Understanding Specialists' Workflow and Decision-Making for Designing Digital Tools

Many decision-support tools aim to support clinical decision-making but clinicians often choose not to use them. One reason is that such tools do not align with the workflows and cognitive processes of clinicians. This challenge is evident in specialties like movement disorders, where diagnostic work is complex, uncertain, and shaped by long-term care. Our research team interviewed movement disorder specialists to understand how they structure diagnostic workflows and reason through complex cases. Our findings show that specialists do not always follow one concrete workflow. Instead, they adapt their activities based on contextual factors—such as diagnostic certainty, resource constraints, administrative needs, and patient/family behavior. Specialists also face a range of challenges—diagnostic, disease-related, logistical, and interpersonal—and draw on their experience to manage them. From these insights, we outline design implications for digital tools that support specialists' diagnostic workflows by improving how information is represented, how clinicians interact with tools during diagnostic work, and how collaboration is supported.

CCS Concepts: • **Human-centered computing → Human-computer interaction (HCI)**.

Additional Key Words and Phrases: Movement disorders, Clinical workflow, Contextual factors, Digital technology, Human-centered healthcare

1 INTRODUCTION

Designers and researchers increasingly create digital tools to support clinicians in improving clinical decision-making. Examples include AI-powered tools that predict cancer grades [13], estimate survival rates for artificial heart implants [61], enable early detection of sepsis [68], and assess fine motor performance in individuals with movement disorders [26]. Despite promising application areas in diagnosis, prognosis and risk assessment, many such tools fail to gain traction in real-world clinical settings: clinicians don't use them [65], abandon them [9], or use them incorrectly [13]. A key reason for such low adoption is a lack of understanding of clinicians' workflows and cognitive processes—specifically, how they work and make decisions [13, 52, 61].

HCI researchers have examined clinical workflows in several medical domains [25, 28, 31, 35, 68]. However, the work practices of domains such as movement disorders—where clinicians rely heavily on visual assessment and longitudinal clinical judgment, often without definitive biomarkers—remain underexplored [1, 11]. Moreover, within a single medical domain, clinicians who specialize in specific conditions often have unique workflow patterns and decision-making needs [63]. Without a clear understanding of specialists' practices, digital tools fail to integrate with existing workflows [59, 61, 62] and do not align with specialists' cognitive processes [52, 68].

Movement disorder care highlights the need for digital tools that support specialists as they interpret subtle signs, compare findings across visits, and manage diagnostic uncertainty. Designing such tools requires understanding how specialists work, the challenges they face, and how they make decisions in practice. Without this understanding, novel

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tools can miss clinicians' needs or even get in the way. Our research presents an interview-based need-finding study to answer the following research questions:

RQ1.1: What are the current workflows for movement disorders specialists?
RQ1.2: What factors shape how workflows are carried out?
RQ2.1: What challenges do movement disorders specialists face in their work?
RQ2.2: How do they tackle some of the challenges?
RQ3.1: What use cases do specialists identify for digital tools to support their work?
RQ3.2: What characteristics do specialists expect such tools to have?

Our study focuses on movement disorders specialists—neurologists with advanced training in diagnosing and treating conditions such as Parkinson's disease, essential tremor, and dystonia [54]. One concrete challenge in movement disorder care work is diagnosis of particular disorders. Symptoms such as tremor, slowness or stiffness frequently overlap across disorders like Parkinson's disease, essential tremor, and atypical Parkinsonian syndromes[1]—making it difficult to distinguish between them [57]. Unlike medical conditions with concrete confirmatory tests—such as diabetes (blood tests) or breast cancer (imaging tests)—most movement disorders lack definitive diagnostic tests. Imaging tools such as DaTscan or MRI provide supportive information but rarely confirm a diagnosis on their own [11, 44]. Additionally, distinguishing features such as changes in symptom progression, treatment response, or the appearance of additional motor and non-motor signs, often emerge only over time, requiring specialists to compare findings across visits and continually revise their impressions as new signs emerge [4, 57]. Since early and accurate diagnosis shapes treatment decisions, delays or errors can significantly affect patients' quality of life.

Our research team conducted semi-structured interviews with six movement disorders specialists to explore their real-world workflows, the challenges they face and how technology might better support their work. Movement disorders specialists' responses provide insights into the workflow and cognitive demands of movement disorders diagnosis, including how to design digital tools for such practice.

Our findings show that specialists do not always follow one concrete workflow. Instead, their approach is flexible and changes depending on the context. Factors such as *diagnostic certainty (or uncertainty)*, *resource constraints*, *administrative needs*, and *patient or family behavior* influence specialists' decision making. We identified four types of challenges that specialists navigate: 1) *diagnostic*: challenges related to making a clinical diagnosis, 2) *disease-related*: challenges that stem from the nature of movement disorders themselves, 3) *logistical*: challenges caused by healthcare system constraints, and 4) *interpersonal*: challenges that arise from communication gaps, especially when patients have difficulty describing their symptoms.

Specialists saw opportunities for digital tools to support their work by enabling remote assessment and monitoring of motor symptoms, supporting collaboration in complex cases, assisting non-specialists with early evaluation and referral, and supporting communication with patients and families. Our study also identifies the conditions and characteristics that shape whether specialists would be willing to use such tools or would be wary of using them in practice. Based on our findings, we reflect on how digital tools might be designed to support specialists' work and we highlight concrete tool ideas based on use cases from specialists' descriptions.

This paper makes two contributions to human-computer interaction and human-centered health research. First, we offer an empirical contribution through an interview study with movement disorders specialists. We document specialists' workflows, the challenges they face in clinical decision-making, and how they navigate some of these

[1] Atypical parkinsonian syndromes are conditions that resemble Parkinson's disease early on but progress differently, such as multiple system atrophy and progressive supranuclear palsy.

challenges. This contribution adds domain-specific insights to the body of human-computer interaction work that examines real-world clinical workflows [13, 51, 59, 63, 64, 68]. Second, we present design implications for future clinical tools grounded in specialists' workflows, challenges, and their ideas for digital tools that can help with clinical work.

2 RELATED WORK

Our work draws on clinical literature on movement disorder diagnosis, human-computer interaction research on why digital tools are abandoned in clinical practice, and prior work on digital tools for movement disorders. Together, synthesizing literature from these cross-cutting topics informs how tools are designed for busy healthcare professionals like specialists.

2.1 How do movement disorder specialists structure their diagnostic work?

Clinical workflows vary across medical specialties. In acute domains such as emergency medicine or the intensive care unit, clinicians must act quickly, triage, and respond to rapidly changing clinical states, such as sudden declines in patient stability [68]. In contrast, in movement disorders which are chronic and progressive conditions, clinicians work on a much longer timescale. These specialists must interpret subtle motor features and weigh overlapping diagnoses over time, often without definitive biomarkers [44]—making diagnosis highly interpretive [11, 30].

Movement disorders provide a concrete example of a clinical specialty where diagnosis relies heavily on clinician interpretation. Movement disorder diagnosis follows an iterative, hypothesis-driven workflow [1, 58]. By observing how patients move, specialists characterize the visible features—such as speed, rhythm, distribution across the body, and how movements change across tasks—to situate symptoms within broad movement disorder categories [4, 11]. Since many movement symptoms look similar, these judgments rely on clinical experience [4, 57]. Standardized rating scales such as the Unified Parkinson's Disease Rating Scale (UPDRS) for Parkinson's disease depend on clinician interpretation as well [30]. Alongside observation, clinicians gather detailed patient histories to understand symptom onset, progression, and triggers [1, 32]. They also use structured physical examinations to understand how movements respond to distraction, effort, or emotional state—features that help distinguish between overlapping disorders [23, 44]. Since most movement disorders lack definitive biomarkers and often evolve slowly, diagnosis is often not finalized in a single visit [8]; instead, specialists compare findings across visits, selectively order investigations, and revise their working diagnosis as new features emerge over time [30, 57].

Clinical literature describes diagnostic processes and often presents them as guidance on how diagnosis should proceed, with an emphasis on formalizing diagnostic criteria and teaching best-practice approaches. Clinical studies typically do not examine how specialists perform or adapt *diagnostic processes* in practice. Prior digital health work has examined neurologists' perspectives on improving Parkinson's disease clinical visits, focusing on communication, visit structure, and care delivery challenges [50]. While such work shows how neurologists manage communication and quality-of-life concerns during visits, it does not examine how movement disorders specialists structure diagnostic work or make clinical decisions.

HCI researchers have extensively examined workflows in domains such as radiology, pathology, sepsis, and emergency medicine, producing valuable insights for designing clinical tools. In movement disorders, substantial work has focused on developing computational methods to detect, classify, or model disease [3, 15, 18]. Far less work has examined movement disorder diagnosis from the clinician's perspective—how specialists interpret symptoms, structure diagnostic work over time, and make decisions. Our study addresses the gap in empirical insights into the workflows and decision-making processes of movement disorders specialists. Additionally, our study shows how contextual factors actively shape which tasks are prioritized, skipped, or revisited. Such insights offer an understanding of how specialists work in practice and highlight opportunities for designing digital tools that align with, rather than disrupt specialists' workflows.

2.2 Clinicians often ignore digital tools when such tools do not fit how clinicians work and make decisions

Clinicians are expected to make "perfect decisions with imperfect information" [40]. Clinical decision-making is an interpretive, hypothesis-driven process shaped by uncertainty, incomplete data, and evolving evidence [17, 29]. Clinicians continually form, revise, and integrate hypotheses while drawing on tacit knowledge and multiple information sources. To support them, digital tools like AI-based decision support tools (DSTs) aim to assist with diagnosis, treatment planning, and prognosis recommendations [15, 62]. While such tools hold promise in clinical decision-making, few are routinely used in clinical practice [9, 12, 27, 61]. One reason is that such tools are often designed without an understanding of specialists' workflows in the real world and how they make decisions [61].

Workflows are often flexible, messy, and shaped by interruptions and coordination needs that technology designers tend to overlook [70]. Research efforts focusing on developing complex technology might not prioritize starting with understanding stakeholders' workflows and needs during the design process [33, 53, 60]. For instance, only 20 of 17,000 papers on AI and clinical decision support systems (CDSS) considered clinicians' needs and experiences [60]. Unsurprisingly, clinicians often ignore or override recommendations from digital tools when such tools interfere with clinicians' established workflows [33, 52].

