CLINICIAN PERSPECTIVES ON INTEGRATING MOTOR LEARNING THEORY AND PRINCIPLES INTO REHABILITATION

by

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A thesis submitted to the School of Rehabilitation Therapy

In conformity with the requirements for

the degree of Master of Science

Queen's University

Kingston, Ontario, Canada

August, 2022

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Abstract

BACKGROUND

Following a neurological injury, motor learning (ML) and the accompanying theories and principles provide clinicians with the structure and guidelines required to maximize functional recovery. Unfortunately, evidence has shown that ML is not being used to its full benefit within rehabilitation. Therefore, an assessment of how clinicians are implementing ML within clinical practice, and an exploration of the barriers and facilitators they face, should be conducted. The objectives of this study were to 1) describe how confident clinicians are integrating ML into clinical practice, 2) describe how ML is integrated into clinical practice, and the clinician perceived barriers and facilitators, and 3) start to determine what clinicians believe would be beneficial moving forward to begin overcoming these barriers.

METHODS

A sequential exploratory mixed methods approach was utilized. Two surveys comprised the quantitative section; one was distributed to a convenience sample of clinicians attending a motor learning workshop (n = 28) and the second was primarily distributed via the Ontario and Canadian Physiotherapy Associations (n = 60). The content of the first survey and the Theoretical Domains Framework were used to inform question development for qualitative interviews (n = 7).

RESULTS

Quantitative: Surveys highlighted barriers and facilitators to integrating ML into clinical practice, such as time, knowledge and understanding, and patient presentations, identified by previously published literature. The second survey highlighted social support as a facilitator. Based on the scales used in the surveys, clinicians have a mid-range confidence level integrating ML within rehabilitation.

Qualitative: While the interviews also highlighted the barriers and facilitators identified by the surveys, they emphasized the nuances of these barriers. How ML is approached within the literature, the realities of clinical practice, and the limited guidance clinicians receive with ML exacerbates the impact of the barriers on their clinical practice.

CONCLUSIONS

The resulting confidence levels and assessments of how ML theories and principles are integrated into clinical practice shows that there are still gaps in the translation of ML-related knowledge into rehabilitation. A future integrated knowledge translation opportunity should be investigated as a potential method of reducing the impact of these barriers on clinical practice.

Acknowledgements

The creation of this thesis was not a solo project, and I am so thankful to everyone who had a hand in getting me across the finish line. It is because of the support and guidance that I've been fortunate enough to receive from all of you that I was able to undertake this adventure.

Dr. Vince DePaul, thank you for all your support, guidance, feedback, and enthusiasm over the course of this thesis; it allowed me to become more passionate about this project than I ever thought possible. I've learned so much from you in the past two years and I am so excited to see where all this newfound knowledge and experience takes me as I enter a career in medicine.

Dr. Afolasade Fakolade, I am incredibly grateful for your insights into all things qualitative. Having zero qualitative experience prior to this paper, your direction and feedback has allowed me to produce a qualitative section that I am truly proud of. Thank you.

To all the clinicians who took time out of their schedules to participate in this project; I am so honoured to have been given the opportunity to hear your stories, share in your knowledge, and experience rehabilitation and motor learning through your eyes. This would not have been possible without you.

To my family and friends, thank you for putting up with me for the last two years. From the endless phone calls when I needed someone to unscramble my thoughts, to the constant "I need a word for….", and the many (many!) cups of tea. Your unwavering support, guidance, and occasional bout of tough love was instrumental in my ability to complete this degree.

Finally, to Mojo the Cat, without whom I'd not be $50 richer.

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List of Abbreviations

The following table outlines the acronyms that appear within the body of this thesis, their meaning, and the page number that they first appear.

Abbreviations	Meaning	Page
CI	Contextual interference	37
EBP	Evidence based practice	49
EE	Enhanced expectations	33
EF	External focus	29
ICF	International Classification of Functioning, Disability, and Health	1
IF	Internal focus	29
KT	Knowledge translation	4
LTP	Long-term potentiation	10
ML	Motor learning	3
OPA	Ontario Physiotherapy Association	73
OPTIMAL	Optimizing Performance Through Intrinsic Motivation and Attention for Learning	32
OT	Occupational therapist	9
PD	Parkinson's Disease	1
PG	Physical guidance	22
PT	Physiotherapist	5
RCT	Randomized control trial	30
SLP	Speech language pathologist	9
TA	Thematic analysis	109
TDF	Theoretical Domains Framework	102

Chapter 1

Introduction

A 2011 survey conducted by Health Canada estimated that 3.6 million Canadians were living with at least one neurological condition (e.g., stroke, Traumatic Brain Injury), Parkinson's Disease (PD)) (Public Health Agency of Canada, 2016). Defined by the World Health Organization as diseases that impact the central and peripheral nervous system, neurological conditions can impact body structures such as the brain, spinal cord, cranial and peripheral nerves, nerve roots, autonomic nervous system, neuromuscular junction, and muscles (World Health Organization, 2016).

One framework used to conceptualize the impact of neurological conditions on an individual's health and well being is the International Classification of Functioning, Disability, and Health (ICF). This framework takes a biopsychosocial approach to comment on and categorize the impacts of disability on an individual's health and well-being. According to the ICF, disability can result from an impairment in body structure or function, activity limitations (e.g., Activities of Daily Living), or participation restrictions (e.g., within a social setting) (McDougall et al., 2010). However, the strength of this framework is that it also frames disability within the context of the individual's lived experiences (e.g., their environment), thereby allowing the ICF to act as a tool that can be utilized to assess an individual's ability to function in society, regardless of the extent or etiology of their impairment (World Health Organization, 2002). When viewed within the scope of the ICF, neurological conditions can impose a wide variety of impairments and limitations on an individual. Most commonly, there appears to be a dichotomy between the mind and the body following a neuroanatomical injury; with a large majority of body function limitations resulting in mental (e.g., amnesia) or movement impairments (e.g., hemiparesis) (Raggi et al., 2015). This dichotomy is also apparent within the activities and participation domains of the ICF, a category that takes a predominantly psychosocial view on disability; limitations in mobility (e.g., walking) and cognitive-relational (e.g., conversations, interpersonal interactions) aspects of living were noted (Raggi et al., 2015).

In addition to the limitations imposed by neurological conditions at an individual level, approximately 10% of Canadians live with at least one neurological condition, resulting in a significant strain on our health care system (Appireddy et al., 2020). When considering the current prevalence of neurological conditions in conjunction with the increasing mean age of Canada's population, with an estimated 23% of Canadians being over the age of 65 by 2031 (Government of Canada, 2014), the prevalence and incidence of neurological conditions is projected to rise concordantly. Currently, neurological conditions often necessitate specialized care, both formally and informally, costing an estimated $9 billion in Canada in 2007 (Tator et al., 2007). One aspect of neurological conditions contributing to the gross cost on both the individual and the health care system is the number of healthy years lost. Disability adjusted life years represent one method of quantifying disease burden. To calculate disability adjusted life years, the number of years of life lost due to premature morbidity and the number of healthy years lost to disability is summed (Murray, 1994); the larger the number, the larger the disease burden. This method, however, has been scrutinized. In order to comment on the impact of disease in this manner, one must necessarily assume that time is the most realistic measure of disease burden (Grosse et al., 2009). Limitations and assumptions aside, a 2007 study using disability adjusted life years reported that only six common neurological conditions accounted for over 500,000 years of healthy life lost, making up 10.6% of the *total* disability adjusted life years for all illnesses in Canada (Gaskin et al., 2017).

Following a neurological injury, recovery and return of function often require specialized rehabilitative services in the days, months, and even years after the onset of disability. A sub-specialty of rehabilitation that focuses exclusively on neurological conditions, neurorehabilitation (Barnes, 2003), is often the means through which individuals can begin to regain lost or impaired cognitive and motor functions.

A comprehensive neurorehabilitation approach has been shown to reduce the occurrence of both long- and short-term disabilities (Dombovy, 2004). As the field evolves and less emphasis is placed on passive movement, methods that promote active, independent functional ability have begun to emerge within the literature (Krakauer, 2006). Currently, one of the most promising approaches is Motor Learning (ML); a focus on understanding the acquisition and/or modification of a movement leading to relatively permanent changes in motor skill execution (Schmidt et al., 2019). Since it offers a clinician a set of rules and guidelines that can be incorporated into clinical sessions, ML is a crucial component of an individual's recovery, often informing a large portion of the rehabilitation of neurological conditions. By emphasizing the ML theories and principles informing the basis of clinical practice (e.g., feedback, guidance, motivation), the rehabilitation workforce can be strengthened to ultimately provide a more effective means of re-learning motor functions that were lost or impaired by neurological conditions.

Published papers have shown that despite ML being an integral component of neurorehabilitation, the associated theories and principles are not being used as effectively as they could be within rehabilitation (Johnson et al., 2022). Currently, there are limited papers commenting on their efficacy when used outside of healthy populations (Fisher et al., 2014). The limited availability of research, alongside unclear descriptions of the ML theories and principles that should be incorporated within neurorehabilitation (Maier et al., 2019), may be reducing the efficacy of rehabilitation and promoting sub-optimal functional outcomes (Levin & Demers, 2020). As a result of these gaps, clinicians have been found to have a limited understanding of the core concepts of ML (Atun-Einy & Kafri, 2019). Although there is a near-unanimous assertion that they are crucial for shaping and structuring practice sessions, clinicians feel unable to provide effective treatment informed by ML, and ultimately implement the theories and principles within their clinical practice to a very small, small, or moderate degree (Atun-Einy & Kafri, 2018).

The underutilization of relevant ML theories and principles contributes to the gaps present in the uptake of best practices within rehabilitation. Currently, only 55-67% of individuals who have had a stroke receive care that is consistent with best practices (Janzen et al., 2016), and studies have shown that there is a substantial delay in the translation of knowledge gained via research and the implementation of that knowledge within a clinical setting (Moore et al., 2017, Juckett et al., 2020). Additionally, when clinical practice does catch up with scientific research, not every discovery or recommendation will be implemented in a clinically relevant manner (Juckett et al., 2020). The length of time and the scarcity of research involving clinical populations allude to significant gaps in the current knowledge base of clinicians involved in delivering neurorehabilitation services. However, with the increasing mean age of the Canadian population, and the resultant increase in the prevalence of neurological conditions, it is expected that there will be an associated increase in the demand for neurorehabilitation services in the near future (Krug & Cieza, 2017; Landry et al., 2008). To cope with this increased demand, there has been a push to both maintain the efficiency of neurorehabilitation and integrate novel theoretical concepts from research into clinical practice.

This field of science, called knowledge translation (KT), is defined by the Canadian Institute of Health Research as a "dynamic and iterative process that includes synthesis, dissemination, exchange and ethically sound application of knowledge to improve the health of Canadians, provide more effective health services and products and strengthen the health care system" (Canadian Institutes of Health Research, 2020, p. 1). Despite effective KT being embedded in a mandate by the Canadian Institute of Health Research (Straus et al., 2009), there is a lack of effort to transfer the relevant information to the intended audience (ie., clinicians) (Bowen & Graham, 2013). The knowledge gaps resulting from the limited transfer of research to clinically relevant guidelines and recommendations, along with other systematic barriers, may be a limiting factor in the delivery of the quality of rehabilitation required to keep up with the increased demands (Bowen & Graham, 2013). Therefore, it becomes worthwhile to consider what is preventing clinicians from being able to incorporate best practice guidelines within their clinical sessions, and what may facilitate their continued uptake.

Since ML plays such a prominent role in effective neurorehabilitation and recovery of function, it may be a key area to target to mitigate knowledge gaps and improve the quality of rehabilitation services. Despite the efficacy of ML when used within neurorehabilitation, limited evidence examines this essential transition from the perspective of the individuals responsible for providing rehabilitation to patients. Given their role in the rehabilitation of individuals following a neurological injury, clinicians, especially physiotherapists (PT), will play a large part in implementing the ML theories and principles targeted for uptake within clinical practice. If clinicians can help to identify gaps in knowledge surrounding the implementation of ML theories and principles into clinical practice, alongside barriers to their integration, the efficacy of future integrated KT opportunities in this field may be enhanced. Therefore, this study will attempt to describe clinicians' perceptions of and experiences with integrating ML theories and principles into clinical rehabilitation, as well as the barriers and facilitators that they face.

Chapter 2
Literature Review

This chapter covers a brief overview of what is currently known about ML theories and principles and how they are integrated into clinical practice. Starting with a general overview of ML, as well as how it is defined and assessed within a rehabilitative context, key principles will then be outlined. While the chosen principles are not an exhaustive list, they do encompass the primary principles involved within day-to-day rehabilitation, as well as those frequently cited by published literature.

The concept of KT is then covered, including its relevance to rehabilitation science and how it is integrated within a rehabilitative context. Finally, this chapter will outline the barriers and facilitators to integrating ML into clinical practice established by previously published literature.

2.1 Motor Learning

ML is defined as a set of internal processes associated with practice and experience that result in relatively permanent changes to motor behaviour (Cano-de-la-Cuerda et al., 2015; Dayan & Cohen, 2011; Kantak & Winstein, 2012; Krakauer, 2006; Schmidt et al., 2019).

Although ML can depict a spectrum of behaviours, the accurate assessment and measurement of an individual's progress is contingent upon a distinction between motor performance and ML. Improvements in motor performance typically involve isolated changes to a motor skill or movement pattern. The isolated nature of these changes, often correlating with a degree of impermanence, means that basing advances in learning *solely* upon improvements made to motor performance is an inaccurate and inadequate representation of skilled learning (Kitago & Krakauer, 2013; Wulf et al., 2010). Since motor performance primarily reflects *temporary* gains in motor skill ability, the extent of the advances made in motor performance is sensitive to the environment and context in which the skill is being learned. This degree of sensitivity allows relatively transient components of the practice conditions, such as the learner's fatigue or boredom, to influence the learning of the target motor skill or behaviour (Dubrowski, 2005). Despite this influence, however, improvements in motor performance can be indicative of the initial stages of motor skill learning. Using these preliminary gains, researchers can assess the potential efficacy of various ML theories and principles.

Once motor skill training has been initiated, the impact of practice can be visualized by large gains in motor performance in a short period of time. However, changes in motor performance observed during training, do not necessarily equate to the learning of the target motor skill – or *motor learning*. Once a person leaves a training or practice session, or series of sessions – it is common for improvements in motor performance to degrade (Kantak & Winstein, 2012; Wulf et al., 2010). This lack of temporal persistence represents the key difference between motor performance and ML. It is short-term improvements to movement execution that are seen within the context of motor acquisition, typically within the span of a single training session. Compared to motor performance, ML reflects *relatively permanent* changes; long-term improvements that can be seen even after the training has ended (usually at least 24 hours later) and within different environment or task contexts. Importantly, conditions that promote the short-term improvements in motor performance seen during training or practice – such as high frequency feedback – are not necessarily the same conditions that promote the more permanent, more durable changes in motor performance associated with motor learning. These conditions for optimal learning are often summarized as motor learning principles.

The distinction between performance and learning also plays a significant role in clinical rehabilitation, primarily concerned with re-learning lost or impaired functions (Krakauer, 2006). Although there are multiple areas and specialities that can be defined within rehabilitation, neurorehabilitation is one area that is highly dependent on the theories and principles that encompass ML. Centered around individuals who have been impacted by neurological disorders such as stroke or traumatic brain injuries (Barnes, 2003), this specialized re-learning operates on the assumption that functional recovery can be achieved via targeted ML training (Kitago & Krakauer, 2013; Krakauer, 2006).

2.1.1 Motor Learning and Neurorehabilitation

Neurological disorders are the third largest health condition requiring rehabilitation after chronic back pain and sensory impairments (Cieza et al., 2020), and one of the primary areas of neurorehabilitation is stroke recovery. Strokes are the third leading cause of death in Canada and impact approximately 10% of Canadians over the age of 65 (Government of Canada, 2019). With over 13.7 million strokes occurring globally each year (Lindsay et al., 2019), strokes are the most prevalent neurological disorder requiring rehabilitation (Cieza et al., 2020). While etiology of stroke can vary by population and region, 87% of stroke cases in North America will be ischemic in origin, resulting in oxygen deprivation of the cortical tissue fed by the thrombosed artery (Gomes & Wachsman, 2013). Although ischemic strokes can impact any vessel, most result in occlusions of the anterior and middle cerebral arteries (Winstein et al., 1999). Oxygen deprivation in brain areas fed by these arterial branches can result in cell death in cortical structures, such as the primary sensorimotor cortices, or subcortical structures, such as the basal ganglia (Winstein et al., 1999). With a large proportion of strokes impacting these brain areas responsible for movement initiation, execution, and control, a common consequence is impairments or deficits in motor control and function.

One of the most common motor impairments to occur following a stroke is hemiparesis, which affects 73-88% of stroke survivors (Sommerfeld et al., 2004; Winstein et al., 1999). Hemiparesis is the complete or incomplete muscle weakness or paralysis of the side of the body contralateral to the location of the infarct (Hatem et al., 2016; Sommerfeld et al., 2004; Winstein et al., 1999), often impacting the upper limbs more severely. More specifically, individuals who have had a stroke can experience varying degrees of motor impairments such as spasticity (Hatem et al., 2016; Li, 2017; Sommerfeld et al., 2004; Winstein et al., 1999), muscle weakness, contracture (Hatem et al., 2016; Li, 2017), and difficulties with movement initiation, execution, timing, and accuracy (Hatem et al., 2016). The prevalence of these resultant motor impairments, and their implications on an individual's functional ability and independence, results in ML being a crucial component of stroke recovery and rehabilitation.

2.1.2 Neuroplasticity

When an individual has a stroke, the ischemia causes a central core of cell damage and death surrounded by a concentric ring of borderline ischemic tissue (McCance & Huether, 2019). Following an injury to the cortical tissue from the ischemia and cell death, neural networks in the perilesional tissue spontaneously attempt to reorganize and restructure the lost or damaged neural connections (Alia et al., 2017). This spontaneous reorganization and restructuring of damaged neural networks, which is "highly sensitive to the experience following the damage" (Alia et al., 2017, p. 2), is called neuroplasticity (Sampaio-Baptista et al., 2018). Following a neurological injury such as a stroke, the ability of the brain to recover and compensate for the lost or damaged motor functions informs the ML theories and principles involved in neurorehabilitation. Individuals who provide rehabilitative services, such as PTs, Occupational therapists (OT) and Speech-Language Pathologists (SLP), can take advantage of the relatively plastic nature of the brain to enhance the recovery and rehabilitation of motor functions.

Although the extent of the neuroplastic changes following an infarct can be indicative of potential rehabilitative success (Boudreau et al., 2010), neuroplasticity alone is not enough to induce the necessary behavioural changes required for maximal functional recovery (Sampaio-Baptista et al., 2018). For this reason, neurorehabilitation is essential for the translation of structural and functional changes made in the brain into discernable changes to motor behaviour patterns. Therefore, rehabilitation that employs methods to maximize the natural neuroplastic mechanisms of the brain has the greatest potential for success. By taking advantage of the brain's ability to form new connections, bypass damaged neural circuits, and reorganize movement pattern representations (Levin & Demers, 2021), neuroplasticity induced by rehabilitative efforts may enhance the body's natural endogenous repair mechanisms and result in faster and more effective recovery (Kitago & Krakauer, 2013; Sampaio-Baptista et al., 2018).

Following a neuroanatomical injury, efficient rehabilitation is critical for recovery. Dromerick et al. (2021) conducted one of the first studies assessing the optimal recovery period for humans following a stroke. They found that integrating task-specific motor training into the rehabilitation of upper extremity impairments was most effective within the first two to three months post-stroke (Dromerick et al., 2021). With much of an individual's natural neuroplastic mechanisms augmenting recovery within the first days and weeks following an ischemic event, it is vital that rehabilitative efforts maximize their efficacy to take advantage of this natural recovery process.

Efficient rehabilitation is dependent on efficient practice. Neurorehabilitation involving repetitive practice has some of the greatest potential for successful recovery of function; long-term potentiation is an often-cited processes that underlies the mechanism of this activity-dependent plasticity (Sanes, 2003). Long-term potentiation is a phenomenon that is characterized by the “facilitation of synaptic transmission following high-frequency electrical stimulation applied to presynaptic neurons” (Pinel & Barnes, 2018, p. 294). Maintaining these high-frequency stimulations of the neurons, often through repetitive practice during rehabilitation, results in the structural changes associated with neuroplasticity: increases in the number and size of synapses and post-synaptic dendritic spines (Pinel & Barnes, 2018), alterations to dendritic and axonal branches (Pinel & Barnes, 2018; Sampaio-Baptista et al., 2018), and increased gliogenesis (Sampaio-Baptista et al., 2018). These changes result in increased strength between the synapses (Pinel & Barnes, 2018) and subsequent encoding of the associated motor patterns, ultimately resulting in the changes to motor behaviour characterized by ML.

Although long-term potentiation is commonly associated with brain structures responsible for learning and memory, such as the hippocampus and the primary motor cortex, it is not restricted to a single brain area. Many brain areas that are active in the early stages of ML differ from those responsible for controlling and executing movements that have already been learned and retained (Luft & Buitrago, 2005). Although ML consists of several stages, and different structural and functional changes can occur throughout the entire learning process, brain areas such as the cerebellum (Nieuwboer et al., 2009), primary motor cortex, and pre-frontal cortex are preferentially active during the initial learning stages (Luft & Buitrago, 2005). As learning continues and motor memories begin to consolidate, different brain regions are activated to reflect the neuronal re-organization that will ultimately stabilize the newly acquired motor memory (Luft & Buitrago, 2005).

2.1.3 Stages of Motor Learning

Despite having a well-cited and agreed-upon functional definition, when viewed within the scope of clinical practice, ML is less rigidly defined (Krakauer, 2006). In 1967, Fitts and

Posner presented a model involving an individual progressing through three distinct stages as they learn or re-learn a novel motor skill. In their influential "Three-Stage Model of Motor Learning", Fitts and Posner proposed that the learning of a motor skill is a continuous process and although certain aspects of the stages occur independently of one another, the borders of these stages overlap to ultimately result in ML progressing in a relatively sequential manner (Anson et al., 2005).

The Cognitive Stage

The first of Fitts and Posner's three stages, the cognitive stage, represents the initial learning of a skill, or the re-learning of a pre-existing skill (Cano-de-la-Cuerda et al., 2015; Nieuwboer et al., 2009; Taylor & Ivry, 2012). During this preliminary learning phase, the cognitive demand that is placed on the individual is very high, and as such, their working memory is heavily involved in the initiation and execution of the motor task (Kantak & Winstein, 2012). As the dynamic components of the movement are explored, individuals must be consciously aware of both the patterns comprising the movement in its entirety, and the proprioceptive feedback generated by executing specific movement sequences. This conscious awareness is crucial for the proper development of the coordinative movement patterns necessary for accurate recreation of future movements and eventual automaticity (Muratori et al., 2013). Although it inevitably results in increased errors and heightened movement variability, conscious awareness is a necessity throughout this stage of ML (Nieuwboer et al., 2009). However, once the individual begins to familiarize themselves with the movement, and the coordinative patterns become more developed and resistant to degradation, the learner's focus begins to shift away from what they need to do to execute the movement and moves towards *how* they will execute the movement (Muratori et al., 2013). As this happens, and the individual begins to progress to the later stages of ML, the motor memory becomes encoded and the cognitive demand that is placed on the individual begins to decrease.

The Associative Stage

The second stage of Fitts and Posner's model is the associative stage. Within this stage, the movements become more refined, and they are executed with less error and variability (Anson et al., 2005; Cano-de-la-Cuerda et al., 2015; Nieuwboer et al., 2009). With the identification of the correct movement patterns made towards the end of the cognitive stage, the preliminary aspects of the associative stage are dedicated towards increasing the speed of the movement without compromising on the accuracy of its intended effect (Anson et al., 2005).

In addition to the interaction between movement speed and movement accuracy, how individuals produce and execute movements are key principles of the associative stage. As motor skill learning evolves throughout this stage, the individual begins to make connections between the pieces that comprise a movement, and the motor skill in its entirety (Cano-de-la-Cuerda et al., 2015). As the distinct components of the skill are further explored, individuals start to intrinsically understand how the movement should be performed. Alongside this understanding comes a further reduction in cognitive demand as individuals become more aware of, and receptive to, the environment that they are learning in; allowing them to begin modifying and adapting the individual components of the movement in response to environmental cues and perturbations (Nieuwboer et al., 2009).

The Autonomous Stage

Throughout the final stage of Fitts and Posner's three-stage model, intrinsic processes take over and the execution of the movement becomes near automatic (Nieuwboer et al., 2009; Taylor & Ivry, 2012). The autonomous stage also seeks to further refine the improvements to motor skill execution that were initiated in the associative stage: speed and accuracy continue to increase, and errors are diminished as the movement becomes resistant to external stressors or other activities (Anson et al., 2005). During this stage, the movement is almost entirely under autonomous control, and the individual can perform components of the movement across different environmental settings and contexts, as well as demonstrate similar levels of skill after periods of time have passed (Cano-de-la-Cuerda et al., 2015).

One distinction that allows researchers to monitor an individual's progression through these three stages is the brain areas activated as a movement is executed. As evidenced by decreases in cortical activity (Anson et al., 2009) and the associated striatum over the course of learning (Dayan & Cohen, 2011), brain imaging studies have shown that lower brain centers preferentially control more automatic movements. The shift from cortical to subcortical neural activity is a strong indicator that intrinsic processes are largely responsible for the movement, and that minimal conscious awareness is being dedicated to the intricacies of the movement execution.

Alternative Theories on the Stages of Motor Learning

Although Fitts and Posner's proposed model of ML is well-known and readily accepted in rehabilitation, it is only one of many explanations for the stages and mechanisms that underlie ML.

Gentile's Two-Stage Model

In 1972, Ann Gentile proposed a two-stage, cyclic model of ML comprised of movement pattern acquisition and adaptation in response to environmental changes. Contrary to Fitts and Posner's view that ML is largely dependent on the amount of time spent practicing, Gentile's model posits that the learner's goals and objectives can also direct ML.

In the first of Gentile's two stages the learner has two objectives: 1) understand the movement pattern that is required by the motor task that they are attempting to execute, and 2) begin to develop a strategy to execute this movement within the constraints of their environment (Cano-de-la-Cuerda et al., 2015; Gentile, 1972; Muratori et al., 2013). In the context of this initial stage, the motor task (e.g., buttoning a shirt) represents the movement goal that the learner is working towards successfully executing. To help them realize this goal, the learner must construct a series of movements, the movement pattern, which will be modified and adapted over several trials until one is found to successfully execute the target motor task (Gentile, 1972).

In this initial stage, the success of the ML is highly dependent on trial-and-error processes. Guided by proprioceptive and environmental feedback, individuals will begin to construct a movement pattern via active exploration of their environment (Muratori et al., 2013). Over multiple trials, an individual will compare the outcome of their attempts at executing the target movement against the movement pattern used during these attempts (Gentile, 1972). A key component involved in successfully executing a motor pattern is identifying regulatory and non-regulatory components. A non-regulatory component may be present within the environment the individual is learning in but has no bearing on the performance of the motor task (Muratori et al., 2013). In contrast, a regulatory component must be present within the environment to successfully execute the intended movement pattern (Muratori et al., 2013). Until the chosen movement plan begins to consistently produce the intended movement effect, the learner will continue to explore potential options and identify influential environmental aspects (Gentile, 1972; Muratori et al., 2013).

Gentile proposes that the learner progresses to the second stage of this model once they begin to develop the general concept of an effective movement pattern (Gentile, 1972). As refinement occurs throughout the second stage, the movement pattern is highly sensitive to the context of the environment the individual is learning in (Cano-de-la-Cuerda et al., 2015; Gentile, 1972). As such, this second stage of learning is characterized by the ability to adapt the movements based on the regulatory and non-regulatory features present in the environment (Gentile, 1972; Muratori et al., 2013); the more regulatory features present, the more an individual will be required to manipulate and diversify the movement pattern (Gentile, 1972). However, when fewer regulatory features are present and the environment is relatively static, the resultant movement pattern will be more similar in nature to the pattern developed in the initial stage of learning (Gentile, 1972).

Bernstein's Degrees of Freedom Model

Bernstein's model of ML is reliant on what has come to be called the "degrees of freedom problem". Degrees of freedom represent the various ways that an individual can control and execute their movements (Berthier et al., 2005). Bernstein's model acknowledges the large number of degrees of freedom that need to be accounted for and controlled in complex movements, the crux of the degrees of freedom problem, and proposes that complex movements are learned by constraining the degrees of freedom during the initial learning process. In the initial learning stages, the degrees of freedom are restricted, and where an advanced or expert learner would independently manipulate their shoulder, elbow, and wrist, a novice learner would "freeze" the joints and utilize their arm as a single unit, effectively creating a movement with minimal dynamic variables (Berthier et al., 2005; Smith et al., 2001). As the movement that the individual is learning becomes more nuanced, they begin to expand their degrees of freedom to permit movement in more planes, involve more joints, and exhibit increased control over the dynamics of the movement process (Berthier et al., 2005; Cano-de-la-Cuerda et al., 2015; Smith et al., 2001). Bernstein postulates that, by controlling degrees of freedom in this manner, it reduces the variability of the movement system and results in more effective movement control (Newell & Vaillancourt, 2001).

2.1.4 Measuring and Assessing Motor Learning

Measuring and assessing ML is an essential component of clinical rehabilitation. Clinicians can use measured advancements in motor function to gauge how much progress an individual has made in their recovery, as well as make distinctions between performance effects and learning. Standardized clinical outcome measures (e.g., the Berg Balance Scale, Fugl-Meyer Assessment etc.) can be utilized to evaluate the presence of motor impairments, or more global motor function, at one or more points in time. However, the progression of learning a specific functional motor skill can also be tracked via assessments of acquisition, retention, and transfer (Kitago & Krakauer, 2013).

Acquisition

Skill acquisition refers to a learner's ability to reduce performance errors in both the kinematic and dynamic components of a motor skill (Krakauer, 2006). The emphasis on error reduction, and the subsequent ability to acquire movement patterns associated with task-specific demands, is an integral component of skill acquisition (Newell, 1991). Clinically, the acquisition of skilled movement can be assessed by addressing variables involved in movement difficulty (e.g., movement time) and movement performance quality (e.g., movement accuracy) (Shmuelof et al., 2012). Since motor skill learning in the initial stages often presents as improvements in motor performance, using such variables, as embedded within the speed-accuracy trade-off, allows for a more objective assessment of the extent of motor skill acquisition.

