers of organized sports) teaching motor tasks to various types of children with and without motor disabilities. For children with DCD specifically, we advise special attention for their motivation and stimulating transfer of learned tasks to daily-life contexts. Moreover, we advise to use self-controlled conditions to enhance motivation, specific feedback to provide a child with information to improve task performance in a next trial, and indirect teaching styles to enhance these children's executive functions.

Our final conclusion is: there is no one-size-fits-all treatment. Therapists are expected to provide tailored treatments adapted to characteristics of child and task to optimize motor learning processes in children. This requires them to put effort into having adequate knowledge about all relevant components in motor learning. Furthermore, they should reflect on the influence of their own level of knowledge, experiences, preferences, and beliefs on the choices they make.

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6.6 Appendix 6.1: Observation tools

Figure 6.6. *Observation tool for instructions and feedback*

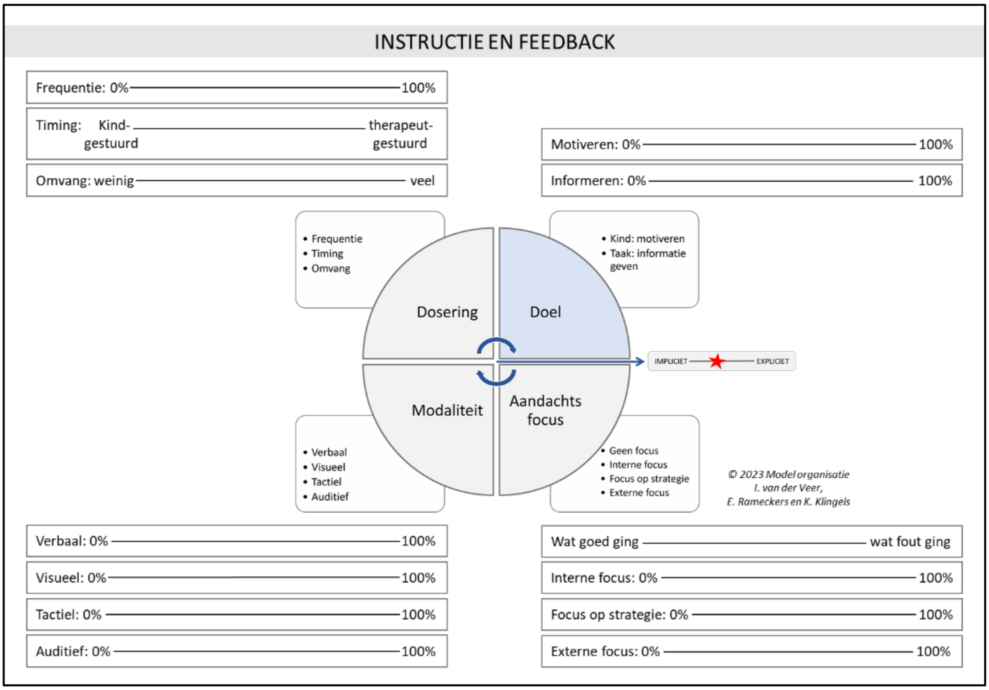
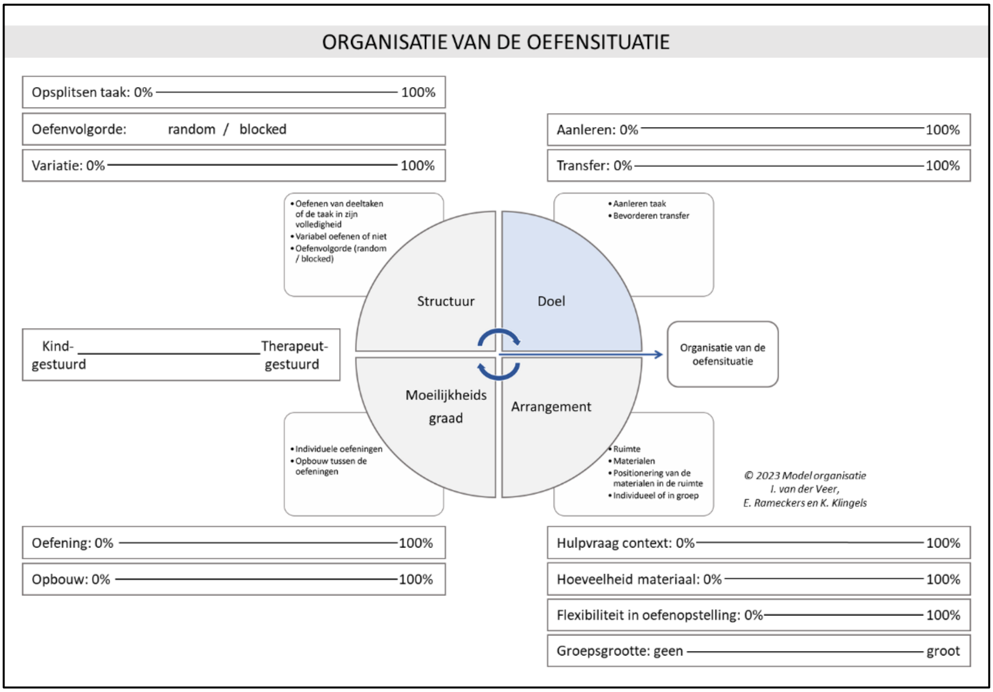