HCI researchers have responded with several workflow studies across clinical domains and have shown that digital tools fail when they do not reflect the cognitive processes of clinicians. For example, clinicians frequently dismissed AI-generated sepsis alerts because the system focused on the wrong clinical need—predicting the final decision rather than supporting the reasoning process that led to the decision [68]. As a result, clinicians felt that the system was challenging their role as experts. Similar patterns have emerged in radiology [65, 66], cardiology [63], and pathology [13, 25] where clinicians disengage from tools that disrupt their judgment, appear at the wrong moment, or produce outputs that require additional interpretation work. In one case, specialists preferred tools that organized information—similar to how mid-level clinicians prepare cases—over tools that attempted to make decisions on their behalf [61].

Additionally, clinicians' use of digital tools can be shaped by the conditions under which care is delivered. For example, environmental and organizational factors—such as lighting conditions, network reliability, staffing constraints, and added workload for nurses or patients—directly influenced whether and how tools were used [9]. Therefore, whether clinicians adopt or use tools also depends on how such tools interact with the realities of clinical work. Our study contributes to HCI research on clinical workflows by examining the workflows and decision-making processes of one group of clinical experts—movement disorder specialists. Rather than focusing solely on producing the final diagnostic outcome, our work investigates how specialists approach *the process of diagnosis*: how they gather information, respond to different challenges, and make decisions. The findings also identify situations in which specialists find digital tools helpful and conditions that shape whether and how specialists choose to engage with such tools.

2.3 Digital tools in movement disorders

Close to the thrust of *Computing in Healthcare*, researchers have explored digital technologies to support clinical assessment and decision making in movement disorders. Such line of research is motivated by the difficulty of observing subtle motor symptoms during brief clinic visits and by the availability of consumer devices that can capture motor behavior outside the clinic.

Prior research has developed a wide range of digital tools across platforms including computers, smartphones, wearables, and video, largely with the goal of objectively capturing and quantifying motor symptoms. Everyday computer use can reveal motor impairments associated with ataxia and Parkinsonism [21]. Smartphone and touchscreen-based systems have used drawing tasks [34], gesture interactions [56], passive sensing [22], and mobile games [37] to distinguish people with Parkinson's disease from healthy controls and quantify symptom severity [3]. At-home wearables and measurements collected across multiple sessions have been used to track symptom fluctuations and correlate motor measures with clinical severity [10, 16]. Video-based tools such as VisionMD convert ordinary video into kinematic features—including tremor cycles, gait metrics, and joint angles—with high reliability [2]. AI models trained on neuroimaging, electrophysiology, and sensor data also perform well in identifying or classifying movement disorders [15]. Researchers have additionally developed tools to support self-care [7, 42] and tools for clinical assessment in related domains such as multiple sclerosis [39].

Taken together, prior work demonstrates substantial progress in measuring and modeling motor symptoms using widely available technologies. However, advances in digital technology have not consistently translated into improvements in diagnosis in part because many systems focus on producing measurements, scores, or classifications rather than on supporting how movement disorder specialists use such information during diagnostic work [3, 18]. To improve data interpretability, Lin et al. [36] presented Hevelius Report, a visualization system that aggregates outputs from a web-based mouse task to help clinicians interpret and compare fine-motor measurements. Branco et al. [10] similarly summarized wearable and self-report data to support clinical review and discussion.

Our study complements such efforts by providing empirical insights into movement disorders specialists' diagnostic work in practice, informing how digital tools might better support specialists' work. Our study takes a formative approach to understanding how movement disorder specialists structure diagnostic work and how digital tools might better support specialist decision-making in practice.

3 BACKGROUND: MOVEMENT DISORDERS

Movement disorders are neurological conditions that affect body movements [14]. Some examples include Parkinson's disease, essential tremor, dystonia, and Huntington's disease. These conditions typically get worse over time and require long-term care, including frequent monitoring and changes to treatment plans as the disorder progresses. Movement disorders specialists are neurologists with advanced training who diagnose and manage conditions such as Parkinson's disease, essential tremor, and dystonia [54]. Such conditions are defined by their clinical features—such as the type, speed, and pattern of movements—which clinicians must understand or describe in detail to guide diagnosis. Most movement disorders are diagnosed clinically with careful observation and description of abnormal movements rather than with laboratory tests or imaging [20]. However, the diagnosis process is far from straightforward. The clinical presentation of movement disorders is often "complex, variable, and sometimes even bizarre" [1], making accurate diagnosis difficult even for experienced specialists [1].

Many movement disorders lack definitive biomarkers [2], requiring clinicians to rely on subjective interpretation of subtle motor signs and patient history. Overlapping symptoms further complicate diagnosis: tremor in early Parkinson's disease can resemble tremor in atypical parkinsonian syndromes, and imaging tools such as DaTscan do not reliably distinguish between them [11]. As a result, misdiagnosis is more likely in early or atypical cases [18]. Additionally, symptoms can look very different from one patient to another and can also change from day to day in the same person,

[2]Biomarkers refer to objective measures that can reliably indicate the presence or progression of a disease (e.g., laboratory tests or imaging). In movement disorders, proposed biomarkers can also be digital, such as measures derived from sensors, video, or smartphone interactions.

making it difficult to assess how the disorder is progressing [18]. Current assessment tools like the Unified Parkinson's Disease Rating Scale (UPDRS)[3] for Parkinson's disease, are limited in their ability to track symptom variability, and assessments often depend on clinician interpretation [44].

Another challenge in movement disorder care is the scarcity of movement disorder specialists. As a result, clinicians often have limited time with each patient, and they must use each appointment carefully to make the best possible decisions for long-term care. Despite clear evidence that specialized care leads to better outcomes [49], only 9% of people with Parkinson's disease receive care from a movement disorder specialist [45]. Instead, most patients see general practitioners or general neurologists who provide important frontline care but may lack the necessary knowledge to diagnose movement disorders or make timely referrals. Taken together, the subjective, variable, and longitudinal nature of movement disorder diagnosis, combined with limited access to specialists, introduces challenges for clinical decision-making.

4 METHOD

We conducted semi-structured interviews with six movement disorders specialists to understand how they work, the challenges they face, and how technology might support their clinical decision-making. Several reasons informed our decision to interview movement disorders specialists. First, most patients initially see general practitioners or general neurologists; however, movement disorder specialists are trained to identify and interpret abnormal movements that non-specialists may miss [1, 20]. Second, unlike many health conditions with definitive diagnostic tests, movement disorders lack objective biomarkers, making diagnosis highly dependent on clinical expertise [44]. As a result, movement disorder specialists provide the clinical "gold standard" for diagnosing Parkinson's disease and related disorders [1, 57]. Diagnostic accuracy is also higher when assessments are made by specialists rather than non-specialists [49]. Since our goal is to understand the workflow and decision-making process for the diagnosis of movement disorders, specialists are the most appropriate population for a formative study. Understanding how experts (like movement disorders specialists) make decisions provides a foundation for designing tools that can eventually assist clinical practice.

Our participants represented a range of clinical backgrounds within the movement disorders specialty. Five participants were based in the United States, and one had worked in both Nigeria and the United Kingdom. These clinicians had between 5 and 20 years of experience. We recruited participants using snowball sampling [24], starting with professional colleagues and contacts and asking them to share our recruitment materials within their networks. The

[3]The UPDRS is a standardized scale used to assess Parkinson's disease severity and progression, covering motor symptoms, non-motor symptoms, daily functioning, and treatment-related complications.

Table 1. Overview of interview participants. PD- Parkinson's disease, ET- Essential tremor, HD- Huntington's disease, PSP- Progressive supranuclear palsy, MSA- Multiple system atrophy, DLB- Dementia with Lewy bodies, FND- Functional neurological disorders

ID	Common conditions treated	Experience
P1	PD, ET, dystonia, tics and Tourette's syndrome	8 years
P2	PD, HD, tremors, chorea	7 years
P3	PD, tremors, balance problems, gait difficulty, stiffness, memory	14 years
P4	PD, Parkinsonism, ET, dystonia, chorea, tics	20+ years
P5	PD, PSP, MSA, DLB	12 years
P6	PD, ET, atypical Parkinsonisms, FND	4–5 years

study team followed up with individuals who expressed interest and scheduled interviews at their convenience. Table 1 provides more details on all participants' demographics.

We conducted all interviews over Zoom. Each session was originally planned for one hour and many participants provided rich, in-depth responses that extended beyond this time schedule. As a result, two interviews were split into two sessions to allow participants to complete their responses comfortably. The interviews ranged from 42 to 110 minutes, with an average duration of approximately 70 minutes. The study team recorded the Zoom interviews with participants' consent in audio and video formats. The study received approval from the Institutional Review Board (IRB) of the authors' institution.

The interviews followed a semi-structured format and were grouped into three sections: i) understanding specialists' workflow in diagnosing movement disorders; ii) identifying the challenges they face in clinical practice; iii) exploring how technology could support their work. Within these sections, we asked participants about their experience with patients, decision-making processes, and current assessment methods for motor performance. We also asked them to describe what kinds of technological support could meaningfully assist their day-to-day workflow or diagnostic reasoning. In addition, we asked whether they would use technology to support their assessments, and under what conditions they would use such tools in their practice. Participants were also asked to walk us through a recent (de-identified) patient case to describe their diagnostic process.

We transcribed the interviews using Otter.ai [43] and manually reviewed each transcript to ensure accuracy. We analyzed the data using an inductive thematic analysis approach [55]. The first author coded the transcripts using atlas.ti [6], exported the codes into Miro [38], and used affinity mapping to group them into broader themes. The first author progressively discussed codes and themes with the second author to synthesize themes to answer the research questions.

5 RESULTS

Our study examines how movement disorders specialists work, the challenges they face in clinical practice, and opportunities for technology to support specialists' work. Hence, our findings are organized around workflows, challenges, and design opportunities. Each discussion subsection maps to our findings for a research question. Sections 5.1 and 5.2 address specialists' diagnostic workflows and the factors that shape how these workflows are carried out in practice (**RQ1.1–RQ1.2**). Section 5.3 examines the challenges specialists face and, where applicable, how they respond to them (**RQ2.1–RQ2.2**). Section 5.4 focuses on use cases specialists identified for digital tools and the characteristics that shape whether specialists would be willing or wary of using such tools in practice (**RQ3.1–RQ3.2**).