The variables that comprise the speed-accuracy trade-off can be used to assess skill acquisition in healthy populations or control groups. However, within clinical populations, interpretation of the results requires consideration of the individual's abilities and limitations. For example, when assessed in a population of individuals who have had a stroke, it was found that the severity of the stroke and degree of functional impairments impeded voluntary movement speeds (Hardwick et al., 2017). Hardwick et al. (2017) found that the time to complete the targeted movement was correlated with the degree of stroke severity. Assessing individuals with both mild-moderate and moderate-severe stroke revealed intergroup differences in the timing of the movement and the movement's quality. Although both groups showed improved motor function post-intervention, there was a negative correlation between the variables composing the speed-accuracy trade-off and the level of impairment (Hardwick et al., 2017). Thus, assessing skill acquisition in this manner adds an additional layer of complexity as an individual's functional ability following a stroke would need to be considered alongside their degree of improvement.

Retention and Transfer

Since an inference of ML requires that the resilience of the motor skill be assessed, retention tests are designed to reflect the strength of the motor memory over time (Kantak & Winstein, 2012). If performance and/or acquisition effects significantly diminish between practice sessions, then the targeted motor task was not effectively consolidated, and consequently, has not yet been learned.

Studies utilize retention to test the efficacy of a targeted intervention. However, the retention interval, which is the time that passes between the culmination of the acquisition trials and the start of the retention trials, can vary between studies (Kantak & Winstein, 2012).

Immediate retention tests can occur from 10 seconds to hours after acquisition trials, while delayed retention tests typically have a retention interval of at least 24 hours (Kantak & Winstein, 2012).

The ability to retain a skill over the retention interval duration depends on the successful consolidation of the associated motor memory (Dayan & Cohen, 2011). While retention tests can elucidate information about the degree of consolidation an individual has achieved, they are not impervious to performance effects (Schmidt et al., 2011). If a retention interval is not sufficiently long enough, performance effects may persist, which may confound the delineation between acquisition and post-acquisition impacts on learning (Christina, 1997). Therefore, for rehabilitative success to be assumed, performance should be measured after a significant length of time has passed to ensure that a patient can *apply* their learning without the guiding forces of their therapist (Christina, 1997). However, in reviewing the literature, it seems that a limited number of studies integrate a longer retention interval into their methodology, many opting to assess immediate retention as a measurement of learning.

Therefore, the final component involved in the assessment of motor skill learning assesses the transfer, or generalizability, of a motor skill. Thought to reflect the flexibility of the motor memory, transfer tests assess learning by evaluating the capacity for motor performance on a related skill (Schmidt et al., 2011). A transfer task is typically similar in movement to the original skill, but there will be a critical difference in a certain component of the skill (e.g., the size and weight of a ball or a different environmental context) (Muratori et a., 2013). Although transfer tests provide the strongest evidence that learning has occurred, they are also cited relatively infrequently as a component involved in the testing and assessment of an intervention. A brief search of published research articles involving blocked versus random practice, a well-known and well-studied aspect of stroke rehabilitation, revealed that out of 11 articles, only four assessed the transfer of the motor skill (Jo et al., 2020; Moliterno et al., 2020; Vámos et al., 2018; Wambaugh et al., 2016). Interestingly, the four assessing skill transfer represented most of the articles that provided support for the targeted interventions.

2.2 Theories and Paradigms of Motor Learning

As demonstrated in the previous section, ML theories and principles have a high degree of relevance to clinical application. Clinicians, such as OTs, PTs, and SLPs, can utilize these principles to manipulate aspects of their therapeutic interactions with patients to maximize health and recovery.

Within the following section, the term "ML theory" will be used to reference a "framework to guide the interpretation of how learning or re-learning movement occurs" (Muratori et al., 2013, p. 2). In general, theories encompass overarching propositions of how humans learn. For example, the Schema Theory proposes that learning occurs because movement patterns produce general rules that can then be recalled and adapted to fit the needs of the new environment or learning context (Schmidt et al., 2019). In contrast, principles will be used to reference the *specific recommendations* that can be adjusted or altered to have the largest impact on the learning outcome (Schmidt et al., 2019).

Thus, the following section will outline key ML theories and principles as they relate to rehabilitation science and practice. Although there are many principles that can be adapted to fit within the scope of rehabilitation, the following ML principles have received the majority of attention within the literature, and therefore have a great deal of relevance to clinical practice: physical guidance and feedback, focus of attention, motivation, practice order, and implicit versus explicit learning.

2.2.1 Augmented Feedback and Physical Guidance

In rehabilitation, sports training and other contexts, feedback is essential to motor learning. In general, feedback comes from two primary sources: intrinsic or extrinsic. Intrinsic feedback originates from sensory and proprioceptive mechanisms inherently involved in the execution of a movement or action (Schmidt et al., 2011). In contrast, extrinsic feedback, which is the form of feedback utilized by clinicians, is provided from external sources with the intention of supplementing or *augmenting* the intrinsic feedback naturally received from the body (Schmidt et al., 2011).

Forms of Augmented (Extrinsic) Feedback

There are multiple dimensions of augmented feedback that can be utilized within a clinician's therapeutic interactions with patients. Given the applicability to clinical practice, there exists relatively clear delineations between the forms of augmented feedback commonly found in the associated literature.

Physical Guidance and Haptic Training

In general, physical guidance (PG) and haptic training are guiding forces used for the purpose of reducing errors present in movement execution (Domingo & Ferris, 2009; Feygin et al., 2002; Marchal-Crespo et al., 2010; Tsutsui & Imanaka, 2003). When PG is used in a rehabilitative context, an expert in the task that is being performed, typically a clinician, will manually guide the patient through the movement execution, providing an accurate proprioceptive depiction of what the movement should feel like when performed correctly (Tsutsui & Imanka, 2003).

While PG can be thought of as an "umbrella term", with relevance to all aspects of rehabilitation involving manual guidance, haptic training is a sub-set of guidance that extends and builds upon this original notion (Feygin et al., 2002). The core processes underlying haptic training revolve around proprioception, the ability to sense where our bodies are in space, and kinesthesis, the sense of movement and position, both of which mediate our haptic awareness and are crucial for proper movement execution (Feygin et al., 2002).

It is interesting to note that, in the literature, PG provided by a clinician is often referenced in lower extremity impairments, specifically in literature assessing gait-related interventions (Domingo & Ferris, 2009; Powers et al., 2021). In contrast, haptic training is commonly referenced in upper extremity studies utilizing robotics and virtual reality interfaces. While they are both forms of guidance, there seems to be a very clear distinction in published studies that is almost entirely dependent on where the guiding forces are originating from.

Knowledge of Results and Knowledge of Performance

Knowledge of Results and Knowledge of Performance are both forms of terminal, verbalizable augmented Fb. KR is feedback that is provided by a clinician after the movement has been executed and offers information on the outcome of the movement with respect to the overall task goal (Schmidt et al., 2011). Found more commonly within the literature, knowledge of results is often used interchangeably with feedback or extrinsic feedback. In contrast to knowledge of results, knowledge of performance is verbalizable information about the *movement pattern* (Schmidt et al., 2011). Knowledge of performance is primarily related to the correction of errors involving the individual’s body position and how they are executing a movement (Schmidt et al., 2011).

Typically, the distinction between knowledge of results and knowledge of performance is straightforward; however, the line can become unclear when how the movement is performed informs a key part of the overall task goal. For example, the goal of a competitive diver is not just to enter the water, rather, *how* they enter the water, and the execution of their dive, becomes the primary focus during that movement. Although in rehabilitation the movements are not as nuanced as a competitive dive, the concept of movement performance overlapping with the movement goal still has a large degree of relevance to the functional movements performed during an individual's recovery. However, within the literature, the distinction between knowledge of results and knowledge of performance is often not made. As a result, the literature refers to most forms of verbalizable, augmented feedback as knowledge of results, although the feedback itself can have properties relating to both the movement outcome and the movement performance.

The Guidance Hypothesis

Within the current body of literature, both feedback and PG can enhance performance by guiding the learner towards the goal response. However, when they are provided in sufficiently high frequencies, they can obviate an individual's intrinsic error detection and correction processes (Sidaway et al., 2008). As referenced in studies utilizing retention and transfer tests, too much guidance, via either PG or feedback, can have *long-term* impacts on ML. This is especially crucial when the distinction between performance and learning is made; excessive guidance enhances performance and impairs learning, while reducing guidance impairs performance but enhances learning. Given this distinction, the guiding properties of augmented forms of information, verbal or physical, have both positive and negative effects on ML.

From a positive standpoint, receiving PG and feedback allows an individual to correct subsequent movement efforts, promoting faster improvement and improved performance during the acquisition trials (Lai & Shea, 1999; Winstein et al., 1994; Wishart & Lee, 1997). Additionally, increased guidance has also been known to confer psychological benefits by reducing frustration, increasing interest and motivation, and providing individuals with feelings of accomplishment and success (Yamaguchi et al., 2020). These psychological benefits may be highly relevant when used within clinical populations, as limitations in mobility and functional impairments can result in decreased self-efficacy and increased frustration (Luker et al., 2015). Despite an individual's ability to immediately correct movements when provided with frequent PG or feedback, it can also lead to the development of movement instability, wherein the individual attempts to over-correct miniscule aspects of the movement in response to the guidance provided by the clinician (Bruechert et al., 2003). Additionally, individuals can develop a dependency on the guidance, using it as a crutch to bolster their movement performance - a common rationale for why performance effects degrade immediately after the guiding properties are removed (Lai & Shea, 1999; Lowe & Buchwald, 2017; Wishart & Lee, 1997). Ultimately, the movement instability and dependency produced by guiding forces interferes with an individual's ability to detect and correct errors based on intrinsic sources, potentially resulting in a large, detrimental effect on the ability to learn a novel motor skill (Bruechert et al., 2003; Lai & Shea, 1999; Lee et al., 1990; Lowe & Buchwald, 2017; Sidaway et al., 2008).

Error detection and correction is thought to drive the progression of ML (Sidaway et al., 2008). When individuals practice within conditions involving minimal or limited errors, such as those found with the provision of frequent PG or feedback, it releases the demands that are typically placed on working memory throughout the learning process (Williams et al., 2016). By reducing movement errors made by providing frequent PG or feedback, it formats the learning as a passive process, lessening the effort required and promoting a dependency on the guidance offered by the clinician. In contrast, when guidance is withheld and learners are allowed to make errors, they become more engaged in the cognitive processes associated with error detection and correction (Sidaway et al., 2008). This engagement recruits neural structures involved in working memory processes and enhances learning.

Use of Augmented Feedback and Physical Guidance in Rehabilitation

The effectiveness of a reduced frequency of guiding forces, either physical or verbal, has been well established in healthy populations. Typically, studies assessing an intervention built upon the principles of guidance will compare varying levels or degrees of guiding forces against constant (100%) or absent (0%) guidance. For the most part, authors provide guidance after 50% of the acquisition trials; however, it is not uncommon to see interventions with guidance after 66%, 33%, or 20% of trials as well. In general, the literature shows improvements in learning, as evidenced by retention or transfer tests, for participants in cohorts receiving reduced frequencies of guidance. Sidaway et al. (2008) demonstrated that university aged students (21.8 ± 4.9 years) learning with 100% PG performed with twice the number of errors on a retention test compared to students learning with 33% PG. This finding also held when knowledge of results was applied to 100% of acquisition trials; cohorts receiving knowledge of results on 33% of trials performed significantly better in retention tests at 10 minutes, 1 day, and 1 week after the acquisition trials (Sidaway et al., 2008). These results have been corroborated by additional studies recruiting healthy participants; Bruechert et al. (2003) found that learning with knowledge of results in 50% of acquisition trials increased response stability and decreased performance variability compared to knowledge of results in 100% of acquisition trials. Furthermore, Lowe & Buchwald (2017) demonstrated that groups learning with knowledge of results on 50% and 20% of acquisition trials had a greater decrease in response error in the short- and long-term retention of a novel speech task compared to learning with 100% knowledge of results.

Despite the consistently positive results found when the frequency of guiding forces is reduced, it is worth noting that the difficulty of the motor task appears to influence the outcome of the intervention. Domingo & Ferris (2009) proposed this principle with their paper on the effects of PG and walking a balance beam. When participants (healthy, university aged students) were learning on a wide balance beam, the results were consistent with other studies; reduced PG improves learning outcomes. However, when the task difficulty was increased by narrowing the width of the beam, the influence of PG became less pronounced. The PG provided to groups learning to balance on a narrow beam, although still detrimental to performance, did not degrade learning outcomes to the extent exhibited by previous studies.

Within clinical populations, variations in task difficulty have been proposed as an explanation for the inconsistencies found within the literature on the benefits of reducing guidance. It appears that guiding forces, when used to correct errors made because of functional limitations or mobility impairments, do not have the same degree of detrimental effects seen in studies involving healthy participants. Powers et al. (2021) demonstrated that learning with 100% visual knowledge of results conferred an advantage to decreasing temporal gait asymmetry in stroke victims. Although the 50% visual knowledge of results group did have decreases in temporal gait asymmetry compared to a control group (0% knowledge of results), it was not significant and was superseded by the clear advantages to learning with 100% knowledge of results. However, when interpreting the results of this study, one does need to be cognizant of the fact that no long-term retention was assessed, making the generalizability of these results limited only to performance or short-term learning effects. Contrary to Powers et al. (2021), Chiviacowsky et al. (2010) did find benefits to learning with reduced guidance in a population of individuals with PD. In their study, receiving knowledge of results on 66% of trials reduced performance variability and absolute constant error on a retention test 24 hours after the acquisition trials. However, other published studies consistently omit long-term retention, preferentially choosing a retention interval of less than 24 hours. Given the positive impact of guidance on motor *performance* that has been previously established, it could be that the benefits conferred by reducing the frequency of guidance are not discernable until *learning* occurs. Since very few studies assess long-term retention or transfer of skills learned under conditions of reduced guidance, the methodology of the current body of literature could be skewing the results on the efficacy of this ML principle within clinical populations.

Despite the inconsistencies in research with clinical populations, there is a common theme of task difficulty influencing the intervention outcome. It appears that, when a task is made sufficiently difficult, it is possible to see benefits of an increased frequency of guidance. From the results of the literature involving both healthy and clinical populations, guidance seems to operate on a bandwidth. With simple tasks, or healthy populations, increasing the frequency with which guidance is provided appears to promote a dependency, and subsequently, reduces the efficiency of intrinsic learning process. In these situations, the negative impacts that receiving guidance on 100% of acquisition trials may be visualized in the learning outcomes. However, as task difficulty increases and greater cognitive demand is placed on the learner, as seen in clinical populations with underlying functional and/or mobility impairments, the effect of increased guidance becomes less pronounced. With clinical populations, individuals may learn motor skills under reduced guidance conditions, but this degree of learning may not be significantly greater than that achieved under 100% guidance conditions. The presence of increased guidance during difficult tasks may facilitate learning because the errors resulting from too little guidance are more detrimental to learning than the dependency promoted by the increased frequency. Based on this, it is unclear which tasks, when used within a rehabilitative context, may benefit from slightly increased frequencies of guiding forces, and which tasks may require less. It becomes necessary, therefore, to tailor the appropriate learning strategy to the specific characteristics of the learned skill (i.e., complexity, difficulty), as well as the experience, baseline skill level, and physical and cognitive abilities of the patient or client.

2.2.2 Focus of Attention

Observational studies have demonstrated that feedback and instruction play a large role in a clinician's therapeutic interactions with patients. Upon observing clinical sessions between individuals who have had a stroke and PTs, Johnson et al. (2013) found that an average of 76 instructions and 22 feedback statements were delivered per treatment session, approximately one every 14 seconds. Similarly, Kal et al. (2018) video-taped 451 minutes of clinical therapy sessions between PTs and individuals recovering from a stroke. Over this duration, PTs provided their patients with 4821 statements (feedback or instructional), averaging out to one statement almost every six seconds (Kal et al., 2018). Given the frequency with which feedback and instructions are provided to patients during a clinical session, it becomes necessary to determine the most effective method of delivering them.

Focus of attention is a highly effective, commonly utilized component of the instructions and feedback provided by a clinician to their patients. Encompassing the location of the individual's attention in relation to the environment, goal, or task (Johnson et al., 2013), focus of attention can be directed by a clinician in two ways; internally or externally. An internal focus (IF) directs the individual's attention towards their bodies and the physical execution of the movement. In contrast, an external focus (EF) draws the patient's attention away from their body and towards the outcome of the movement with respect to the environment or task goal. In a group of healthy individuals, an EF was found to significantly improve learning on a ski simulator task (Wulf et al., 1998). When the EF group was directed to exert a force on the outer edge of the ski simulator as they were performing slalom-like movements, it resulted in higher scores than an IF group in both amplitude and frequency measures across two days of assessments (Wulf et al., 1998). Additionally, when using the frequency and amplitude measures to compare the IF group and the control group, who were told to focus on their feet and given no instructions respectively, it was found that the control group outperformed the IF group as well (Wulf et al., 1998).

As a mechanism of explaining the impact of an EF, the constrained action hypothesis was proposed. This hypothesis states that, when an individual's attention and awareness is directed towards their body, as with an IF, it interferes with the automatic control processes governing movement execution (Johnson et al., 2013). By becoming consciously aware of their movement execution, an individual will constrain the degrees of freedom present in the movement, promoting "micro choking" episodes (Wulf et al., a 2010) and reducing the movement's automaticity and fluidity.

Use of Focus of Attention in Rehabilitation

In addition to a well-supported theoretical background, an external focus of attention has also shown to be efficacious in clinical populations. When individuals post-stroke were provided with an EF point lateral to their trunk, they showed significant improvement in maximum lateral body weight shift compared to an IF group (Mückel & Mehrholz, 2014). Additionally, after training with an EF, a population of individuals with PD decreased their sway on a balance task and reduced subsequent falling episodes (Landers et al., 2005). However, there have been studies published that are inconsistent with these results. A double blinded randomized control trial

(RCT) assessing balance in individuals post-stroke found no benefit to learning with an EF. Here, individuals were tasked with maintaining medio-lateral balance on a balance board, a task which has historically proven to be difficult for individuals following a stroke (Kal et al., 2019). Based on the primary outcome measure, the threshold rotational stiffness of the board, an EF did not confer any significant learning advantages over an IF. However, when the secondary outcome measure (single task sway) was assessed, the EF group showed significant improvement over the IF group. These results, in conjunction with the results of a systematic literature review involving 725 individuals receiving rehabilitative services, suggest that promoting a specific focus of attention may be most effective when approached on a case-by-case basis (Kakebeeke et al., 2013; Kal et al., 2019). While the literature review is limited by the methodological quality of the included studies, it does offer evidence that there may be increased benefits to learning when instructions and statements are tailored to the individual instead of adopting a uniform use of an EF. However, further, high-quality evidence is necessary to support this conclusion.

Although some research demonstrates that an EF enhances short-term learning relative to an IF or no focus of attention, there is a distinct lack of assessments conducted more than 24 hours after the initial acquisition trials. When ML is defined as the ability to maintain gains in a novel motor skill over time, there are limited published studies that assess the potential benefits of an EF from a *learning* perspective. The few studies that involve a long-term learning assessment (retention and/or transfer tests) typically involve healthy participants or children. Given these participant demographics, it becomes difficult to generalize the findings to clinical populations, and even more difficult to provide information on how these results could be translated into clinically relevant guidelines.

Having clinicians provide rehabilitation that is informed by high quality, methodologically sound literature is necessary for improving the effectiveness of rehabilitative services. While one can find support for the advantages of an EF within the literature, observational studies consistently show clinicians providing a greater proportion of internally focused instructions and feedback. Johnson et al. (2013) found that 67% of statements delivered by a PT during their interactions with stroke victims were internally focused, and only 22% were externally focused. Additionally, the EF statements provided were typically vague and inexact. Providing partial support for these results, an observational study by Kal et al. (2018) demonstrated that 30% and 19% of instructional statements promoted an external and internal focus of attention respectively. However, when assessing the feedback provided by the clinicians, there was a clear preference to provide statements that promoted an IF. Interestingly, within a follow-up questionnaire, 100% of clinicians (19/19) indicated that they were familiar with the concept of focus of attention and understood the difference between an internal and an external focus. However, 84% (16/19) stated that they deliberately chose when to implement a specific focus of attention; preferring to utilize EF statements with individuals who had been in rehabilitation longer or those with cognitive impairments (Kal et al., 2018). This finding does present an interesting direction for future research: determining individual characteristics that may benefit from an IF and expanding on the suggestions by Kakebeeke et al. (2013) and Kal et al. (2019) regarding potential benefits to approaching focus of attention on a case-by-case basis. However, given the current body of evidence supporting the benefits of an EF, and the established learning advantages when rehabilitation is started as soon as possible, it could be argued that clinicians' understanding of *when* to implement a specific focus of attention may be limiting the effectiveness of this ML strategy.

2.2.3 Motivation

While motivation is not a novel concept within the scope of ML and rehabilitation, recently, there has been renewed interest in this principle as a mechanism for enhancing and improving rehabilitation outcomes. Due to the subjectivity of motivation, however, the feasibility of obtaining an objective assessment of a patient's motivational status has been questioned (Siegert & Taylor, 2004). Further compounded by the novelty of this ML principle, from a clinical perspective, there is a distinct lack of consensus surrounding the use of motivation within rehabilitation.

Despite being a well known, and rather intuitive, component of rehabilitation, motivation is primarily referenced in theoretical propositions and indirectly in explanations for measurement outcomes. However, alongside the resurgence of interest in motivation, there have been hypotheses that motivation can play a more active role in ML. Within the recent literature, various practice conditions associated with the social-cognitive and affective aspects of motivation have been proposed to influence ML outcomes (Wulf & Lewthwaite, 2016). In adopting this view, motivation becomes embedded within a *cultural* perspective (Wulf & Lewthwaite, 2016), which, alongside individual aspects, takes into consideration the influence of the social and environmental components involved in learning.

The OPTIMAL Theory

First proposed by Gabriele Wulf and Rebecca Lewthwaite in 2016, the OPTIMAL Theory (Optimizing Performance Through Intrinsic Motivation and Attention for Learning) is described as situating human movement at the interface of social, cognitive, and affective behaviour (Wulf & Lewthwaite, 2016). The authors stipulate that human movement, and by extension ML, can not be understood without careful consideration of the factors underlying intrinsic motivation and attentional focus, factors which may lead an individual to preferentially execute one movement over another. Therefore, to optimize the learning environment, and by extension the learning itself, the needs that are associated with intrinsic motivation must be fulfilled. While this is a comprehensive theory, it emphasizes *how* to bring about highly skilled movement, proposing that enhanced expectations and autonomy-supportive conditions, alongside an external focus of attention, promote environmental conditions that facilitate ML (Wulf & Lewthwaite, 2016).

Although the previous section on focus of attention did not position this ML principle within the scope of motivation and the OPTIMAL Theory, the mechanisms underlying this principle and its overall effectiveness are the same. Where the OPTIMAL Theory differs, however, is that focus of attention is a component of learning that, when used in *conjunction* with the principles covered by intrinsic motivation, aids in the creation of an environment ideal for enhancing motor-related skills and behaviours.

Enhanced Expectations

While the authors of the OPTIMAL Theory use Enhanced Expectations (EE) to refer to a "…range of forward directed anticipatory or predictive cognitions or beliefs about what is to occur" (Wulf & Lewthwaite, 2016, p. 4), the concept has also been used in other prominent theories (e.g., Bandura's Self Efficacy Theory). The classic example of EE is the placebo effect; wherein an imitation of a treatment can result in realized physiological outcomes (Kienle & Kiene, 1997). In relation to ML, enhancing an individual's expectations for success, or allowing them to believe that they will be successful, creates anticipation and confidence, both of which can ultimately be used to help direct the resultant motor behaviour.

In one study, 34 undergraduate students were randomized to two groups and asked to putt a golf ball towards a hole with a circle around it. While both groups were told that a ball landing anywhere within the area encompassed by the circle was considered a "good" trial, the EE group was putting towards a hole surrounded by a circle with a larger radius than that of the control group. Predictably, since the EE group was led to believe that they had superior skills, as evidenced by more golf balls landing within the bounds of the circle, they outperformed the control group on tests of retention and transfer (Palmer et al., 2016). Additionally, in a population of older adults, a demographic that typically experiences reductions in self-efficacy relating to functional ability (Seeman et al., 1999), the EE group again outperformed the control group (Wulf et al., 2012). Prior to working on balance using a stabilometer platform, the EE group was told that "active people like you, with your experience usually perform well on this task" (Wulf et al., 2012, p. 5). Using this simple wording, the EE group was able to maintain a significantly longer time in balance compared to the control group in a retention test, as well as significantly higher self-efficacy ratings in both the practice trials and retention tests (Wulf et al., 2012).

Autonomy

Autonomy is the second component of intrinsic motivation that is encompassed by the OPTIMAL Theory. Providing patients with opportunities for autonomy within their learning environment helps to satisfy the biological and psychological needs underlying intrinsic motivation. Additionally, the presence of autonomy provides opportunities for the inherent, reward-based responses that are associated with the exercise of control (Wulf & Lewthwaite, 2016). Recently, literature has been showing strong support for the benefits of incorporating autonomy-supportive conditions within practice, even if those conditions are completely incidental to the task being performed. For instance, when a cohort of high-school students were recruited to practice a ball-throwing task, individuals in the autonomy-supportive condition were allowed to select the colour of the ball that they were to throw at the target. Keeping all other aspects of the task and instructions the same, when compared to the control group, who were simply handed the ball, the autonomy-supportive group showed greater learning outcomes as evidenced by increased throwing accuracy (measured in cm to the target centre) (Wulf et al., 2014).

Use of Motivation in Rehabilitation

While plenty of studies have provided support for the benefits of learning under the conditions outlined by the OPTIMAL Theory, there is a distinct lack of literature involving clinical populations. Given that most papers recruit healthy individuals, the generalizability of this particular theory to rehabilitation becomes a major limitation when assessing its overall effectiveness as a ML strategy.

Despite this limitation, one fascinating study did assess the effectiveness of EE in a group of individuals with PD. Recruiting 35 participants, Parkinson's medication was withheld, then 12-18 hours later, individuals underwent a baseline PET scan, followed by an open-label dose of oral levodopa and a second baseline PET scan (Lidstone et al., 2010). The following day, individuals were told that they would be receiving a novel medication with either 25%, 50%, 75%, or 100% active levodopa. All participants received a placebo. When the follow-up scan was performed, individuals in the 75% group had significantly increased levels of dopamine within the putamen and ventral striatum regions, levels which were comparable to those obtained during the baseline scans following the administration of the open-label levodopa (Lidstone et al., 2010). While the authors are unsure why the most significant increase was found in the 75% group, these study results show that enhancing expectations can have a tangible, physiological effect on individuals with clinical pathologies.

In another study involving individuals with PD, 28 participants were recruited to assess the benefits of self-controlled practice on their ability to balance on a stabilometer platform. Participants were assigned to either the self-control or yoked control group based on gender and clinical disease stage. The self-control group was told that a balance pole would help to facilitate performance and were allowed to choose when to use the pole throughout the practice trials. The individuals in the yoked group were told to use the pole on the trials selected by their matched counterparts. While both groups increased their overall balance time across all 10 practice trials, the self-control group typically maintained their balance for longer periods of time than the yoked group (Chiviacowsky et al., 2012). Balance continued to improve for both groups over the course of the retention trials; however, time in balance was significantly longer for the self-control group, despite neither group having access to the balance pole during the retention phase.

Overall, motivation has been shown to be an effective and relatively straight-forward mechanism to promote enhanced ML effects. However, given the recently renewed interest in motivation as a ML strategy, and limited studies incorporating clinical populations, it has resulted in limited evidence available for clinicians to help guide their incorporation of this principle within a clinical setting.

2.2.4 Practice Structure: Contextual Interference

One of the most fundamental principles involved in rehabilitation is practice (Krakauer, 2006). Historically, rehabilitation has involved vast amounts of repetition of a single movement or skill, however, recent evidence has emerged showing that repetition of simple movements, without varying *how* the movement is performed or the *types* of movements performed, can decrease learning and lead to poorer retention and transfer of the behaviour over time (Kitago & Krakauer, 2013; Levin & Demers, 2020). With rehabilitation and the science of ML starting to shift away from this type of simple repetition, variable practice has been introduced as a strong rehabilitative strategy. Variable practice, which involves practicing more than one motor skill or task within a given session (Schmidt et al., 2019), may be organized based on the randomness of the practiced movements, and is comprised of blocked, serial, and random order practice. Blocked practice involves practicing one skill multiple times prior to moving onto the subsequent skill (e.g., AAABBBCCC) (Schmidt et al., 2019), serial practice is a sequence of skills repeated over and over (e.g., ABCABCABC) (Schmidt et al., 2019), and finally, random order practice is the complete randomization of the order of skills (e.g., BCABDCBAC) (Schmidt et al., 2019). While all three forms of variable practice are found to be more effective than constant practice (Corrêa et al., 2014), it is this organization and scheduling of random practice that leads to the introduction of Contextual Interference (CI) throughout the learning process (Schmidt et al., 2019).

The basic premise behind CI is "forgetting to remember", wherein different iterations of tasks will be intermixed with one another to increase the variability of the practice, as well as the different forms of the selected motor skill (Schmidt et al., 2019). The mechanism behind why CI works is not entirely understood; however, it is commonly thought to increase the effort associated with learning via the intermixing of different tasks and task iterations (Magill & Hall, 1990). Additionally, with the intermixing of tasks, it increases the distinctiveness of the movement patterns, and the associated motor memories, while requiring *active* recall when attempting to recreate the previously executed motor program.

Use of Contextual Interference in Rehabilitation

When used within healthy populations, CI (or random practice) is generally associated with increased learning benefits (Aiken & Genter, 2018; Porter & Beckerman, 2016). However, there have been conflicting results when CI is used within a clinical context. Additionally, the studies that have been done using clinical populations preferentially recruit individuals who have had a stroke, which may limit the generalizability of the findings to other clinical populations.

Jo et al. (2020) implemented a feeding task with a group of 14 individuals at least three months post-stroke. The intervention consisted of two cohorts, a blocked practice group and a random practice group, performing three tasks in the order assigned by their group designation. Acquisition tests were performed at the first, fourth, and seventh sessions, a post-test assessment after the last acquisition trials, and a follow-up test three weeks later. While there were no significant differences between the groups in the acquisition and retention tests, there was a significant difference in the time to complete the task when the transfer was assessed, as well as the random practice group showing a significantly greater variance of movement time over the blocked group in the pre-tests and follow-up testing (Jo et al., 2020). In contrast to the positive results found by Jo et al. (2020), Rhea et al. (2012) found no significant differences in the performance of blocked and random practice groups in a split-belt treadmill test.