Figure 6.7. *Observation tool for organization of practice*



Summary

Children perform many motor tasks during an average day. For instance, at home when getting dressed or while playing, or at school when writing or participating in physical education classes. Typically developing children learn motor tasks almost effortlessly; however, atypically developing children experience difficulties learning these motor tasks. But what is meant by motor learning? Motor learning can be described as a set of processes associated with practice or experience leading to relative permanent changes in motor behaviour.

A specific type of atypically developing children, are children with developmental coordination disorder (DCD). They have mild-to-severe problems in motor learning resulting in low motor abilities, and associated problems like reduced physical fitness, obesity, and various social-emotional problems such as lower levels of perceived self-competence and self-efficacy, social exclusion, and loneliness. As a consequence of these motor and non-motor problems, children with DCD participate and engage less in daily-life activities at home, school, play and organized sports.

Physical and occupational therapists in paediatric clinical care teach motor tasks to children with low motor abilities, also to children with DCD. They provide evidence-based interventions, in which they intent to promote specific types of motor learning processes (e.g. implicit and explicit motor learning), and use motor learning strategies (MLSs) to improve children's motor performances. The various MLSs can be categorized into instructions, feedback and organization of practice. For optimal motor learning, it is suggested that therapists should adapt their use of MLSs to characteristics of a child, task and environment. However, a previous study showed that physical therapists in adult clinical care experienced difficulties understanding the construct of motor learning, and that they had limited knowledge about implementing MLSs into their professional clinical care. It is to be expected that therapists in paediatric care experience these difficulties as well, because even less is known about effectiveness of MLSs used in children with and without DCD.

After reviewing literature about motor learning, we identified three knowledge gaps that may hinder therapists in their use of MLSs when teaching motor task to children. Firstly, little is known about effectiveness of various elements of MLSs used in children with and without DCD, and how characteristics of child and task might modify effectiveness. Secondly, it remains unclear how MLSs can be used to promote (more) implicit and (more) explicit motor learning processes. Thirdly, little is known about therapists' current use of MLSs in children with DCD, and how characteristics of child and task guide their choice for MLSs. We aimed to advance the understanding of therapists' use of MLSs in children with and without DCD by conducting four studies. We used a qualitative approach because that was the logical first step according to our perspectives.

In **Chapter 2** we reported the results of our systematic literature review investigating effectiveness of instructions and feedback with external focus applied with specific frequencies (reduced versus continuous), modalities (visual versus verbal) and/or timing (child-controlled versus instructor-controlled) used to teach functional motor tasks to typically and atypically developing children. The 13 included studies were of low methodological quality, and difficult to compare due to heterogeneity into study characteristics like population, task, experimental and control interventions, and outcome measures. A best-evidence synthesis was performed of which the summary synthesis showed mainly no or conflicting evidence for frequency. However, moderate evidence was found for child-controlled (also known as self-controlled) timing of feedback on retention, and limited evidence for visual instruction on retention and transfer. The results of this review are in line with previous systematic reviews investigating effectiveness of elements of MLSs in (a)typically developing children, who also found predominantly no or conflicting evidence based on studies of low methodological quality. We recommended clinicians to use self-controlled feedback in children, and researchers to explore how to improve methodological quality of studies investigating effectiveness of MLSs.

In **Chapter 3** we explored the opinions of 29 international experts on how to use MLSs to promote implicit and explicit motor learning processes in children with and without DCD. The experts (with backgrounds in children's motor learning in clinical care, education, and/or research) completed two consecutive questionnaires with open-ended questions. Furthermore, in Questionnaire 2, experts classified suggested MLSs on 5-point Likert scales (from implicit to explicit motor learning). The results of the Likert scales showed large variation. The analyses of the open-ended questions resulted into two themes. Experts experienced difficulties classifying MLSs as promoting either (more) implicit or (more) explicit motor learning (Theme 1). They mentioned that there was too little known about the construct of implicit and explicit motor learning, and how children actually learned. Experts provided us with insights into the need for clinical decision making when choosing MLSs, including the importance of having adequate knowledge about motor learning and the need for adapting MLSs to characteristics of child and task (Theme 2). Lastly, they provided many suggestions on how to model and adapt instructions, feedback and organization of practice (Appendix 3.2). We recommended future research to focus on: understanding how the various motor learning mechanisms in children work, interact, and may be manipulated to promote (more) implicit or (more) explicit motor learning; and gaining a better understanding on how characteristics of child and task can guide clinical decision-making processes.