5.1 Specialists' Tasks—observation, gathering patient history, conducting physical examination, and clinical diagnosis

In this section, we describe four tasks that structure movement disorders specialists' diagnostic work: observing the patient, gathering patient history, conducting the physical examination, and arriving at a clinical diagnosis. These tasks broadly align with components described in the clinical literature (Section 2.1), but specialists' accounts reveal how such tasks are carried out in real-world practice and the factors that shape their use during clinical interactions. We briefly summarize the tasks below.

5.1.1 Observation to form initial hypotheses. Observation often starts before the formal examination. From the moment the patient enters the room—or when the specialist approaches the patient—specialists watch carefully for signs in the patient's movements, posture, facial expressions, and behavior. These early observations help form initial hypotheses of possible diagnoses. Specialists' observations also guide what questions specialists ask patients and help identify abnormalities that may point to specific movement disorders. For example, if a patient shows reduced arm swing or masked facial expression [4], the specialist might ask targeted questions about Parkinsonism.

> *"...when a patient walks in, ... I observe the walking pattern, the arm swing, the way the patient talks, the face, those are the things I will observe, and then I'll ask my questions."* (P2)

> *"Let's say the patient comes in and says, 'I came here for evaluation of Parkinson's disease.' You say, 'Why Parkinson's disease?' And then, observation of the patient as you interact with the patient, from the moment you walk in the room, how does that patient move and speak and think and respond to questions."* (P4)

5.1.2 Gathering patient history to narrow possible diagnoses. Patient history comprises three types of information.

(1) **Motor symptoms**—such as tremors, balance issues, and stiffness—help specialists narrow down possible movement disorders.
(2) **Non-motor symptoms**—such as sleep disturbances, mood changes, and hallucinations—provide supporting cues, especially when motor symptoms overlap across conditions.
(3) **Other contextual information**—such as the chief complaint(s), past medical history, medications, social and family history—helps specialists understand the patient's overall health and risk factors.

> *"I pretty much have my standard list of questions...when I'm doing a history. The general 'What brings you in?', 'What are you most concerned about?' And then specific to their movement disorders; 'What symptoms have you noticed?'... then I'll go through my non-motor questions. 'Do you have sleep issues?'...then I'll... [go through] past medical history, medications, allergies, [and] family history."* (P6)

In gathering patient history, specialists request patients—and often caregivers—to speak freely to understand patients' concerns. Then they follow up with specific questions to rule in or out certain diagnoses.

> *"...the most important thing is what the patient and their caregiver tell me... even though I don't do formal tools of assessment, I do get to ask thorough questions and detailed questions to the patient and... assess based on what they are telling me."* (P1)

> *"...gathering history from patients, allowing them to speak on what their concerns are...[and] asking questions that I want to know the answers to rule in or out certain disorders."* (P6)

5.1.3 Conducting physical examination to confirm or refine hypotheses. Physical examination allows specialists to identify and characterize abnormal movement patterns to confirm or refine their working diagnosis. Physical exams typically include two components:

(1) **General neurological examination** covers functions such as sensation, motor strength, reflexes, coordination, gait, and tone.
(2) **Focused examination** allows specialists to explore specific features of a patient's movement—such as tremor type or slowness—to better understand the phenomenology[5] of the disorder.

> *"The neurologic exam includes a full general neurologic exam. And then we do a focused exam on like movement disorders as well as like the symptom or problem that the patient is coming in for."* (P1)

[4] Masked facial expression refers to reduced facial expressiveness commonly observed in Parkinsonism.
[5] Phenomenology refers to the clinical features that characterize a movement disorder, such as the speed, frequency, rhythm, and pattern of movement.

> *"We do a focused examination for the patient to either confirm what we are thinking, and then we make our diagnosis and treat the patient."* (P2)

> *"...through the examination, you want to understand what is the abnormal pattern of movement. So you're going to say to yourself, is this a tremor, or is this something else?... be it dystonia or chorea[6] ?"* (P4)

Clinicians sometimes use standardized assessment scales—such as the Unified Parkinson's Disease Rating Scale (UPDRS) for Parkinson's disease—alongside the physical exam. Such tools are often used after the clinician has established a diagnosis, to quantify disease severity or track disease progression over time.

> *"...[the scales] are more of a method of tracking disability, medication response, change in symptoms. You can attach those scales to any person and get a number, but that number doesn't mean anything unless it's used in the right clinical context."* (P6)

Information from physical exams helps specialists distinguish between similar disorders by revealing motor clinical features.

5.1.4 Clinical diagnosis by synthesizing findings from previous tasks to diagnose. Specialists make clinical diagnoses by synthesizing information gathered across observation, patient history, and physical examination. Observation provides early visual cues—such as changes in posture or facial expression—that help form initial impressions and guide the rest of the assessment. Patient history provides insights into motor and non-motor symptoms, along with contextual factors like medications and family history, all of which help narrow possible conditions and identify patterns. Physical examination allows specialists to check for movement abnormalities and confirm or adjust their thinking.

At the end of the diagnostic workflow, diagnosis relies heavily on the specialist's judgment—how the clinician weighs different pieces of information, interprets symptom patterns, and reasons about likely explanations.

> *"We diagnose many of the diseases...based on what we see the patient doing in clinic...the patient has tremor, bradykinesia, rigidity. We say this is a form of Parkinsonism... and of all the possible types...we think this patient is more likely to have Parkinson's disease, as opposed to another disorder in that family."* (P4)

> *"The key phrase is pattern recognition...[We] put symptoms and exam findings together into a syndrome."* (P5)

Specialists described using clinical judgment alongside formal diagnostic criteria, when available or feasible to apply, and comparing observed symptoms with those criteria to assess diagnostic fit.

> *"Most of our movement disorders diagnoses are based on criteria...for Parkinson's, the movement disorder society has a criteria that says, if someone meets this checklist, then they have Parkinson's disease."* (P1)

> *"You use existing criteria, clinical diagnostic criteria, when possible, and that gets you to...a diagnosis."* (P5)

> *"...for the UK PDS Brain Bank criteria... [the] patient must have bradykinesia...and then any other one of either ridigity, tremor or postural instability. So we already make our diagnosis based on those criteria,"* (P2)

> *"To make a diagnosis of Parkinson's, you have four motor features that a patient can present with...tremor, slowness, stiffness, postural instability. You need three of those four to make a clinical diagnosis..."*(P3)

Together, these four tasks—observation, gathering patient history, conducting physical examination, and clinical diagnosis—represent main tasks of the specialist's workflow as seen in Table 2.

[6]Dystonia and chorea are types of movement disorders. Dystonia involves sustained or repetitive muscle contractions that cause twisting movements or abnormal postures. Chorea involves brief, irregular, dance-like movements that can affect different parts of the body.

Table 2. Summary of clinical tasks, the types of information clinicians gather, and how they use that information to support diagnosis and decision-making.

	Main Tasks	
Task	**Information Gathered**	**How Clinicians use this Information**
Observation	Patient's movement, posture, arm swing, facial expression, spontaneous behaviors	Forming hypotheses, identifying abnormalities, planning follow-up questions
Patient History	Patient's complaints, motor symptoms, non-motor symptoms, medical/family/social history	Narrowing diagnoses, identifying comorbidities, focusing the physical exam
Physical Exam	Movement patterns, rigidity, reflexes, balance	Confirming or refining diagnosis, determining movement phenomenology, assessing severity
Clinical Diagnosis	Synthesized data from prior steps; diagnostic criteria when applicable	Assigning diagnosis, planning further steps or treatment
	Supporting Tasks	
Assessment Scales	Symptom severity (*e.g.*, UPDRS scores)	Tracking disease progression, documenting disability for research, surgery, or insurance
Diagnostic Testing	Imaging (*e.g.*, DaTscan), genetic, or physiological tests	Clarifying uncertain cases, supporting or revising diagnosis, helping patients understand diagnosis
Consult with Colleagues	Case summaries, video recordings, test results	Getting opinions, validating reasoning, managing diagnostic uncertainty

5.2 Contextual factors that shape how workflow tasks are carried out

Although observation, patient history, physical examination, and clinical diagnosis are central to clinical workflows, these tasks are **not always performed in a fixed order or to the same depth**. Instead, specialists adjust the order of tasks based on contextual factors, which include: (1) diagnostic certainty or uncertainty, (2) resource constraints, (3) administrative needs, (4) patient or family behavior. These factors shape how clinicians perform core tasks, and help explain why they sometimes skip certain tasks marked as supporting in Table 2. We share how these factors influence how clinicians prioritize, sequence, adjust, and carry out their tasks.

5.2.1 Diagnostic certainty (or uncertainty). Specialists adjust their workflow based on how certain (or uncertain) they are about their initial suspicion of a patient's diagnosis. When they feel confident early on—typically due to a clear presentation of a familiar disorder—they may skip or shorten tasks they judge unnecessary. For example, in a case that resembles Parkinson's disease, a specialist may choose not to perform certain parts of the neurological exam because the findings are unlikely to alter their diagnosis.

> *"...there is a suspicion for Parkinson's disease. I may or may not spend much time on the sensory exam or deep tendon reflexes... because I don't need that information."* (P4)

However, when specialists feel uncertain—especially in cases involving overlapping or unusual symptoms—they often prioritize tasks that yield more information. In such cases, specialists may focus more on gathering a detailed patient history or engaging the patient's family to better understand the context of the symptoms, while placing less emphasis on the physical examination at that stage. Such context includes when symptoms first appeared, how they have changed over time, how they affect daily activities, and observations from family members who have seen the symptoms outside the clinic.

> *"...most of the effort was based not on seeing the movements and analyzing the movement pattern, but... on talking to the patient and talking to his relatives ... asking them a series of questions about the context of these movements."* (P4)

Comorbidities can also decrease diagnostic certainty. Conditions like hypertension, diabetes, or a history of stroke prompt clinicians to order additional tests (e.g., MRI) to explore alternate causes or confirm a suspected diagnosis.

> *"For a patient who is hypertensive, diabetic or has had a stroke... I might like to do a brain MRI because it could be vascular Parkinson's [7]."* (P2)

In essence, specialists dynamically prioritize, add/remove, and carry out tasks based on the level of diagnostic certainty. When specialists are less certain, they adopt a more investigative approach—rearranging the workflow, delving deeper into the patient's history, and using ancillary tests.