One interesting point of note is that support for the CI effect seems to be in part dependent on the methodology employed by the studies. Upon further examination of the literature, the studies that report no benefit from the CI effect typically do not include assessments of transfer in their methodology, preferring to use acquisition and immediate retention tests to assess the intervention's outcome. In contrast, of the studies that provide support for the benefits of CI, the majority implement at least long-term retention tests, while more commonly, tests of transfer are also included. This does present an interesting point, however, regarding the applicability to clinical practice, as well as the ability for clinicians to determine whether an intervention is suitable for their patient populations and learning goals. It could be that CI and random order practice do allow for enhanced learning benefits when used within a clinical context, or at least, within a population of individuals who have had a stroke. However, due to inconsistencies in the chosen methodologies, it appears that there is conflicting evidence available that supports the utilization of this principle within a clinical setting, which may deter clinicians from incorporating it within the scope of their clinical practice sessions.

2.2.5 Implicit and Explicit Learning

Implicit and explicit learning are primarily concerned with *how* an individual is learning and obtaining the relevant task information. As a result, implicit versus explicit learning encompasses an overarching concept that has the ability to influence many different principles involved in ML, such as feedback and focus of attention. The following section provides an overview of the mechanisms behind implicit and explicit learning, as well as their use in rehabilitation, without associating these concepts to a specific ML principle previously covered in this chapter.

When an individual learns a motor skill implicitly, they do not generate an awareness of the procedural components involved in the execution of the skill (Boyd et al., 2007; Pohl et al., 2001). To explain this lack of awareness, it has been hypothesized that implicit learning bypasses the acquisition of the declarative knowledge associated with the initial stages of motor skill learning (Kal et al., 2018). As a result, implicit learning results in decreased cognitive demands and the accumulation of procedural knowledge independent of working memory processes (Kal et al., 2018; Kleynen et al., 2019; Masters et al., 2004). As evidenced by enhanced movement speed and decreased movement effort, implicit learning can confer advantages to motor skill learning (Masters et al., 2004). However, individuals often have difficulty articulating the components of the skill and the rules that are associated with the motor task (Masters, 1992; Pohl et al., 2001).

From a clinical perspective, an individual's lack of awareness that learning is occurring, and their inability to articulate accurately and reliably what they have learned, implies that it may be difficult for clinicians to directly assess the magnitude of motor skill learning that occurs under implicit conditions (Boyd et al., 2007). Instead, any learning that occurs implicitly must be inferred via comparing changes that arise in the movement pattern against the individual's baseline skill level (Boyd et al., 2007). Recently, however, studies have begun attempting to conceptualize methods for more reliably assessing whether implicit learning transpired over the course of a learning session. Utilizing a serial reaction time task in a group of university students, Haider et al. (2011) determined that reaction time drops in an experimental context could be used to infer that learning occurred via implicit mechanisms. Here, a decrease in reaction time, coinciding with a lack of awareness of the repeating pattern, was associated with implicit learning. Demonstrating strong reliability, their experimental methodology was replicated in a second study, showing that 34% and 41% of participants had a reaction time drop in experiment one and experiment two respectively (Haider et al., 2011). Their experiments, while restricted to a research context with limited applicability to rehabilitation, presents a starting point for a sound methodological option that may be used to determine the magnitude of any resultant implicit learning.

In contrast to implicit learning, learning under explicit conditions requires that an individual be aware of the facts and rules that encompass their target motor task (Masters, 1992). This awareness allows clinicians or researchers to directly assess explicit learning by evaluating the depth and strength of an individual's awareness of the content of the learning session and the components of the skill or task that they are attempting to execute (Masters et al., 2004). As a result of this awareness, however, explicit learning is heavily dependent on the cognitive and working memory processes required to generate the verbalizable knowledge associated with movement performances (Kal et al., 2018).

Use of Implicit and Explicit Learning in Rehabilitation

Improvements in performance under conditions of implicit learning, paired with the absence of articulable knowledge, indicate that implicit and explicit learning relies on different learning systems (Haider et al., 2011). Although it is hypothesized that there are distinct neural mechanisms underlying both implicit and explicit learning, they are commonly thought of as the extreme ends of a continuous spectrum (Kal et al., 2018). Where implicit learning is one end, representing learning that occurs without any involvement of working memory and declarative processing, explicit learning is the opposite end, where learning is entirely dependent on the involvement of working memory and is represented by the ability to both process and articulate declarative knowledge (Kal et al., 2018). Thus, rehabilitative efforts can utilize this spectrum to incorporate implicit and explicit learning principles into clinical sessions. Although they are depicted on a spectrum, the strategies commonly used in implicit learning seem to center on minimizing the use of explicit, declarative knowledge (Kal et al., 2018), and rather than promoting conditions of implicit learning, the processes surrounding explicit learning are preferentially inhibited.

Interestingly, despite a strong theoretical rationale suggesting that implicit strategies may afford benefits to learning a novel motor task, studies have reported conflicting results on the efficacy of an implicit approach to ML. A comprehensive literature review conducted by Kal et al. (2018) reported inconsistencies in the benefits of learning with an implicit strategy. Although the included studies underreported their bias assessments, requiring the authors to perform descriptive analysis, most of their comparisons did not show any differences in performance when learning under implicit versus explicit conditions (Kal et al., 2018). However, their results did support that the strength of implicit learning is more evident in delayed retention tests, with superior motor performance in dual-task contexts under implicit conditions (Kal et al., 2018). Of the 25 controlled trials included in the review, two showed superior dual task performance with implicit learning, four showed lower dual task costs (reduced deterioration of the motor skill) with implicit learning, and three showed both superior dual task performance and reduced dual task cost with implicit learning (Kal et al., 2018). In comparison, only two studies definitively showed that an explicit motor learning strategy promoted superior dual task learning compared to an implicit learning strategy (Kal et al., 2018). Despite the weak overall support for learning with an implicit strategy in the studies comprising this review, the results of Kal et al. (2018) do suggest that a particular form of implicit learning, analogy learning, was more consistently beneficial to ML outcomes.

The theoretical concepts underlying implicit learning also suggest that it may be an effective rehabilitative strategy for individuals who have experienced cognitive and/or motor impairments from neuroanatomical deficits (e.g., stroke or traumatic brain injury). Particularly, it has been demonstrated that some implicit learning mechanisms are preserved in individuals with amnesia (Baddeley & Wilson, 1994), stroke (Jie et al., 2021; Orrell et al., 2006), and Multiple Sclerosis (Deroost et al., 2014). Following a stroke, for example, subsequent cognitive impairments may make it difficult for individuals to process the verbal, explicit information commonly provided by clinicians throughout their rehabilitation (Jie et al., 2021; Orrell et al., 2006). Although limited by small sample size, Orrell et al. (2006) demonstrated that errorless (implicit) learning promoted the retention of fewer explicit, verbal rules associated with components involved in a balance task. Alongside the reduction in verbalizable rules, which is crucial for implicit learning, individuals with a stroke demonstrated enhanced retention. They reduced interference effects from a secondary, cognitive task when learning under implicit conditions (Orrell et al., 2006). Supporting the results of Orrell et al. (2006), Jie et al. (2021) also provide evidence that implicit learning is preserved in individuals who have had a stroke. However, their results contradict the notion that learning implicitly confers any benefit to stroke rehabilitation. Analyzing the walking speed of individuals in the chronic stage of stroke recovery using a 10-metre walk test, Jie et al. (2021) showed no statistically significant intergroup differences between implicit and explicit learning. However, this study may have been limited by the participant demographics. There was a great deal of variation in the physical and cognitive abilities of the participants across the treatment groups, and while variability does reflect the realities of clinical rehabilitation, the degree present within this study may have had negative implications on the results (Jie et al., 2021).

In addition to individuals who have had a stroke, individuals with amnesia (Baddeley & Wilson, 1994) and Multiple Sclerosis (Deroost et al. 2014) also maintain components of their implicit learning abilities. Deroost et al. (2014) implemented a serial reaction time task with groups of individuals who either had relapsing-remitting or progressive Multiple Sclerosis. By assessing alterations in reaction time, the authors determined that sequence learning, which is a component of implicit learning, was preserved in individuals with progressive Multiple Sclerosis, but not in individuals with relapsing-remitting Multiple Sclerosis (Deroost et al., 2014). Baddeley & Wilson (1994) went a step further and not only determined that implicit learning is preserved in amnesic individuals, but they also concluded that they have a high probability of learning more effectively with implicit learning than with explicit learning. However, they hypothesized that, since working memory and declarative knowledge are impaired in amnesic individuals, and given the involvement of these systems in explicit learning processes, if any learning is to occur, it must be done in an implicit manner (Baddeley & Wilson, 1994).

The trend of evaluating the preservation of implicit learning is not solely confined to the studies referenced. While many studies document the preservation of implicit learning mechanisms and imply that it may be more beneficial than explicit learning in a variety of clinical populations, there is limited evidence supporting or discrediting the use of implicit learning strategies outside of experimental contexts. Additionally, most studies seem to focus on the theoretical implications and the mechanisms behind how implicit learning works, or else they seek to determine the most effective method of measuring the amount of learning that occurred implicitly. Currently, most studies that assess the feasibility of an implicit style of learning do so with a population of healthy individuals by utilizing methodology that may be inaccessible, or irrelevant, to clinicians. In summary, given the context that would be relevant to clinicians and individuals requiring rehabilitative services, there is a distinct lack of research that reports on the perceived differences between learning with implicit versus explicit strategies. Therefore, future research should implement feasibility studies and report on the effectiveness of this ML strategy when compared to the standard of care in rehabilitation.

2.2.6 Summary of Motor Learning Theories and Principles

This section has established that, while ML theories and principles are grounded in strong theoretical rationales and empirical evidence in healthy populations, the research that has been done in clinical populations, and more specifically neurological patients, is limited, and at times, conflicting. Despite the conflicting results when used in rehabilitative populations, it is important for clinicians to have an awareness of this body of literature. With this awareness, specific attention can be given to ML principles that may have a high degree of relevance to their patients, as well as the ability to intentionally adjust or manipulate variables associated with the principles themselves.

2.3 Knowledge Translation

The limited availability of research conducted with clinical populations, along with a lack of clinical guidelines and contexts where clinicians may not have a comprehensive understanding of the principle under investigation, demonstrates that there is a KT gap within rehabilitation. KT is widely defined as a field that promotes the uptake of relevant research and best practices into clinical settings through the synthesis, dissemination, and application of knowledge (Atun-Einy & Kafri, 2019; Levac et al., 2015). In general, the goal of KT in rehabilitation is to enhance the quality of the services provided to expedite recovery and return of function. However, when clinicians are faced with barriers to integrating up-to-date evidence within their clinical sessions, whether through systematic barriers or a lack of knowledge, it can result in the delivery of services that are inconsistent with best practices.

2.3.1 Knowledge Translation Cycle

Within today's health care setting, there is a debate on how many patients receive care that is based on current evidence. Moore et al. (2017) cites that more than 50% of patients receive care that is not based on current evidence, while Janzen et al. (2016) cites 55-67% of patients receive care that is informed by, and consistent with, best practices. While there have been criticisms on the lack of research utilization within a clinical setting (Turner & Whitfield, 1997), it is important to note that KT is a complex process requiring collaboration among multiple parties involved in all aspects of rehabilitation. Though critical appraisal of research can, and does, influence the overall uptake of best practices within clinical rehabilitation, *systematic* changes require the implementation of both a knowledge creation cycle, where knowledge is first generated, and an action cycle, where the generated knowledge begins to be implemented into clinical practice.

The Knowledge Creation Cycle

Although the knowledge creation cycle and the action cycle (Figure 1) are represented together, they are two distinct processes informed by the results of the other. The inner funnel, the knowledge creation cycle, represents the degrees of knowledge creation and is comprised of the primary mechanisms of research utilized within health care (Graham et al., 2006). As the funnel narrows, knowledge advances from the initial inquiry phase to the knowledge synthesis phase, and finally to the tools and products found in the final phase. As the knowledge evolves throughout the knowledge creation cycle, it becomes more specific and relevant to the interested stakeholders (Graham et al., 2006).

The Action Cycle

Once the knowledge has been distilled, the action cycle (the outermost ring) is the part of the KT process that results in the implementation of the information generated by the knowledge creation cycle (Graham et al., 2006). The action cycle takes a planned action approach to deliberately induce change in the target area (Graham et al., 2006). Planned action approaches are utilized when individuals, in this case it could be the policy makers, researchers, or the clinicians themselves, want to have a high degree of control over the variables that are being manipulated to increase or decrease the likelihood of a change occurring (Graham et al., 2006). Using this approach, the action cycle builds upon knowledge that has been previously generated, and through the assessment of barriers, identifies areas for future research to address the identified problem. The identification of barriers is also key in determining what is preventing the knowledge from being utilized or implemented within the relevant settings (Janzen et al., 2016). Once these barriers have been identified, targeted interventions can be modified and adapted to address and correct them. Then, in the final stages of the action cycle, the implemented intervention is monitored to assess the effectiveness, as well as receive feedback on whether the change has made a tangible impact on the target outcomes (Janzen et al., 2016; Graham et al., 2006).

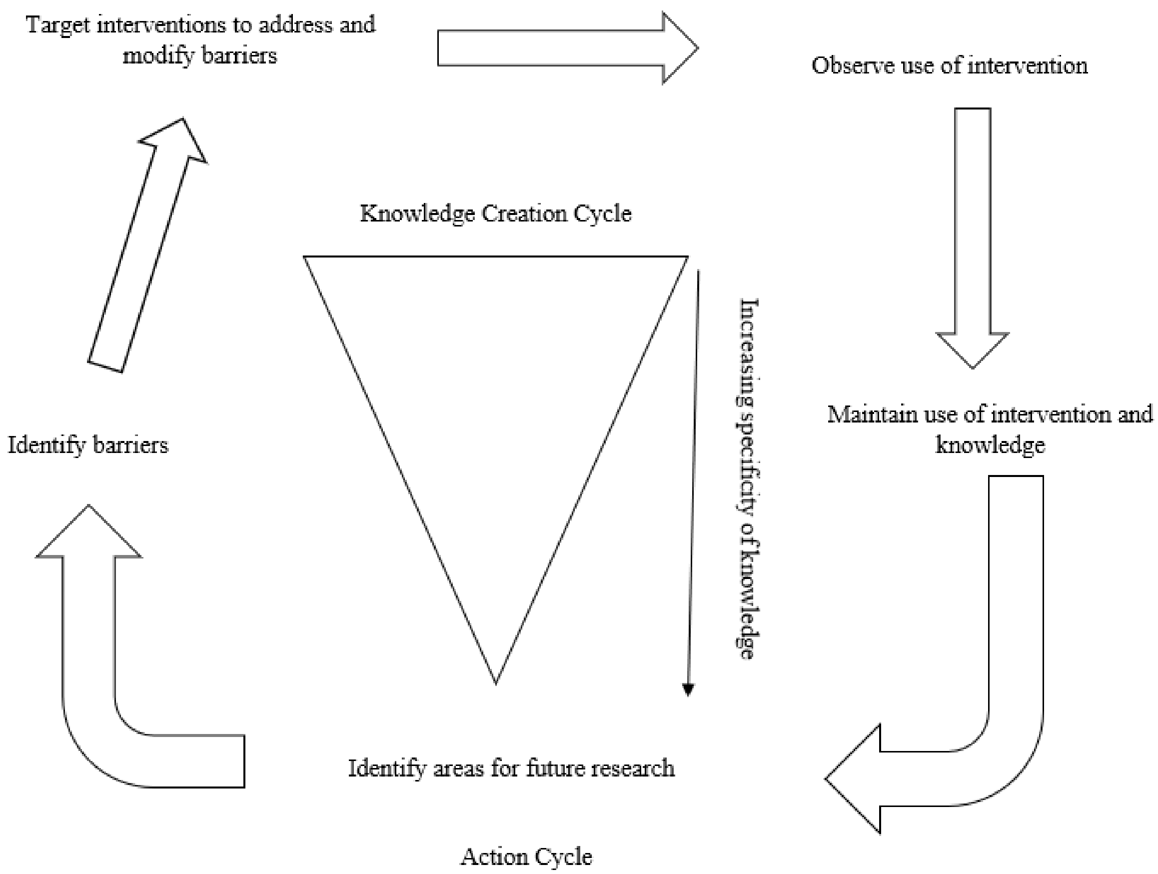

Figure 1 Knowledge to action process. Figure modified from knowledge to action process outlined by Graham et al. (2006)

2.3.2 Individuals Impacted by Knowledge Translation

Considering that successful KT outcomes can be assessed by changes in behaviour, attitude, or knowledge, it is important to consider who may be impacted throughout this process within a rehabilitation setting (Janzen et al., 2016).

PTs are members of the interdisciplinary health team that manage the rehabilitation, health promotion, and illness prevention of individuals who are injured, ill, or disabled (Ontario Physiotherapy Association, 2014). Within this role, PTs are responsible for assessing and promoting the individual's return to function by encouraging physical independence and advancing functional capacity (Ontario Physiotherapy Association, 2014).

Like PTs, OTs are involved in the recovery and rehabilitation of individuals with injuries or disabilities. However, where a PT may emphasize overall functional mobility and independence, an OT will work with an individual to overcome specific participation restrictions. Activities of daily living, such as personal hygiene or dressing, or productivity, such as working or going to school, are common areas where an OT may provide an individual with support and assistance (Canadian Association of Occupational Therapy, 2016).

SLPs are responsible for identifying, diagnosing, and treating disorders relating to communication and swallowing (Speech-Language and Audiology Canada, 2016). From a ML perspective, SLPs can be responsible for a wide range of clinical presentations such as speech delays and disorders, issues with swallowing and eating, or cognitive communication disorders (Speech-Language and Audiology Canada, 2016).

Given the roles of PTs, OTs, and SLPs, they are often directly involved in the rehabilitation of individuals with motor impairments. As such, it becomes necessary for them to understand, employ, and if appropriate, tailor the previously mentioned ML theories and principles throughout the course of their patient's recovery. However, they are also the individuals who will be impacted by both the limited evidence available that examines the translation of ML-related knowledge to clinical practice, and the applicability of the ML principles to the specific contexts and patient populations that they practice within.

2.4 Application of Motor Learning and Evidence-Based Practice in Rehabilitation

Incorporating evidence-based practice (EBP) into rehabilitation is critical to achieving optimal patient outcomes and developing the field. With advances in science and knowledge furthering our understanding of rehabilitative principles and strategies daily, effective rehabilitation is highly dependent on sound and relevant clinical decision making. However, a lack of EBP in rehabilitation, regardless of the etiology of this course of action, can result in significant lapses occurring between the discovery of more effective rehabilitative methods, and their eventual implementation into clinical practice (Turner & Whitfield, 1997).

2.4.1 Barriers to Implementation

There is a noticeable lack of peer-reviewed research that has specifically examined the integration of ML theories and principles into clinical practice. However, in the limited work that has been done, a small number of researchers have begun to identify barriers at both the individual and system levels – themes supported in the broader literature related to integrating EBP into clinical rehabilitation. In terms of the ML-specific literature, two quantitative studies have examined how PTs integrate ML principles into clinical practice. Atun-Einy & Kafri (2018) found that clinicians are aware of the central tenets of ML principles, but don't necessarily structure their practice according to guidelines and recommendations from the literature. Barker et al. (2015) implemented a survey assessing PTs knowledge of ML theories and principles, finding similar results; PTs tend to overutilize principles such as PG and feedback, while they have knowledge gaps in areas such as motivation and implicit versus explicit learning. In 2019, Atun-Einy & Kafri (2019) followed up with qualitative interviews examining PTs perceptions of ML theories and principles in clinical practice. Only one observational study has been conducted, again recruiting PTs; Johnson et al. (2022) observed their use of various ML theories and principles within clinical practice. All these studies have found similar results; PTs seem to understand ML theories and principles yet are not structuring their practice in a manner that is consistent with what the literature recommends as best practices. In all studies, PTs were preferentially utilizing increased amounts of PG, promoting an internal focus of attention, and delivering increased amounts of verbal feedback.

Although there has been a limited number of studies looking at the integration of ML theories and principles, a much broader body of research has been conducted regarding integrating EBP into clinical practice. Many studies have reported similar findings; barriers such as a lack of knowledge or understanding or limited self-efficacy, as exemplified by the ML-related research, or a lack of time, contribute to the uptake of best practices within rehabilitation. Using this parallel research in conjunction with what is known about the integration of ML, it may help understand what some of the barriers are to integrating ML theories and principles into clinical practice. The following section will explore these barriers as they relate to ML, and the field of rehabilitation science more broadly.

Incomplete Understanding of Motor Learning

Given the broad and complex nature of ML, an incomplete understanding of ML theories and principles, or limited self-efficacy with the implementation of the associated theories and principles, is, understandably, one of the most frequently cited barriers to implementation. One study by Atun-Einy & Kafri surveyed 289 PTs on their perceptions of ML and asked the PTs to rate their self-efficacy implementing various components within their clinical practice (Atun-

Einy & Kafri, 2018). The results showed that 33% had limited confidence explaining the effect of repetitions, and 40% had limited confidence explaining the different types of feedback. This lack of confidence with fundamental components of ML was further evidenced by 29% of respondents reporting that they felt unable to provide treatment informed by ML principles. Despite clinicians universally agreeing that ML is a central component of their clinical practice (Atun-Einy & Kafri, 2019), the majority (61%) of PTs reported that they implement ML theories and principles to a very small, small, or moderate degree (Atun-Einy & Kafri, 2018).

In the survey conducted by Atun-Einy & Kafri (2018), they found that the way ML was approached in initial professional programs contributed to the PTs' confidence levels applying the principles to clinical practice. Additionally, Bramley et al. (2018) conducted a quantitative study involving 14 Canadian PTs. They determined that, of the eight PTs who completed the associated questionnaire, four received less than five hours of ML education over the entire duration of their degree, and two received 5-10 hours. Only one received more than 10 hours of ML specific education. Typically, when clinicians are presented with opportunities for education centered on ML, most of the teaching is conducted via didactic style lectures (Bramley et al., 2018), with minimal opportunity to practice in clinically relevant scenarios (Mc Grath et al., 2015). Further compounding this, there is a relatively high degree of heterogeneity present in the language used to describe and outline the ML theories and principles from both a theoretical and clinical standpoint. When this heterogeneity is translated into education and preferentially delivered via a didactic teaching style and minimal hands-on opportunities, it can easily result in clinicians obtaining knowledge of ML in fragments, rather than through a structured, systematic learning processes.

Barriers Relating to Integrating Research Evidence into Practice

Previous research has reported that low self-efficacy and lack of understanding are predominant barriers that clinicians experience when integrating ML theories and principles into clinical practice (Atun-Einy & Kafri, 2018, 2019). However, the way that ML interventions are outlined in the research may also contribute to the barriers that clinicians face. As evidenced by a study assessing the integration of EBP, despite a particular intervention having a high degree of clinical relevance, the overall effectiveness was compromised when the intervention was outlined in a manner that did not resonate with the clinicians (Moore et al., 2017). Unfortunately, this is cited as being a common occurrence, and clinicians have reported feeling confused and uncertain about the results of various interventions as they are presented in the literature (Iles & Davidson, 2006; Scurlock-Evans et al., 2014). Although not related to ML, a 2014 scoping review involving 13 studies reported on the abilities of PTs to critically appraise general research literature. Of the participants included in these 13 studies, 50% reported that they were confident appraising the literature, but often had a high degree of difficulty interpreting statistical results (Scurlock-Evans et al., 2014). While this does partially stem from gaps in a clinician's knowledge and abilities, the statistical results found in research are often complex and difficult to understand. Many papers also fail to provide a description of their results in terms that are more suited to a clinician reader; primarily reporting measured outcomes via statistical tests and graphs that may be less interpretable to non-researcher clinicians, while making overarching conclusions on the "bigger picture" clinical implications within the discussion section (Hardwick et al., 2017; Wambaugh et al., 2016).

In addition to the manner in which the results are presented, published papers on ML-specific interventions rarely offer recommendations on how to apply the target intervention within a clinical setting (Kleynen et al., 2017). When a paper concludes on the effectiveness of their chosen ML principle, they typically report on the effectiveness within the confines of the laboratory setting in which it was assessed. There is a noticeable lack of papers that outline a clinical situation in which the ML principle could be useful, or otherwise offer a description of how it could be manipulated to best fit a particular environment or patient population (Kleynen et al., 2017). Conversely, when papers do offer recommendations or clinical guidelines for a particular ML theory or principle, it has been noted that the methods and strategies often have a substantial degree of variability between them, resulting in limited opportunity for a clinician to reach a consensus on the overall effectiveness of the intervention (Charlton et al., 2021). One limitation found within the current body of research is that no papers have been published incorporating clinicians' perspectives on this barrier as it relates to ML. However, a 2003 study assessing clinicians' attitudes and beliefs regarding EBP found that 30% of the participating clinicians felt that the results of research articles were not widely generalizable to their specific patient populations or clinical practice settings (Jette et al., 2003).

In general, one solution that has been proposed to overcome barriers relating to the research methodology, presentation of results, and overall generalizability, is to involve more clinicians within the research process. Having the individuals responsible for integrating the results into clinical practice involved in the research process could alter how results are presented and outlined. However, there seems to be a limited number of clinicians actively engaged in clinical research. Zidarov et al. (2013) proposed that a lack of interaction between the researchers and potential end users contributes to the underutilization of research and findings. The lack of interaction was further supported by Scurlock-Evans et al. (2014), who emphasized that research is not readily accessible to clinicians from both an understanding and participatory standpoint.

Perceptions and Attitudes Towards Evidence-Based Practice

In EBP, many barriers have been found that are outside of a clinician's control. However, their perceptions and attitudes towards research were also cited as a barrier within the published literature. In a 1997 study, Turner & Whitfield surveyed 321 hospital-based PTs in England and Australia. Many of these clinicians indicated that they did not seek out published papers and used the available research in minimal quantities throughout their clinical decision-making. Although this study was from 1997, more recent studies have offered further support for the attitudes and perceptions of clinicians operating as a barrier to the integration of EBP into rehabilitation. Scurlock-Evans et al. (2014) revealed in their systematic literature review that some clinicians feel that engaging in the steps related to EBP is not their responsibility, regardless of their views on the importance of basing clinical decision-making on current bodies of evidence. Additionally, there were various misconceptions identified that reduced the clinicians' willingness to participate in EBP; concerns that engaging in EBP would reduce the degree of therapeutic autonomy the clinicians and their patients held over the practice sessions, as well as a belief that the drive towards EBP was based on economic decision making, rather than the quality of care (Scurlock-Evans et al., 2014), a view which has also been shown to align with patient beliefs about health care priorities (Moore et al., 2017).

At the individual level, negative attitudes and perceptions have been identified as barriers to integrating EBP into clinical rehabilitation (Salbach et al., 2007; Zidarov et al., 2013). However, looking more broadly, clinicians' negative attitudes and perceptions have also been promoted by a lack of peer support and peer isolation (Condon et al., 2016; Salbach et al., 2007). Inadequate support of EBP within rehabilitation by peers and educators may result in the underutilization of research and a preference for on-the-job training. Indeed, one study reporting on clinicians' knowledge of safe patient handling found that 46% cited on-the-job training as their primary source of education (Mc Grath et al., 2015). The danger with this, and a lack of EBP in general, is that it becomes unclear how much of this on-the-job training reflects best practices, and how much is simply local customs and clinic-specific norms.

Patient Presentation Barriers

Patient presentations were another barrier cited by literature relating to the integration of EBP. When patient presentations do not conform to the EBP guidelines outlined in the literature, clinicians lack the self-efficacy required to manipulate the components of the intervention to best meet the needs of the individual (Condon et al., 2016). Furthermore when clinicians disagree with the results presented in the literature or do not believe that the results apply to their patients, it furthers the divide between the policies and recommendations promoted by EBP, and the actions of clinicians (Condon et al., 2016). In terms of patient barriers relating to the integration of ML principles, functional limitations, age, patient population (e.g. neurorehabilitation versus musculoskeletal rehabilitation), and patient motivation were also cited (Atun-Einy & Kafri, 2018; Barker et al., 2015).

Administrative Barriers

In addition to the clinician and patient-specific barriers, administrative barriers were commonly cited in the literature. Clinicians universally mentioned a lack of time as one barrier that made EBP inaccessible or difficult to partake in (Schreiber & Stern, 2005). A study published by Salbach et a. (2007) recruited 270 Canadian PTs providing rehabilitative services to individuals who have had a stroke. Mentioned by 82% of survey respondents, a lack of protected time to search and appraise the literature was one of the largest barriers to participating in EBP (Salbach et al., 2007). While attempting to integrate ML principles, clinicians cited that a major component of this lack of time relates to the inadequate patient-to-therapist ratios and the subsequent pressure placed on them by their institution to discharge patients (Barker et al., 2015). The lack of institutional support, increased caseloads, financial constraints, and limited access to relevant databases may result in the promotion of workplace environments that do not support professional development within the field of ML (Atun-Einy & Kafri, 2018).

2.4.2 Aspects that Facilitate Application

Aspects of clinical practice that facilitate the integration of ML and EBP into rehabilitation were surprisingly underdeveloped within the published literature. If appropriately adapted, many of the barriers cited in the literature could also function as facilitators.

Given the high degree of relevance that a clinician's initial professional education has on their ability to integrate ML into rehabilitation, appropriate hands-on learning opportunities and continuing education sessions were the most frequently cited facilitators. A study by Vaz et al. (2021) assessed the self-efficacy and ML-related knowledge of 28 third-semester PT students after a 60-hour ML course. After the course concluded, the students' self-efficacy relating to ML concepts significantly increased compared to baseline levels, an increase which also correlated with higher scores on a knowledge-based assessment (Vaz et al., 2021). One of the strengths of this study was that the intervention combined a theoretical knowledge of ML with the opportunity for hands-on practice and exploration of the theoretical concepts. Further strengthened by the high degree of validity of the knowledge and self-efficacy tests utilized at baseline and follow-up, this study is one of the first to offer support for the positive benefits of early and *active* ML education.

One unique facilitator mentioned in the literature relating to EBP was that the level of education clinicians received correlates with their perspectives on EBP and their skill level undertaking the necessary participatory steps. The more recently an individual completed or participated in higher education (e.g., Masters degrees or continuing education), the more likely they were to integrate information and recommendations from journal articles and research into the structure of their clinical practice (Iles & Davidson, 2006; Turner & Whitfield, 1997; Zidarov et al., 2013). Specifically, more recent post-graduate training was associated with greater use of research, more positivity toward EBP, and greater confidence in self-reported EBP skills and knowledge (Iles & Davidson, 2006; Zidarov et al., 2013). However, one limitation identified by Iles & Davidson (2006) was that, while over 50% of respondents stated that they frequently integrated evidence from the literature into their practice, less than 25% cited that they were critically appraising the research. Additionally, while clinicians reported that they had a strong understanding of terms relating to EBP, such as bias, treatment effect size, and confidence interval, none could satisfactorily explain these terms in accordance with essential teaching criteria (Iles & Davidson, 2006). Therefore, while more recent post-graduate education does appear to facilitate the implementation of EBP into clinical sessions, clinicians are still having difficulty discriminating between valid and invalid evidence and may be overestimating their level of understanding in self-reported questionnaires and studies.