Studies three and four explored paediatric physical therapists' (PPTs) use of MLSs in children with DCD, using observations and interviews. In **Chapter 4**, we analysed 10 video-taped treatment sessions of PPTs teaching motor tasks to children with DCD to gain insight into their use of instructions and feedback. We developed a newly video-based analysis plan to suit the explorative character of our research question. The analyses resulted into three themes. Therapists' intention with the instructions and feedback was to motivate children or to provide them with specific information about the task (Theme 1). Therapists preferred a direct or indirect teaching style (Theme 2). A direct style used concrete instructions and feedback to provide a child with information about the task performance (e.g. a therapist tells a child to extend the arm while throwing), whereas an indirect style used questions (e.g. what went wrong?) and/or manipulations of task and context to guide a child to the correct movement solution. Finally, five parameters were identified that were used to model instructions and feedback: focus of attention, modality, information content, timing, and frequency (Theme 3). The results showed that therapists adapted instructions and feedback to child and task. However, more insight is needed into how characteristics of child and task guided their choice for specific types of instructions and feedback.

How these characteristics guided PPTs' choice for specific types of MLSs was the focus of our interview study. In **Chapter 5**, we reported the results of the analyses of 10 individual and two focus-group interviews with PPTs who had different levels of experience in teaching motor tasks to children with DCD in various work settings. Six themes emerged from the data. Therapists provided tailored treatments (Theme 1). However, their clinical decision-making processes were mainly guide by their knowledge, experiences, and beliefs, and only to a limited extent by characteristics of child and task. Secondly, therapists' teaching style was either (more) direct or (more) indirect (Theme 2). Their main reason for choosing a specific style was the assumption of whether executive functions could be trained or not. Because executive functions can be trained, we recommended to use indirect teaching styles in children with DCD. Furthermore, therapists stressed the importance of enhancing motivation (Theme 3), practicing at the optimal level (Theme 4), and stimulating automatization and transfer in children with DCD (Theme 5). They gave many suggestions on how they enhanced motivation, automatization and transfer, resulting in large variation in use of MLSs. Lastly, therapists considered task complexity as relevant in guiding their choice for MLSs (Theme 6). However, more insight is needed into which MLSs should be preferred based on task complexity. The results of this study indicated the importance of the level of education on teaching motor tasks to children with DCD, and the need for implementing knowledge about motor learning into therapists' clinical care.

This thesis was a first step in advancing the understanding of therapists' use of MLSs to teach motor tasks to children with and without DCD. Four main conclusions can be drawn. Conclusion 1, clinical decision making is fundamental when teaching motor tasks, and having adequate knowledge about all relevant components of motor learning, and the population of learners (e.g. children with DCD) is an important prerequisite. Conclusion 2, therapists should use MLSs to meet five generic principles in motor teaching: (1) enhance motivation; (2) practice meaningfully; (3) practice at the optimal level; (4) increase time on task; and (5) stimulate transfer. MLSs can be adapted to an individual child by carefully considering: teaching styles; intentions with the MLSs; and how to model the various parameters for instructions and feedback and organization of practice. Conclusion 3, in children with DCD therapists should have special attention for their motivation and stimulating transfer of learned tasks to daily-life contexts. Self-controlled conditions are evidence-based MLSs to enhance motivation. Furthermore, we advise therapists to use indirect teaching styles to train the executive functions of these children. Lastly, our final conclusion (Conclusion 4), there is no one-size-fits-all treatment. Therapists are expected to provide tailored treatments adapted to characteristics of child and task to optimize motor learning processes in children. This requires them to put effort into having adequate knowledge about motor learning, and the population of interest, for example, children with DCD. Furthermore, they should reflect on the influence of their own level of knowledges, experiences, preferences, and beliefs on the choices they make.

Samenvatting

Gedurende een dag voeren kinderen veel motorische taken uit: bijvoorbeeld thuis, als ze zich aankleden of aan het spelen zijn, of op school tijdens de schrijf- of gymles. Vaak leren normaal ontwikkelende kinderen (ook wel typisch ontwikkelende kinderen genoemd) motorische taken zonder enige moeite. Echter voor kinderen die zich atypisch ontwikkelen is het leren van motorische taken een veel grotere uitdaging. Maar laten we eerst duiden wat we bedoelen met *motorisch leren*? Een kind leert motorisch als er een relatieve permanente verandering optreedt in het motorisch gedrag als gevolg van oefening of ervaring. Verandering is permanent als een kind het motorisch gedrag ook kan reproduceren als het een tijdje niet geoefend heeft.

Een specifieke populatie atypisch ontwikkelende kinderen zijn kinderen met developmental coordination disorder (DCD). Ze ervaren matige tot ernstige problemen met het leren van motorische taken. Dit resulteert in beperkte motorische mogelijkheden en bijkomende problemen zoals verminderde fysieke fitheid, obesitas en verschillende sociaal-emotionele problemen zoals verminderde competentiebeleving en zelfvertrouwen, uitsluiting van sociale activiteiten en eenzaamheid. Als gevolg van de motorische en bijkomende problemen participeren kinderen met DCD minder frequent in dagelijkse activiteiten op school, thuis, tijdens spel en/of georganiseerde sport. Als ze participeren, dan zijn ze vaak minder betrokken.