5.2.2 Resource constraints. Specialists adjust their workflow based on available resources—such as time, diagnostic tools, and personnel. When time is limited, specialists may limit the depth of tasks—for example, skipping standardized assessment scales during physical examination if those results will not impact immediate decisions.

> *"Most often, I'm very limited by time in clinic and I don't have time to add these scales... because I already do an exam and gather the information that I need."* (P1)

> *"...there are inevitably visits..where you may not do the MDS UPDRS because you didn't have time."* (P4)

Tool availability also shapes specialists' choices. If no standardized assessment scale exists for a disorder, specialists use their own judgment instead.

> *"There are no standardized scales for those [like chorea or hemiballismus [8]]... you pick it clinically... and then evaluate for the diagnosis."* (P2)

When medical assistants are available, routine tasks like cognitive testing or vitals can be delegated, allowing specialists to focus on diagnostic reasoning.

> *"When the MAs do these things for us, it saves me time... but in other institutions, the physicians might end up having to do these things themselves."* (P1)

In resource-limited settings, experienced specialists also adapt by internalizing tools like the UPDRS and applying them informally.

[7] Vascular parkinsonism refers to parkinsonian symptoms caused by cerebrovascular disease, such as strokes, rather than by neurodegeneration typical of Parkinson's disease.

[8] Chorea and hemiballismus are movement disorders involving involuntary movements. Chorea involves brief, irregular, dance-like movements that can affect different parts of the body. Hemiballismus is a more severe form, involving large, flinging movements, usually on one side of the body.

> *"I don't necessarily do a formal UPDRS... I just do it naturally. At this point I can do it in my head... I know what I'm looking for."* (P3)

These adjustments—skipping, adjusting, delegating, or streamlining—reflect how clinicians flexibly manage resource constraints.

5.2.3 Administrative needs. Specialists described how external demands—such as insurance documentation, research study protocols, and surgical evaluations—influence how and when they use certain tools in clinical care. An example is the use of standardized assessment scales like the Unified Parkinson's Disease Rating Scale (UPDRS). Clinicians often use such tools *after* they have have decided on a diagnosis, primarily to quantify symptom severity or monitor disease progression.

> *"I guess the scales themselves don't necessarily help us diagnose because they are more of a method of tracking disability, medication response, change in symptoms."* (P6)

Specialists noted that they might skip using such tools when the results are unlikely to influence immediate clinical decisions. However, clinicians rely on such tools when they need to document for specific purposes such as insurance coverage, research participation, or surgical evaluation.

> *"But sometimes I need to document these things for insurance reasons, or research study reasons, or patients are undergoing a surgical evaluation, and that's most often when I utilize these tools."* (P1)

> *" I don't even necessarily do a formal UPDRS...I can do it in my head. I can get a number...if I have to document it for insurance purposes, or surgical clearance purposes, that's a different story."* (P3)

5.2.4 Patient and family behavior. Specialists adapt their workflow based on how patients and their families engage during the clinical interaction. When patients seem hesitant or uncertain about a diagnosis, clinicians may take extra steps—such as ordering additional tests or proposing trials to help the patient better understand or accept the diagnosis.

> *"When I order a DaTscan, it is really to either reassure the patient that my clinical diagnosis is correct, even though I already know it's correct or if they really are sort of in a gray area between, like a tremor predominant Parkinson's, or an essential tremor, or drug induced tremor, and Parkinson's, then it can be helpful in crystallizing the diagnosis. "* (P3)

These adjustments also influence the time and depth of tasks. Some patients or family members ask more questions or need more time to process the information, which can extend certain steps like gathering patient history.

> *"Some patients ask more questions… you might spend a longer time with them… even when you're giving them the diagnosis. So yes, patient and family factors do affect our workflow."* (P1)

These contextual factors show that although movement disorders specialists have a common set of clinical tasks, *how they prioritize, sequence, or carry out those tasks* depends on their judgment and the unique circumstances of each patient.

5.3 Challenges faced by specialists and how specialists tackle them

We present the challenges described by specialists in their clinical work, particularly around diagnosis. These challenges—and how specialists respond to some of them—offer insights into their cognitive processes. This section highlights how specialists think through complex, uncertain, and evolving clinical situations.

5.3.1 Diagnostic challenges. Diagnostic challenges refer to the difficulties clinicians face when working toward a diagnosis. These include: diagnostic dilemma, subjectivity in assessment, and limitations of diagnostic tools.

(1) **Diagnostic dilemma:** Specialists described experiencing uncertainty in arriving at a diagnosis in some cases.

> *"Sometimes you have difficulty making a diagnosis for your patient, sometimes you're not sure what exactly the patient has."* (P2)

Such dilemmas often arise for several reasons, including overlapping symptoms across disorders, subtle or early presentations, age-related changes, cases that do not fit diagnostic criteria, and the limits of existing criteria. Movement disorders often present gradually, and many disorders share similar motor features such as tremor, stiffness, or slowness—making it difficult to determine a clear diagnosis from a single visit.

> *"...the atypical Parkinson's—the Multiple System Atrophy, Progressive Supranuclear Palsy, they look like Parkinson's, but they are not idiopathic Parkinson's."* (P2)

Early symptoms may also be easily overlooked or attributed to other causes, and key signs may not yet have appeared, leaving multiple possibilities open.

> *"...somebody that has Parkinson's disease... might have MSA or PSP in the beginning, and we're just not aware of it, because certain more clarifying clinical symptoms ...haven't declared themselves yet."* (P3)

Uncertainty increases in older adults, whose age-related changes overlap with early signs of disease.

> *"If someone has decrementing bradykinesia and I'm not seeing a tremor, it's hard for me to tell is this the very beginning of Parkinson's...or is this just them getting old?"*(P1)
>
> *"But if someone who is 70, 80, or 90 starts developing signs of Parkinsonism, distinguishing what's the disease from the effects of normal aging can become more difficult."* (P4)

Diagnostic uncertainty also arises when patients show symptoms that suggest a disorder but do not yet meet formal diagnostic criteria.

> *"the other difficulty is when you're seeing something that doesn't quite fit into an accurate box..."*(P6)

Finally, diagnostic criteria are limited, as they do not always account for every patient's unique experience or presentation.

> *"the criteria was developed based on most people will have these symptoms, but there's no two Parkinson's patients that are the same."* (P1)

(2) **Subjectivity in assessment:** Diagnosing movement disorders often relies on the clinician's judgment. Specialists described sources of subjectivity in assessment, including differences in how clinicians interpret subtle signs, variation in how standardized scales are applied, and the limits of what can be observed during a brief exam.

Specialists interpret subtle motor signs—like tremor amplitude, slowness, or rigidity—based on what they see during short clinic visits. Such interpretations can vary from one clinician to another, which can lead to inconsistent conclusions.

> *"...our inter-rater reliability is not great depending on the disease... Diagnosis A from one movement specialist, diagnosis B from a second one, diagnosis C from a third, and I finally, as the last stop, giving diagnosis D. That's a very typical situation."* (P5)

Clinicians often reach different conclusions because the symptoms they assess do not always present clearly. Even clinicians with similar training and years of experience can disagree on whether a symptom should be considered normal, subtly abnormal, or clearly abnormal.

> *"I might see a patient and say, I think there's a subtle abnormality here. And one of my colleagues with just as much experience will say, Oh no, it's clearly abnormal. And someone else will say, I think it's actually normal."* (P4)

Standardized assessment scales like the UPDRS aim to standardize evaluations; however, specialists might still interpret the scale's categories differently. Clinicians rely on their own judgment when mapping what they observe onto the scale's categories.

> *"…everything we do is subjective up to a point. You have one movement disorder specialist do the UPDRS...and another movement disorder specialist do the UPDRS...they definitely won't be exactly the same."* (P3)

One reason for such variation is the heavy reliance on what the clinician sees and estimates. Clinicians judge features like tremor amplitude during the exam, without tools that precisely measure these features in routine clinical practice.

> *"... we're not using a ruler in clinic to say this is five centimeters... what I see as five centimeters might be...different from what one of my colleagues [sees]."* (P1)

Additionally, specialists noted that some movement patterns are difficult to assess through observation alone. In some cases, movements are subtle, and in others, movements from different conditions can look similar. As a result, clinicians may recognize the presence of a movement—such as tremor—but still struggle to judge its characteristics or determine its underlying cause through human vision.

> *"... most tremors, we're able to [diagnose] with our naked eye... but some patients are more challenging where... the tremor is difficult to fully assess with the limitations of my human eye."* (P1)
>
> *"Tremor is a very common, very frequent complaint, and you might just say, well, isn't it easy to see tremor?...but I would say, we think we can recognize tremor, but because tremor of different causes can look remarkably similar, diagnosing the different causes of tremor can be challenging."*(P4)

(3) **Limitations of diagnostic tools:** Specialists noted limitations of diagnostic tools including the lack of definitive tests, reduced usefulness in early stages of disease, limits in accuracy and reliability, and the increased time and effort required for routine use. Specialists emphasized that no single diagnostic tool can offer a definitive diagnosis for most movement disorders. Instead, diagnosis relies on clinical judgment, often after the disease has progressed. Diagnostic tools like DaTscans, synuclein markers, and genetic panels can provide helpful clues, but such tools do not support early diagnosis.

> *"By the time that Parkinson's disease is clinically diagnosed by someone like me in the office, 40 to 60% of dopamine-producing cells at the base of the brain... are already lost."* (P5)

Clinicians also highlighted that diagnostic tools are not always accurate or reliable. In some cases, test results may point toward a diagnosis that does not hold up over time.

> *"We have genetic risk factors... but those don't guarantee someone is going to develop Parkinson's disease. And even our scans that we use, such as a DaTscan or a synuclein marker, skin biopsy, or CSF, are not 100% accurate."* (P6)
>
> *"I've had patients that tested positive on the DaTscan. I told them they had Parkinson's. And over the years, it didn't make sense that they had Parkinson's; they just didn't fit...you repeated the DaTscan again, it comes back negative... these tests aren't as great as we think they are."* (P1)

Beyond accuracy, some tests are labor-intensive, time-consuming or invasive for routine care. One specialist described a colleague who performed detailed neurophysiological assessments using accelerometers and electrodes. While the data was rich, the process required substantial time and effort, making it feasible only for a small number of selected cases.