Chapter 3

Purpose of Thesis

The published literature focusing on rehabilitation interventions involving ML often covers broad topics with information suitable for researchers and academics, but not necessarily clinician readers. A substantial KT gap is apparent when the research presentation is evaluated in conjunction with the complexities present in the ML principles themselves. While previous studies have begun identifying the various barriers and facilitators clinicians experience when attempting to integrate ML within clinical rehabilitation, there is still limited information available. Given this limited information and the strong relevance that ML has to clinical practice, further, in-depth examination of these barriers and facilitators is warranted, as well as an examination of the factors that may be compounding the existing knowledge gap. Additionally, few studies have reported recommendations, influenced by clinicians, for opportunities that may assist in reducing this KT gap in the future. Therefore, the initial overarching purpose of this thesis was to describe and understand the perspectives and experiences of clinicians regarding the integration of ML theories and principles into clinical rehabilitation practice. Within this overarching purpose, there were initially three primary objectives for the study; 1) to describe the confidence level of clinicians regarding the integration of specific ML theories and principles into practice, 2) to identify clinicians' perceived barriers and facilitators to the integration of ML, and 3) to begin to determine why the limitations are present, and what clinicians believe would be beneficial moving forward to start overcoming them. However, as the study progressed, the objectives, and associated research questions, evolved. This evolution was primarily driven by the content of the barriers and facilitators that were being described by the clinicians, as well as reflection on if the objectives were closely followed, what the subsequent write-up and recommendations would look like after the study had concluded. Therefore, the objectives were updated to reflect this and are as follows; 1) describe how confident clinicians are integrating specific ML theories and principles into clinical practice, 2) describe how clinicians integrate ML into clinical practice, and the clinician perceived barriers and facilitators to this integration, and 3) start to determine what clinicians believe would be beneficial moving forward to start overcoming these barriers.

Taking a sequential exploratory mixed methods approach, there were two primary data collection components. The first was the quantitative component; an initial survey was run amongst a small group of clinicians attending a ML workshop, which was then followed by an updated survey distributed to a broader audience. The primary purpose of the surveys was to gain a broad understanding of clinicians' comfort levels in implementing and manipulating variables associated with common ML theories and principles. Additionally, both surveys began assessing the barriers and facilitators clinicians face while attempting to integrate ML within their clinical practice. In keeping with the chosen methodology, a secondary objective of the survey was to help inform the content of the interviews, which made up the qualitative component of the study. The primary purpose of the interviews was to gain an in-depth understanding of clinicians' experiences with integrating ML theories and principles into clinical practice, the associated barriers and facilitators, and their perceptions on strategies to facilitate greater integration within rehabilitation in the future.

Chapter 4

Quantitative Works - Surveys

4.1 Introduction

Published studies assessing ML theories' translation into clinically applicable principles primarily take a qualitative approach.(Atun-Einy & Kafri, 2019; Bramley et al., 2018). Given this qualitative background, previous literature has begun to identify barriers and facilitators that clinicians face throughout the process of their clinical decision-making. However, despite a good evidence background, it is still relatively unknown how confident clinicians are in their understanding of ML theories and principles. Therefore, it was determined that a quantitative assessment, in the form of a survey, was warranted to offer more information on this area. Utilizing a survey would provide an opportunity for direct comparison of the confidence levels against one another; allowing for an assessment of strengths and potentially identifying areas to target for improvement.

In this component of the research, two surveys were conducted. The primary intent of the first survey was to assess the knowledge and confidence of clinicians registered for a continuing education workshop on integrating ML strategies into task-oriented training. Upon completion and initial analysis of the first survey, it was determined that a revised survey would be distributed to an increased and broader sample of clinicians.

4.2 First Survey

The primary objective of the first survey was to inform a continuing education workshop held in November 2021. Additional objectives were to 1) describe clinicians' confidence in implementing ML theories and principles into clinical practice, 2) describe the barriers and facilitators that clinicians face while integrating ML into clinical practice, and 3) obtain data that could be used to inform interview question to probe the clinicians' experiences more in-depth. After assessing the results, the first survey was also used to assess the feasibility and determine the appropriateness of the length and types of questions.

4.2.1 Materials and Methods

4.2.1.1 Recruitment

A convenience sample of clinicians registered in a ML workshop held by the Central East Stroke Network in November 2021 were contacted to participate in the survey upon registration. Approximately 95 clinicians were emailed a letter of invitation and a link to complete the online survey. As the workshop was primarily geared towards neurological rehabilitation (e.g., stroke), most of the registered clinicians were PTs or OTs practicing within this area. Due to the anonymity of the survey, there were no inclusion or exclusion criteria for those participating outside of being registered to attend the workshop.

The survey was promoted again at the workshop and left open until December 2021 for clinicians to complete. As an incentive to participate, individuals had the option of entering their name into a draw for a $50 Amazon gift card. The draw was conducted on March 8, 2022 by assigning numbers to interested clinicians' emails and running a random number generator online.

All clinicians provided informed consent prior to completing the survey, which was reviewed and approved by the Queen's University Health Sciences Research Ethics Board.

4.2.1.2 Instrument

Using the survey program Qualtrics, the first survey was comprised of four distinct categories totalling 59 questions (Appendix B). Parts A and B, demographics and work experience, totalled 17 questions (6 in Part A and 11 in Part B), all tailored towards obtaining a brief outline of the demographics and background of the participating clinicians. Part C was comprised of 20 questions on the clinicians' previous knowledge of ML theories and principles, as well as their confidence implementing them into clinical practice. In general, these questions consisted of a Likert-type scale ranging from 1-10, with anchors at 1 (not confident), 5 (moderately confident), and 10 (very confident). There were two primary question types; the first included a brief description or definition of the ML theory or principle under investigation. The clinician was asked to rate their confidence in identifying or defining key components. The second question type also included a brief description or definition, but the clinician was asked to rate their confidence in manipulating or implementing the principle into their clinical practice. The ML theories and principles evaluated included acquisition, retention, and transfer, practice variability, physical guidance, feedback, blocked versus random practice, continuous versus discrete skills, and motivation. While this is not an exhaustive list, these principles were selected to represent those that have been most commonly explored in ML research, particularly research related to rehabilitation. In addition, these were seen to be the most relevant to typical clinical practice, including the interaction between therapist and patient or client. Part D encompassed 16 questions centred on how ML theories and principles are currently taught in an educational setting. This section consisted of open-ended and multiple-choice answers and attempted to understand the extent of the ML education the clinicians had received in their initial professional degree programs. The final section, Part E, comprised six open-ended questions relating to the barriers and facilitators experienced by clinicians as they attempt to integrate these ML theories and principles into their clinical practice. This section was used to inform many of the interview questions and provided a base for probing the clinician's experiences in the qualitative portion of this study.

4.2.1.3 Data Analysis

Descriptive analysis was chosen as the method of data analysis. The principal investigator (MMM) manually reviewed each of the initial surveys (n=28) and categorized the questions in accordance with the associated survey category. The demographics and work experience were compiled into a table (Table 1), and the questions pertaining to the clinician's confidence were assessed based on the range, average confidence level, and standard deviation. Questions that involved a written answer were compiled and summarized using descriptive content analysis. All the numerical data analysis was conducted via Microsoft Excel.

4.2.2 Results

4.2.2.1 Feasibility

Overall, out of 95 individuals who were emailed with a letter inviting them to participate in the survey, there were 28 submitted with varying degrees of completeness. Most surveys were completed to the end of Part C, but then the response completeness gradually decreased over Part D and E. Due to the low number of responses, and the anonymous nature of the survey, all recorded responses for each question were included within the analysis, regardless of the completion status of the participant's entire survey. However, one individual was a social worker, and their responses to the questions concerning practice-oriented elements were not included within any of the statistical results or figures.

At the end of Part B, only 24 complete responses were recorded. The four incomplete responses were comprised of 2 individuals who opened the survey, but did not fill anything out, and 2 individuals who only partially completed the first two sections. All 24 clinicians started the subsequent section (Part C), however, only 16 clinicians completed it in its entirety, most dropping out around the mid-way point of the section. At the beginning of Part D, 15 clinicians had started the section, with one stopping after the first question, and the remaining 14 clinicians finishing the section in its entirety. Finally, 11 clinicians completed the final section (Part E) at varying degrees; nine completed the section in its entirety, one clinician skipped the first two questions, and a second skipped the final two questions. One of the challenges of determining the response rate for the survey was the use of branch logic. Clinicians could be sent to different questions depending on their responses. Upon reviewing the results, it appears that the clinicians did not complete the survey in the entirety, but in reality, not all questions were displayed to every participating clinician. The presence of branch logic also it makes it difficult to determine the questions that the clinicians *could* have answered, but chose not to complete.

Of the 11 clinicians who completed the entire survey, the duration for completion ranged from eight minutes to one hour five minutes. However, the average length of time for completion was 29 minutes, with eight clinicians completing the survey in 26 minutes or less. After the workshop held in November, a few clinicians did comment on the length of the survey, and while they wanted to provide as much information as possible, they felt it was a significant time commitment to write out their answers in the text boxes provided.

4.2.2.2 Demographics

For the most part, clinicians were PTs or OTs who had completed either a BSc or an MSc. The clinicians predominantly worked within neurological rehabilitation, and though the primary patient population was variable, individuals with stroke did make up a slight majority. The time that clinicians had been practicing ranged from one month to 35 years, with initial degrees being completed anywhere from 1985 to 2021. Table 1 outlines the demographic information in more detail.

Table 1. Demographics of the Clinicians who Participated in the First Survey

Demographic Measure	Number of Responses (n = 24)
Years of Experience	
0-5	1
6-10	4
11-15	9
16-20	4
20+	6
Degree Obtained[a]	
Bachelor of Science	10
Master of Science	9
Diploma	4
Other	
Master of Health Sciences	1
Master of Social Work	1
Area of Work[b]	
PT	8
OT	9
SLP	2
OTA/PTA	4
Other	
Kinesiology	1
Social Work	1
Primary Clinical Area	
Neurological Rehabilitation	14
Musculoskeletal Rehabilitation	3
Cardiorespiratory Rehabilitation	1
Other	
Mixed (Community)	1
Mixed (Hospital)	2
General Rehabilitation	3
Primary Clinical Population	
Stroke	10
Geriatrics	1
Mixed	9
Other	
Acute Medicine	1
General Rehabilitation	1
Individuals with spasticity	1
Traumatic Brain Injury	1
Primary Clinical Setting	
In-patient acute care	5
In-patient rehabilitation or long-term care	4
Out-patient care	6
At home care	8
Other	1

[a] Participants were only able to select one option for their highest level of education [b] One individual only completed this question before stopping. All other participants completed the entire section, making the total number of responses for this question 25, with the other questions response rates being 24

4.2.2.3 Integration of Motor Learning Theories and Principles

Overall, the average confidence level integrating various ML theories and principles into clinical practice fell between 5 and 6.5 on a 10-point scale (1-10). Confidence levels were lowest for *delaying or reducing the frequency of feedback*, with an average of 5.11 and a standard deviation of 2.14. These values also aligned with the lowest range in data (1-8). Identifying tasks that would introduce *variability* into a clinical session had the largest overall range (1-10), with all other assessed theories and principles falling over a range of 2-10. Interestingly, despite a moderate degree of variability in the average confidence levels associated with implementing the individual theories and principles, clinicians reported having the highest average confidence (6.33 ± 1.91) *adapting ML principles to meet the needs of individual patients*. The rating for this question also had one of the smallest SD of the data set; despite the limited response rate, there were more answers clustered around the mean compared to the other ML principles assessed. Figure 2 outlines the assessed principles and theories, and the associated confidence levels, in more detail.

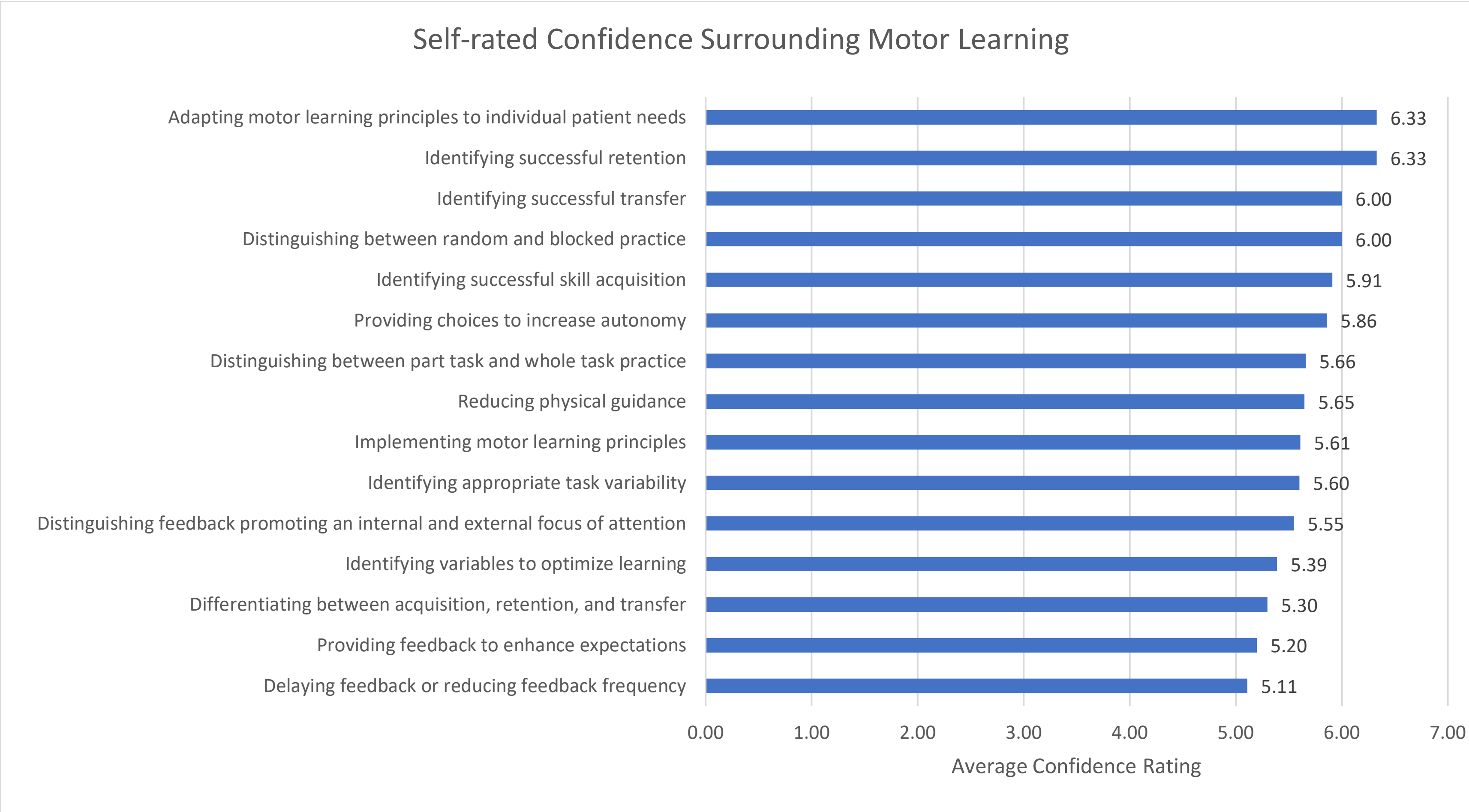

Figure 2. Average confidence level implementing and manipulating ML theories and principles as reported by clinicians. Data labels denote the average confidence level of the clinicians on a scale from 1-10. Assessed motor learning theories and principles are displayed horizontally.

The moderate confidence clinicians reported in their ability to *identify feedback promoting an internal versus an external focus of attention* was corroborated by the limited number of clinicians who had prior experience with this ML principle. When clinicians were asked which ML theories and principles they had previously heard of, *enhanced expectations* was the option selected most infrequently. The most recognized principle was the concept of *reducing PG to promote learning*. Despite many clinicians being familiar with the concept of reducing PG, it was associated with only a mid-range confidence level; 5.65 ± 2.30. Furthering this, when clinicians were asked to describe how they would attempt to reduce the amount of PG that they provide to prevent their patients from becoming dependent on it, most emphasized a gradual reduction in PG over multiple sessions. The concept of facilitation versus support was also mentioned a few times within the written responses; clinicians would reduce guidance only to the point where it would allow patients to complete the tasks using their own movements, while still maintaining a "hands on" approach. Additionally, a few clinicians mentioned that they would attempt to reduce PG by modifying the environment so that PG was not necessary (e.g., by simplifying the task goal) or by providing guidance in a different manner (e.g., verbally).

While there was a general trend of clinician's being moderately confident implementing various ML theories and principles, there was almost unanimous agreement that these principles are relevant to everyday clinical practice. Of the 16 responses to this question on the survey, 75% (12) stated that ML theories and principles are extremely relevant, 19% (3) indicated that they are moderately relevant, and 6% (1) stated that they are only somewhat relevant. No clinician selected the option indicating that ML theories and principles are not at all relevant to their clinical practice.

4.2.2.4 Motor Learning Related Education

Generally, the amount of structured education relating to ML in initial professional programs was not thought to be adequate. Clinicians reported receiving minimal to moderate opportunities to learn about ML-related concepts and principles. However, despite some range among the answers and the subjectivity of the question scale, when asked if the amount of structured education received was enough to prepare them to apply ML within clinical practice, 79% (11/14) stated that it was not. Many clinicians stated that there was minimal opportunity to practice implementing the theories and principles within clinically relevant settings, such as labs or clinical practice. Multiple clinicians also referenced the theory-driven nature of their ML education; stating that most of their education was disseminated via lectures and seminars, and that they had learnt more about the integration of these theories and principles in post-graduate courses or continuing education sessions.

Given the lack of opportunity to practice implementing the ML theories and principles in a hands-on manner, many clinicians recommended that more lab opportunities be integrated into their initial professional programs. Limiting the time spent teaching theories and dedicating more time to clinical skills sessions under the supervision of a knowledgeable instructor or tutor was highly recommended.

Despite the apparent lack of opportunity to practice integrating these theories and principles, clinicians seem to have a relatively solid understanding of when and how to apply ML principles within clinical practice. When asked how they would apply self-selected ML principles, the majority of clinicians referenced changing the environment to incorporate variability within the practice structure. For example, one clinician cited that, during a walking task, the patient could be taken outdoors to practice overground walking on a variety of surfaces and among different environments. Additionally, dressing could be done in various environments, such as in the bedroom to model waking up in the morning, or in the bathroom, to model after a shower or bath.

There were also a variety of ML principles that were cited as being difficult to apply within clinical practice. Most commonly were acquisition, retention, and transfer, decreasing PG and feedback, as well as distinguishing between an internal focus and an external focus of attention.

4.2.2.5 Barriers and Facilitators to Integration

Barriers

Of the 10 clinicians that answered the question about barriers, one stated that they felt there were no barriers to implementing ML theories and principles within clinical practice, and a second responded that they did not know. Therefore, eight answers were generated from the available data, each answer sometimes containing more than one barrier. Of these eight answers, six included time as the primary barrier, four included resources or environmental barriers (e.g., lack of equipment, funding, lack of planning time etc.), three included mentions of a lack of knowledge or practice opportunities, two mentioned social determinants (e.g., lack of debriefing with peers), and one mentioned that the client's emotional state could occasionally act as a barrier as well.

Facilitators

There were also eight completed and usable answers to the question asking what aspects facilitated the integration of ML theories and principles into clinical practice. Overall, these answers were more varied and covered a wider breadth of situations and contexts. However, social aspects, such as being able to meet with a team to discuss cases or collaboration among co-workers and peers was mentioned a couple of times. It also seems that having the appropriate resources facilitates implementation; adequate planning time, video modules and online resources, as well as technology were all mentioned as well.

Following initial analysis of the first survey, the results demonstrated that there were areas where the survey could be improved upon to obtain a more comprehensive understanding of the research question under investigation. Therefore, the survey was updated and relaunched to focus more on the application of various ML theories and principles into clinical practice.

4.3 Second Survey

The overall aim of the second survey was to gain a broad view of clinicians' confidence with various ML theories and principles. The survey was also condensed, as length was a common concern for the clinicians who had completed the first survey, and the Likert-type scale representing confidence was changed from a 10-point scale to a 7-point scale. A 7-point scale was chosen for its increased internal consistency and the support for its superiority from studies assessing human information-processing capabilities and short-term memory capacity (Preston & Colman, 2000).

The objectives of the second survey were to 1) describe how confident clinicians are integrating specific ML theories and principles into clinical practice, 2) describe how clinicians integrate ML theories and principles into clinical practice, and the barriers and facilitators that they face while doing so, and 3) start to determine what clinicians believe would be beneficial moving forward to start overcoming these barriers.

4.3.1 Materials and Methods

4.3.1.1 Recruitment

One of the primary differences between the first and second surveys was the broader approach to recruitment. Where the first survey used a convenience sample of clinicians already registered for a continuing education workshop, the second survey was primarily distributed through the Ontario Physiotherapy Association (OPA) via an e-blast. The e-blast was sent out on March 9, 2022, to all OPA members, which includes physiotherapists as well as physiotherapy assistants. The survey was also distributed to members of the Neuroscience Division of the Canadian Physiotherapy Association. This was also sent in an e-blast in February 2022.

Additionally, the survey was promoted on social media (e.g., Twitter) using a brief post and a PowToon video, as well as being re-distributed to Queen's University PT alumni on May 3, 2022, via a co-author. Due to the anonymity of the survey and the broad recruitment strategy, there were no inclusion or exclusion criteria.

As an incentive to participate in the survey, individuals had the option of entering their name into a draw for a $50 Amazon gift card. The survey was closed in June 2022 and the draw was conducted on July 30, 2022 by assigning numbers to the emails of the interested clinicians and running a random number generator online.

All the participating clinicians provided informed consent prior to completing the survey, which was reviewed and approved by the Queen's University Health Sciences Research Ethics Board.

4.3.1.2 Instrument

Following the first survey and the comments and suggestions from the clinicians who completed it, the second survey underwent revisions. The final version of the Qualtrics survey contained an initial section on informed consent, followed by 52 questions organized into four separate categories (Appendix C). The first part, Demographics, contained 14 questions similar in nature to those outlined in the first survey. However, answer options relating to patient populations (e.g., stroke, musculoskeletal conditions) and primary work setting (e.g., in-patient acute care, at home care) were expanded upon to reflect the broader demographics expected of the participating clinicians. A question pertaining to the country that the clinician currently practices in was also added based on the same rationale.

Part B consisted of 19 questions covering the clinicians' comfort with and knowledge and understanding of ML theories and principles. Within this block, the majority of the questions were altered to enhance their applicability to clinical practice. For example, in addition to asking how confident clinicians were in identifying when retention had been achieved, they were also asked to pick a statement that best described how they would determine whether a patient had learned the target skill. In this manner, the options were more relevant and meaningful to the clinicians participating in the survey while still obtaining the desired information. Additionally, the Likert-type scale that assessed the clinicians' confidence with the various ML theories and principles included anchors at all seven points. This was done to decrease the variability present between the answers (McKelvie, 1978) and increase the sensitivity of the scale to hopefully prevent the "neutral" mid-point, four in this case, from being over-used when the clinicians were unsure of their actual confidence levels (Chyung et al., 2017). Response numbers and the associated anchor points are provided in Table 2.

Table 2. Response anchors from the second survey

Response Number	Anchor
1	Not confident at all
2	Limited confidence
3	Mildly confident
4	Somewhat confident
5	Moderately confident
6	Very confident
7	Extremely confident

Part C was comprised of 12 questions on the clinicians' ML-related education, which included multiple choice questions, multiple select questions, and opportunities for brief written answers. Overall, this section was shortened based on the results of the first survey and excluded questions relating to the workshop held in November. This section also excluded questions relating to journal clubs but included more options for resources that clinicians had used or felt would be beneficial to them in the future.

The final section, Part D, included seven questions on the barriers and facilitators clinicians face when attempting to integrate ML into clinical practice. The seven questions were comprised of multiple choice and multiple select questions, as well as brief written options. Additionally, questions about the ML theories and principles that clinicians found easiest and most challenging to integrate were added, as well as a question about the overall relevance of ML to their clinical practice.

4.3.1.3 Data Analysis

The data analysis was descriptive in nature. Each survey (n= 63) was reviewed by the principal investigator (MMM) and questions were categorized based on the associated survey parts. Demographics were compiled into a table, while the confidence levels were assessed based on the average and standard deviation, which was automatically calculated by the survey program, Qualtrics. Many of the questions with numerical responses were compiled into tables, while all the written responses were assessed for general trends or outlying opinions.

4.3.2 Results

4.3.2.1 Feasibility

Overall, the second survey had a larger sample size compared to the first survey. A total of 63 responses were recorded, however, three surveys were submitted prior to changes being reflected within the published version of the survey. Of these three surveys, two were completed only to the informed consent, and therefore had no bearing on the results. However, one survey was completed in its entirety, and given the nature of the changes made to the questions (e.g., the Likert scale), this survey was excluded from the statistical results (e.g., figures, tables). Therefore, a total of 60 responses were included within the results section, 40 of which (66%) were fully completed. This is an increase in completion rate compared to the first survey, which saw only 9/28 (32%) of clinicians completing the survey.

Of the survey responses that were partially completed (20/60), the majority completed the Demographics and Knowledge and Understanding of ML Theories and Principles (Parts A and B, respectively). Most clinicians who did not complete the entirety of the survey dropped out half to two-thirds of the way through, while four stopped after the informed consent section, and two completed the entirety of the survey except for a final couple of questions.

Despite the greater completion rate, length continued to be a slight concern, although not to the same degree as the initial survey. Of the 40 clinicians who completed the entire survey, the time to completion ranged from two minutes to three hours 46 minutes. However, it is important to note that participants had the option to exit the survey and come back to it at a later point in time. Additionally, the time to complete the survey also represents the time that it was open on their computer, not necessarily how much time they spent completing the questions, which may have skewed the time to completion. The majority of clinicians (30/40) completed the survey in under 30 minutes, while only four took longer than one hour.

In addition to the greater completion rate for the second survey, a few clinicians who opted to participate in the interview component commented on the relevancy of the survey to clinical practice; stating that the structure of the questions allowed them to take as much away from the survey as they were giving back. A few mentioned that while completing the survey, they were able to begin thinking about how the various ML theories and principles could be integrated into their practice in the future, and subsequently, were able to immediately alter some components of their clinical sessions to reflect recommendations from the ML-related literature better.

4.3.2.2 Demographics

Similar to the first survey, the majority of participating clinicians were practicing PTs or OTs who had completed either a Bachelor's degree or a Master's degree in their chosen field. Given the broader distribution of the survey, however, there was more variation within the clinical areas where the clinicians worked; there was a near even mix of clinicians working in acute care, in-patient rehabilitation, and out-patient care. While clinicians had the option of selecting multiple primary patient populations, geriatrics and neurology (stroke and non-stroke populations) made up a clear majority. Interestingly, when clinicians expanded upon other primary patient populations, the majority worked in a pediatric setting (e.g., neonatal motor development, pediatric neuromuscular issues). The years since clinicians graduated from their professional programs span 32 years (1988-2020), with 2019 being the most common year of graduation. With the exception of three clinicians who were working in the UK, every other clinician worked in Canada. Table 3 outlines the demographic information in more detail.

Table 3. Demographics of the Clinicians who Participated in the Second Survey

Demographic Measure	Number of Responses (n = 57)
Highest Level of Completed Education	
Diploma	1
Bachelor of Science	17
Master of Science	33
PhD	4
Other	2
Degree Program Completed	
Physiotherapy	44
Occupational Therapy	10
Speech/Language Pathology	3
Years of Clinical Experience	
0-5	15
6-10	7
11-15	7
16-20	10
20+	18
Current Job Title	
Clinician	47
Researcher/Scientist	3
Administrator	2
Educator	3
Other	2
Primary Clinical Setting	
In-patient acute care	16
In-patient rehabilitation	14
Out-patient care	13
At home care	5
Other	5
N/A – Do not work in a clinical setting	4
Primary Patient Population*	
Geriatrics	32
Stroke	31
Neurology other than stroke (e.g., TBI)	31
Musculoskeletal Conditions	20
Cardiorespiratory conditions	17
Complex medical populations (e.g., chronic renal disease)	17
Critical Care (ICU, CCU)	9
Other	7

*Clinicians had the option to select more than one population

4.3.2.3 Integration of Motor Learning Theories and Principles

In the second survey, there was a total of 13 ML theories and principles assessed. Questions relating to the clinician's confidence were primarily asked in two ways; 1) rating their confidence in adjusting components of their practice in accordance with recommendations from the literature, and 2) rating their confidence in identifying and discriminating between key parts of various theories and principles. Overall, the average confidence levels fell between 4.43 and 5.45 on a 7-point scale (1-7). Confidence levels were lowest for the ability to *adjust instructions or feedback to promote an external focus of attention* (4.43 ± 1.33), and highest for *the ability to implement whole-task practice for continuous skills* (5.45 ± 1.08). A*djusting instructions and feedback to promote an external focus of attention, implementing random-order practice schedules, delaying or reducing feedback frequency*, and the *ability to implement whole-task practice for continuous skills* had a response range of 1-7. All other ML theories and principles assessed had a range of 2-7. However, the *ability to implement whole-task practice for continuous skills*, despite having one of the largest ranges, had one of the smallest SDs and was the principle that clinicians felt most comfortable with. Figure 3 illustrates the ML theories and principles, and the associated confidence levels, in more detail.