(Kinder)fysiotherapeuten en ergotherapeuten leren motorische taken aan kinderen met beperkte motorische capaciteiten, dus ook aan kinderen met DCD. Hiervoor gebruiken ze op evidentie gebaseerde interventies. Tijdens deze interventies stimuleren ze specifieke motorische leerprocessen in het kind (bijvoorbeeld impliciet en expliciet motorisch leren). Ook gebruiken ze motorische leerstrategieën (MLSen) om de uitvoering van de motorische taken te verbeteren. De verschillende MLSen kunnen gecategoriseerd worden naar instructie, feedback en organisatie van de oefensituatie. Om zo optimaal mogelijk te oefenen, moeten therapeuten hun keuze voor MLSen afstemmen op karakteristieken van het kind, de taak en de omgeving. Echter heeft een eerdere studie aangetoond dat fysiotherapeuten, werkzaam met volwassenen, het construct 'motorisch leren' moeilijk begrijpen en dat ze niet goed weten hoe ze het gebruik van MLSen moeten implementeren in hun professionele handelen. Het is te verwachten dat therapeuten die kinderen behandelen hetzelfde probleem ervaren, voornamelijk omdat er wetenschappelijk gezien nog minder bekend is over het gebruik van MLSen bij kinderen met en zonder DCD.

Na het bestuderen van de wetenschappelijke literatuur over motorisch leren, hebben we drie kennishiaten geïdentificeerd. De ontbrekende kennis belemmert therapeuten mogelijk in het gebruiken van MLSen in hun dagelijkse zorg voor kinderen. Ten eerste is er weinig bekend over de effectiviteit van de verschillende MLSen die gebruikt kunnen worden bij kinderen met en zonder DCD. Ook weten we nog te weinig hoe karakteristieken van het kind en de taak deze effectiviteit mogelijk beïnvloeden. Ten tweede is het onduidelijk hoe MLSen gebruikt kunnen worden om (meer) impliciete en (meer) expliciete leerprocessen bij kinderen te stimuleren. Tot slot is er nog weinig bekend over het huidige gebruik van MLSen door therapeuten bij kinderen met DCD en hoe karakteristieken van het kind en de taak hun keuzes beïnvloeden.

Deze thesis heeft tot doel om het inzicht met betrekking tot het gebruik van MLSen door therapeuten in de behandeling van kinderen met en zonder DCD te vergroten. We hebben vier studies uitgevoerd, waarbij we gekozen hebben voor een kwalitatieve benadering omdat dit volgens ons een logische eerste stap was.

In **Hoofstuk 2** rapporteerden we de resultaten van ons systematische literatuuronderzoek. Deze studie onderzocht de effectiviteit van instructie en feedback met externe focus toegepast in specifieke frequenties (gereduceerd versus continu), modaliteiten (visueel versus verbaal) en/of timing (kind gestuurd versus instructeur gestuurd) om functionele motorische taken te leren aan kinderen met een typische en atypische motorische ontwikkeling. De 13 geïncludeerde studies waren van methodologische lage kwaliteit en moeilijk te vergelijken door verschillen in studie karakteristieken zoals populatie, taak, experimentele en controle interventies en gehanteerde uitkomstmaten. De beschrijvende analyse van de resultaten (best-evidence synthesis) liet zien dat er hoofdzakelijk geen of tegenstrijdige resultaten waren gevonden voor het effect van frequentie. Wel werd er matige evidentie gevonden voor het effect van kind gestuurde timing van feedback op retentietesten, ook wel zelfgestuurde feedback genoemd. Tevens werd er beperkte evidentie gevonden voor het effect van visuele instructies op retentie- en transfertesten. De resultaten van dit literatuuronderzoek kwamen overeen met de resultaten van eerdere systematische literatuuronderzoeken die effectiviteit onderzochten van verschillende MLSen gebruikt bij (a)typische ontwikkelende kinderen. Deze onderzoeken vonden ook overwegend geen of tegenstrijdige resultaten gebaseerd op studies van methodologische lage kwaliteit. We adviseerden therapeuten om gebruik te maken van zelfgestuurde feedback bij kinderen en onderzoekers om aandacht te hebben voor de methodologische kwaliteit van studies.