> *"He [the specialist conducting these assessments] would spend at least an hour with the patient...and then interpreting the data afterward...also took so much time and effort...it was only the most challenging patients we would refer to him that he would agree to take on."* (P1)

How specialists respond to diagnostic challenges: Specialists navigate diagnostic dilemmas by using ancillary tests, giving the case more time, consulting with colleagues, and drawing on clinical experience. These actions help specialists make and revise decisions when the diagnosis is uncertain.

Clinicians use ancillary tests—like imaging or genetic tests—to gather additional evidence when symptoms alone do not clearly indicate a diagnosis. Such tools reduce uncertainty and help with a differential diagnosis. For example, specialists may use a DaTscan to help distinguish between Parkinsonism and essential tremor.

> *"But then sometimes people have subtle features...that suggest Parkinson's, but they don't meet the full checklist for me to actually say, yes, you have Parkinson's. And I'm not really sure. These are the patients where I'm like, Okay, let's order DaTscan. I have this as an ancillary test that can guide me as to like, are these subtle features the very beginning of Parkinson's disease, or an unusual presentation of Parkinson's disease, or... someone's just getting old."* (P1)

Specialists may delay diagnosis in order to re-evaluate the patient over time. Instead of relying on a single visit, clinicians may see the patient again after several months and observe how symptoms change or whether new signs emerge. Repeating observation allows clinicians to revise or refine the diagnosis as more information becomes available.

> *"there's nothing that's 100% ... we put all that information together and make the most likely diagnosis based on it...and always re evaluate as you have more information. There are some patients that I've revised their diagnosis after a period of time, based on new information that I have"* (P1)

> *"I'm seeing the patient now, I may see the patient another couple of months from now, and then another six months later... that repetition of observations is very helpful."* (P4)

> *"there's so much crossover between those diagnoses...and it's often the situation where time is really what we need to see how this person progresses"* (P6)

To help resolve difficult cases, clinicians may formally consult with more experienced clinicians, informally ask for opinions, or bring the case to formal grand rounds or team discussions in their movement disorders division.

> *"... sometimes, when we see challenging patients, we record a video... So we have weekly meetings in the Movement Disorders Division; one of those weekly meetings, one time a month, we do video rounds. I would show my colleagues the video and talk to my colleagues about the patient's story... and get their thoughts and their input."* (P1)

> *"Sometimes you have difficulty making a diagnosis for your patient, sometimes you're not sure what exactly the patient has. So what I do most times is... I consult colleagues, sometimes I consult senior colleagues...We also have meetings regularly... where we have videos of our patients...we will discuss with them"* (P2)

Finally, many participants noted that years of training, repeated exposure to different cases, and learning to recognize subtle patterns help them navigate ambiguous presentations with greater confidence.

> *"I think it really is all about that experience of seeing all the different ways that these sorts of diseases can present and the ways that they don't present as well… and just getting those repetitions of seeing it over and over again to develop those sort of patterns."* (P6)

5.3.2 Disease-related challenges. Specialists described challenges that stem from the nature of movement disorders themselves. Symptoms vary widely across patients, change within the same patient over time, interact with other health conditions, and often worsen as the disease progresses.

A common issue is the **unpredictable nature of symptoms** across patients and within the same individual. Even when two patients share a diagnosis, their symptoms may present in highly idiosyncratic ways. And for a single patient, symptom expression can change significantly from one day—or even one moment—to the next.

> *"...there's no two Parkinson's patients that are the same. And some people might not have your classical symptoms and still have Parkinson's."* (P1)

> *"...but they [same patient] have tremendous fluctuations, ups and downs in their symptoms and their examination findings over the course of the day."* (P5)

This variability—between and within patients—makes diagnosis and monitoring difficult. Clinicians can only evaluate what they see in a brief visit, which may not represent the patient's full experience. Adding to the complexity, some patients present with **comorbidities** like hypertension, diabetes, or cardiovascular disease. Such health conditions can worsen motor symptoms or make it harder to distinguish which symptoms stem from the movement disorder and which do not.

> *"...having more medical problems, actually if they're poorly managed and not well treated, often makes it more difficult to treat the movement disorder."* (P1)

> *"Patients with other medical conditions tend to have worsened symptoms. They tend to have worse symptoms than patients without."* (P2)

Finally, specialists pointed out that **most movement disorders are progressive**, with symptoms worsening over time.

> *"...so most of the conditions I see worsen, it's just the unfortunate reality of movement disorders, most of them are neurodegenerative diseases that get worse over time."* (P1)

These challenges are inherent to the disease, and specialists do not necessarily have strategies to tackle them except through their clinical experience and judgment.

5.3.3 Logistical challenges. Specialists described logistical challenges that shape how they deliver care—particularly a shortage of movement disorder specialists, limited time during clinic visits, and long delays between follow-up appointments. These issues often intersect, leading to care that might feel rushed, fragmented, or delayed.

A **shortage of movement disorder specialists** limits access to care at multiple levels. Many patients never see a specialist at all, while others face long delays before they receive a diagnosis or begin appropriate treatment.

> *"The vast majority of patients living today will likely never see a movement disorder specialist in their lifetime."* (P5)

This gap increases the risk of misdiagnosis and delays in treatment, particularly when patients first consult general practitioners or general neurologists who may lack training in recognizing movement disorder presentations.

A related challenge is the **limited time available during clinic visits**, driven by the need to see more patients in shorter appointment windows. As a result, clinicians often have to make trade-offs about what to prioritize in each clinic visit. Clinicians may skip rating scales, which used to be routine, and instead focus on more targeted assessments.

> *"These tools, like the MDS-UPDRS… I used to do this for each Parkinson's patient every time. But because of pressures to see more patients with less time, I'm not able to do that anymore the way I did."* (P1)

Finally, the combination of staffing shortages and overloaded schedules contributes to **long gaps between follow-up visits**, even for patients already under specialist care. Participants reported that appointments are often scheduled six or more months apart, making it difficult to monitor disease progression or respond to new symptoms in a timely manner.

> *"Some might get 6-month or 7-month appointments to see us."* (P2)

> *"We're so busy right now… I barely have the capacity to see my own patients, who often go longer than they need to before their next visit."* (P1)

These long intervals disrupt continuity of care and reduce specialists' ability to adjust treatment plans based on more recent observations.

5.3.4 Interpersonal challenges. Another challenge specialists often face involves the interpersonal side of care—especially when relying on patients to explain their symptoms. Getting an accurate history is key to diagnosing and managing movement disorders, but not all patients can clearly communicate their symptoms or remember important details. This is particularly common in patients who have cognitive problems or limited awareness of their condition.

> *"So I think part of the challenges is that so much of it is based on history, and not all of our patients are very good historians, or very aware of symptoms… Certainly, we have a patient population that deals with cognitive issues, and so getting a reliable history can be difficult."* (P6)

How specialists respond to interpersonal challenges: To address this challenge, specialists often rely on collateral information from family members or caregivers who are more familiar with the patient's condition. These individuals can offer helpful details, clear up confusion, and describe symptoms the patient may not notice or be able to explain.

> *"I think it's very important to have collateral information from caregivers and other people, and I definitely encourage caregivers to come to appointments and ask caregivers questions too, because sometimes people are not aware of the full deficits that they have, and their caregivers may see things that they might not appreciate about what's going on."* (P1)

5.4 Use cases for new digital tools in specialists' work

We describe concrete situations in which specialists said digital tools could support their work, including remote assessment and monitoring of motor symptoms, collaboration between specialists, support for non-specialists who see patients first, and communication with patients and families (Sections 5.4.1–5.4.4). We then describe the characteristics specialists want from digital tools and the characteristics they are wary of (Sections 5.4.5–5.4.6). These findings describe where tools could fit into specialists' work and what conditions shape their usefulness.

5.4.1 Remote assessment and monitoring of motor symptoms. In remote settings like telehealth visits, specialists are often limited in their ability to observe fine motor symptoms—particularly those that require close observation or hands-on examination. Participants noted that certain aspects of motor assessment such as tremor amplitude, slowness of movement, or muscle tone are harder to evaluate remotely.

Table 3. Summary of clinical challenges specialists face and the strategies they use to manage diagnostic, disease-related, logistical, and interpersonal challenges

Challenge Type	Specific Challenges	How Specialists Respond
Diagnostic	• Diagnostic dilemma (due to overlapping or subtle symptoms, criteria not met in early stages) • Subjectivity in assessment • Limitation of diagnostic tools	• Use ancillary tests (e.g., DaTscan) • Re-evaluate over time • Consult with colleagues • Rely on clinical experience
Disease-related	• Symptom variability (between and within patients) • Comorbidities • Disease progression	• Use judgment to interpret fluctuations and clinical context
Logistical	• Limited time per visit • Shortage of specialists • Long gaps between appointments	• Prioritize essential tasks • Skip low-impact assessments
Interpersonal	• Patients with cognitive impairments • Incomplete or inaccurate self-reports	• Gather collateral information from families or caregivers

> *"In tele-visits, I'm much more limited by what I can see based on the quality of video that the patient has, how tech-savvy the patient is, how easy it is for them to follow the instructions I give them. But even with the highest quality video, and even if the patient is tech savvy, video doesn't give me as good of information as… being in person and fully seeing what's happening. So like, a tremor, I can assess it through video, but it's probably not going to be the same quality as in person… I can't assess tone through a video."* (P1)

Specialists expressed interest in digital tools that could help capture information they cannot access remotely. Beyond telehealth, participants also described wanting support for detecting subtle or variable motor changes that may not show up clearly during a brief exam.

> *"...a tool that monitors people's movements...with much higher resolution than we can do in clinic, might pick up subtle problems before the clinician can pick them up"* (P4)

Another specialist wanted support for tracking symptoms between visits, adjusting medications, and flagging changes that could indicate safety risks.

> *"After they go home, monitoring them for medication adjustments, symptom tracking, and prediction of concerning events like falls or aspiration pneumonia—these are things we're really interested in tracking"* (P5)

Some also thought that objective movement data could help guide clinical decisions over time.

> *"You can objectively gauge the prognosis of these symptoms...it will be useful at the first visit and then to compare subsequent visits."* (P2)

One specialist connected these needs to clinical research, noting that current clinical rating scales are limited and that more precise digital assessments could improve both care and clinical trials.