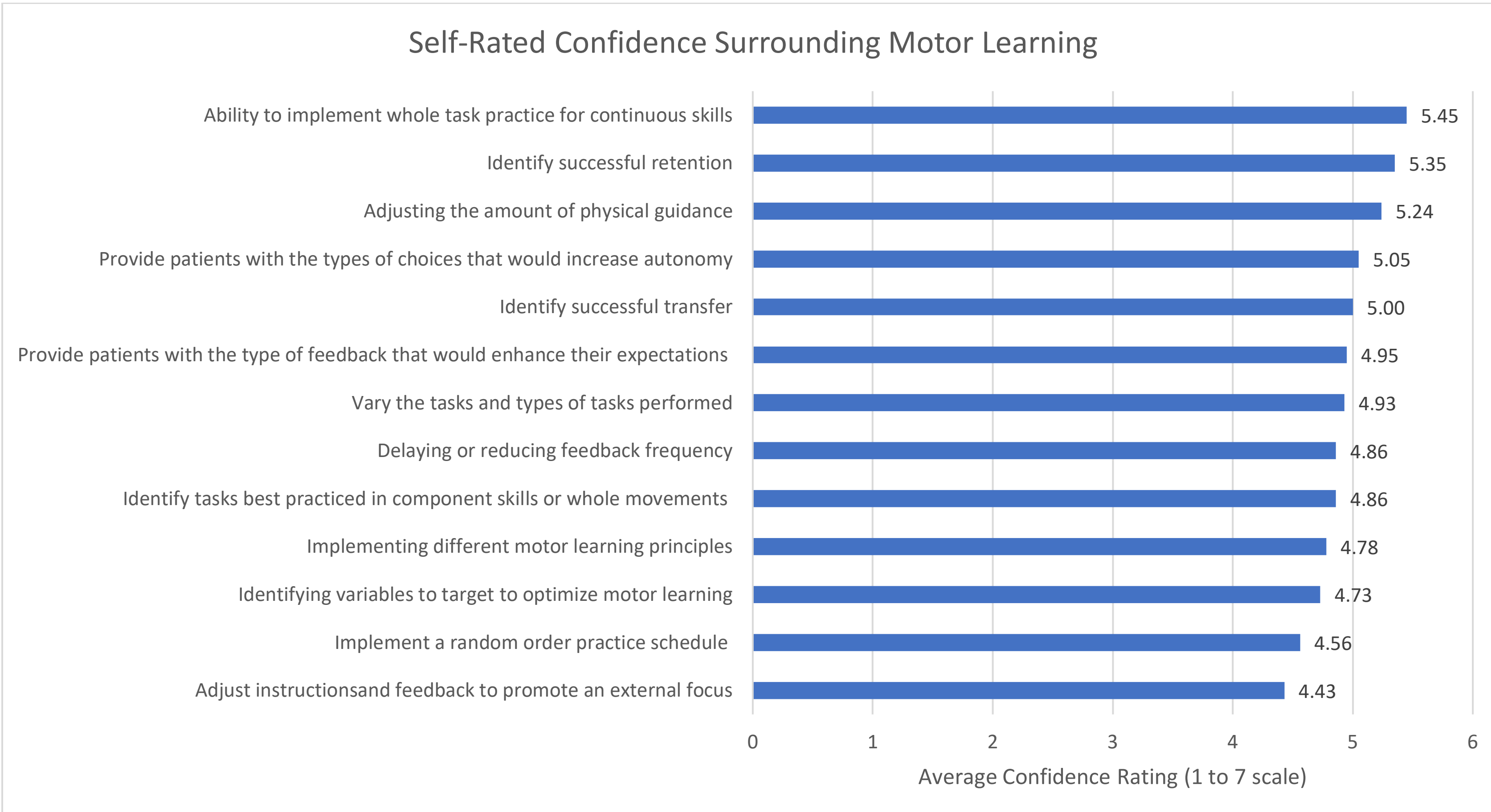

Figure 3. Average confidence levels of clinicians implementing various ML theories and principles into their clinical practice. Data labels represent the average confidence levels as reported by clinicians on a scale from 1-7. The assessed ML theories and principles are displayed horizontally.

Interestingly, there seemed to be some agreement between the degree of confidence that clinicians had with various ML theories and principles and the frequency with which the principles were utilized in clinical practice setting. *Implementing whole task practice for continuous skills* (highest average confidence) and *adjusting instructions and feedback to promote an external focus of attention* (lowest average confidence) were similarly ranked in terms of their frequency of use. *Whole task practice for continuous skills* was the principle cited as having the highest frequency of use (Table 4), however, *providing feedback or instructions with an external focus of attention* was second from the bottom. *Promoting autonomy, incorporating a variable practice schedule*, and *random practice* were all even in terms of the amount of confidence clinicians had and how often they were cited as being used within clinical practice. The final three principles (*reducing physical guidance, enhancing expectations,* and *decreasing or delaying feedback*) had some discrepancy between confidence and frequency of use. Most interestingly, *enhancing expectations* was cited as being used the most infrequently, but had an average confidence level in the top 50%. The same also held true for *adjusting the amount of physical guidance*; wherein the average confidence that clinicians had incorporating the principle into clinical practice was comparatively higher than its reported frequency of use. The opposite was true for *reducing or delaying the frequency of feedback*; it was cited as being used relatively frequently in clinical practice, but the associated average confidence level was in the bottom 50%.

Table 4. Motor learning theories and principles previously used

ML Theory or Principle	Number of Responses* (n = 42)
Whole task practice for continuous skills may improve learning	34
Promoting learning autonomy can enhance learning	29
Reducing or delaying feedback can enhance learning	28
Variable task practice promotes better retention and transfer	26
Excessive physical guidance can impede learning	24
Random practice can enhance learning	23
Providing feedback or instructions with an external focus of attention	22
Promoting enhanced expectations can enhance learning	19
None of these strategies	1

*Clinicians were able to select more than one option

In addition to assessing their confidence with various aspects of ML theories and principles, the clinicians were also given opportunities to provide examples of how they typically *integrate* ML into their clinical practice. One of the areas that clinicians had the least confidence in was their ability to implement a *random order practice* schedule. Of the responses to this question, 49% (22/45) of clinicians stated that they practice several different tasks within one session in a variety of ways, practicing multiple repetitions of Task A, then Task B, then Task C, which is indicative of blocked practice. In contrast, the option that was aligned with random order practice (moving back and forth between Task A, Task B, and Task C throughout the practice session), was selected by 29% (13/45) of clinicians. The other two response options (devoting a session to practicing a single task over and over and "it depends") were selected by 2% (1/45) and 20% (9/45) of clinicians respectively. Clinicians who selected the "it depends" option were given a space to elaborate further; the majority stated that the types of tasks involved in the session, task complexity, and the patient's cognitive and learning abilities influenced how much variability they incorporated into their clinical sessions.

Acquisition, retention, and transfer are three components of learning that allow a clinician to track and measure their patient's progress objectively. When asked how they would assess the acquisition, retention, and transfer of a transfer skill (moving from a bed to a wheelchair), most clinicians would assess their patient's ability to execute a similar task. See Table 5 for a breakdown of the responses.

Table 5. How do clinicians determine learning has occurred

Response Option	Number of Responses* (n = 50)
Observe or test their performance at the beginning of the next therapy sessions	27
Observe or test their performance on the practiced skill (e.g., transferring out of a wheelchair) and an unrelated practiced skill (e.g., transferring to a regular chair from a bed)	27
Observe or test their performance of the skill at the end of the week(s) or after multiple sessions	21
Assess patient using a standardized outcome measure at key points in rehab (e.g., FIM, Berg)	19
Observe or test their performance of the skill during the therapy session	19
Observe or test their performance of the skill at the end of the therapy session	16

*Clinicians were able to select more than one option

The timing of feedback delivery was another area where clinicians were assessed on how they integrated the ML principle into clinical practice. The most common response to the question "Which of the following statements best describes how you will determine whether the patient has learned the skill?" was "it depends", selected by 38% (19/50) of clinicians. Common considerations included safety, patient ability or stage of learning, cognition, and environmental/learning context. In addition to it depends, 26% (13/50) stated that they provide feedback after the patient attempts the skill a few times, 24% (12/50) provide feedback as soon as the patient makes an error (including mid-performance) to allow for error correction, and 12% (6/50) provide feedback immediately after the patient performs the skill, and after every attempt.

Although the timing of feedback delivery can be generally considered, the phrasing of the feedback can also be modified to promote an internal or an external focus of attention. An internal focus of attention was preferred by the participating clinicians; 42% (20/48) stated that they typically provided feedback promoting an internal focus of attention, while only 17% (8/48) typically provided feedback that promotes an external focus of attention. An additional 6% (3/48) were not sure how they typically delivered feedback, and 35% (17/48) chose the option for “it depends”. Considerations for “it depends” were, again, patient ability, stage of learning, and environmental/learning context. However, there was a common theme of clinicians providing both internal and external feedback; often starting with more internal feedback, and as the patient becomes more familiar with the task, and better able to demonstrate advances in learning, the clinician would slowly transition to feedback promoting an external focus of attention.

While most questions within this part assessed the participant’s confidence with individual ML theories and principles, as well as how they integrate some of the key components within their clinical practice, Table 6 outlines how relevant the clinicians felt ML is to their clinical practice. In general, most clinicians felt that ML was very or extremely relevant to their practice, with both answers receiving 33% of the responses. However, when provided with the opportunity to explain their choices, there was a surprising degree of variability. Although most clinicians felt that ML had a high degree of relevancy, allowing them to have more structure within their clinical sessions, provide patients with an increased sense of motivation, and offer a method to provide sound, clinically relevant therapy, a few stated that their patient populations precluded them from maximizing the efficacy of ML. Additionally, a few responses centred around the emergence of normal movement patterns; some clinicians asserted that ML had limited benefits until their patients could execute these movement patterns more independently.

Table 6. Relevance of motor learning theories and principles to clinical practice

Relevance to clinical practice	Number of Responses (n = 42) (%)
Not relevant at all	0 (0%)
Slightly relevant	5 (12%)
Moderately relevant	9 (22%)
Very relevant	14 (33%)
Extremely relevant	14 (33%)

4.3.2.4 Motor Learning Related Education

The questions relating to education were primarily centred around the clinicians' experiences with ML in their initial professional programs, as well as future opportunities and resources that they felt would be beneficial. Table 7 outlines the responses on the amount of structured ML education that the clinicians received in their initial professional programs.

Table 7. Amount of ML education received in initial professional programs

Amount of ML education received	Number of Responses (n = 44) (%)
No time dedicated at all	6 (14%)
Minimal opportunity[1]	18 (41%)
Moderate opportunity[2]	15 (34%)
Significant opportunity[3]	5 (11%)

[1]E.g., a single lecture, no time to apply in lab or clinically
[2]E.g., a mixture of lecture and lab practice
[3]E.g., multiple lecture or lab sessions, a full course

The clinicians' views on whether the amount of structured ML education was enough to prepare them for clinical practice was split evenly down the middle; with 50% (22/44) believing that it was, and the other 50% believing that it wasn't.

Clinicians also provided information on the resources that they had used since graduating to support their application of ML principles into clinical practice. Table 8 outlines the resources that have been used, while Table 9 outlines the resources that the clinicians felt would be beneficial to support the integration of ML into future clinical sessions.

Table 8. Resources used by participants since graduating

Resource used	Number of times selected* (n = 42)
Peer mentors/colleagues	30
Continuing education courses/workshops	29
Online resources	22
Peer-reviewed research articles	17
Clinical practice guidelines	15
Community of practice to discuss cases	11
Textbooks	11
Case studies (written or video)	6
N/A – I haven't accessed any resources	5
Other	3
Posters	2

*Clinicians were able to select more than one option

Table 9. Resources that would assist the integration of ML into clinical practice

Resources wanted	Number of times selected* (n = 42)
Online resources	33
Continuing education courses/workshops	30
Peer mentors/colleagues	26
Community of practice to discuss cases	24
Podcasts	23
Clinical practice guidelines	20
Access to research articles to read on own time	18
Case studies (written or video)	15
Receiving relevant papers via email	15
Journal club	9
Textbook recommendations for reading	7
Posters	3
Other	0

*Clinicians were able to select more than one option

Using the same response anchors as seen in Table 2, the average of the clinician's self-rated confidence in their ability to critically appraise ML-related literature, and implement the relevant aspects into their clinical practice, was found to be 4.47 ± 1.37, or "somewhat confident".

It was found that 56% (24/43) of the clinicians had participated in a continuing education course or workshop. Of the continuing education courses taken, the vast majority were Neurodevelopmental Treatment courses. Other common responses included general neurological-based courses, stroke-specific courses, or seminars/webinars focusing exclusively on specific ML theories and principles (e.g., feedback, cuing).

4.3.2.5 Barriers and Facilitators to Integration

Table 10 and Table 11 represent the ML theories and principles that clinicians found the most challenging and the easiest to apply to clinical practice, respectively. While *whole task practice of continuous skills* seems to be the easiest ML principle to apply clinically, there was a surprising amount of variability present in the rest of the results. Interestingly, *reducing the amount of physical guidance provided to enhance learning* was ranked by the clinicians as simultaneously one of the most challenging and one of the easiest principles to integrate into clinical practice. *Variable task practice* and *random practice* seem to be consistent across both categories. Of note are the concepts of *autonomy* and *enhanced expectations*; they are both consistently the two principles that clinicians seem to have the most difficulty with from a clinical perspective. *Enhanced expectations,* in particular, had an average confidence level that was middle range, one of the lowest stated frequencies of use in a clinical setting, and cited least frequently when asked which principle was the easiest to integrate.

Table 10. Most challenging motor learning theories and principles to apply in a clinical setting

ML Theory or Principle	Number of times selected* (n = 40)
Excessive physical guidance may impede learning	14
Variable task practice promotes retention and transfer	13
Promoting learning autonomy can enhance learning	12
Promoting enhanced expectations can enhance learning	12
Random practice can enhance learning	11
Reducing or delaying feedback frequency can enhance learning	8
Whole task practice of continuous skills can enhance learning	6

*Clinicians had the option to select more than one principle

Table 11. Easiest motor learning theories and principles to apply within a clinical setting

ML Theory of Principle	Number of times selected* (n = 41)
Whole task practice of continuous skills can enhance learning	23
Excessive physical guidance may impede learning	18
Reducing or delaying feedback frequency can enhance learning	17
Variable task practice promotes retention and transfer	14
Random practice can enhance learning	11
Promoting learner autonomy can enhance learning	11
Promoting enhanced expectations can enhance learning	9

*Clinicians had the option to select more than one principle

When interpreting the results of Table 10 and 11, one does need to acknowledge that the clinicians had the ability to select more than one option, and it is unclear how many clinicians did select more than one principle. Additionally, the context that the clinicians were using to guide their responses was not known; the different patient populations of the participating clinicians alone may have impacted how the clinicians were viewing and applying the principles. Thus, the principle of reducing PG, while selected as one of the more challenging principles, was also selected as one of the easier principles to integrate within clinical practice.

Clinicians were asked what aspects facilitated their integration of ML into clinical practice, and what were some of the barriers that they faced. For the most part, there was a large degree of overlap between the barriers and facilitators present when integrating ML into clinical practice. Facilitators primarily centred around patient-specific characteristics, such as motivation, cognitive status, or commitment to therapy, as well as support and mentoring from peers and other clinicians. Generally, the clinicians reported that, the more intact a patient's cognitive or mental status, the easier it is to integrate ML. Additionally, peer support was not isolated to just other clinicians; having members of the multi-disciplinary health care team (e.g., physiotherapy assistants, occupational therapy assistants) and the patient's family members actively participating in *similar* approaches to therapy, and rehabilitation, facilitated the implementation of ML, and subsequently improved patient learning and outcomes. However, the opposite also constituted a barrier to integration; a few clinicians mentioned that when other members of the patient's care team were practicing in a manner that was inconsistent with ML principles, it made it difficult to realize the full benefit of using concepts such as reduced feedback or PG within their clinical sessions.

Where facilitators emphasized patient characteristics, barriers emphasized resources and environmental components of practice; a common barrier to integration was a lack of resources and environmental constraints. Clinicians emphasized wanting to be able to provide therapy within an environment that could be manipulated or altered to introduce variability into the clinical sessions. While there was inconsistency in the root cause of this barrier, adequate resources (e.g., equipment) seemed to be the most common.

While the above barriers and facilitators had a relatively high degree of consistency in the responses, the most frequently mentioned barrier and facilitator, by a large degree, was time. Time was mentioned in 42% (14/33) of the responses relating to barriers to integration and slightly less at 33% (10/30) of the responses relating to facilitators. Interestingly, a lot of the responses that cited time as a barrier centred around caseload volumes; the feasibility of exploring ML theories and principles in a clinical context seems to be reduced by the number of patients that a clinician must see in a day. Many clinicians stated that if their caseloads could be altered to have more opportunities for 1:1 time with their patients, it could increase the utilization of ML theories and principles within the context of their clinical sessions.

4.4 Discussion

4.4.1 Confidence Integrating Motor Learning into Rehabilitation

One of the objectives of the quantitative portion of this study was to describe how confident clinicians are integrating ML theories and principles into their clinical practice, and to assess how they integrate key principles within a rehabilitative setting.

Based on the rating scales used, the clinicians were found to be somewhat- to moderately-confident with the integration of the chosen ML theories and principles into their clinical practice. However, there was a great deal of discrepancy between the confidence levels found among the individual ML theories and principles assessed across both surveys. Given the differences in the scales used to assess confidence between the first and second surveys, the order of the principles, when arranged by descending confidence level, does give some insight into these differences. One area of difference is the confidence clinicians had *adjusting or delaying the amount of physical guidance* provided to patients; with a comparatively higher average confidence level in the second survey compared to the first. A similar difference was seen with the principle of *reducing or delaying feedback frequency*, while *providing feedback that promotes an external focus of attention* was skewed in the opposite direction. The discrepancies between the two scales used in the surveys (e.g., 10-point versus 7-point) made it difficult to comment on the differences in average confidence levels. In addition to the differences in the scales, another major difference between the two surveys was the wording of the questions asking about confidence. In the first survey, many of the questions were more hypothetical or knowledge-based, asking clinicians how confident they would be distinguishing between two variables, or their confidence identifying the appropriate contexts or situations to apply a certain principle. In contrast, the second survey emphasized the implementation of the principles, asking questions on how confident the clinicians were applying them to their clinical practice. Thus, the phrasing used in the second survey could have increased the relevancy of the questions to clinical practice in a manner that allowed them to resonate more with the clinicians, and as such, may have promoted the general trend of increased confidence in the assessed principles.

In addition to the difficulties directly comparing confidence levels between the two surveys, the scarcity of information surrounding clinicians' confidence with ML makes comparisons to the current body of literature even more challenging. Using a 1-5 Likert scale on a continuum from "strongly disagree" to "strongly agree", Atun-Einy & Kafri (2018) also found mid-range self-efficacy scores in their survey on the relevancy of ML to PT practice. However, while comparable, the scores from the second survey do seem to be slightly higher on average. For example, Atun-Einy & Kafri (2018) asked their participants to respond to the statement "I feel confident that I can provide treatment based on the principles of motor learning" and received an average of 2.98 ± 0.89, which was slightly above the mid-line of their scale. In comparison, clinicians were asked in the second survey to rate their confidence implementing different ML principles, and the average confidence was 4.78 ± 1.16 on a scale from 1-7. Differences aside, there does seem to be more relation in the range of confidence levels between the second survey and previous literature versus the first survey.

What was moderately surprising about the results from the second survey was how the confidence levels compared against one another. In particular, clinicians seem to have a very high degree of confidence in their ability to implement *whole task practice for continuous skills*, which was also rated as the easiest principle to use and the principle that clinicians implemented most often prior to completing the survey. Within the ML literature, there is very little that emphasizes the use of whole-task practice within a clinical setting. However, given that a large portion of the participating clinicians work within neurorehabilitation (stroke and non-stroke populations), it could be assumed that a lot of their patients may be presenting with the types of motor deficits (e.g., walking) that typically benefit from whole-task practice. In this regard, the patient populations may contribute to how confident the clinicians are using this principle over the other ones assessed. Additionally, the patient populations may also explain the ease with which continuous skills are implemented and the reported frequency of use.

In contrast to the slightly surprising result of the ML principle that clinicians had the most confidence with, the ML principles with the lowest associated confidence levels, implementing a *random order practice schedule* and an *external focus of attention*, were expected. Despite random order practice being relatively “middle-ground” in terms of how difficult clinicians find the principle to apply, and how frequently it is used in clinical practice, it was one of the most frequently mentioned principles in written comments discussing barriers to integration, typically within the context of a lack of knowledge or understanding. As can be seen in the assessment of clinician’s knowledge done by Barker et al. (2015), only 44.2% of clinicians correctly stated that random practice would enhance the learning of an individual attempting to learn several different sports-related skills. In contrast, 76.9% of clinicians identified the correct skills best practiced in their entirety (whole task practice) compared to skills that are best practiced as component skills (Barker et al., 2015).

As opposed to the lack of knowledge and understanding that seems to underlie the lower confidence associated with random practice, it can be assumed that the novelty of an external focus of attention is contributing to the associated confidence level of this ML principle. While the promotion of an external focus of attention is not truly a novel concept in rehabilitation, or the literature, this ML principle has recently received renewed interest within context of motivation and the OPTIMAL theory. Given the delay between research and the translation of the knowledge created by the research into clinically relevant guidelines (Juckett et al., 2020; Moore et al., 2017), it is not outside the realm of possibility that this principle, as outlined and described within the recent literature, has simply not yet made it into everyday clinical practice. However, given the ease with which an external focus of attention has been successfully integrated into research contexts, and the lack of confidence that clinicians in this survey displayed with this principle, it further highlights the need for effective KT within the field of rehabilitation science. What is interesting, however, is that the other two components involved in the OPTIMAL theory, autonomy and enhanced expectations, scored much higher in terms of confidence. Currently, a unique aspect of this study is that it directly examines all three components of motivation involved in the OPTIMAL Theory. While other studies have assessed clinicians' use of an external focus of attention (Johnson et al., 2013; Kal et al., 2018), none have assessed their confidence providing patients with autonomy supportive choices or placing patients within situations that would enhance their expectations for future performance. One possible explanation for the increased confidence levels with these two components is that, compared to an external focus of attention, autonomy and enhanced expectations may be integrated more naturally into clinical practice. As reported by Atun-Einy & Kafri, (2019), PTs tend to be very intuitive when using ML principles, and instead of planning out their sessions and consciously thinking of which principles will be used and when, the use of ML typically occurs on an ad hoc basis. Although clinicians may not be consciously aware of when they are providing autonomy supportive choices or enhancing expectations, interviews done by Maclean et al. (2002) on methods of increasing patient motivation in stroke rehabilitation emphasize that intention is not always required to have a positive effect; 56% of the clinicians interviewed stated that allowing their patients to set goals for themselves (autonomy) had a positive effect on patient motivation. It does seem that, while often not labelled as “autonomy supportive choices” or “enhanced expectations”, these two concepts of motivation are used quite naturally in rehabilitation by clinicians. Thus, the predilection towards these two ML principles may account for the increased confidence levels, while an external focus of attention, although still encompassed by motivation, is not as intuitive owing to the need for a baseline theoretical knowledge.

In addition to assessing confidence levels, one of the strengths of the second survey was that clinicians were able to provide examples of how they integrate certain principles within their clinical practice. Although comparisons of confidence levels between the two surveys and other papers is challenging, this format does allow for a direct comparison between how clinicians are integrating certain principles into clinical practice and how the literature recommends that they be used. There were four ML principles that were assessed in this manner; measuring and differentiating among acquisition, retention, and transfer (counted as one principle), random practice order, feedback frequency, and internal versus external focus of attention. In general, clinicians were assessing retention and transfer in a manner that is consistent with recommendations from the literature; assessing retention at the beginning of the next session, or after time has passed, and utilizing similar skills to test the generalizability of what has been previously learnt. In contrast, the other three ML principles assessed had varying degrees of separation between how the clinicians are practicing and what is recommended. Adjusting instructions to promote an external focus of attention had the lowest average confidence level of all the ML principles assessed and was one area where clinicians were consistently practicing in a manner that contradicts recommendations. As reported by Beck et al. (2018) in their single-blind RCT, the dual task step time for a group of individuals with PD increased with an external focus of attention, and was hypothesized to improve the functioning of autonomic control networks. However, despite the positive results from this study, and others, 42% of the responses to this question in the second survey reported that the typical content of their feedback and instructions was internally focused, while only 17% was externally focused. Additionally, 35% indicated that "it depends" and 6% were unsure. These results are consistent with those of Johnson et al. (2022), who, on observing clinicians during therapeutic interactions with patients, reported that 56% of instructions delivered were internally focused, while only 13% were externally focused.

Delaying feedback or reducing the frequency with which feedback is provided was another ML principle found to have a lower average confidence level in both surveys. While the timing of the delivery of feedback was found to be very dependent on patient characteristics, clinicians tended to indicate that they provide immediate and frequent feedback to their patients; 24% of clinicians in the second survey stated that they typically offer immediate feedback, 12% typically offer immediate feedback after every attempt, and 26% typically offer feedback after a few attempts. Again, this is consistent with other studies, primarily observational in nature, where it has been noted that clinicians provide very frequent feedback to their patients, at times verbalizing one feedback statement every 10-14 seconds (Johnson et al., 2013, 2022).

The final ML principle assessed, blocked versus random practice, is one area with little background within the current body of literature. While published studies offer support for the effects of increased randomization within the structure of a clinical session, there is limited information available assessing how clinicians utilize this concept within their practice. Atun-Einy & Kafri (2018) found that the majority (56.2%) of clinicians in their study implemented variable practice to a large or very large degree; however, they did not include quantifiers on what variable practice was, and as such, clinicians were operating on their own definition of the term. Blocked and random practice do fall under the umbrella of variable practice; however, most of the current literature favours the use of random practice over blocked practice in terms of positive, long-term effects on learning. Where this survey offers a new insight is by *differentiating* blocked from random practice within the question options. Contrary to what the literature supports as being more effective, 49% of clinicians within the second survey selected blocked practice as their primary method of introducing variability within their clinical sessions. Thus, future research should consider this distinction when observing how clinicians implement variable practice to assess the full extent of how all components of this ML principle are being utilized.

4.4.2 Motor Learning Related Education

When considering the results of both surveys, one of the most prominent differences was around the perceptions of clinicians on the ML education that they received in their initial professional programs. Whether or not the amount of structured education was enough to prepare them for clinical practice had a perfectly even split in the second survey. These results were similar to the results of Bramley et al. (2018), who evaluated clinician educators on the ML-related content of initial professional programs; 62.5% of their participants believed that the ML portion of professional education is adequate, and 37.5% stated that it is not, or that they are not sure. However, the first survey results were skewed towards no, with 79% (11/14) believing that it was not enough. The demographics of the participating clinicians, in particular the practice area, may explain some of the discrepancy between the answers to this question. In the first survey, most of the clinicians were practicing in a specific area of rehabilitation, neurorehabilitation, primarily with individuals who have experienced a stroke. In contrast, the clinicians participating in the second survey had a broader range of patients. The specificity of the patient population within the first survey may require a more in-depth knowledge and understanding of the ML theories and principles being utilized within the scope of the clinicians' clinical interactions with patients. In contrast, having a broader patient population may not require as in-depth of knowledge, and therefore, may have led the clinicians participating in the second survey to believe that the ML component of their initial professional program was adequate.

In addition to the demographics, the number of responses to this question in the first survey does contribute to this discrepancy, and although it is interesting to note the stark difference in the results to the same question, perhaps more meaningful to the scope of this study are the explanations given by the clinicians for their choice. While the numerical results are split evenly in the second survey, the written answers across *both* surveys take a slightly negative outlook on the ML education found in initial professional programs. In particular, clinicians felt there were not enough opportunities to practice implementing the ML theories and principles in a clinically relevant manner. This comment was echoed by the majority of clinicians across both survey iterations.

While the majority of written comments expressed slightly more negative views on their ML education, there were also comments in favour of the breadth and depth of their professional degrees. Given the comments on the lack of laboratory-based exposure to ML found among clinicians who answered "no", it is not surprising that many of the comments favouring the education they received mentioning multiple hands-on opportunities, labs, and clinical experiences. In contrast to the practice of physiotherapy, which is arguably a very hands-on profession, ML is a very theory driven concept. It has been shown that, if ML education is delivered via an active learning style (e.g., labs), it can increase students' self-efficacy and knowledge of ML concepts during objective assessments (Vaz et al., 2021). Furthermore, there is agreement within the current body of evidence stating that learning in a clinical context, and actively participating in interactions with patients, is preferred over classroom or didactic learning (Ernstzen et al., 2009; Lindquist et al., 2004). However, this clear preference is in direct opposition to how PT programs are typically taught across Canada; the majority of programs deliver ML-related content via didactic style lectures, with a high degree of variability in opportunities for clinical engagement (Bramley et al., 2018).

Despite the majority of clinicians believing that their ML-related education was enough to prepare them for clinical practice, there are some gaps present when considering their current body of knowledge. A survey study conducted in 2015 found that despite a high overall knowledge of ML principles (78.5%), certain principles (e.g., focus of attention, random order practice) scored much lower in comparison (Barker et al., 2015). These areas were consistent with areas identified by this survey as having a lower confidence level (e.g., promoting an external focus of attention), of having methods of integrating ML within clinical practice that are not consistent with current evidence (e.g., preference of blocked over random practice), or both.

How professional programs teach ML-related skills, and the clinician's subsequent body of knowledge was mentioned as being within the scope of the requirements for *entry-level* practice. Clinicians felt prepared to enter clinical practice given the expectations for their knowledge upon completing their degree. Interestingly, within the current literature there are no papers that expand upon the distinction between entry-level ML knowledge, and the knowledge base of clinicians who have been practicing for a number of years. However, when considering the expected professional competencies of newly graduated PTs, the Canadian Council of

Physiotherapy University Programs outlines the expected ML knowledge within their section on movement science, specifying that the effects of practice, feedback, and cognition are among the core competencies required for graduation (Canadian Council of Physiotherapy University Programs, 2019). Even though these ML principles are a component of the knowledge required for PTs to practice, the Canadian Council of Physiotherapy University Programs states in their curriculum guide that, since some of the areas listed as core knowledge may have been previously obtained in undergraduate learning or pre-requisite courses, "… not all of [the] topics are consistently included within a professional entry-to-practice physiotherapy program curriculum" (Canadian Council of Physiotherapy University Programs, 2019, p. 12). This sentiment was echoed by the clinicians participating in the second survey who stated that their current knowledge of ML related concepts primarily stems from their undergraduate degrees, most commonly a Bachelor of Science in Kinesiology. Additionally, given the minimal guidance outlined in the requirements for entry-to-practice programs, it is ultimately up to the individual programs to determine the breadth and depth of the ML-education provided. This degree of variability has been exemplified by the perspectives of PT students undergoing their professional degrees across multiple different Canadian institutions (Bramley et al., 2018). Additionally, when considering how ML is taught in OT and SLP entry-to-practice programs, there is little information available outlining entry to practice requirements related to this specific content area – making it difficult to draw conclusions about the pre-existing knowledge base of OTs and SLPs. Considering the current core competencies for OT and SLP programs, the required knowledge and understanding of ML theories and principles may not be explicitly mentioned for Canadian programs (Canadian Association for Occupational Therapists, 2021; The Canadian Alliance of Audiology and Speech-Language Pathology Regulators, 2018).