In **Hoofdstuk 3** exploreerden we de visies van 29 internationale experts over het gebruik van MLSen om impliciete en expliciete motorische leerprocessen te stimuleren bij kinderen met en zonder DCD. De experts (met ervaringen met motorisch leren bij kinderen vanuit klinische zorg, onderwijs en/of onderzoek) vulden twee opeenvolgende vragenlijsten in die voornamelijk bestonden uit open vragen. Daarnaast vroegen we de experts om in Vragenlijst 2 MLSsen te classificeren op een 5-punts Likert schaal (van impliciet naar expliciet). De resultaten van de Likert schalen lieten een grote variatie zien. De analyse van de open vragen resulteerde in twee thema's. Experts vonden het moeilijk om MLSen te classificeren naar eerder (meer) impliciet of (meer) expliciet motorisch leren stimulerend (Thema 1). Ze gaven te kennen dat er te weinig bekend was over het construct 'impliciet en expliciet motorisch leren' en over de leerprocessen van kinderen. Daarnaast gaven de experts veel inzicht in het belang van klinisch redeneren om te komen tot een keuze van strategie (Thema 2). Ze gaven aan dat het hebben van adequate kennis over motorisch leren een belangrijke voorwaarde is om tot een goede keuze te komen. Ook benadrukten ze dat deze keuze afgestemd moet zijn op karakteristieken van het kind en de taak. Tot slot gaven ze veel suggesties over hoe instructies, feedback en de organisatie van de oefensituatie gemodelleerd zouden kunnen worden (Appendix 3.2). We adviseerden dat toekomstig onderzoek zich richt op: het beter begrijpen hoe motorische leerprocessen van kinderen werken, interacteren en gemanipuleerd kunnen worden om eerder (meer) impliciet of (meer) expliciet motorisch leren te stimuleren; en het verkrijgen van meer inzicht in hoe karakteristieken van het kind en de taak het klinisch redeneren kunnen sturen.

In studies drie en vier exploreerden we het gebruik van MLSen door kinderfysiotherapeuten bij kinderen met DCD, door gebruik te maken van observaties en interviews. In **Hoofdstuk 4** analyseerden we 10 gefilmde behandel sessies van kinderfysiotherapeuten waarin zij motorische taken leerden aan kinderen met DCD. Deze analyse had tot doel om meer inzicht te krijgen in hun gebruik van instructie en feedback. We ontwikkelden een nieuw analyse plan voor het analyseren van de video's. Dit was nodig in verband met het exploratieve karakter van onze onderzoeksvraag. De analyse resulteerde in drie thema's. De therapeuten gebruikten instructies en feedback om kinderen te motiveren of om hen specifieke informatie te geven over de uitvoering van de motorische taak (Thema 1). De therapeuten hadden een voorkeur voor of een (meer) directe of (meer) indirecte stijl van doceren (Thema 2). Bij een directe stijl werden concrete instructies en feedback gegeven die een kind stuurde naar de juiste uitvoering van een taak (er werd bijvoorbeeld gezegd dat een kind zijn arm moest strekken tijdens het gooien). Bij een indirecte stijl van doceren werden vragen gebruikt (er werd bijvoorbeeld gevraagd wat er goed of fout ging) en/of aanpassingen van de taak en de omgeving gedaan om het kind naar de juiste uitvoering van een taak te coachen. Tot slot werden er vijf parameters geïdentificeerd die gebruikt werden om instructies en feedback te modelleren: aandachtsfocus, modaliteit, omvang, timing en frequentie (Thema 3). De analyses lieten zien dat kinderfysiotherapeuten hun instructie en feedback aanpasten aan het kind en de taak. Echter meer inzicht is nodig in hoe karakteristieken van het kind en de taak hun keuzes voor bepaalde typen instructies en feedback beïnvloeden.

De vraag hoe karakteristieken van kind en taak de keuzes van kinderfysiotherapeuten beïnvloeden stond centraal in onze interview studie. In **Hoofdstuk 5** rapporteerden we de resultaten van de analyses van 10 individuele interviews en twee focusgroepen met kinderfysiotherapeuten. De kinderfysiotherapeuten hadden verschillende mate van ervaring in het werken met kinderen met DCD in de 1ste en/of 2de lijn. De analyse leidde tot zes thema's. Kinderfysiotherapeuten leverden maatwerk in hun behandeling (Thema 1). Echter werd hun klinisch redeneerproces sterk gestuurd door hun kennis, ervaringen, voorkeuren en overtuigingen, en slechts in beperkte mate door karakteristieken van het kind en de taak. Ten tweede, kinderfysiotherapeuten hanteerden een directe of indirecte stijl van doceren (Thema 2). Het voornaamste argument om voor een directe of indirecte stijl te kiezen was de aanname of executieve functies getraind konden worden of juist niet. Aangezien executieve functies getraind kunnen worden, adviseerden we een indirecte stijl van doceren bij kinderen met DCD. Verder benadrukten de kinderfysiotherapeuten het belang van het bevorderen van motivatie (Thema 3), het optimale niveau om op te oefenen (Thema 4) en het stimuleren van automatiseren en transfer bij kinderen met DCD (Thema 5). Ze gaven veel suggesties omtrent hoe MLSen gebruikt konden worden om motivatie, automatisatie en transfer te bevorderen. Deze suggesties lieten ook zien dat de variatie in het gebruik van MLSen tussen kinderfysiotherapeuten groot was. Tot slot gaven de kinderfysiotherapeuten aan dat de complexiteit van een taak een rol speelde in hun keuze voor bepaalde MLSen (Thema 6). Echter meer onderzoek is nodig om te bepalen welke MLSen de voorkeur zouden moeten hebben afhankelijk van de complexiteit van een taak. De resultaten van deze studie waren een indicatie dat het niveau van opleidingen en/of scholingen met betrekking tot motorisch leren een belangrijk aandachtspunt is. Daarnaast zou kennis over motorisch leren geïmplementeerd moeten worden in het professionele handelen van therapeuten.