> *"Digital tracking has a lot of potential to improve on and hopefully replace these imperfect assessments by having more reliable, quantitative, digital assessments of subtle changes."* (P5)

5.4.2 Supporting collaboration between specialists. Specialists may consult with expert colleagues when they come across complex or uncertain cases. Often, they discuss case details by verbally describing symptoms and clinical observations, like abnormal movement patterns.

Different specialists may notice different features or weigh the same observations differently, even when reviewing the same patient.

> *"Different neurologists will weigh information differently and will come to different conclusions. And the reality is that, how can you say that someone is right and someone is wrong?"* (P4)

Specialists described these disagreements as common in movement disorders, where distinctions between conditions can be subtle. In such situations, clinicians noted that team discussion could benefit from having shared information that goes beyond verbal descriptions. As one specialist explained, objective data could add a concrete reference point to collaborative discussions.

> *"...if we have objective data from tools...it could always be information that could be added to the discussion, when I say the DaTscan showed this, I say this measure or this tool or assessment also showed that"* (P1)

5.4.3 Supporting activities of non-specialists. Specialists pointed out that many patients delay getting a correct diagnosis because they first meet non-specialists—such as general practitioners or general neurologists—who may not have the training to recognize movement disorders. These delays can lead to misdiagnoses, inappropriate treatments, or long wait times before the patient is referred to the right specialist. This problem reflects a larger issue: the shortage of movement disorder specialists.

One specialist described how these delays happen in practice.

> *"A patient presents with back pain, slowness… and instead of referring them, they treat lumbar spondylosis for two years. But the back pain was actually from rigidity, not a vertebrate problem."*(P2)

Because most patients are first seen by non-specialists, several participants suggested that tools could help non-specialists recognize early signs of movement disorders—such as rigidity, bradykinesia, or abnormal movement patterns—before symptoms are misattributed to other conditions. Earlier recognition could help non-specialists decide when a referral to a movement disorder specialist is warranted, reducing delays caused by misdiagnosis or prolonged treatment for unrelated conditions.

Some participants described simple diagnostic support tools that could allow non-specialists enter observed symptoms and receive disease suggestions to flag cases that require referral to a specialist.

> *"For people that don't have the experience of movement disorders, these tools might be helpful...to get information that can aid them in their diagnosis when they don't have that expertise that I do."* (P1)

> *"If there is an online system where every doctor can type symptoms and it comes out with suggestions...then they can easily refer to us."* (P2)

Specialists also described tools that could support non-specialists examine movement features more reliably. Video-based pose estimation could provide quick assessments for initial evaluation.

> *"A video-based pose estimation tool could be used outside the movement disorders clinic by general neurologists and non-neurologists, since they see the vast majority of patients."* (P5)

Specialists who raised these issues emphasized that digital tools could support non-specialists by helping them recognize early movement disorder signs, examine movement features, and identify appropriate referral options.

5.4.4 Supporting communication between specialists, patients, and families. Specialists shared that even when they feel confident in a diagnosis, patients and families may be unsure, confused, or hesitant to accept it. This often happens since most movement disorders are diagnosed clinically—based on what experts observe and how they interpret those observations. In these cases, patients and families tend to look for more concrete data to help them understand and trust the clinical assessment.

> *"...but I always think there's going to need to be some sort of objective confirmation, because people like to see things in black and white."* (P3)

5.4.5 What makes movement disorder specialists willing to use digital tools. Specialists were enthusiastic about the possibility of new tools that align with their existing workflows, provide clear and useful information, and support clinical decision-making without adding burden. In particular, specialists valued tools that produce quick, clear measurements that complement their existing assessments. One participant noted that tools could be more useful if they translate measurements into forms that align with established clinical rating scales, instead of presenting raw data alone.

> *"But if there was [a tool] that could tell you the amplitude and frequency of the tremor, the amount of rigidity that a patient is experiencing, and disseminate that into the different components of the UPDRS. Then that obviously would make it more objective than subjective."* (P3)

Participants also emphasized that any tool must be validated and trusted. Specialists said they are more willing to use tools that researchers have tested, shown to be accurate, or endorsed by trusted organizations or colleagues.

> *"If there is a tool that has been formally proven, demonstrated to help you rule in, rule out diagnoses, absolutely yeah. Why not?"* (P4)

> *"If the International Movement Disorders Society And Parkinson's Network supports it... I'll be glad to use it. It will make my work easier and more objective."* (P2)

5.4.6 What makes movement disorders specialists wary of digital tools. Specialists described several factors that make them wary of adopting digital tools in their work. In particular, they expressed concern about tools that consume time, generate large volumes of data with little clinical value, or risk biasing clinical judgment.

Time was a primary concern. Specialists explained that clinic visits are already tightly scheduled and tools that require additional time to set up, interpret, or review would likely not be used.

> *"...tools that consume time, no one is going to use them… If you want a tool to actually be useful and be used, it has to save time"* (P1)

> *"If someone is comfortable with doing the UPDRS routinely in their head, like they can get through that quickly. If the tool were to slow that down, then that would not necessarily be helpful"* (P3)

> *"...tremor could be analyzed much greater detail, either with visual or physiological tools, where you say, I'm going to analyze the exact frequency [and] amplitude of that tremor, using accelerometers, or electrophysiology; but that takes time. We don't typically do that. We rely on our vision [and] our senses" (P4)*

Some participants were also cautious about tools that generate large amounts of data without clear clinical value. When tools produce information that does not directly support decision making, participants see the added data as extra work.

> *"...there's also other tools...that can notice...abnormal movement... And so we get all this information. I just don't know how much value any of that information has. If all of it gets sent to me, I don't find that helpful...otherwise, it's too much data to deal with in a clinical setting."* (P6)

Finally, specialists stressed that tools should be introduced in such a way that it does not bias their clinical judgment. They preferred to form their own assessments first and then use digital information as a supplement rather than a replacement.

> *"I don't think I want it to bias me...I want to do my own assessment and keep an open mind before we know how accurate it is."* (P1)

6 DISCUSSION

Our study examined movement disorders specialists' diagnostic work, highlighting the challenges specialists face, how they navigate challenges, and opportunities for digital tools to support specialists' work. We found that specialists rely on a common set of diagnostic tasks—observation, gathering patient history, conducting physical examination, and forming a clinical diagnosis—but do not follow these tasks in a fixed order. Instead, specialists streamline and adapt their workflow by choosing which tasks to focus on, shorten, skip, or revisit based on diagnostic certainty, resource constraints, administrative needs, and patient or family interaction.

Specialists face diagnostic challenges such as symptom overlap and subtle signs that create diagnostic uncertainty, variation in how clinicians judge movements, and limitations of current diagnostic tests. Disease-related, logistical, and interpersonal challenges also affect how clinicians carry out their work. Specialists saw value in tools that capture subtle motor features for remote visits and between-visit monitoring, provide shared visual/quantitative anchors for team discussion, help non-specialists flag cases for referral, and present clear evidence to patients and families. Specialists are willing to use tools that align with their workflows and are wary of tools that consume time in already busy clinical schedules. In the sections that follow, our research team reflect on the findings to discuss what they imply for designing tools in the movement disorders domain, highlight opportunities for tools to support specialists' work, and provide two illustrative tool ideas based on our findings. Finally, we acknowledge the limitations of our study and suggest directions for future work.

6.1 Designing useful digital tools for specialists needs to assist the adaptive processes they demonstrate

Specialists do not always follow a fixed workflow: they streamline their workflow—choosing which tasks to focus on, skip, or revisit—based on diagnostic certainty, resource constraints, administrative needs, and patient or family behavior. These adaptations reflect how specialists' decision making demonstrates flexibility, allowing them to prioritize more relevant aspects in each case.

6.1.1 Specialists streamline their approach when certain and investigate more when uncertain. In initial steps—when observing the patient or hearing the chief complaint from patients/caregivers, specialists form an initial working idea of the concern. When specialists feel certain in the initial impression (for example, when symptoms match a familiar presentation), they proceed by focusing on a small set of confirmatory steps, such as conducting a focused physical exam or asking targeted history questions. When certainty is lower—such as in cases with overlapping or atypical symptoms—specialists slow down, revisit earlier steps, gather more detailed history, or consider alternative explanations [1, 20, 48]. In some cases, clinicians deliberately delay making a final diagnosis, treating uncertainty as part of sound clinical judgment rather than as a failure to make a decision. Our findings reflect how diagnostic work unfolds in practice and align with prior research showing that real-world clinical work rarely follows "textbook workflows" [59].

Our findings suggest that tools that support diagnostic work will benefit from integrating with the adaptive process taken by specialists. *Provide multiple starting points to interact with a case.* Clinicians should be able to begin with whichever task is most relevant to the case at hand. For example, specialists in our study sometimes started by reviewing a key symptom observed as the patient walked into the room, while in other cases they began with an extended patient or caregiver history before examining movement in detail. support flexible switching between tasks. *Allow flexible switching between tasks.* Clinicians often moved back and forth between tasks rather than completing them once. For instance, specialists described revisiting observation after gathering history, or returning to history questions after noticing an unexpected movement during the exam.

6.1.2 Clinicians' support needs vary across cases, not only by expertise. Over time, specialists shift from step-by-step methods taught in medical school to more strategic, personalized ways of working. They learn to prioritize tasks that yield more clinical value and skip or adjust those unlikely to change the outcome. Our results echo prior findings: experienced clinicians emphasize what matters most and discard unnecessary steps when confident in their judgment [20, 46]. This approach allows specialists to focus on high-value cues—such as a patient's responses to questions or subtle facial expressions (e.g., reduced facial movement seen in Parkinson's disease)—rather than running every test.

At the same time, our findings show that expertise alone does not determine how deeply clinicians engage with diagnostic tasks or what kinds of support they seek. Specialists in our study described moments of uncertainty despite their expertise, especially when symptoms were ambiguous or did not align with classic diagnostic patterns. In movement disorder care, such cases are common, especially in early-stage or atypical presentations [30, 57]. When uncertainty increased, the same clinicians slowed down, revisited observations, or sought additional information—for example, by ordering imaging tests or examining quantitative details to confirm or challenge their initial impressions. Such shifts occurred across cases for the same specialist.