4.4.3 Barriers and Facilitators

Time was by far the most universal barrier to integrating ML, and one of the most commonly cited areas that, if changed, would promote the uptake of more effective rehabilitative practices. This concept has also been reiterated in multiple qualitative studies on this topic. In one report, Salbach et al. (2007) found that 82% of their participants cited time as a major barrier to integrating EBP into clinical practice. While not specific to the integration of ML, given the scarcity of ML-related literature, and the participant population used in the referenced study (PTs), the relevance should not be understated. Additionally, when directly assessing the perspectives of PTs on the integration of ML, time as a barrier was also referenced by Atun-Einy & Kafri (2019). Interestingly, despite time being mentioned by a large majority of the clinicians participating in the second survey, it was most frequently mentioned in reference to the demands associated with working in an acute-care setting. Even though the anonymous nature of this survey does not allow for an in-depth consideration of the barriers and facilitators that may be unique to different fields of rehabilitation, it does present a novel research gap. Previously, participants have been generalized into one large demographic (e.g., PTs, OTs), or else members of a very specific demographics (e.g., working within stroke rehabilitation). However, one area that has received little attention within the literature is a comparison of the experiences of clinicians with ML (including barriers and facilitators) across different fields of rehabilitation.

Another interesting finding within this section was how infrequently a lack of knowledge was mentioned as being a barrier. When a lack of knowledge was mentioned, it was typically not mentioned as a specific barrier, and was usually referenced when speaking of the difficulties integrating variable and/or random practice into a clinical setting. In the same study done by Atun-Einy & Kafri (2019), a lack of knowledge of ML principles was cited as being the largest barrier to the integration of ML, with 38.2% of responses centering around this topic. In contrast, only one clinician in the second survey reported that a lack of knowledge and understanding constituted a barrier. One possible explanation for the discrepancy between previous literature and this study is that this study had a large proportion of the responses come from recent graduates. Given that many of the participating clinicians graduated in 2019, much of the information learned in their initial professional program, including ML, may still be "fresh" in their minds, reducing the impact of a lack of knowledge that may otherwise be seen in populations with more years in clinical practice. Another potential explanation is simply the limited number of usable responses (n = 35) to this question in the second survey. Given the low response rate, and the emphasis placed on a lack of time to practice, it could be that clinicians do have a limited understanding, but that time constitutes a *larger* barrier to the integration of ML theories and principles within the population surveyed. Nonetheless, given the limited emphasis placed on knowledge within the scope of the second survey, it is an area that requires future investigation to determine if clinicians' knowledge of ML has increased, and as such, has reduced the impact of this barrier.

Although many of the responses centred around time (as both a barrier and a potential facilitator), one unique facilitator mentioned was structured opportunities for engaging in continuing education or workshops surrounding ML. Structured educational opportunities was a frequently requested resources that clinicians felt would help to facilitate the integration of ML theories and principles into clinical practice. However, this seemed to come with the stipulation that the learning opportunities should involve peer-to-peer interactions, as well as mentoring opportunities from individuals who were experienced in the field of ML.

The current body of literature, this study included, commonly reports on the barriers clinicians face when attempting to integrate ML (or EBP) into their clinical sessions, with little emphasis placed on facilitators. However, given that a common facilitator mentioned by the literature are opportunities for continuing education and workshops, there is little in terms of recommendations on what *types* of opportunities would benefit the clinicians. Despite the second survey reporting that clinicians would like more peer support, the format and content of these opportunities should be further examined. In doing so, it would help to provide clinicians with workshops and other continuing education prospects that would be most beneficial to their learning and self-identified knowledge gaps.

Overall, the results generated from the surveys confirm what has been found previously in other bodies of literature. In general, clinicians have a moderate degree of confidence integrating ML into clinical practice, however, their methods for integrating ML may not be entirely consistent with recommendations from the literature. While the questions in the section on education went more in-depth into how ML is taught in professional degrees compared to previous works, the results continue to emphasize what is currently known. Additionally, the primary barrier of time has been well-established within the literature as a component of clinical practice that prevents the integration of ML theories and principles. The consistency between this study and other papers assessing similar topics has further highlighted the need for effective KT within this field. One method of obtaining this information is via qualitative research methods, such as interviews. In keeping with the sequential explanatory mixed methods approach taken with this study, the following chapter will address the research question and objectives from a qualitative perspective.

Chapter 5

Qualitative Work – Interviews

5.1 Introduction

Barriers to the integration of ML theories and principles, such as time and a lack of knowledge and understanding, have been previously established by published studies (Atun-Einy & Kafri, 2019; Salbach et al., 2007). These aspects of clinical practice have been found to prevent clinicians from utilizing ML theories and principles to their full benefit and therefore, have the potential to limit the overall efficacy of the rehabilitation provided.

As evidenced by the results of the quantitative phase of this study, there are still substantial knowledge gaps that relate to the integration of ML theories and principles into clinical practice. One area that warrants further consideration is the behaviours that facilitate or impede the integration of ML into practice. Additionally, effort should be put into identifying learning opportunities, as recommended by clinicians, that may assist with the translation of ML theories and principles into clinical practice. Therefore, the objectives of the qualitative phase of this study were to: 1) further explore how clinicians integrate ML into their clinical practices, as well as the barriers to and facilitators of successful integration; and 2) to elicit the clinicians' perspectives on potential KT strategies to enhance the translation of ML theories and principles into clinical practice.

5.2 Methods

5.2.1 The Theoretical Domains Framework

The Theoretical Domains Framework (TDF) was designed to identify sources that influence the behaviour of health care professionals to guide research in the field of implementation science (Atkins et al., 2017). With the objectives of this phase of the study centering around understanding the experiences and behaviours of clinicians to guide recommendations for KT opportunities, the TDF was used to help structure the interview questions and guide.

Drawing from 33 psychological theories, Michie and colleagues (2005) identified 128 relevant constructs, which were further distilled down to 12 constructs that were key in both understanding and *changing* the behaviour of health care professionals (Michie et al., 2005). In the initial version of the TDF, the 12 constructs were knowledge, skills, social/professional role and identity, beliefs about capabilities, beliefs about consequences, motivation and goals, memory, attention, and decision processes, environmental context and resources, social influences, emotion, behavioural regulation, and the nature of the behaviours (Michie et al., 2005). It is important to recognize that the TDF is not a theory. Rather than offering a means or explanation for the relationship between constructs, the TDF offers a lens through which to view the etiology of behaviour, both desired and realized (Atkins et al., 2017).

Although no formal guide exists that outlines exactly *how* the TDF should be integrated within research methodology, the framework has been used extensively within the field of implementation science and KT. Despite the lack of formal guidelines, the TDF was validated in a study done by Cane et al. (2012), which resulted in good support for the TDF and the generation of three key advantages to using it within implementation science; 1) a comprehensive view and outlook on the reasons behind why individuals execute certain behaviours, 2) a high degree of clarity behind the sources of behavioural influence, and 3) the ability to draw conclusions relative to why behaviours change and the proposed techniques for inducing desired behaviours (Cane et al., 2012). In addition to this validation study, these three benefits have also been extensively reported by researchers who have utilized this framework (Atkins et al., 2017).

Another outcome of the validation study was the development of a second version of the TDF, building and expanding on the components outlined by the Capability, Opportunity, Motivational-Behaviour framework. While the differences between the initial and second versions of the TDF are minimal, the initial version of the TDF has been found to have a broader range (Collet et al., 2016). In a systematic literature review of 552 papers, 36% were found to have barriers that were not covered within the scope of the second version of the TDF (Collet et al., 2016). While both versions have been validated and used extensively within the published literature, the broader scope found within the initial version, as well as an increased emphasis placed on barriers, was thought to be more conducive to the novelty of this research.

5.2.2 Recruitment

Upon completing the survey, clinicians were directed to a separate survey and asked to indicate their interest in a follow-up interview. Given that the first survey was used to inform the majority of the interview questions, all but one clinician was recruited via the second survey. Despite a range of clinicians participating in the surveys, it was decided beforehand that the scope of the interviews would be limited to PTs only. The rationale behind this decision was that, given the high degree of relevance that ML has to the field of physiotherapy (Kitago & Krakauer, 2013; Sampaio-Baptista et al., 2018), and the novelty of this research, this relevance may better lend itself to the generation of recommendations for future KT opportunities. Additionally, the relevance may promote the generation of stronger conclusions about the behaviours of the clinicians that contribute to the persistence of the barriers.

Following their self-identification, interested clinicians were emailed with a letter of information by the principal investigator (MMM) and a day and time was set for virtual interviews. Table 12 outlines the demographics of the participating clinicians in more detail.

As a thank you to the clinicians, and in recognition of them taking time out of their schedules to interview, they were all offered a $10 electronic gift card to a location of their choosing (e.g., Tim Hortons, Amazon, Chapters)

Table 12. Demographics of Clinicians who were Interviewed

Measure	Participant[i]						
	Henry	Justin	Mary	George	Jane	Laura	Emma
Years Practicing	10	32	10	31	3	30	3
Degree	MSc. in PT	PT Degree	MSc. in PT	BSc. In PT	MSc. in PT	PT Degree	MSc. in PT
Primary Clinical Area	Neurorehabilitation	General Practice	Neurorehabilitation	Adult/Geriatrics	General medicine/acute care	Neurorehabilitation	Acute care
Primary Clinical Population	Stroke	Variable[a]	Traumatic brain injury	Motor vehicle collisions & mobility issues	Variable[b]	Stroke	Variable[c]
Primary Clinical Setting	In-patient	Community-based	In-patient	Community-based	Acute care/in-patient	In-patient	In-patient

[i]The names of the participants represent pseudonyms used to maintain anonymity. [a]Primarily motor vehicle collisions and geriatrics. [b]Primarily general medicine. [c]Primarily high-acuity patients.

5.2.3 Interview Guide

Since the methodology for this study was a sequential exploratory approach, the results of the first survey were used to inform the general structure of the interview guide. Additionally, using the initial version of the TDF with 12 domains (Michie et al. 2005), the interview guide was designed to explore a wide range of perspectives and experiences of various ML theories and principles, as well as assess the barriers and facilitators that may impact the integration of ML into clinical practice. Sample questions include "to what extent do you provide physical guidance" and "what would the outcome be if these facilitators were removed or altered?".

The initial interview guide was developed by the principal investigator (MMM) in accordance with the TDF framework and was piloted with one co-author (AF) with experience in qualitative research. Following the completion of the first interview, the guide underwent minor revisions (primarily to the wording of questions) with input from both co-authors (AF, VD). See Appendix D for a copy of the interview guide.

5.2.4 Interview Protocol

Interviews were conducted virtually via Zoom (Zoom Video Communications, Inc.) during April and May of 2022. Given the in-person restrictions put in place by both Queen's University and Public Health due to the COVID-19 pandemic, virtual interviews were chosen as the sole interview method. One study conducted by Archibal et al. (2019) with nurses (also members of the allied health professionals) found that virtual interviews were a feasible alternative to in person interviews. Each interview was recorded with two devices; a Sony IC-Recorder as well as the audio and video recordings found on the Zoom platform (Version 5.10.4). Prior to each interview, the interviewer (MMM) explained the study purpose and interview protocol, as well as offering the clinicians time to ask any questions that they may have about the procedure. Verbal consent was obtained prior to the interview commencing, and explicit permission was given by the clinicians for audio and video recording.

Interviews started with some “ice breaker” type questions, such as primary work setting and patient population, both to provide context for each of the clinicians’ responses, and to allow them to become comfortable with the interviewer prior to discussing more in-depth topics. Clinicians were then provided with a definition of ML; a set of internal processes associated with practice and experience that result in relatively permanent changes to motor behaviour (Cano-de-la-Cuerda et al., 2015; Dayan & Cohen, 2011; Kantak & Winstein, 2012; Krakauer, 2006; Schmidt et al., 2019), and asked whether the definition resonated with them. Providing a definition of ML at the beginning allowed an understanding of how the clinicians view the concept before going more in-depth into how they approach various theories and principles. The interviews also explored the clinicians’ initial education, which included recommendations for hands-on opportunities and CE sessions, before discussing the barriers and facilitators that they have faced while integrating ML into rehabilitation. Where relevant, questions included probes that allowed for further elaboration or clarification of responses. At the end of every interview, clinicians were allowed to expand upon any areas that they felt required more discussion or offer comments on areas that were not covered within the scope of the interview.

All interviews were conducted by the principal investigator (MMM), who made brief notes on non-verbal aspects that may give context to the discussion, and any thoughts or ideas that may be relevant to the analysis process. Following the completion of each interview, the principal investigator took time to write reflections on how the interview had gone, draw connections between interviews or map out areas of overlap, and write out questions and areas of uncertainty based on what was discussed.

The clinicians' anonymity was protected by assigning a unique alpha-numeric number to all their artifacts and documents (e.g., video recording, audio recording, transcription etc.), and a pseudonym for use within the written portion of the research. On completion, the original audio recordings were securely stored on the hand-held recording device in the principal investigators' home. A digital copy of the audio recordings and the video recordings (Zoom) was securely saved on the principal investigator's password-protected laptop. These digital audio recordings were used as the primary source for transcription, with the Zoom recordings used as back up and to clarify any areas that were unclear. The principal investigator transcribed the first two interviews verbatim into Microsoft Word (2021), and the final five were transcribed verbatim by a professional transcription company, GoTranscript. The transcripts were then imported into a software program used for qualitative and mixed-methods analysis (NVivo 12, Version 12.6.1.970).

5.2.5 Data Analysis

The six major steps involved in reflexive thematic analysis (TA) outlined by Braun and Clarke (2021) provided the primary method for the qualitative analysis. Braun and Clarke describe TA as "… a method for developing, analyzing, and interpreting patterns across a qualitative dataset, which involves systematic processes of data coding to develop themes…." (Braun & Clarke, 2021, p. 4). Using reflexive TA allows for a critical reflection on the role of the researcher and the processes involved in both data collection and analysis (Braun & Clarke, 2021).

Although the TDF was used to guide and inform the interviews, an inductive analysis approach to data coding allowed for a more organic development of themes. Additionally, inductive analysis has been lauded for its ability to express the lived experiences and perspectives captured by the data set (Braun & Clarke, 2006), which is congruent with the aim of this study.

Following interview transcription, the principal investigator underwent data-set familiarisation. In this stage, it is recommended that the individual coding the data reads and re-reads the transcripts to "immerse" themselves within the data and become more familiar with the content (Braun & Clarke, 2021). Within this stage, each transcript and audio recording were reviewed multiple times. The principal investigator then advanced through the interviews chronologically and coded approximately 330 individual pieces of text within NVivo. To obtain a richness of the data, some codes, such as "*learning opportunities should be relevant and accessible*" and "*incorporating ML into clinical practice*", were semantic, or surface level codes; which remain true to the underlying meaning, often by mimicking the language used by the participants (Braun & Clarke, 2021). In contrast, some codes, such as "*having their hands tied*" and "*working outside of the culture*" were more latent in nature, where the meaning is often implicit or abstract (Braun & Clarke, 2021).

The third phase of data analysis involved the initial development of themes. From 15 codes, six initial themes were developed by grouping related codes together. For example, "*it depends*", "*minimal structure and guidelines*", and "*rehabilitation is changing and evolving*" were all grouped together under the working theme named "*variability*". During this process, the co-authors acted as "critical friends" to offer alternative ways of viewing the codes and themes that had already been developed. Thematic maps were also generated, allowing the researcher to assign visual relationships between the codes to aid in developing themes. See Figure 4 for a visual of the final thematic map.

Following the development of rough themes, as recommended by Braun and Clarke (2021), the principal investigator took a step back from the qualitative analysis to allow for fresh eyes when the codes and themes were revisited. Upon returning to the data, the transcripts were reviewed in a different order than the initial coding process. It was during this stage that the six themes initially developed were altered and distilled down to four unique themes, with one theme containing a sub-theme.

There was a great deal of overlap in the final two stages of the analysis process, which included refining, defining, and naming themes and the write-up. The themes were checked for clarity and content to ensure a central organizing component and that the theme had clear boundaries while not trying to encompass too much content (Braun & Clarke, 2021). Within the analysis and writing portion, the principal investigator aimed to portray an analytic story that would provide a rich overview of the interview content and the perspectives and experiences of the participating clinicians.

5.3 Results and Discussion

Overall, seven clinicians completed one semi-structured interview ranging between 52 and 67 minutes in duration. Following the analysis, four themes were generated, with one theme containing a sub-theme. The four themes were: 1) "*clinicians' approach to patient care"*, which involves the sub-theme: "*gaps and absent components of clinical practice*"; 2) "*working outside the culture*"; 3) "*nice in theory, but my hands are tied*"; and 4) "*variability in clinical decision-making pathways"*. Figure 4 outlines the thematic map, which includes the themes, the sub-theme, and the codes.

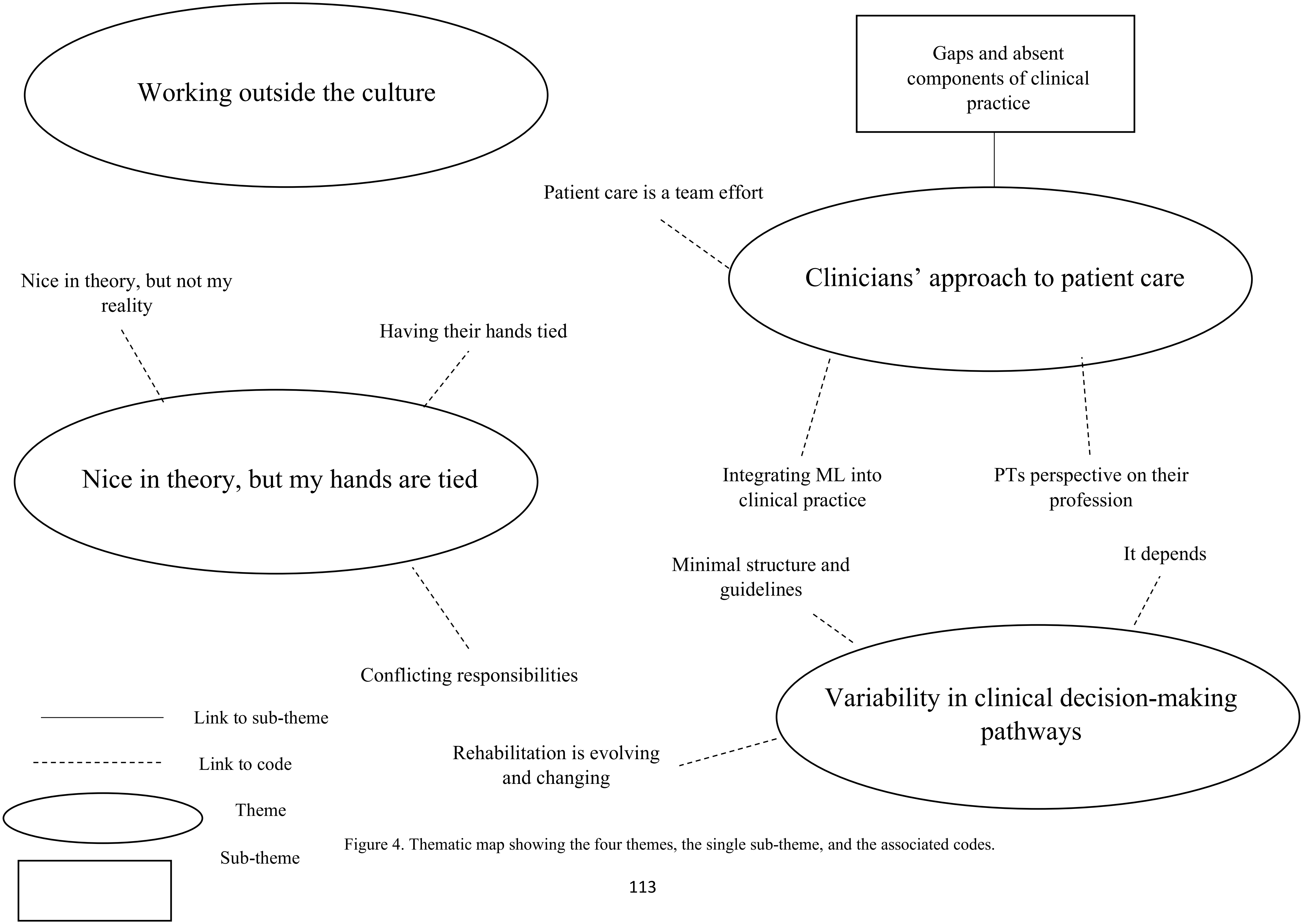

Figure 4. Thematic map showing the four themes, the single sub-theme, and the associated codes.

The themes are outlined and discussed below, with model quotes included for further clarity. While the first theme is primarily centered on the barriers and facilitators that clinicians experience while integrating ML into clinical practice, barriers have been identified across other themes. As a result, they may be discussed multiple times within each of the relevant themes. Discussion points outlining support from other bodies of literature and how these results may challenge the existing literature will be included in each theme.

There was a great deal of overlap between the themes in terms of the TDF domains that were used throughout the analysis to explain the behaviours and provide future avenues to aid in the integration of ML into clinical practice. The primary domains of the TDF that assist with the interpretation of these behaviours are Knowledge, Social/Professional Role and Identity, Social Influences, and Environmental Context and Resources.

Clinicians' approach to patient care

This theme, which is composed of one sub-theme (gaps and absent components of clinical practice), encompasses how clinicians approach rehabilitation and patient care, including the integration of various ML theories and principles, and some of the barriers and facilitators that they face while doing so. All the clinicians shared stories and anecdotes that highlighted patient experience as one of the most important determinants of their approach to rehabilitation. In doing so, the clinicians were found to take a primarily patient-centric approach to rehabilitation, frequently placing the needs and goals of the individual at the forefront of their rehabilitative efforts:

> … the word that you keep saying, experience, I want to help them experience, and I want to use all those … tools or components of motor learning … the environment, the type of task that they are going to be doing, how I'm going to modify them … (Henry).

Many of the ML theories and principles were mentioned by the clinicians within the context of adapting them to fit the individual's requirements and the environment in which the learning was occurring.

PG and feedback were the two ML principles that were mentioned the most frequently, often with a significant degree of overlap between them. In many instances, clinicians shared that they would provide their patients with the "… kinesthetic, verbal, [and] cognitive preparation…" for a movement, followed by "… the physical piece…" (Justin). It was interesting to note that many clinicians knew the central tenets of these ML principles; less can sometimes be more when assessing the long-term impacts on learning. However, many clinicians also noted that they frequently provided more PG and feedback to their patients than is potentially recommended in the literature. While the examples were given with the caveat that the amount of PG and feedback was dependent on the individual, there were concerns about the safety of reducing PG with acutely ill patients. Additionally, feedback was cited as one of the easier principles to use, primarily because it can be so readily adapted to meet the needs of the patient, the learning environment, or the task at hand. The patterns noted here are consistent with previous literature indicating that clinicians are consistently providing high amounts of both PG and feedback within their rehabilitative sessions (Johnson et al., 2013, 2022). Clinically, this may indicate that, although the rehabilitation being provided is not *ineffective*, it may not be as effective as it *could* be. By taking advantage of these ML principles with their patients, the clinicians may be able to further the individual's learning to promote the maintenance of the learning effects over a longer period of time.

Extending upon this notion, while clinicians do seem to have a solid understanding of the ML principles, many acknowledge that they may not be practicing in accordance with best-practice guidelines, noting that "… it's hard to find literature that speaks to the particular needs of each patient" (Laura). While previous literature has recommended that educational opportunities involve the integration of theoretical and practical knowledge (Atun-Einy & Kafri, 2019), it seems that clinicians also want a strong sense of peer-peer interaction within these opportunities:

> … it is hard to sometimes find the time to look through the literature, and sometimes it's hard to critically evaluate something on your own … I think maybe journal clubs could help with that, if people are dedicating time together to look at new research, and then talking about how you could actually implement it into practice; whether it's feasible or whether it's not feasible. (Jane).

The TDF highlights social support as an area of the domain "social influences" that can result in positive behavioural changes within the field of KT (Atkins et al., 2017). Social learning, which is the practice of observing, internalizing, and reproducing behaviour modeled by others (Horsburgh & Ippolito, 2018), is an efficacious way of improving the quality of health care that is provided by allied health professionals (Wilcock et al., 2009). Although clinicians indicated that further opportunities for social support would be beneficial to their clinical practices, little is known about how to best integrate these types of opportunities in the context of ML and rehabilitation.

In contrast to how social support was reported to facilitate the implementation and uptake of ML best practices, time was consistently stated by the clinicians as one of the most prominent barriers. Unlike some of the other barriers that were mentioned (e.g., safety within the context of reducing PG), time was relevant to the integration of almost every ML principle discussed while also impacting the uptake of ML-related best practices within rehabilitation:

> I would say I try to make it a priority but … with caseload demands and trying to balance everything else, ideally, we would have more time in the day to do some of this on work time but, it's not that it's not a priority, but we just don't have time … there's always a demand, it's nonstop. It's hard to find that time to prioritize getting that stuff done. It's at the sacrifice of patient care, but it's also not at the sacrifice of patient care. It's for the betterment of patient care. You end up doing it more on your own time ... (Emma).

While there are many domains within the TDF that can be utilized to explain the concept of time as a barrier, "environmental context and resources" has a high degree of relevance. This is in large part due to the sub-domain: "availability and management of resources", which emphasizes the systematic nature of this barrier. Furthermore, time has been well established by previous literature as a barrier that impacts the integration of both ML (Atun-Einy & Kafri, 2019), and more broadly, EBP (Schreiber & Stern, 2005), into clinical practice. The findings of this study suggest that how the clinicians are perceiving their caseload volumes, the limited time spent in rehabilitation by certain patient populations, and a lack of protected time to critically search and appraise the relevant articles and databases may be contributing to workplace environments that do not support professional development within the field of ML (Atun-Einy & Kafri, 2018).

Working outside the culture

Clinicians shared situations where the integration of ML theories and principles into their clinical sessions resulted in them working outside of or against the current culture of practice. This was especially prevalent when the clinicians were attempting to practice in a manner consistent with best practice recommendations in the literature:

> I heard some clinicians saying [that you are either a] hands off or a hands-on physiotherapist. Why does it have to be like that? What about the principles of motor learning? Use the hands when you need to, everybody gets to be happy. But … you either touch the person or not. It's just very strange ... (Henry).

Clinicians shared that the very creation of a culture of practice has pushed them to work outside of it. Examples of integrating various ML principles often came with the caveat that there is not an inherently "right" or "wrong" way of practicing. Many clinicians acknowledged that the purpose of ML is to help guide their practice and to provide a framework that enhances patient rehabilitation. In allowing these ML principles to influence the structure of their practice, clinicians commented that, at times, their actions felt disconnected from those of their peers.

The presence of a culture of practice was felt most strongly discussing the integration of PG and autonomy within their clinical sessions. The concept of risk management, which is a key component across both principles, was cited as being a primary contributor to this divide. Clinicians shared that, in some cases, allowing for learning was also allowing for risk; in the case of PG, it is allowing for more independence on the part of the patient, while a portion of autonomy is allowing the patients to decide *when* to accept that risk on themselves. However, recognizing the presence of risk sets them apart from their peers because many other clinicians "… feel the obligation to accept those own risks on themselves, and not explain to the patient the potential risks of things" (George). The TDF outlines "social and/or group norms" within the domains "social/professional role and identity" and "social influences". In this context, the presence of the group norms surrounding clinicians' approaches to ML not only explains how behaviour change can be targeted with future KT interventions, but it also seeks to explain why this gap persists within rehabilitation. If educational opportunities could be created that focus on altering the group norms and perceptions about ML, and emphasize the alignment of these norms and perceptions with best-practice recommendations or guidelines, it may facilitate the uptake of ML and promote more cohesion within rehabilitation. In previous literature, positive social influences and the alteration of group norms have been found to influence changes in behaviour related to the uptake of a novel outcome measure within a group of PTs working in in-patient rehabilitation (Romney et al., 2018). Although not directly related to ML, this finding does present a plausible avenue to increase the uptake of ML within rehabilitation.

Nice in theory, but my hands are tied

Whether clinicians were describing how they integrate ML principles into clinical settings, or their access to resources that would help improve patient outcomes, they shared instances where they attempted to practice in a certain way, but, due to the contexts that they were practicing in, they were being prevented from doing so. Upon explaining how they approach rehabilitation and the integration of ML, clinicians commented on their *ability* to act, noting that it can be “challenging” when their own “[capacities are] at odds with best practices” (Emma). Although not irrelevant to their clinical practice, the way that ML theories and principles have been outlined within the literature requires clinicians to weigh the context that the research has been conducted in against the context that they are practicing in. Clinicians emphasized that, given the abilities of the individuals that they are working with, when presented with information in the form of a research article, they feel obligated to question whether the results “[make] sense when [they’ve] got a human being in front of [them]” (Justin). Reducing the amount of PG was one principle that clinicians had difficulty integrating in a manner that is consistent with best practice recommendations. Although the benefits of this principle were noted, at times, reducing the amount of PG provided was not possible while fostering a positive and safe learning environment:

> … because we're working with patients that are so acutely unwell, sometimes there's lines, or tubes in the way. It's a nice theory, but I need to make sure that the patient is safe … I think with higher functioning patients, if they have a certain baseline level of strength, I think it makes sense to cut back on the physical guidance. Evidence shows that it helps motor learning. I just think with a very acute population, I'd be in trouble (Jane).

The above quote shows that reducing PG may not be feasible or safe within some patient populations. However, this quote also emphasizes that an existing knowledge gap could be an awareness of the appropriate situations to integrate certain ML principles. Clinicians may be missing opportunities to integrate ML principles into their clinical practice by the pressures that they are facing to ensure the safety of their patients. As such, decreasing PG is not always the correct answer, but a nuanced understanding of the principle, and knowledge of the correct *contexts* to integrate it in, may help to increase utilization within a clinical setting. However, it is important to note that the onus for this knowledge-to-practice gap can not be placed entirely on clinicians. Literature assessing the efficacy of various ML theories and principles is often conducted in non-rehabilitation populations, and when clinical populations are used, they are primarily comprised of individuals who have had a stroke (Kitago & Krakauer, 2013; Levin & Demers, 2020). Additionally, many individuals with stroke are in the chronic phase of their recovery. A scoping literature review of 39 studies assessing the use of ML in individuals post-stroke found that 79% of the studies included individuals in the chronic stage of stroke recovery, 15% included individuals in the late sub-acute stage of stroke recovery, and 5% had participants in the early sub-acute phase (Gregor et al., 2021). Given the focus on stroke in the existing literature on ML, the contexts of the studies may not always align with the clinicians' working conditions. The TDF outlines that environmental context and resources, as well as knowledge, can influence behaviours relating to KT. Since the ability to tailor evidence to a relevant context is a key component of KT (Straus et al., 2009), it is possible that knowledge of how to best manipulate ML principles to suit different, variable patient populations, and learning environments, is needed to help clinicians integrate ML when the study demographics do not align with their working conditions.