Met deze thesis is een eerste stap gezet in het bevorderden van de inzichten omtrent het gebruik van MLSen door therapeuten om kinderen met en zonder DCD motorisch taken te leren. We trekken vier overkoepelende conclusies. Conclusie 1, klinisch redeneren is essentieel bij het leren van motorische taken aan kinderen. Het hebben van adequate kennis over alle relevante aspecten van motorisch leren en de populatie waaraan je motorische taken leert (bijvoorbeeld kinderen met DCD) is een belangrijk voorwaarde. Conclusie 2, therapeuten moeten MLSen gebruiken om aan vijf generieke principes binnen het motorisch leren te voldoen: (1) bevorder motivatie, (2) oefen betekenisvol, (3) oefen op het optimale niveau, (4) bevorder time on task, en (5) stimuleer transfer. Therapeuten worden verwacht MLSen aan te passen aan het kind door specifieke keuzes te maken in: hun stijl van doceren (direct of indirect), het doel dat ze willen bereiken met de MLSen en hoe ze de verschillende parameters van instructie, feedback en de organisatie van de oefensituatie modelleren. Conclusie 3, als het gaat om kinderen met DCD, dan moeten therapeuten extra aandacht hebben voor motivatie en het stimuleren van transfer van geleerde taken naar de dagelijkse context. Zelfgestuurde oefencondities zijn op evidentie gebaseerde

MLSen om motivatie te bevorderen. Ook adviseerden we therapeuten om een indirecte stijl van doceren te hanteren als er sprake is van problemen in de executieve functies. Tot slot, Conclusie 4, er is geen *one-size-fits-all* behandeling. Voor een optimaal motorische leerproces van een kind, moeten therapeuten maatwerk leveren. Dit betekent dat ze moeten zorgen dat hun kennis over motorisch leren en de populatie die het betreft (bijvoorbeeld kinderen met DCD) toereikend is om deze zorg te leveren. Ook moeten ze reflecteren op de invloed van hun eigen kennisniveau, ervaringen, voorkeuren en overtuigingen op de keuzes die ze maken.

Dankwoord

Het zit er op! Na vier intensieve jaren ben ik aan het einde gekomen van een traject waarin ik ontzettend veel geleerd heb over onderzoek, motor learning en motor teaching en over mezelf. Ik ben trots op het eindresultaat, maar dit resultaat was er nooit geweest zonder de hulp van velen.

Van alle motorische leerstrategieën die er zijn, is de analogie (een beeldspraak) mijn favoriet. In mijn werk als kinderfysiotherapeut gebruikte ik deze vrijwel dagelijks. Ook als docent en onderzoeker gebruik ik analogieën met regelmaat. Waarom? Omdat een beeld alleszeggend is, de *juiste* analogie maakt het geven van veel en gedetailleerde informatie overbodig. In mijn dankwoord maak ik dan ook graag gebruik van de analogie van een **puzzel**. Een moeilijke puzzel brengt uitdaging met zich mee; het vraagt inzicht, doorzettingsvermogen en zonder hulp en samenwerking kom je er niet. In dit promotietraject mocht ik mijn ervaringen als kinderfysiotherapeut meenemen in het onderzoek, waardoor ik de mooie kans kreeg een bijdrage te leveren aan het bouwen van de brug tussen wetenschap en praktijk. Het type onderzoek waar ik het meest enthousiast van word. De afgelopen vier jaar waren met regelmaat een puzzel, om meerdere redenen. Ten eerste vanwege de vele vraagstukken die er zijn binnen dit hele interessante maar complexe onderwerp, dus wat ga je doen? Terugkijkend denk ik dat we een aantal relevante onderzoeken uitgevoerd hebben, die een steentje bijdragen in het leggen van de puzzel. Maar we zijn er nog niet, er zijn nog vele vraagstukken te doorgronden. Ten tweede, onderzoek doen verloopt met 'ups' en 'downs', het is soms even zoeken naar het juiste puzzelstukje om weer verder te kunnen. Maar ik heb geleerd dat tegenslagen ook waardevol zijn en dat je er nog beter van wordt. Tot slot, hebben Bart en ik tijdens mijn promotietraject Fien mogen verwelkomen. Het behouden van de balans tussen werk en privé was zo nu en dan ook een puzzel, zeker ten tijde van de Corona pandemie. Maar zoals gezegd, uitdagingen maken een puzzel interessant en met hulp kom je wel. Er zijn dan ook veel mensen die ik wil bedanken.