Our findings suggest that tools designed solely around clinician expertise (e.g., novice versus expert) may miss important variation in how specialists work across cases. Prior HCI work shows that experienced clinicians often prefer tools that perform brief quality checks on their assessments, while less experienced clinicians seek detailed explanations as learning aids to help build confidence [65, 66]. Our findings extend this insight by showing that experienced specialists may want different kinds of support depending on the demands of a specific case. In straightforward cases, tools that offer lightweight validation—such as brief summaries or quick checks that align with established clinical criteria—may be sufficient to confirm a working hypothesis without interrupting workflow. In more ambiguous cases, tools may need to support deeper investigation, for example by surfacing relevant patient history, enabling closer inspection of movement data, or prompting questions that help clinicians evaluate competing hypotheses.

6.1.3 When uncertainty persists, specialists extend diagnostic work. While certain cases may seem routine, diagnostic work is often shaped by uncertainty. When uncertainty persists, specialists extend their workflow in several ways: 1) *order diagnostic tests* (e.g., DaTscan) to clarify ambiguous findings. 2) *re-evaluate over time*, allowing patterns to emerge across visits. 3) *consult colleagues*, especially for rare or complex presentations. These strategies are not part of the core workflow but become essential in managing diagnostic uncertainty. Similar *"wait and see"* approaches and collaborative practices have been documented in other domains, such as heart failure decisions and AI-based decision support [61, 63].

Our findings suggest that tools supporting diagnostic work under persistent uncertainty should align with existing strategies specialists use. *Make "wait and see" reasoning explicit across visits.* Tools could help clinicians make explicit *what they are waiting for.* For example, a clinician might indicate that they are monitoring whether tremor amplitude increases, whether asymmetry emerges, or whether symptoms improve with treatment of a comorbidity. The tool could then surface these clinician-defined questions at follow-up visits. *Support longitudinal comparison tied to clinical questions.* Tools could help clinicians compare observations across visits in ways that reflect clinicians' diagnostic decision-making processes. For example, showing side-by-side video clips or quantitative summaries that focus on the specific features the clinician wanted to monitor (e.g., progression of bradykinesia versus stability of tremor). *Facilitate collaborative review for complex cases.* When consulting colleagues, specialists described sharing patient videos and discussing specific observations. Tools could support such practice by organizing selected video clips, brief quantitative summaries, and relevant history into a shared view used during case discussions or video rounds. Clinicians could indicate which features they want input on allowing collaborators to reason from the same reference. Situating tools within these existing routines—instead of introducing new, standalone workflows—may better align with how specialists manage uncertainty in practice.

6.2 Opportunities for technology and AI to support movement disorder specialists' work

Our study results highlight three conceptual dimensions at which technology and AI may support movement disorder care: *representation*, *interaction*, and *collaboration*. Representation concerns how movement and clinical evidence are captured and displayed, such as supporting visual comparison of subtle motor features across tasks or visits. Interaction concerns how clinicians engage with tools during diagnostic work, including when to access lightweight summaries versus more detailed information as uncertainty changes. Collaboration concerns how tools support shared reasoning, such as enabling specialists to review the same visual or quantitative evidence during case discussions. We discuss how thinking along these dimensions helps generate ideas for tools; further, we instantiate some ideas into concrete tool designs in the next subsection.

6.2.1 Representation: Supporting how movement disorders are observed and tracked over time. A substantial body of prior work has focused on improving how movement disorders are represented by transforming motor behavior into quantitative, persistent signals. Such systems capture observable aspects of movement—such as timing, speed, regularity, and amplitude—and store them in forms that allow later review or comparison. For example, studies of computer and mouse interactions extract features such as mouse trajectories, movement speed, pauses, or tapping variability to characterize fine motor control [21, 69]. Typing and gesture-based systems analyze keystroke timing, pressure, or gesture dynamics to capture slowness or irregularity in movement [5, 56]. Other approaches use smartphone-based drawing tasks or games to quantify tremor, precision, or motor coordination [34, 37]. Smartphone-based sensing and wearables enable repeated measurement of movement patterns over days or weeks to track symptom fluctuations [10, 67]. Video-based approaches use pose estimation and motion analysis to derive features such as tremor frequency, gait parameters, or joint angles from ordinary video recordings [2].

Together, the output of such tools functions as external representations. Norman characterizes such external representations as *cognitive artifacts* that help make relevant patterns perceptible and easier to compare, particularly when representations are *well matched to the task at hand* [41]. In the context of movement disorder care, quantitative digital representations of motor performance might find greater utility when they are designed to support/complement concrete tasks such as patient observation (Sections 5.1.1 - 5.1.4) and remote tracking (Sections 5.4.1). For example, AI techniques may help organize observations across visits to emphasize change over time, support side-by-side comparison of prior and current movement, or highlight aspects of movement that warrant closer inspection without producing diagnostic conclusions. Our findings show that specialists rely on their own judgment for diagnosis and find tools helpful when they provide visual or quantitative references that make subtle differences easier to see and compare over time, consistent with prior work emphasizing clinician autonomy [13, 68]. We illustrate one such representation-focused opportunity in the next subsection through *MotorLens*, an example tool concept that helps clinicians inspect and reason about subtle movement patterns during remote care.

6.2.2 Interaction: Supporting how tools are integrated into movement disorder specialists' workflow. Movement disorder specialists adjust how they work through a case based on diagnostic certainty and the constraints of a given visit (Section 6.1). This suggests that specialists do not *interact* with information in a fixed or uniform way. Instead, specialists move between brief review and deeper inspection as uncertainty arises and as new information becomes available. Such patterns suggest interaction-level opportunities for technology to better align with specialists' workflow by supporting when and how clinicians engage with representations of movement data. For example, tools could remain lightweight during routine cases by presenting brief summaries or key changes since the last visit, while allowing clinicians to selectively access more detailed views—such as prior videos or movement traces—when a case is uncertain. AI could support such adaptive interaction by organizing representations for progressive disclosure, emphasizing what has changed since prior visits, and maintaining context about what has already been reviewed. Such support could allow clinicians to revisit unresolved questions across visits without having to re-examine information from scratch.

6.2.3 Collaboration: Supporting how specialists work through uncertainty with others. Our findings show that movement disorder specialists frequently manage diagnostic uncertainty through collaboration—by consulting colleagues, coordinating with non-specialists who see patients first, and relying on caregivers to provide additional context. Such practices point to concrete opportunities for technology—and in some cases AI—to support coordination across people involved in care. One opportunity concerns supporting triage and referral. For example, AI could help non-specialists recognize when specialist input is likely needed and support referral by structuring and transmitting relevant information to specialists such as short movement videos or key symptom descriptions. Technology could also support specialist collaboration by organizing information discussed across case reviews meetings, keeping track of which observations support or contradict different hypotheses, and preserving context across meetings. At the same time, such collaboration meeting often relies on verbal discussion making it difficult to revisit how interpretations evolved. Such patterns suggest opportunities for tools that support shared review by organizing evidence and discussion without making diagnostic decisions. In this role, AI could help structure information discussed during meetings or highlight unresolved points, reducing coordination and memory burden while leaving interpretation to clinicians. We illustrate one such collaboration-focused opportunity in the next subsection through *ShowBoard*, an example tool concept designed to support shared case review among specialists.

6.3 Example tool concepts to illustrate design opportunities

To make a subset of the design opportunities identified in Sections 6.1 and 6.2 more concrete, our study presents two illustrative tool concepts that might assist specialists' work. These concepts are presented as concrete examples of how digital tools could fit into specialists' clinical workflows and decision-making processes. For each tool idea, our study provides a scenario and description of the tool's functionality. These tool concepts are included to ground the discussion and to motivate future design and validation work.

6.3.1 Remote assessment of motor symptoms during telehealth visits. Our findings suggest that remote motor assessment tools can support specialists during video-based telehealth visits by helping them see subtle motor symptoms they might otherwise miss. To illustrate a representation-focused design opportunity identified in Section 6.2.1, our study describes an example tool concept, "MotorLens", that a patient uses on their phone before a visit.

We simulate a scenario where a specialist conducts a follow—up video visit with a patient who reports mild hand tremors and slowed movement. Since the video quality is poor and the patient's movement are very subtle, the specialist struggles to observe details like tremor characteristics or slowness. Prior HCI work has shown that brief, structured motor tasks can capture fine-grained movement features [21]. *MotorLens* builds on such line of work by illustrating how outputs from such tasks could be surfaced to movement disorder specialists during remote visits.

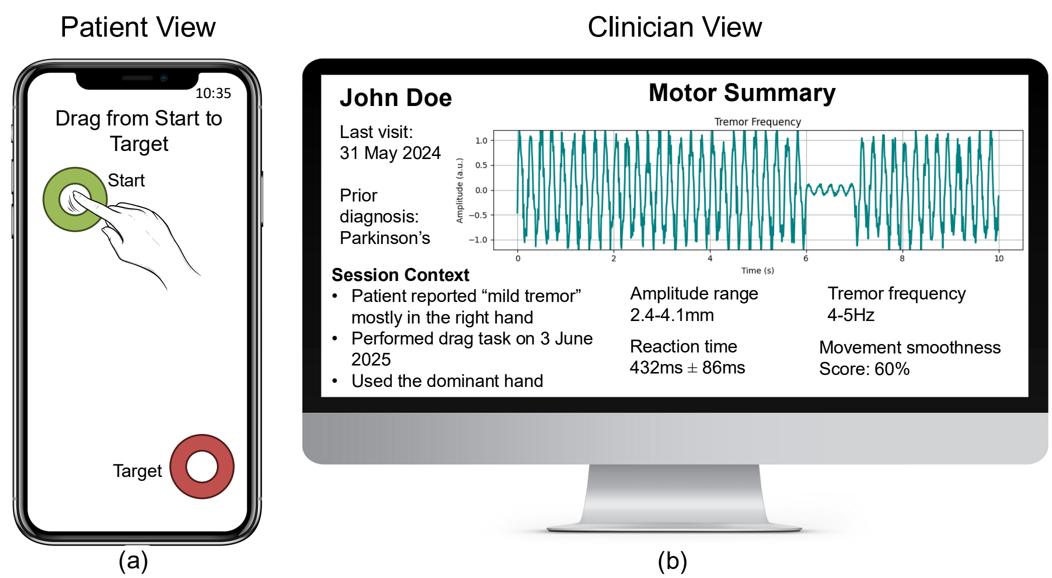

Fig. 1. *MotorLens* helps specialists observe patient's hand movements during remote visits by showing results from a touchscreen-based task the patient completed beforehand. Specialists rely on observation, but remote visits often makes fine motor details hard to see. (a) Patient-facing interface: The patient completes a short touchscreen task by dragging from start to target. (b) Clinician-facing interface: a web based tool that summarizes result from the patient's task, giving specialists context to interpret hand movements. The plot simulates Parkinson's tremor with a 4–5Hz rhythm and scaled amplitudes, offering a realistic on-screen pattern.