Clinicians commented that, even when their patient populations do not preclude them from integrating ML as recommended in the literature, there are still aspects of rehabilitation practice that do. In addition to preventing clinicians from practicing in a certain manner, these barriers can also reduce the amount of autonomy that clinicians have over their clinical sessions. These experiences were often expressed alongside feelings of frustration, wanting to shape their practice one way, or approach treatment in a particular manner, but being actively barred from doing so by the structure of the system they work in. Time, in particular, was a key contributor to this feeling. Upon discussing the integration of general EBP into clinical practice, one clinician commented that:

> One thing that always comes up with families and patients, and rightly so, is, "you told me that I have like five weeks in rehab. What if my goals aren't achieved by the end of those five weeks?" It's always hard to explain to them that based on government public funding, this is how much time you're allotted, we don't have a ton of flexibility. We know you won't be 100% or you might not be - we make sure everyone's safe to go home, but it might not be the easiest. That's one thing that I think everyone struggles with, time from that perspective, and then just it's a funding model. We don't really have too much say in that. (Mary).

As a barrier to EBP, time has been well-established within the existing literature (Schreiber & Stern, 2005). Although limited research has explored time in relation to ML, a study by Atun-Einy & Kafri (2019) provided support for this barrier existing within a ML-specific context, which agrees with this study's findings. The clinicians participating within this study, however, went more in-depth into time as a barrier compared to previous research. There did seem to be multiple dimensions of time that impact their ability to integrate ML into their clinical practice; the time that the patients spend in rehabilitation (as evidenced above), the time allocated for individual sessions, and the time that clinicians have in their workday outside of patient interactions to keep up to date with research literature all contributed to the barrier of time.

Although time was the primary contributor to the frustration expressed by clinicians, many other institutional barriers to the integration of ML theories and principles, such as appropriate staffing to complete further recommended care, also contributed. While limited literature has been conducted in the context of ML-related KT, the feelings of frustration shared by clinicians have been supported in literature assessing their perspectives on the integration of general EBP into their clinical sessions (Rappolt & Tassone, 2002). Extending upon these feelings of frustration, clinicians shared that the limited acknowledgement of these barriers has further exacerbated the impact that they have on clinical practice. Clinicians are attempting to work within the constraints of the current system, however, further attention should be brought to the fact that “there’s gaps that are not for lack of effort, it’s just [a] lack of resources” (Emma).

Variability in clinical decision-making pathways

Clinicians shared that there is a distinct absence of a single source pathway to help guide and facilitate their clinical decision-making. Since a large portion of their rehabilitation practice is dependent on so many different factors, such as patient presentations, workplace environments, or even expectations from the clinics and hospitals that they work in, they find it difficult to approach ML in a set manner. Regardless of the area of rehabilitation that the clinician worked within, when discussing how they approach the integration of ML principles, they were all needing to “… qualify in several ways” (George). Due to this level of variability, many clinicians were varying their approach to ML based on the characteristics and abilities of their patients:

> … it really depends on the person that you're working with, it depends on the context that that person is working in and their environment, it depends on their ability to take in information, both in terms of volume, speed, physical capability to carry out what they understand, it changes with respect to … whether you're looking to improve them so that they switch to another environment, or whether they're going to be remaining in this environment … so, variable, I guess, I use different techniques for different people (Justin).

Many clinicians indicated that, due to the variability present within their clinical sessions, they often lacked *consistency* in how they practice. The absence of clear, relevant recommendations was felt most acutely in this regard. Due to the variable nature of their practices, and the rapid way that rehabilitation is currently changing alongside the influx of new information, a current gap in the knowledge to practice framework is a lack of a structured approach to ML. While the ability to adapt ML principles to individual patient populations and characteristics should not be viewed as a negative aspect, without relevant and accessible recommendations and guidelines, how to *best* integrate the ML principles may be open to individual interpretation.

Furthering this, clinicians also reported that the lack of consistency in how ML is approached extends to members of the multidisciplinary care team, and their entire approach to patient care:

> A big barrier here for us is the transfer of care between the therapy team and [the] nursing team. An overall multidisciplinary team barrier, so there's inconsistencies there with offering too much guidance or not, perhaps, the optimal level of guidance. When we try to reduce it, is it reduced across the whole entire team? (Laura).

As Laura expressed with this quote, consistency of care across the multidisciplinary team acts as a barrier to integrating ML best practices within rehabilitation. As a mechanism of overcoming this barrier, clinicians highlighted the need for more best-practice guidelines that are relevant to their patient presentations and the way that rehabilitation is delivered within a clinical setting. As outlined in the TDF, there are multiple domains that have been targeted to increase the uptake of novel interventions and best-practices within the field of rehabilitation. For instance, the need for more structured guidelines, as exemplified by the clinicians in this study, would be encompassed by the "environmental context and resources" domain, which covers both "resources" and “material resources”. While still lacking information directly related to the integration of ML, one study used the TDF to assess the barriers and facilitators relating to the integration of a novel virtual reality intervention within five stroke rehabilitation units. This study found that the majority of the facilitators for the integration of this intervention originated from the “environmental context and resources” domain (Glegg & Levac, 2018), which offers evidence for the efficacy of providing clinicians with resources to assist with the uptake of novel interventions, and potentially best practice recommendations, into rehabilitation.

In providing clinicians with guidelines to adopt a more structured approach to the integration of ML, the inconsistencies found both within clinical practice and the multidisciplinary care team could be mitigated. Additionally, these guidelines could help to ensure that patient care is in accordance with recommendations from the literature. The constant influx of new information within the field of rehabilitation, in conjunction with the lack of guidance on how to integrate ML best practices into their clinical sessions, caused one clinician to reflect on whether they were providing the best possible care for their patients:

> Probably like most physiotherapists, I think I know something, and then when you start reading the questions and realize all the research that's been done on this, you start to realize you really don't know that much of the actual research … That was kind of an eye-opener for me because I thought, well, I thought I knew what was best for my patient, but maybe I don't. (George).

This quote emphasizes some of the consequences of the current KT gap within the field of rehabilitation science. Without structured guidelines to assist clinicians with the delivery of best-practices, clinicians may not be aware of *how* they can be altering their clinical sessions to ultimately provide more effective and efficient patient care.

Overall, the results from the interviews have expanded upon the results generated by the surveys. While no new barriers or facilitators were discovered over the course of the interviews, what was emphasized were the nuances involved in the previously identified barriers. Aspects of rehabilitation, such as internal consistency and limited resources, give considerable weight to the impact that the barriers have on a clinician's interactions with their patients. Additionally, the way that ML interventions are approached within the literature, including the choice of participant demographics, may impose a substantial barrier to the integration of ML within a clinical context.

Therefore, an integrated knowledge translation opportunity may be warranted. It appears that clinicians want a single-source guideline or recommendation for not only clinician appropriate definitions and explanations of ML theories and principles, but also *relevant* recommendations for how ML principles can be manipulated and adapted to fit the context of their patient populations and learning environments. Using the principle of reduced PG as an example, this resource could outline what the principle entails (i.e., reducing PG can promote learning benefits) and what is currently known about the principle from a research perspective. Then, recommendations could be generated that would assist clinicians with adapting and manipulating this principle to best fit the needs of their individual patients and patient populations. One of the key considerations that should be given to the creation of this resource is that the recommendations should *not* be prescriptive; rather the recommendations should act as a tool that clinicians can use to guide them as they are structuring their clinical sessions. Additionally, nuances that are present within the individual principles should be outlined. Using PG again as an example, there are some instances within clinical practice where it may not be safe or feasible to reduce PG. Making clear that, since patients present on a spectrum in terms of physical and cognitive abilities, the use of ML principles should be considered on a spectrum as well.

If clinicians and researchers could partner to create this type of resource, whether the final product took on the form of a continuing education opportunity or a document outlining relevant recommendations, it may allow clinicians to utilize ML theories and principles more effectively within their day-to-day practice. If proven successful, this resource could enhance the quality of rehabilitation services and improve recovery and return of function for individuals impacted by neurological conditions.

Chapter 6

Limitations and Conclusions

This final chapter will outline the limitations that were inherent in both the quantitative and qualitative works, followed by the overarching conclusions that can be drawn upon the completion of both components.

6.1 Limitations

Given the novelty of this research, there were several limitations to this study that warrant addressing.

6.1.1 Limitations in the Quantitative Work

The primary limitation apparent in the quantitative work, which is relevant to both the surveys, was recruitment and survey completion. Although the goal of the first survey was to inform a continuing education workshop, limited responses made it necessary to re-launch the survey to a broader audience. Additionally, this re-launched survey did not have the anticipated response rate, which limits the overall generalizability of the results. In addition to the response rate, the recruitment methods may have also introduced generalizability issues into the results. Allowing the clinicians to self-select their participation within the surveys may limit the scope, as individuals who self-select may have greater personal interest and/or knowledge of the topic under consideration.

Secondly, while the use of descriptive analysis for the surveys was justified based on the scope of the research questions and objectives, it does introduce an opportunity for bias in the quantitative results. While the principal investigator attempted to remain unbiased throughout the descriptive analysis, there were no quality assurance measures taken. Although the results of the quantitative portion of the study were in line with the results of previously published studies, future methodology should consider involving a second researcher within the descriptive analysis process to reduce this opportunity for bias.

The way the few statistical tests were run, particularly in the second survey, also posed a limitation. Although there was little complexity involved in the statistical assessments, the analysis was done using the auto-populated data found within the survey program, Qualtrics. Random samples were checked for accuracy using an external program (Excel) to mitigate the risk of this bias. However, to ensure complete accuracy for future work, the statistical tests should be run independently of the survey software in a designated statistical program.

6.1.2 Limitations in the Qualitative Work

As evident from the quantitative work, recruitment was also a limiting factor found within the qualitative component of the study. Although data saturation is not considered a goal within TA, there were a limited number of interview participants. The small sample size was somewhat due to time constraints on the researcher's part; however, the final few interviews offered limited new information. Thus, while a few more interviews would have reduced the impact of this limitation, they may have only strengthened the certainty with which conclusions could be drawn and may not have added any further richness to the data set.

Similarly to the quantitative work, the transferability of the results may have been impacted by the recruitment methods. The ability for the clinicians to self-select their involvement in the interviews posed a limitation for this portion of the study. Having the clinicians indicate their interest in an interview may have resulted in individuals with enhanced knowledge and comfort with the topic participating. Although this does present a benefit in that the conversations could be more targeted and greater scope of information could be generated, it does call into question the generalizability of the results. In a similar vein, the inclusion of just

PTs, and no other rehabilitation providers (e.g., OTs, SLPs) within the interviews will also influence the transferability of the results and the conclusions that are drawn. While appropriate for the scope of this paper, and the relevance that ML has to the PT profession, future work may consider the inclusion of a broader participant population to fully understand how ML is integrated within a rehabilitative context.

Finally, the analysis process could have been strengthened by further quality assurance measures, for example via member checking. Although frequent counsel was sought with both co-authors (VD and AF), and following recommendations from the literature, both acted as "critical friends" to increase the lens through which the data was viewed, data analysis (coding and theme generation) was conducted by one person. The analysis may have been further strengthened if preliminary results were reviewed by the clinicians who completed an interview, both to ensure that they were accurate in capturing their lived experiences, and that they were reflective of the opinions shared over the course of the interviews.

6.2 Conclusions

This study attempted to outline clinicians' confidence levels with various ML theories and principles, describe their perspectives of the integration of the principles into their clinical practice, and identify barriers and facilitators that they face while doing so. Clinicians from various sectors of rehabilitation were found to have a moderate level of confidence integrating and manipulating various ML theories and principles, as well as a solid degree of understanding of the components of the principles themselves.

The current body of evidence primarily examines barriers and facilitators through the broader lens of the integration of EBP. While the results of this study have reiterated what was previously known about these barriers, it is one of only a few studies to demonstrate the existence of these barriers and facilitators within a ML-specific context. Additionally, as evidenced by the results of the interviews, clinically relevant recommendations and guidelines for applying ML theories and principles are often scarce and difficult to interpret. This has resulted in a disconnect between the recommendations for clinical practice, and how clinicians are integrating ML into their rehabilitation sessions. Thus, this study has emphasized the persistence of these barriers and highlighted the knowledge to practice gaps that continue to exist within this field.

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Appendix A

Recruitment Email and Ethics Consent Forms

Recruitment Email

Study Title: Clinician perspectives on integrating motor learning theory and strategies into rehabilitation

Principal Investigator: Mikhaila Merrell-McBride, School of Rehabilitation Therapy, Queen's University

Supervisor: Dr. Vincent DePaul, School of Rehabilitation Therapy, Queen's University

My name is Mikhaila, and I am a MSc. candidate in the School of Rehabilitation Therapy at Queen's University. I am conducting a research project entitled "Clinician perspectives on integrating motor learning theory and strategies into rehabilitation" for my master's degree under the supervision of Dr. Vince DePaul. The purpose of this study is to gauge gaps in understanding surrounding motor learning theories and application to rehabilitation, as well as perceived barriers and facilitators to applying these strategies in a clinical setting.

I am contacting you to participate in an online survey in which you will be asked to complete an online survey on clinician understanding of motor learning principles and strategies, as well as their relevant application to rehabilitation. The survey is primarily comprised of multiple-choice answers, although there are some opportunities for written answers. Participation will require approximately 20 minutes of your time.

If you are interested in participating in this study, please see the attached letter of information and associated consent form, as well as a link to complete the survey. At the end of the survey, you have the option of indicating via a secondary link that you are interested in participating in a follow-up interview. If you indicate interest, you will be contacted by the principal investigator with an additional letter of information. The interview will be conducted online via Zoom and will take approximately 45 minutes to 1 hour.

If you have any questions about the project, please contact me by email at mikhaila.merrellmcbride@queensu.ca.

Thank you in advance for considering my request

Mikhaila Merrell-McBride

This study has been reviewed for ethical compliance by the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board (HSREB). For ethics concerns please contact the Queen's University Health Sciences and

Affiliated Teaching Hospitals Research Ethics Board (HSREB) at 1-844-535-2988 (Toll free in North America) or hsreb@queensu.ca.

Participant Informed Consent Form

Survey

Study Title: Clinician perspectives on integrating motor learning theory and strategies into rehabilitation

Principal Investigator: Mikhaila Merrell-McBride, School of Rehabilitation Therapy, Queen's University

Supervisor: Dr. Vincent DePaul, School of Rehabilitation Therapy, Queen's University

I am inviting health care professionals who provide rehabilitative services to patients to take part in a research study. The purpose of this study is to gauge gaps in understanding surrounding motor learning theories and application to rehabilitation, as well as perceived barriers and facilitators to applying these strategies in a clinical setting. If you agree to take part, you will be asked to complete an on-line survey. There are no known risks to completing this survey. We will also be collecting some personal information in the survey such as educational background, length of time you have been providing rehabilitative services, and age. We need this information to gauge the demographics and knowledge base of the individuals who complete the survey. By participating in this survey, it will help to target knowledge gaps and potential questions surrounding motor learning more accurately in rehabilitation. Study results will add to the body of literature surrounding health care provider's perspectives on motor learning theory in rehabilitation and help enhance the quality of rehabilitative services by identifying gaps in knowledge.

Participation in this survey is voluntary and will take approximately 20 minutes of your time. You do not have to answer any questions you don't want to. You can stop participating at any time. At the end of the survey, you will be directed to a second link where you will be invited to participate in a follow-up interview. This interview will be conducted on an online platform (Zoom) and will take approximately one hour to complete.

As a thank you for participating in this survey, your name may be entered in a draw to win a $50 gift card (eg. $50 Amazon gift card). Please contact Mikhaila Merrell-McBride at mikhaila.merrellmcbride@queensu.ca to enter your name into the draw. The winner will be drawn after the survey closes.

This survey will be anonymized and not linked to your contact information or name in any way. Due to this, it is not possible to withdraw your answers once the survey has been submitted. If you wish to stop the survey at any time you may simply close the browser and your results will not be saved or added to the data set. Once submitted, the anonymized data will be stored on an encrypted file and any documents that link real names to anonymized data will be stored separately. At the end of the study, any identifiers will be removed from the data set and the remaining data will be stored in the Queen's University Institutional Repository indefinitely. Throughout the study, only the principal investigator and supervisor will have access to the data. The Queen's University and Affiliated Health Sciences and Affiliated Teaching Hospitals research ethics Board (HSREB) may require access to your study-related records to monitor the ethical conduct of research.

If you have any further questions about participating in this study do not hesitate to contact Mikhaila Merrell-McBride at mikhaila.merrellmcbride@queensu.ca or Dr. Vincent DePaul at Vincent.depaul@queensu.ca.

This study has been reviewed for ethical compliance by the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board (HSREB). For ethics concerns please contact the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board (HSREB) at 1-844-535-2988 (Toll free in North America) or hsreb@queensu.ca.

Participant Informed Consent Form

Interview

Study Title: Clinician perspectives on integrating motor learning theory and strategies into rehabilitation

Principal Investigator: Mikhaila Merrell-McBride, School of Rehabilitation Therapy, Queen's University

Supervisor: Dr. Vincent DePaul, School of Rehabilitation Therapy, Queen's University

You are being invited to take part in the interview portion of this research study as indicated within the initial survey on knowledge and application of motor learning theory within rehabilitation. The purpose of the interviews is to gain a more in-depth understanding of the perspectives rehabilitation providers have surrounding the use of motor learning theory in rehabilitation, including potential barriers and facilitators to application in clinical practice.

If you agree to take part, the interview will be conducted over an online platform (Zoom) for approximately one hour. You will be asked for permission to record the interview and you may turn off your camera. Only the audio-recordings will be used for transcription purposes. Since video and audio recordings will be generated, there is a privacy risk associated with participating in the interview. However, all measures will be taken to protect your privacy over the course of this study. Recordings will be stored on a secure, encrypted hard drive, and a document linking the study ID and pseudonym to the video and audio recordings will be securely stored in a separate location. We acknowledge that reflecting on your knowledge and clinical practice can be tiring. If this is the case, you may take a break or end the interview. Some personal information will be collected at the beginning of the interview such as age, gender, length of time practicing, and the area of rehabilitation you practice in to gain a full understanding of the various perspectives held by rehabilitation providers.

Your participation in this study will help to inform the continuing education workshop to be held on motor learning in rehabilitation by Dr. Vincent DePaul and hosted by the Central East Regional Stroke Network in November 2021. Study results will also add to the body of literature surrounding health care provider's perspectives on the integration of motor learning theory in rehabilitation practice and help enhance the quality of rehabilitative services by identifying gaps in knowledge.

As a thank you for participating in this interview, you will be offered a $10 gift card to one of a few locations (i.e. Tim Hortons, Amazon). After the interview, please contact Mikhaila Merrell-McBride (mikhaila.merrellmcbride@queensu.ca) to receive the gift card.

Participation in this study is voluntary; you do not have to participate if you do not want to. You can change your mind without penalty at any point in the interview. If you withdraw from the interview, you can choose if you would like to have the information we have already gathered from you used within the study. If you withdraw during the interview, any audio and video recordings will be permanently destroyed. After the interview, you may withdraw from the study up until April 30, 2022, by contacting the Principal Investigator at mikhaila.merrellmcbride@queensu.ca and letting me know that you would like to withdraw your data from the study. If you choose to withdraw from this study, the information that you have provided throughout the interview process will be permanently deleted and removed from the secure hard drive that was used for storage. All hard copies of personal information will be destroyed. Any video or audio recordings will be permanently deleted and removed from the transcription software and secure hard drive. After the April 30, 2022 date, if you choose to withdraw from the study, please contact me and let me know. If I am able to, I will remove any direct quotes from the body of the research paper and I will not use direct quotes at any conferences or presentations. However, due to the nature of the data analysis process, the answers you provided may be used to generalize or theorize about results and themes found in the overall data set.

Your confidentiality will be protected by replacing your name with a pseudonym in all publications and by having a study ID number in all study records. The anonymized data will be stored on an encrypted file and any data that links real names to the pseudonyms or anonymized data will be stored separately. At the conclusion of the study, identifiers will be removed from the data sets and the remaining data will be entered into the Queen's University Institutional Repository, where the data and final paper will be stored indefinitely. Only the principal investigator and supervisor will have access to the data during the study process. The Queen's University and Affiliated Health Sciences and Affiliated Teaching Hospitals research ethics Board (HSREB) may require access to your study-related records to monitor the ethical conduct of research.

I plan to publish the results of this study in academic journals. I will be including direct quotes from the interview within the publication. I will never include any real names with quotes, and I will do my best to ensure that quotes can not identify participants. During the interview, please let me know if you say anything you do not want me to quote.

If you have any further questions about participating in this study do not hesitate to contact Mikhaila Merrell-McBride at mikhaila.merrellmcbride@queensu.ca or Dr. Vincent DePaul at Vincent.depaul@queensu.ca.

This study has been reviewed for ethical compliance by the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board (HSREB). For ethics concerns please contact the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board (HSREB) at 1-844-535-2988 (Toll free in North America) or hsreb@queensu.ca.

This Letter of Information provides you with the details to help you make an informed choice. All your questions should be answered to your satisfaction before you decide whether or not to participate in this research study. Keep one copy of the Letter of Information for your records. You have not waived any legal rights by consenting to participate in this study.

Verbal Consent Script: Participant Interview

Principal Investigator: Mikhaila Merrell-McBride

Supervisor: Dr. Vince DePaul

Study Title: Clinician perspectives on integrating motor learning theory and strategies into rehabilitation

Participant ID:____

I confirm the following:

I have explained all aspects of this study to the participant as outlined on the letter of information.
I answered all of the participant's questions to their satisfaction and the participant had sufficient time to consider their participation in this study.
The participant was informed that they may choose to stop their participation at any time for any reason without penalty.
The participant was informed that their legal rights would not be affected by consenting to participate in this study.
The participant verbally agreed to participate in this study and to follow the study procedures.
The participant was provided with a copy of the Letter of Information for their records.
The participant consented to the use of Audio Recording/Use of Quotes
The participant consented to the use of Video Recording

____________________	____________________	________________
Signature of the person conducting the verbal consent discussion	Printed name	Date

Queen's University

Verbal Consent Log for Documenting Informed Consent

Study Title: Clinician perspectives on integrating motor learning theory and strategies into rehabilitation

Participant Study ID	Consent obtained for:	Date of verbal consent discussion	Name of individual conducting the verbal consent discussion	Signature of individual conducting the verbal consent discussion
	All questions asked by the participant were addressed A copy of the LOI was provided to the participant Verbal consent was obtained for study participant Explicit verbal consent obtained for: Audio Recording Use of Quotes Video Recording			
	All questions asked by the participant were addressed A copy of the LOI was provided to the participant Verbal consent was obtained for study participant Explicit verbal consent obtained for: Audio Recording Use of Quotes Video Recording			
	All questions asked by the participant were addressed A copy of the LOI was provided to the participant Verbal consent was obtained for study participant Explicit verbal consent obtained for: Audio Recording Use of Quotes Video Recording			

Appendix B

First Survey

Block A: Demographics

This survey is organized into the following four sections; Demographics; Knowledge and Understanding of Motor Learning Theories and Principles; Motor Learning and Education; and Barriers, Facilitators, and Application. The first section of this survey will ask you a few questions about your background. This will help us to gain an understanding of the backgrounds and experiences of the clinicians participating in this survey.

What is your highest level of education completed?

- Diploma
- Bachelor of Science (BSc)
- Master of Science (MSc)
- PhD
- Medical Doctor (MD)
- Other

Please enter your level of education below.

Which degree program have you completed or are currently in the process of completing?

- Physiotherapy
- Occupational Therapy
- Speech/Language Pathology
- Physiotherapy assistant
- Other (Please specify)

Please specify

What year did you complete your last degree program?

Block B: Work Experience

How many years of clinical experience do you have?

- 0-5
- 6-10
- 11-15
- 16-20
- 20+

What is your primary area of clinical practice?

- Neurology
- Cardiorespiratory
- Muscoloskeletal
- Other (Please specify)

Please specify any other area of clinical practice

How long have you been working in this field?

Which clinical population do you primarily work with (eg. stroke, cerebral palsy, traumatic brain injury etc.)?

What area best describes where you currently work?

- Clinician
- Research/Scientist
- Administrator
- Educator
- Student
- Other

Please specify what type(s) of courses you teach or are involved in teaching.

Please specify your current program of study.

Please specify your area of work if it was not provided as an option in the previous question stem.

If you work in a clinical setting, what area best describes where you work? If you do not work in a clinical setting, please skip this question or write "N/A".

- o In-patient acute care
- o In-patient rehabilitation or long term care
- o Out-patient care
- o At home care
- o Other (Please specify)

Please specify

Block C: Understanding of the Use and Application of Motor Learning
The next questions will assess your knowledge of and confidence applying specific motor learning principles and variables. These questions are designed to gauge the overall understanding the clinicians participating in this survey have of motor learning theories and principles.

Motor learning principles are guidelines or recommendations on the aspects of your therapeutic interactions with clients that can be manipulated or adjusted during clinical practice to optimize motor learning and recovery. How confident are you in your ability to identify which variables to target to optimize learning when working with patients?

▼ 1 - Not confident ... 10 - Very confident

Key motor learning principles include practice schedule, feedback, instructions, and strategies to enhance motivation. How confident are you implementing different motor learning principles (eg. practice schedule, feedback, motivation etc.) into your clinical practice?

▼ 1 - Not confident ... 10 - Very confident

Acquisition, retention, and transfer are the three primary components that can be used to assess and measure motor learning. How confident are you distinguishing between these three components of motor learning?

▼ 1 - Not confident ... 10 - Very confident

Acquisition involves assessing an individual's initial learning or performance of a new skill. How confident are you in your ability to identify when skill acquisition has been successful?

▼ 1 - Not confident ... 10 - Very confident

Retention involves assessing whether an individual can successfully execute all or part of a previously learnt task after time has passed. How confident are you in your ability to identify whether retention has been achieved? For example, this could be by measuring performance on the same task or an iteration of the task at the beginning of the next session.

▼ 1 - Not confident ... 10 - Very confident

Transfer involves applying a previously learnt skill to a new task or context. How confident are you in your ability to identify when the transfer of a motor skill has been successful?

▼ 1 - Not confident ... 10 - Very confident

Providing individuals with physical guidance that exceeds a certain threshold can reduce the efficacy of the learning and cause the individuals to become dependent on the guidance provided. How confident are you in your ability to identify when it is appropriate to reduce the amount of physical guidance you provide for the purposes of motor learning?

▼ 1 - Not confident ... 10 - Very confident

If appropriate, how would you attempt to reduce the amount of physical guidance you provide your patients to prevent them from becoming dependent on it? Please briefly describe.

Providing feedback that promotes an internal focus of attention, for example the position of a patient's hand and arm as they are throwing a ball, can lead to decreased learning and reduce a patient's ability to retain the motor components of the target skill. In contrast, providing feedback that promotes an external focus of attention, for example telling the patient to aim at a particular point on a target, can increase motor performance. How confident are you in your ability to distinguish between feedback that promotes an external versus an internal focus of attention?

▼ 1 - Not confident ... 10 - Very confident

Reducing the frequency of feedback or delaying the provision of feedback has been shown to enhance motor learning compared to providing immediate feedback or providing feedback on a more frequent schedule. How confident are you in your ability to identify when to delay feedback or reduce the frequency of feedback for the purposes of motor learning?

▼ 1 - Not confident ... 10 - Very confident

Practicing skills in a random order (eg. ADBC, DCBA, or BACD etc.) can lead to more effective learning compared to practicing skills in a blocked order (eg. AAAA, BBBB, or CCCC etc.). How confident are you in your ability to distinguish between random order practice and blocked order practice?

▼ 1 - Not confident ... 10 - Very confident

Practice variability seeks to improve the retention of motor skills by intermixing different tasks or task iterations. How confident are you in your ability to identify an appropriate amount of variability to incorporate into your clinical practice?

▼ 1 - Not confident ... 10 - Very confident

Continuous skills, such as walking, are best practiced in their entirety. In contrast, discrete skills, such as a tennis serve, are best practiced by breaking down the movement into component skills or chunks of movements. How confident are you in your ability to identify which tasks are best practiced as a whole task versus practiced as a part task?

▼ 1 - Not confident ... 10 - Very confident

Motivation to learn motor skills can be enhanced when individuals have autonomy over aspects of the practice or practice conditions. How confident are you in your ability to identify the types of choices that would provide your patients with increased autonomy?

▼ 1 - Not confident ... 10 - Very confident

Providing patients with feedback that enhances their expectations of their future performance(s) has been shown to increase learning and retention. For example, telling someone that people of their age typically do well on a ball throwing task allows them to hit the target with a higher degree of accuracy compared to a group that is told nothing about their ability prior to executing the task. How confident are you in your ability to identify the type of feedback that would enhance your patients' expectations of their future performances?

▼ 1 - Not confident ... 10 - Very confident

How many of the motor learning theories and principles had you heard of/were aware of before completing this survey? Please select all that apply.

- o Acquisition, retention, and transfer
- o Practice variability
- o Reduced physical guidance
- o Providing feedback that promotes an external versus an internal focus of attention
- o Reducing feedback frequency or delaying the provision of feedback
- o Blocked versus random practice
- o Variable task practice
- o Continuous versus discrete skill practice
- o Autonomy
- o Enhanced expectations

Given the examples of motor learning theories and principles provided so far in this survey, how confident would you be adapting them to best fit the needs of individual patients?

▼ 1 - Not confident ... 10 - Very confident

In general, how relevant do you feel motor learning theories and principles are to your clinical practice?

- o Not relevant at all
- o Somewhat relevant
- o Moderately relevant
- o Extremely relevant

Please briefly explain your reasoning

Block D: Motor Learning and EducationThe next few questions relate to how motor learning theories and principles are currently taught, and how they should be taught in the future. This is to help understand what areas could be improved upon in the future.

In your post-secondary education (eg. a Physiotherapy degree), how much time was intentionally dedicated to learning about motor learning theories and principles?

- No time dedicated to motor learning
- Minimal opportunity (eg. a single lecture, no time to apply in lab or clinically)
- Moderate opportunity (eg. a mixture of lecture and lab practice)
- Significant opportunity (eg. multiple sessions or a full course)

Do you feel that the amount of structured education you received was adequate to prepare you to apply motor learning within a clinical setting?

- Yes
- No

Please briefly explain your answer.

Have you attended any continuing education sessions related to integrating motor learning theories and principles into practice?

- Yes
- No

Please briefly describe the continuing education session(s) that you attended.

Did you attend the motor learning workshop held by Dr. Vince DePaul in November 2021?

- Yes – I did attend the workshop
- No – I did not attend the workshop
- I am registered to attend the workshop but have not yet gone

What other resources have you used to support your application of motor learning theories and principles in clinical practice? Please choose all that apply.