Een puzzel heeft **4 hoekstukken**: de fundamenten van de puzzel, de basis om vanuit te vertrekken. Eugene Rameckers, Katrijn Klingels, Carolien Bastiaenen en Evi Verbecque, jullie waren mijn hoekstukken.

Beste Eugene, een van de voornaamste redenen waarom ik aan dit traject begonnen ben, was omdat jij mijn copromotor zou zijn. Al 19 jaar mag ik onder jouw begeleiding groeien en bloeien: eerst als student kinderfysiotherapie, daarna als collega docent en de afgelopen jaren als promovenda. Maar ik ben er van overtuigt dat dit nog geen eindstation is, we hebben nog veel werk te verrichten samen. Vooral jouw persoonlijke betrokkenheid waardeer ik enorm. Je hebt altijd tijd voor me, ik kan alles met je bespreken en je daagt me uit om grenzen te verleggen. Ik heb vaak het gevoel dat jij al weet welk pad ik ga bewandelen, terwijl ik zelf nog druk zoekende ben. Ik heb genoten van onze inhoudelijke discussies over motorisch leren en onze gezamenlijke missie om de kennis te vertalen voor het werkveld. Ik wil je ontzettend bedanken voor alles en ik kijk uit naar hetgeen dat nog komen gaat.

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En dan zijn er nog alle **individuele puzzel stukjes**, elk met zijn/haar eigen rol binnen het geheel. Maar allen belangrijk om de puzzel gelegd te krijgen. In willekeurige volgorde wil ik graag collega’s, vrienden en familie bedanken voor het tonen van interesse, het bieden van steun, het meedenken, het geven van feedback en/of het zorgen voor ontspanning en afleiding.

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Als de puzzel bijna gelegd is, dan zijn er de **laatste paar puzzelstukjes**: de belangrijkste stukjes die de puzzel compleet maken. Bart, Katrijn en Fien, jullie maken mij compleet.

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About the author

Ingrid van der Veer was born on April 21st 1981 in Weert, the Netherlands. In 1999, she obtained her high school diploma (VWO) at Philips van Horne Scholengemeenschap, Weert, the Netherlands. She obtained her bachelor degree physical therapy in 2003 at Hogeschool Zuyd, Heerlen, the Netherlands. She then started working as a (paediatric) physical therapist, and combined this with obtaining her master's degree paediatric physical therapy (2004-2009) at Avans+, Breda, the Netherlands. In November 2009, she started teaching at the Master Pediatric Physical Therapy at Avans+, while continuing her work as a paediatric physical therapist (PPT). As a PPT, she developed expertise in primary school children with various motor learning disabilities like children with developmental coordination disorder (DCD). Her teaching focused on the topics: task analysis, motor learning interventions, and children with various motor learning disabilities. Furthermore, she supervised master theses, and was a member of the exam committee. Because of an increasing interest in scientific research, she obtained her master's degree clinical epidemiology at University of Amsterdam – Amsterdam Medical Centre (UVA-AMC) in 2015. Since 2016, she has participated in various committees of the Dutch Association of Pediatric Physical Therapists, focusing on DCD (e.g. translating the international DCD recommendations into Dutch practical guidelines). From 2016 to 2020, she was member of the board of a Regional Association for Pediatric Physical Therapists, which organized educational activities. In December 2018, she started her PhD at Hasselt University, Belgium, under the supervision of Prof. Dr. Katrijn Klingels (promotor, Hasselt University), Prof. Dr. Eugene Rameckers (co-promotor, Hasselt University), and Prof. Dr. Caroline Bastiaenen (co-promotor, Maastricht University). During her PhD, she performed research to gain a better understanding of therapists' use of motor learning strategies in children with and without DCD, of which the results are published in this doctoral thesis, and in international peer-reviewed journals. She was involved in teaching activities at the Master Rehabilitation Sciences & Physiotherapy, and supervised theses. For one year, she was chair of the meetings for pre- and post-doctoral researchers. Ingrid will continue her research work as a post-doctoral researcher at Hasselt University, which she will combine with teaching at the Master Pediatric Physical Therapy at Hogeschool Utrecht, the Netherlands.