MotorLens (Fig. 1) is a touchscreen-based tool that helps specialists observe motor symptoms during telehealth visits by generating visual and quantitative summaries from short motor tasks the patient completes beforehand. Patient perform activities—such as dragging from one point to another—on their phone. The tool analyzes the motion to extract features that are often difficult to detect over video—such as tremor amplitude and frequency, reaction time, and movement smoothness. *MotorLens* presents the results to the clinician as a compact summary that includes contextual details like symptom reports and prior diagnoses. By showing plots of tremor characteristics, the tool can help specialists spot movement patterns they might have missed—due to poor video quality or subtle nature of symptoms—and focus their questions on the most relevant symptoms. A future study can evaluate such a tool by answering the following research questions: 1) What motor performance data do specialists use during remote care? 2)

Does feedback from touchscreen-based motor tasks reduce uncertainty during telehealth visits? 3) How should motor task data be summarized to support decision-making in remote settings?

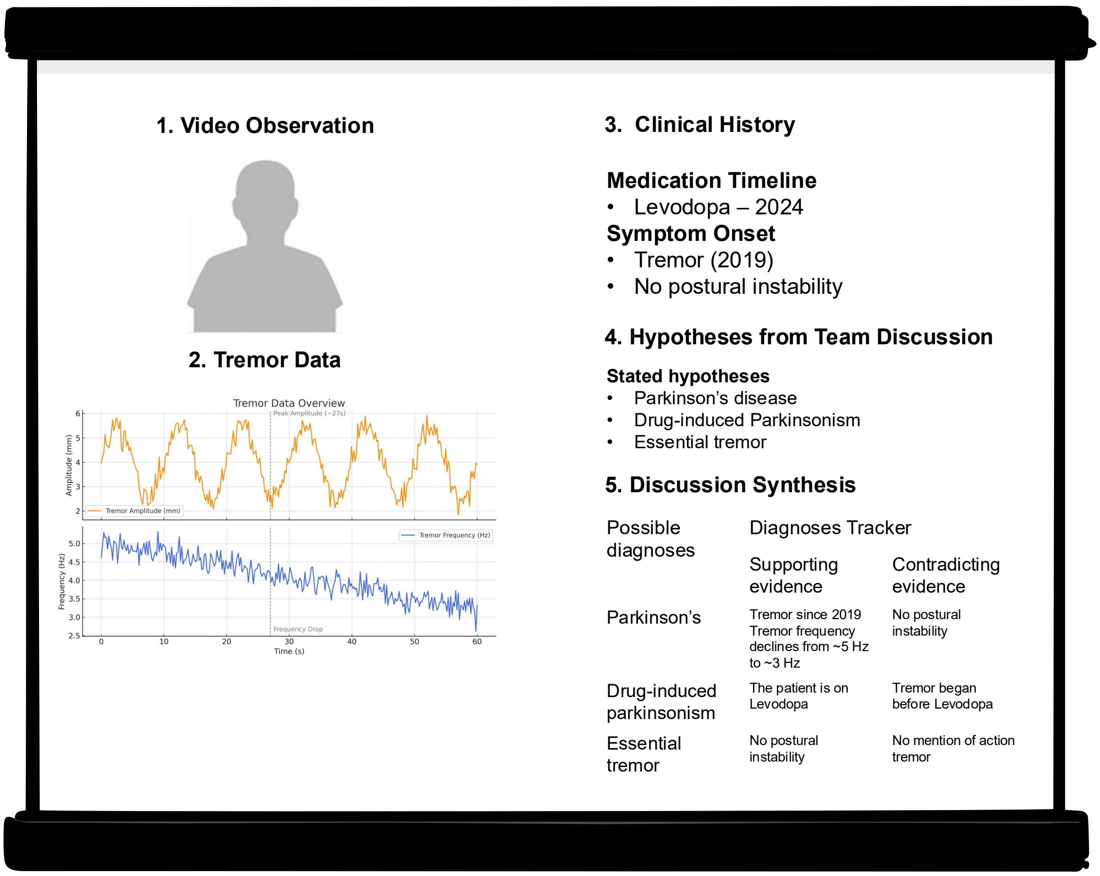

Fig. 2. Our proposed tool "Showboard" is a collaborative case review tool (shown on a large shared display) that supports team decision-making by helping specialists visually organize key clinical information. The tool embodies the idea that visual and quantitative representation of motor symptoms can support clearer discussion than verbal descriptions alone. *Showboard* brings together video observation, tremor data, clinical history, hypotheses from team discussion, and a discussion synthesis panel that highlights supporting and contradicting evidence. The plot shows tremor frequency dropping and amplitude fluctuating over a 60-second session. *Showboard* surfaces relevant patterns to support shared decision-making and planning—without suggesting decisions.

6.3.2 Showboard: A collaborative case review tool for shared decision-making. Our findings show that movement disorder specialists frequently work through diagnostic uncertainty by consulting colleagues, particularly during case discussions and video rounds. To illustrate a collaboration-focused design opportunity identified in Section 6.2.3, our study describes "ShowBoard", an example tool concept designed to support shared case review among specialists. We simulate a movement disorders healthcare meeting where a specialist shares a complex tremor case for discussion with colleagues and seniors. The patient video, test results (e.g., DaTscan), and clinical notes are available. Specialists do not agree in their early impressions.

Showboard (Fig. 2) is a low-fidelity prototype for a large shared display (like a projector screen) that supports collaborative case reviews. The tool supports decision-making by organizing what is known from teams' discussions and patient history, and helping clinicians consider relevant information. The tool does not suggest a final diagnosis. Due to lack of better tools, specialists rely heavily on "telling" during discussions. Shared understanding improves when clinicians can "see" and reason around visual and quantitative evidence (e.g., tremor plots). Our proposed tool can help reveal, not decide, by prompting reflection, rather than giving answers. The tool interface (Fig. 2) includes five panels:

(1) Video observation shows recorded patient movement.
(2) Tremor data visualizes tremor amplitude and frequency over time, based on data extracted from patient video or touchscreen-based assessments.
(3) Clinical history organizes patient history and test results either entered directly by a clinician or transcribed from the team's discussion.
(4) Hypotheses lists working diagnoses entered directly by a clinician or transcribed from the team's discussion.
(5) Discussion synthesis organizes supporting and contradicting evidence for each hypothesis based on team discussion and clinical history.

A future study can evaluate such a tool by answering the following research questions: 1) Does the tool's visual layout help specialists notice relevant patterns or missing details that they might otherwise overlook? 2) Do specialists find the information shown in the tool helpful and relevant to their teamwork?

6.4 Limitations and Future Work

Our study focused on one stakeholder group—movement disorder specialists. Movement disorder specialists play a central role in diagnosis, but they work alongside other team members—nurses, therapists, general neurologists, and caregivers [47]—who also influence decisions. Future work can explore how digital tools can support collaboration across this broader care team.

Our study offers insight into how movement disorder specialists make decisions and adapt their workflow. We interviewed six specialists—similar to other formative HCI studies in clinical domains [13, 68]—due to the scarcity and busy schedules of these experts. While this number may seem small, it represents a meaningful proportion of this highly specialized field. In the United States, there are only approximately 660 practicing movement disorder specialists, with just six serving rural areas [45]. These few specialists are expected to meet the needs of over one million people living with Parkinson's disease alone—a single type of movement disorder [45]. Given this situation in healthcare, we believe that recruiting even a small number of these specialists to understand their needs is an important step ahead. Additionally, movement disorder specialists are extremely busy due to the demanding interpersonal and investigative nature of their work, the population pressure, and the many responsibilities they juggle across multiple hospitals systems across geographies. For example, one of our participants is licensed to work in five different U.S. states. We prioritized depth over quantity. We believe that our choice of not more than six participants was a good choice since insights plateaued in our study, suggesting we reached thematic saturation for our research goals.

Additionally, most participants were based in the United States, often working in high-resource academic settings. This may limit generalizability to countries or clinics with different healthcare structures, fewer resources, or different ways of providing care. For example, clinicians in rural China often shorten tasks or multitask to cope with high patient loads and limited staff support [59]. Future work can explore how workflows and technology needs vary in other geographies and institutional setups.

Furthermore, interviews are limited in their ability to capture reasoning *as it unfolds*. Although participants shared thoughtful reflections, they may miss real-time cognitive processes which are difficult to recall from memory. Experts may not fully explain their decision-making process because some of their thinking might happen automatically and without them noticing [19]. Observational studies or video recordings of patient meetings could complement our findings by showing the anatomy of specialist workflow and how they make decisions in real-time.

Finally, while the tool concepts presented in this paper are illustrative, validating how such tools fit into specialists' workflows is an important next step. Future work could involve brief co-design sessions with movement disorder specialists to examine whether such tool concepts address challenges they recognize and fit within their time constraints and routines. In early, informal conversations with specialists at a professional meeting, we found that clinicians responded best to materials that were short, grounded in real cases, and easy to understand at a glance, and that they quickly focused on whether a tool would save time, or support decision-making during visits or team discussions. These observations suggest that future validation should prioritize lightweight, scenario-based evaluation and focus on how tools support specialists' workflows and decision-making processes.

7 CONCLUSION

This study explored the workflows and decision-making processes of movement disorder specialists. Our goal is to inform the design of tools that fit real-world clinical practice. We found that specialists do not follow a fixed sequence of tasks. Instead, they adapt their workflow based on contextual factors—such as diagnostic certainty, resource constraints, administrative needs, and patient or family behavior. We also identified four major categories of challenges—diagnostic, disease-related, logistical, and interpersonal—and showed how specialists develop strategies to navigate them. These insights give us a realistic picture of how clinical work unfolds in practice.

Based on these findings, our study outline design implications for digital tools that aim to support movement disorders specialists' diagnostic work. These implications highlight how tools could better align with specialists' adaptive workflows, and support clinical decision-making processes. By centering specialists' perspectives, our study provides a foundation for future research on designing tools that reflect clinical realities. Future work can build on these insights by prototyping and evaluating such tools in practice, in collaboration with the specialists they aim to support.

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