- Textbooks
- Online resources
- Posters
- Peer mentors/colleagues
- Community of practice with other professionals to discuss cases

Please briefly explain any other resources that you have used. If you have not used any other resources, please leave the answer box blank or write "N/A", What resources are lacking that you feel could help support your application of motor learning theories and principles in your clinical practice? Please choose all that apply.

- o Textbooks
- o Online resources
- o Posters
- o Peer mentors/colleagues
- o Community of practice with other professionals to discuss cases

Please briefly explain any other resources that you feel would be helpful. If you do not feel any other resources would be helpful, please leave the answer box blank or write "N/A".

How often do you seek out resources (eg. peer reviewed articles) to learn about up-to-date motor learning principles or theories?

- o At least once a month
- o Every few months
- o 1-2 times a year
- o Never
- o N/A – I do not spend the majority of my time in clinical practice

Academic papers are one method of staying up to date with current literature relating to motor learning. How confident are you in your ability to critically appraise literature and implement the relevant aspects into your clinical practice?

▼ 1 - Not confident at all ... 10 - Very confident

Journal clubs are one option that may allow clinicians to confer with their peers about specific questions and issues regarding motor learning, as well as provide a foundation to incorporate evidence-based practice into their clinical decision making. How interested would you be in attending a journal club that focused on motor learning principles in the context of rehabilitation?

- o Not interested
- o Somewhat interested
- o Neutral
- o Moderately interested
- o Very interested

Please briefly explain your answer.

Given your current understanding of motor learning theories and principles, how would you recommend it be taught in an entry to practice professional education setting (eg. a Physiotherapy degree) in the future? For example, this could be more lecture time devoted to learning about motor learning or lab work/clinical skills to practice implementing the principles in a real-life setting. Please explain.

Block E: Barriers, Facilitators, and Application of ML Theories and Principles

These last questions are about some of the barriers and facilitators clinicians face when applying motor learning theories and principles into clinical practice. They are geared towards both identifying these barriers and facilitators, as well as moving towards solutions to either enhance or overcome them.

These are all of the motor learning theories and principles that were covered throughout this survey; Acquisition, retention, and transfer, practice variability, reduced physical guidance, providing feedback that promotes an internal vs. external focus of attention, reducing feedback frequency or delaying the provision of feedback, blocked vs. random practice, variable task practice, continuous vs. discrete skill breakdown, autonomy, enhanced expectations. Based on the list above please select two motor learning principles and provide a brief example of how you could apply them in clinical practice. Please state the motor learning principle(s) you have chosen.

Motor learning principle 1:

Motor learning principle 2:

Which of the above motor learning principles do you find most difficult to apply in a clinical practice setting? Why?

In general, what factors promote or facilitate your implementation of motor learning theories and principles into your clinical sessions?

In general, what are some barriers to you implementing motor learning theories and principles into your clinical sessions?

Appendix C

Second Survey

Informed Consent:
Please read the following Information as it outlines the information required to provide informed consent for participation in this survey.

Letter of Information

I am inviting health care professionals who provide rehabilitative services to patients to take part in a research study. The purpose of this study is to gauge gaps in understanding surrounding motor learning theories and application to rehabilitation, as well as perceived barriers and facilitators to applying these strategies in a clinical setting. If you agree to take part, you will be asked to complete an on-line survey.

There are no known risks to completing this survey. We will also be collecting some personal information in the survey such as educational background, length of time you have been providing rehabilitative services, and age. We need this information to gauge the demographics and knowledge base of the individuals who complete the survey. By participating in this survey, it will help to target knowledge gaps and potential questions surrounding motor learning more accurately in rehabilitation. Study results will add to the body of literature surrounding health care provider's perspectives on motor learning theory in rehabilitation and help enhance the quality of rehabilitative services by identifying gaps in knowledge.

Participation in this survey is voluntary and will take approximately 20 minutes of your time. You do not have to answer any questions you don't want to. You can stop participating at any time.

At the end of the survey, you will be directed to a second link where you will be invited to participate in a follow-up interview. This interview will be conducted on an online platform (Zoom) and will take approximately one hour to complete.

As a thank you for participating in this survey, your name may be entered in a draw to win a $50 gift card (eg. $50 Amazon gift card). Please contact Mikhaila Merrell-McBride at mikhaila.merrellmcbride@queensu.ca to enter your name into the draw. The winner will be drawn after the survey closes.

This survey will be anonymized and not linked to your contact information or name in any way. Due to this, it is not possible to withdraw your answers once the survey has been submitted. If you wish to stop the survey at any time you may simply close the browser and your results will not be saved or added to the data set. Once submitted, the anonymized data will be stored on an encrypted file and any documents that link real names to anonymized data will be stored separately. At the end of the study, any identifiers will be removed from the data set and the remaining data will be stored in the Queen's University Institutional Repository indefinitely.

Throughout the study, only the principal investigator and supervisor will have access to the data. The Queen's University and Affiliated Health Sciences and Affiliated Teaching Hospitals research ethics Board (HSREB) may require access to your study-related records to monitor the ethical conduct of research. If you have any further questions about participating in this study do not hesitate to contact Mikhaila Merrell-McBride at mikhaila.merrellmcbride@queensu.ca or Dr. Vince DePaul at vincent.depaul@queensu.ca.

This study has been reviewed for ethical compliance by the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board (HSREB). For ethics concerns please contact the Queen's University

Health Sciences and Affiliated Teaching Hospitals Research Ethics Board (HSREB) at 1-844-535-2988 (Toll free in North America) or hsreb@queensu.ca.

A copy of the above letter of information is attached and can be downloaded for your records by clicking the link below.

Letter of Information

Having read the letter of information, do you consent to participate in this research study? (Choosing yes will take you to the survey.)

- Yes
- No

Block A: Demographics

Thank you for agreeing to participate in this study on the application of motor learning theories and principles in clinical practice.

This survey is organized into the following four sections:
A) Demographics
B) Knowledge and Understanding of Motor Learning Theories and Principles
C) Motor Learning Education
D) Barriers, Facilitators, and Application
The first section of this survey will ask you a few questions about your work and education background to give an overview of the demographics of the clinicians participating in this survey.

What is your highest level of completed education?

- Bachelor of Science (BSc)
- Diploma
- Master of Science (MSc)
- Medical Doctor (MD)
- PhD
- Other (Please specify)

If you selected "Other", please specify your highest level of completed education in the text box below.

Which of the following clinical degree/diploma programs have you completed or are currently in the process of completing?

- Physiotherapy (PT)
- Occupational Therapy (OT)
- Speech/Language Pathology (SLP)
- OTA/PTA
- Other (Please specify)

If you selected "Other", please specify the program you have completed or are currently in the process of completing in the text box below.

What year did you complete your most recent degree/diploma program?

How many years of clinical experience do you have?

- 0-5
- 6-10
- 11-15
- 16-20
- 20+

Which of the following best describes your clinical work? (choose all that apply): Patients/clients with:

- Stroke
- Neurology other than stroke (e.g. Parkinson's, Acquired Brain Injury)
- Musculoskeletal conditions
- Cardiorespiratory conditions
- Complex medical populations (e.g. Chronic renal disease)
- Critical care (ICU, CCU)
- Geriatrics - Older adults with a variety of diagnoses
- Other (Please specify)

If you chose "Other" for the clinical populations you work with, please specify in the box below.

Which option best describes your current job title?

- Clinician
- Researcher/Scientist
- Administrator
- Educator
- Student
- Other (Please specify)

If you selected "Other" for your job title - please specify your title or position in the box below.

What setting best describes where you primarily work?

- In-patient acute care
- In-patient rehabilitation
- Out-patient care
- At home care
- Other (Please specify)
- N/A - I do not work in clinical setting

If you selected Other, please specify in the box below.

What country do you currently work in?

Block B: Knowledge and Understanding of Motor Learning Theories and Principles
The next group of questions are designed to gauge survey participants' awareness and understanding of motor learning theories and principles, as well as their confidence implementing them into clinical practice.

Improvement or recovery of motor skills is central to physical rehabilitation.
Motor learning strategies or principles are evidence-based strategies that can help clinicians decide how to adjust or manipulate specific aspects of therapy in order to optimize motor learning and recovery in their patients/clients.

How confident are you in your ability to identify which variables to target to optimize learning when working with patients with a variety of clinical presentations?

- 1 - Not confident at all
- 2 - Limited confidence
- 3 - Mildly confident
- 4 - Somewhat confident
- 5 - Moderately confident
- 6 - Very confident
- 7 - Extremely confident

Key motor learning strategies relate to practice schedule, feedback, instructions, and strategies to enhance motivation.

How confident are you implementing different motor learning strategies (eg. practice schedule, feedback, motivation etc.) into your clinical practice?

- o 1 - Not confident at all
- o 2 - Limited confidence
- o 3 - Mildly confident
- o 4 - Somewhat confident
- o 5 - Moderately confident
- o 6 - Very confident
- o 7 - Extremely confident

Imagine that you are working with a patient to learn how to transfer from bed to wheelchair independently. Which of the following statements best describes how you will determine whether the patient has learned this skill? (You may select more than one answer).

- o Observe or test their performance of the skill during a therapy session.
- o Observe or test their performance of the skill at the end of the therapy session
- o Observe or test their performance of the skill at the beginning of the next therapy session.
- o Observe or test their performance of the skill at the end of the week(s) after multiple sessions.
- o Observe or test their performance on the practiced skill (e.g. transferring to wheelchair) and a related unpracticed skill (eg. transferring to a regular chair from bed)
- o Assess patient using a standardized outcome measure at key points in rehab (e.g. FIM, Berg)

Assessing Retention involves assessing whether an individual can successfully execute a previously practiced task or skill after time has passed (e.g. 24 hours later).

How confident are you in your ability to identify when a patient has successfully retained a previously practiced motor task or skill?

- 1 - Not confident at all
- 2 - Limited confidence
- 3 - Mildly confident
- 4 - Somewhat confident
- 5 - Moderately confident
- 6 - Very confident
- 7 - Extremely confident

Transfer involves applying a previously practiced skill to a novel task or context. (e.g. walking over grass after practicing walking over tile floor)

How confident are you in your ability to identify when a patient has successfully transferred a previously practiced motor skill to a novel task or context?

- 1 - Not confident at all
- 2 - Limited confidence
- 3 - Mildly confident
- 4 - Somewhat confident
- 5 - Moderately confident
- 6 - Very confident
- 7 - Extremely confident

Feedback is essential to (re)learning functional skills. Which of the following statements best describes your typical approach to providing feedback during therapy sessions?

- I tend to provide feedback or guidance as soon as I see the patient make a movement error, including in mid-performance so they can learn the correct way to perform a motor skill.
- I tend to provide feedback immediately after the patient performs the skill/task - after every attempt.
- I tend to provide feedback after the patient attempts the skill a few times.
- It depends. (Please briefly explain what it depends on in text box below.)

In many cases, reducing the frequency of feedback or delaying the provision of feedback can enhance motor learning compared to providing immediate, or high frequency feedback.
How confident are you in your ability to delay feedback or reduce the frequency of feedback in a clinical setting to enhance your patients' learning of a motor task or skill?

- 1 - Not confident at all
- 2 - Limited confidence
- 3 - Mildly confident
- 4 - Somewhat confident
- 5 - Moderately confident

- 6 - Very confident
- 7 - Extremely confident

Providing individuals with physical guidance (e.g. hands on assistance/handling) that exceeds a certain threshold can reduce the efficacy of the learning and cause the individuals to become dependent on the guidance provided.

How confident are you in your ability to adjust the amount of physical guidance that you provide for the purposes of optimal motor learning?

- 1 - Not confident at all
- 2 - Limited confidence
- 3 - Mildly confident
- 4 - Somewhat confident
- 5 - Moderately confident
- 6 - Very confident
- 7 - Extremely confident

Instructions and feedback can be designed to encourage an internal focus of attention (i.e. attention to the position or movement of the body/body part), or an external focus of attention (i.e. attention to the environment or the effects of the body on the environment) in learners and patients. external focus of attention, (e.g. telling the patient to aim for a particular part of the object/target), *typically* enhances performance and learning. Which of the following best describes the TYPICAL content of your feedback and instructions:

- Internal Focus of Attention
- External Focus of Attention
- I'm not sure
- It depends (Please briefly explain what it depends on in text box below.)

Instructions that promote an internal focus of attention, (e.g. position of the hand and arm as they reach for an object), may impede performance and learning of that motor skill. In contrast, instructions that promote an

How confident are you in your ability to adjust your instructions and feedback to promote an external focus of attention during therapy sessions?

- 1 - Not confident at all
- 2 - Limited confidence
- 3 - Mildly confident
- 4 - Somewhat confident
- 5 - Moderately confident
- 6 - Very confident
- 7 - Extremely confident

Which of the following best describes how you typically organize therapy sessions?

- I devote a session to practicing a single task over and over to make sure the patient learns the skill before moving onto another skill.
- Patients practice a number of different tasks, or one task in a variety of ways, in a single session. With multiple repetitions of Task A, then reps of Task B, and so on.

- Patients practice a number of different tasks, or one task in a variety of ways, in a single session. Moving back and forth between Task A, Task B, and Task C during the session.
- It depends. (Please briefly explain what it depends on in text box below.)

Practice variability seeks to improve the retention of motor skills by intermixing different tasks or task iterations within a single practice session.

How confident are you in your ability to appropriately vary the tasks and types of tasks that are involved in your clinical sessions?

- 1 - Not confident at all
- 2 - Limited confidence
- 3 - Mildly confident
- 4 - Somewhat confident
- 5 - Moderately confident
- 6 - Very confident
- 7 - Extremely confident

In many individuals, practicing skills in a random order (eg. BDCA, ACDB, CBAD etc.) can lead to more effective learning compared to blocked practice (eg. AAAA, BBBB, CCCC etc.). This is particularly true for individuals with intact cognition.

How confident are you in your ability to implement a random order practice schedule into your clinical sessions?

- 1 - Not confident at all
- 2 - Limited confidence
- 3 - Mildly confident
- 4 - Somewhat confident
- 5 - Moderately confident
- 6 - Very confident
- 7 - Extremely confident

Continuous skills, such as walking, are best practiced in their entirety (whole task practice). In contrast, serial skills, such as a dressing, can be practiced by breaking down the task into component skills (part task practice). How confident are you in your ability to identify which tasks are best practiced in component skills or chunks of movements versus being practiced in their entirety?

- 1 - Not confident at all
- 2 - Limited confidence
- 3 - Mildly confident
- 4 - Somewhat confident
- 5 - Moderately confident
- 6 - Very confident

- 7 - Extremely confident

How confident are you in your ability to implement whole task practice for continuous tasks like walking in your clinical practice setting?

- 1 - Not confident at all
- 2 - Limited confidence
- 3 - Mildly confident
- 4 - Somewhat confident
- 5 - Moderately confident
- 6 - Very confident
- 7 - Extremely confident

Motivation to learn motor skills can be enhanced when individuals have autonomy over aspects of the practice or practice conditions.
How confident are you in your ability to provide your patients with the types of choices that would increase their autonomy and enhance their learning of motor tasks or skills?

- 1 - Not confident at all
- 2 - Limited confidence
- 3 - Mildly confident
- 4 - Somewhat confident
- 5 - Moderately confident
- 6 - Very confident
- 7 - Extremely confident

Providing patients with feedback that enhances their expectations of their *future* performance(s) has been shown to increase learning. For example, individuals who are told that people of similar age and abilities usually learn a particular skill (e.g. transfers) well, typically perform that skill better than individuals who are not given this instruction.
How confident are you in your ability to provide your patients with the type of feedback that would enhance their expectations of their future performance(s)?

- 1 - Not confident at all
- 2 - Limited confidence
- 3 - Mildly confident
- 4 - Somewhat confident
- 5 - Moderately confident
- 6 - Very confident
- 7 - Extremely confident

If appropriate, use the box below to provide additional comments regarding the relevance of motor learning principles to your practice.

Block C: Motor Learning Education
The next few questions relate to how motor learning theories and principles are currently taught, and how they should be taught in the future. This will help us understand how motor learning education could be improved.

In your formal professional education (eg. a Physiotherapy degree), about how much time was dedicated to learning about motor learning theories and principles?
- No time dedicated at all
- Minimal opportunity (eg. a single lecture, no time to apply in lab or clinically)
- Moderate opportunity (eg. a mixture of lecture and lab practice)
- Significant opportunity (eg. multiple lecture or lab sessions, or a full course)

Do you believe that the quality of structured education you received in your professional education was adequate to prepare you to apply motor learning in a clinical setting?
- Yes
- No

Please briefly explain your answer.

Since graduating, which of the following resources have you used to support your application of motor learning principles in clinical practice? Please select all that apply.
- Textbooks
- Online resources
- Posters
- Peer-reviewed research articles
- Peer mentors/colleagues
- Community of practice with other clinicians to discuss cases
- Continuing education courses/workshops
- Clinical Practice Guidelines
- Case studies (written or videos)
- Other (please explain below)
- N/A - I really haven't accessed any resources related to motor learning

If you selected other, briefly explain any other resources that you have used to support your application of motor learning theories and principles.

Have you ever attended any continuing education sessions that specifically included a focus on the integration of motor learning principles into clinical practice?
- Yes
- No

If yes, please briefly describe the continuing education session(s) that you attended.

Which of the following resources would you consider using in the future to support you to integrate motor learning theories and principles into clinical practice? Please select all that apply.

- Textbooks recommendations for reading
- Online resources
- Posters
- Peer mentors/colleagues with experience and knowledge in the area
- Community of practice with other professionals to discuss cases

- Access to research articles to read on my own
- Journal club – to discuss research on the topic
- Clinical practice guidelines
- Continuing education courses/workshops on the topic
- Case studies (written or video)
- Receive relevant papers or resources via email
- Podcasts – brief episodes covering cases, topic reviews, etc.
- Other (please explain below)

If you selected Other - Please briefly explain.

Research articles are one method that clinicians sometimes use to stay up to date with current literature related to motor learning. How confident are you in your ability to critically read motor learning literature and implement relevant aspects into your clinical practice?

- 1 - Not confident at all
- 2 - Limited confidence
- 3 - Mildly confident
- 4 - Somewhat confident
- 5 - Moderately confident
- 6 - Very confident
- 7 - Extremely confident

If able, please elaborate regarding your use of research articles.

Block D: Barriers, Facilitators and Application
These last questions are concerned with the barriers and facilitators that clinicians may experience when integrating motor learning theories and principles into their clinical practice.

Which of the following motor learning strategies have you tried to implement in your clinical practice prior to completing this survey? Please select all that apply.

- Reducing feedback frequency or delaying the provision of feedback can enhance learning
- Providing feedback or instructions that promote an external focus of attention
- Excessive physical guidance can impede learning
- Variable task practice promotes better retention and transfer
- Random practice can enhance learning
- Whole task practice for continuous skills may improve learning
- Promoting learner autonomy can enhance learning
- Promoting enhanced expectations can enhance learning
- None of these strategies

Which of the following motor learning principles do you find **easiest** to apply in a clinical setting? (Select all that apply)

- Reduced feedback frequency or delayed feedback may enhance learning
- Excessive physical guidance may impede learning
- Excessive physical guidance may impede learning
- Variable task practice promotes retention and transfer
- Random practice can enhance learning
- Whole task practice of continuous skills may improve learning
- Promoting learner autonomy can enhance learning
- Promoting enhanced expectations can enhance learning

In general, what factors promote or facilitate the implementation of motor learning theories and principles into your clinical practice sessions?

Which of the following motor learning principles do you find the **most challenging** to apply in a clinical setting? (Select all that apply)

- Reduced feedback frequency or delayed feedback may enhance learning
- Excessive physical guidance may impede learning
- Excessive physical guidance may impede learning
- Variable task practice promotes retention and transfer
- Random practice can enhance learning
- Whole task practice of continuous skills can enhance learning
- Promoting learner autonomy can enhance learning
- Promoting enhanced expectations can enhance learning

In general, what are some barriers that you face while attempting to implement motor learning theories and principles into your clinical practice sessions?

In general, how relevant do you feel motor learning theories and principles are to your clinical practice?

- Not relevant at all
- Slightly relevant
- Moderately relevant
- Very relevant
- Extremely relevant

Appendix D

Interview Guide

Relation to the TDF.

This interview guide was created using the TDF as a framework for the development of the interview questions. The bolded aspects associated with various questions represent the domains covered within the TDF.

Introduction;

- Informed consent
- About them (eg. how long have you been practicing? In what area? Why that area? What were their motivations for participating in the interview?)
- General overview of the interview;
- How familiar are you with the term motor learning theories and principles?
    - When this research related to how individuals learn motor skills is done in rehabilitation/clinical populations, it is sometimes summarized under the term Motor Learning Principles or strategies – which has been proposed for a number of years to be a resource that can be used to guide therapists as they work with patients and clients
    - But, as with any research-based knowledge, the application of motor learning related theories and research can be inconsistent in clinical practice
        - Creates a bit of a gap between what is considered "best practices" according to the literature and what is feasible for a clinician to implement with patients
    - As I mentioned in the informed consent piece, my aim is to understand your perspectives and experiences as a clinician and how they relate to the application of these motor learning strategies within your clinical practice
        - There are no right or wrong answers → I'm looking for your honest opinions and personal anecdotes/experiences

Any questions for me?

My perspectives on motor learning from a research perspective may be different to yours coming from a clinical perspective. Going to outline how I understand motor learning, then we are going to start by looking at how my views align, or don't align, with your experiences. Going to 1) Define what ML is, and 2) quickly outline what factors may affect ML

1) Definition; rather "textbook-y"; "a set of internal processes associated with practice and experience that result in relatively permanent changes to motor behaviour"

Can be broken down into a couple key pieces that I believe may be relevant to clinical practice;

- Internal processes; neuroplasticity underpins a lot of the "how" of motor learning (both how some of these strategies work and how we can be taking advantage of them → Can build off this in clinical practice to induce the relevant/necessary behavioural changes

- Second part is relatively permanent changes; I start thinking about the delineation between motor performance motor learning as a way of interpreting the success of the motor skill learning in research

2) Second piece that is important from a research perspective, and maybe a clinical perspective too, are factors that affect motor learning. Current research has identified certain conditions or factors that positively or negatively affect motor learning.

For example;

- Practice; what an individual practices, how much they practice
- Instructions; What a therapist or coach instructs the person to do or think about
- Feedback; what feedback is provided and when it is given
- Guidance, how much a person is supported or guided during training

Motor learning can be challenging though, because it's not as simple as "one size fits all"; the optimal motor learning strategy usually depends on the characteristics and experiences of the person learning, the activity or skill being learned, and the environment that they are performing the activity in.

Knowledge; Based on how I've described by understanding of learning from a research perspective, what parts resonated with you as a clinician?

- Was there anything that didn't resonate or that you disagreed with?

Let's start with an example; can you briefly describe for me a typical patient and situation that you would encounter in your clinical practice?

- [Probe; could be a single patient or a common scenario from a lot of different patients → "so what is the skill that they are learning?"]
- Focus on an activity that requires the patient to learn or re-learn a motor skill
    - OT; relearning to perform their self-care in the morning
    - PT; relearning how to walk (or more specifically, walk in their home)
        - Run using a corrected gait pattern
        - Lift safely at work
    - Determine some goals/objectives for the task based on the description/patient description

Memory, Attention, and Decision-Making Processes; Based on this patient description, or the selected task, walk me through how you would structure a clinical session (or the types of tasks that you would practice and how) to help your patients realize their goals/objectives.

Depending on what is talked about/mentioned, use the below probes/sections to further clarify/expand on target variables

I realize that it may be a bit artificial to think about these variables in isolation, but it may help us to understand how therapists make decisions related to these different motor learning strategies.

<u>Practice:</u> How do you decide what they will practice/work on in a session(s)?

[Probes]

- What activity are they working on?
- Do they practice more than one?
- In what order do they practice? Blocked – the same task repeated over and over, or serial random – mixing up different tasks within a single session

<u>Feedback:</u> How much feedback do you provide?

- How do you decide what feedback you give?
- How do you give it?
- How do you decide when to give feedback?
- What types of feedback do you provide?

[Probes]

- DO you try to give feedback immediately, or do you delay it?
- Are you more likely to give feedback when a person makes a mistake or when they've performed well, or both equally? Do you tend to give feedback when there are errors?
- DO you ever have patients self-evaluate their own performance? How do you do this?

Guidance: To what extent do you provide physical guidance?

- Do you ever provide physical guidance, for example with your hands, during practice?
- If yes, how do you decide when to provide or withdraw guidance?

Instructions: Thinking back to our patient example at the beginning, when you have a patient about to practice that specific activity or skill, what kinds of instructions would you give?

[Probes]

- Do you tend to use IFoA instructions (body parts) or EFoA (environment)
    - If yes, how do you decide which to use?

Motivation.

Autonomy – We know from research that people tend to learn motor skills better when they have some sense of autonomy or control over their situation. How does this play a role in the organization of your therapy sessions?

- If yes, can you elaborate on this?

[Probe]

- For example, how do you involve the patient in decision making, about practice? Feedback? Task?

Relative expectations – We also know from research that people tend to learn motor skills better when they expect a positive outcome of the training or therapy sessions. How does this play a role in the organization of your therapy sessions?

- If yes, can you elaborate on this?

[Probe]

- For example, do you ever provide examples of other patients who have achieved this skill/recovered this function?

What patient factors/characteristics would you take into consideration when making decisions related to the motor learning variables that we have just discussed?

[Probe]

- For example, what you practice in a session, when you give feedback, what instructions you give etc.

- Does the patient's cognitive function contribute to your decision making?

Beliefs about Capabilities; When you think about how you plan your therapy sessions (thinking about practice, feedback, guidance, FoA, motivation etc.), how much do you consciously think about motor learning principles and apply evidence-based practice or information from other sources (eg. literature, textbooks etc.)

  - For example, there is evidence that motor learning can be enhanced by;
    - Delaying or limiting feedback and guidance
    - Practicing a variety of activities in random order
    - Encouraging an external focus of attention (on the environment rather than on the body)
    - Encouraging autonomy and positive expectations of outcome
- Can you elaborate on how you incorporate these principles? (if yes)
- Can you elaborate (if no)

- What specific strategies would you be more likely to apply within your practice compared to others?

  - What aspects or characteristics of this strategy allow you to apply it?

[Probe]

- Is it the simplicity of it? Time it takes to apply? Applicability of the strategy to your patients?

- What other factors would you say make it more likely to apply this strategy?

[Probe]

- Your experience with it? Frequency of use? The way you learned it (eg. course, colleague)

- Which of these principles/strategies do you not apply or have difficulty applying to your practice?

  - What aspects or characteristics of this strategy make it difficult to apply?

[Probe]

- Is it the complexity of it? Time it takes to apply? Applicability of the strategy to your patients?

- What other factors would you say make it more likely to apply this strategy?

[Probe]

- Lack of experience with it? Negative experience (failed to make a difference)? Inconsistent with overall treatment approach/philosophy?

- Can you think of any advantages/negatives to using these motor learning strategies?

  - If yes, can you elaborate?

Beliefs about Consequences; How much value is there in trying to use these motor learning strategies more consistently in your practice?

- What are some disadvantages/negatives to trying to use these motor learning strategies?
    - If yes, can you elaborate?

Do you believe that the advantages to using these motor learning strategies outweigh any of the negatives/disadvantages?

If you believe that the advantages outweigh the disadvantages, what aspects outside of the strategies themselves and their effectiveness promote your use of the motor learning stratgies? eg. policy, procedure, personal understanding etc.

- If the advantages don't outweigh the disadvantages, why do you think there are so many downsides to these principles?
    - What aspects not directly related to the strategies/patient characteristics present a barrier?
        - Eg. institutional, policy/procedure, personal understanding etc.

If you were to practice implementing these strategies with a completely healthy individual, what would some of the disadvantages/negatives be?

Reinforcements; What would the outcome be if these facilitators were removed or altered?

Anything else to add or clarify based on what we've discussed so far? Questions? Concerns?

In addition to wanting to understand clinician perspectives and some of the barriers and facilitators that they face, we also want to understand (or at least start to understand) and address what clinicians need → no point guessing so might as well ask the people who are directly involved/impacted

Purpose of this study is not only to outline these barriers and facilitators in more detail, but a key part of understanding and addressing what clinicians need is understanding why these barriers are present in the first place and what options are available/would be useful to clinicians to start addressing them in the future.

Survey; - purpose, brief explanation of results

Asked a question of the clinicians to determine if they believed that the amount of structured education they received on ML specifically was enough to prepare them to apply it in clinical practice → most clinicians in the survey said that it wasn't enough and explained that they had minimal opportunity to both learn about and practice clinical skills relating to ML in their initial professional program

Skills; Tell me about your experiences with motor learning in your initial professional program

- What courses did you take?

- What areas were good? What areas needed improvement?

- Was there any opportunity for lab work/hands on practice?

Re; presentation for PT Neuromotor course → 20 minutes to give an overview of ML (difficult to fit it all in) and almost 2 years learning in MSc and barely scratched the surface

Environmental Context and Resources; If you could design a lab/course/learning opportunity for students to practice applying ML skills to clinically applicable situations/contexts, outline what that may look like

- If you'd had an opportunity like this in your initial professional program, how would your views/the way you approach ML today be different (better or worse) **(Intentions)**
- How have your views/experiences with ML changed from when you first graduated and began practicing to now?
    - o If you've participated in any continuing education workshops, can you briefly describe them?

How do you supplement your learning?

Outline of structure of ML workshop in November → "lectures" then case studies in small groups to discuss and brainstorm ideas before coming back to larger group discussions

Behavioural Regulation; If you were to seek out opportunities to learn more about ML and its relevance to clinical practice, describe the types of opportunities that would benefit you most

- What would be the most helpful?
- What topics would it cover?
- How would it be structured?

Looking back at the survey, CE workshops/formal opportunities weren't the only things that were suggested. Another potential opportunity is a journal club, or even more informally, a community of practice or peer mentors → can be used to discuss cases, brainstorm tx options, share knowledge/info etc.

- Would you utilize something like this? Why/why not?

Social Influences; How would being a part of this type of interactive learning/discussion/community setting impact your understanding of ML and how you approached your clinical practice?

- Upsides?
- Downsides?
- Pro/con?

Social/Professional Role and Identity; In doing background research for this study, a few papers cited that some clinicians believe independent learning (eg. research) is outside the scope of their professional duties and responsibilities. How do you view your responsibilities regarding staying up to date with advances in rehabilitation?

- How much do you prioritize staying UTD with these advances?

Any final questions/comments/concerns?

Anything that you wanted to say or tell me that you didn't get an opportunity to?

Anything else you'd like to elaborate on now that you've had an opportunity to think about it?