List of publications and presentations

Publications

Published

- Evi Verbecque, Charlotte Johnson, Eugene Rameckers, Angelina Thijs, **Ingrid van der Veer**, Pieter Meyns, Bouwien Smits-Engelsman, Katrijn Klingels. Balance control in individuals with developmental coordination disorder: A systematic review and meta-analysis. *Gait & Posture* 2021;83:269-279. doi.org/10.1016/j.gaitpost.2020.10.009
- **van der Veer IPA**, Verbecque E, Rameckers EAA, Bastiaenen CHG, Klingels K. How can instructions and feedback with external focus be shaped to enhance motor learning in children? A systematic review. *PLoS One* 2022;17(8): e0264873. doi.org/10.1371/journal.pone.0264873
- **van der Veer IPA**, Bastiaenen CHG, Goetschackx M, van der Wielen-Heezius NNF, Rameckers EAA, Klingels K. Therapists' use of instructions and feedback in motor learning interventions in children with developmental coordination disorder: a video observation study. *Phys Occup Ther Pediatr* 2023 Apr: 1-19. doi: 10.1080/01942638.2023.2194408.
- **van der Veer IPA**, Bastiaenen CHG, Rameckers EAA, Klingels K. Experts' perspectives on how to promote implicit and explicit motor learning in children: a mixed-methods study. *Child Care Health Dev* 2023. doi.org/10.1111/cch.13147

Manuscripts under second review

- **van der Veer IPA**, Rameckers EAA, Steenbergen B, Bastiaenen CHG, Klingels K. How do paediatric physical therapists teach motor skills to children with Developmental Coordination Disorder? An interview study. Submitted to *PLoS One*

Presentations

Oral presentations

- **van der Veer I**, Rameckers E, Klingels K. Het spinnenweb van motorisch leren. Symposium: Het spinnenweb van motorisch leren bij kinderen met DCD, UHasselt, Belgium, October 2020 & March 2021 *(Member of the organisation)*
- **van der Veer I**, Klingels K. Motorisch leren in de behandeling van kinderen met DCD. Kinepedia, Belgium, May 2021 (*Invited)*
- **van der Veer I.** De toepassing van het motorisch leren, een heel gepuzzel. Symposium: DCD anno 2021, SCEM, the Netherlands, September 2021 (*Invited)*
- **van der Veer I**, Rameckers E, Bastiaenen C., Klingels K. Child and task characteristics that guide therapists' use of motor learning strategies: a qualitative study. 2nd European Paediatric Physiotherapy Congress, Italy, October 2022
- **van der Veer I.** Kinderen motorisch laten leren, hoe doe ik dat? Regionale vereniging voor kinderfysiotherapeuten, the Netherlands, November 2022 (*Invited)*

Workshops

- **van der Veer I**, Rameckers E, Klingels K. Motorisch leren toegepast op grof motorische taken. Symposium: Het spinnenweb van motorisch leren bij kinderen met DCD, UHasselt, Belgium, October 2020 & March 2021 *(Member of the organisation)*
- **van der Veer I**, de Groot T, Rameckers E. Het kind leert (motorisch) en wat is jouw rol? Congres: Kinderfysiotherapeut 3.0: this is your playground, NVFK, the Netherlands, October 2021 (*Invited)*
- **van der Veer I**, Goetschalckx M. Developmental Coordination Disorder. PXL opleiding lichamelijke opvoeding & bewegingsrecreatie, Belgium, March 2023 (*Invited)*

Poster presentations

- **van der Veer I**, Rameckers E, Verbecque E, Bastiaenen C, Klingels K. Impliciet en expliciet motorisch leren bij kinderen met DCD, een studieprotocol. NVFK najaarscongres, the Netherlands, October 2019
- **van der Veer I**, van der Wielen-Heezius N, Goetschalckx M, Bastiaenen C, Klingels K, Rameckers E. The development of a protocol to analyze therapists' use of motor learning principles in children. 14th International DCD Conference, Canada, July 2022
- **van der Veer I**, Rameckers E, van der Wielen-Heezius N, Goetschalckx M, Bastiaenen C, Klingels K. Therapists' use of instructions and feedback in motor learning in children with Developmental Coordination Disorder. 14th International DCD Conference, Canada, July 2022
- **van der Veer I**, Rameckers E, Steenbergen B, Bastiaenen C, Klingels K. How do therapists teach children with Developmental Coordination Disorder motor skills? An interview study. 35th annual meeting European Academy of Childhood Disability, Slovenia, May 2023
- **van der Veer I**, Bastiaenen C, Goetschalckx M, van der Wielen-Heezius N, Klingels K, Rameckers E. Therapists' use of instructions and feedback in motor learning interventions in children with Developmental Coordination Disorder: a video observation study. 35th annual meeting European Academy of Childhood Disability, Slovenia, May 2023
- Velghe S, Rameckers E, Meyns P, **van der Veer I**, Goetschalckx M, Johnson C, Hallemans A, Verbecque E, Klingels K. A highly intensive activity-based balance camp for children with Developmental Coordination Disorder: a pilot study on its feasibility and effectiveness. 35th annual meeting European Academy of Childhood Disability, Slovenia, May 2023
- Velghe S, Rameckers E, Meyns P, **van der Veer I**, Johnson C, Hallemans A, Verbecque E, Klingels K. An intervention protocol of a highly intensive activity-based balance training camp in children with Developmental Coordination Disorder. 35th annual meeting European Academy of Childhood Disability, Slovenia, May 2023