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 develop design claims and design possibilities that aim to support specialists' work. This work highlights opportunities for designing decision-support tools that align with clinical judgment—especially in specialties marked by uncertainty and evolving information.

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

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

1 INTRODUCTION

Tool designers and researchers are increasingly creating digital tools to support clinicians in improving clinical decision-making. Examples include AI-powered tools that predict cancer grades [5], estimate survival rates for artificial heart implants [33], enable early detection of sepsis [37], and assess fine motor performance in individuals with movement disorders [13]. Despite promising application areas, many such tools fail to gain traction in real-world clinical settings. A key reason for this low adoption is a lack of understanding clinicians' workflows and cognitive processes— specifically, how they work and make decisions [5, 27, 33].

Clinical workflows remain underexplored in designing digital tools even though the goal of such tools is to improve clinical work [7]. Furthermore, specialists in particular diseases often have unique workflow patterns and decision-making needs. However, many novel tools fail to integrate with existing workflows [31, 33] and do not align with specialists' cognitive processes [27, 37]. When research efforts employ human-centered approaches, they often begin by developing a prototype [25]. This preemptive prototyping assumes how clinicians work and what they need; often, this leads to design choices that may or may not reflect real-world clinical work. An AI-powered clinical decision support system deployed in rural clinics clashed with how clinicians handled patient care [31]. The system caused frustration, was poorly integrated into practice, and struggled to earn clinicians' trust. To design digital tools that support specialist practice, it would help to understand how specialists work, the challenges they face, and how they make decisions.

Author's Contact Information:

Manuscript submitted to ACM

Without this understanding, novel tools can miss clinicians' needs or even get in the way. To that end, we conducted an interview-based need-finding study to answer the following research questions:

- **RQ1:** What are the current workflows for specialists?
- **RQ2:** What challenges do they face in their work, and how do they tackle some of these challenges?
- **RQ3:** How can we design tools to augment their work?

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 [29]. We conducted semi-structured interviews with six movement disorders specialists to explore their real-world workflows, the challenges they encounter, and how technology might better support their work. These specialists manage complex conditions with subtle symptoms and nuanced changes, making their decision-making processes a valuable use case for understanding how to design effective clinical tools.

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.

Building on interview findings, our work identifies patterns in how specialists structure their work, respond to challenges, and reason through uncertainty. We synthesize insights into design claims—reasoned assumptions about where and how technology can better support movement disorders specialists in their work. These design claims highlight points of intervention where digital tools could offer support based on specialists' challenges and suggestions. Finally, we generate design possibilities (based on design claims) for digital tools to support specialists. Our research suggests developing tools that support:

(1) *Collaboration between specialists*, especially in complex or uncertain cases;
(2) *Remote assessment*, allowing specialists to observe and monitor motor symptoms outside clinical settings;
(3) *Activities of non-specialists*, such as general neurologists or primary care providers, to help them identify and refer potential movement disorder cases earlier; and
(4) *Communication efficacy*, improving the exchange of information between specialists, patients, and families.

This paper makes two contributions to human-computer interaction and human-centered health research. First, we offer an empirical contribution through an interview study of movement disorders specialists. We document specialists' workflow, the challenges they face in clinical decision-making, and how they navigate some of these challenges. This adds to the body of human-computer interaction work that examines real-world clinical workflows [5, 26, 31, 35–37]. Second, we present design possibilities for future clinical tools. These possibilities are grounded in specialists' challenges and their ideas for digital tools that can help with clinical work.

2 RELATED WORK

This section reviews prior research on designing digital tools to support clinicians in their work.

2.1 Understanding workflows is important but rarely done

Clinicians have to make "perfect decisions with imperfect information" [18]. To support them, digital tools like AI-based decision support tools (DSTs) assist with diagnosis, treatment planning, and prognosis recommendations [34]. While such tools hold promise in clinical decision-making, few are routinely used in clinical practice [3, 4, 14, 33]. A key reason is that such tools are often designed without an understanding of how specialists actually work— particularly specialists' workflows and how they make decisions [33]. In many cases, tool designers poorly understand stakeholders' workflows and needs during the design process [16, 28, 32]. For instance, only 20 of 17,000 papers on AI and clinical decision support systems (CDSS) considered clinicians' needs and experiences [32].

Unsurprisingly, clinicians often ignore or override recommendations from digital tools when such tools do not fit into their workflows [16, 27]. 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 [37]. This made clinicians feel that the system was challenging their role as experts. Such systems may provide accurate outputs, but if they fail to match clinicians' reasoning or the real-time constraints of clinical care, it is unlikely that clinicians will adopt them. Additionally, when workflows are not considered early in the design process, tools risk creating extra burdens for clinicians and may ultimately be abandoned [3, 33]. For example, the performance of a deep learning model for detecting diabetic retinopathy in hospitals was influenced by socio-environmental factors such as poor lighting conditions, slow internet, and the additional burden on nurses and patients [3]. This example underscores how the success of a digital tool also depends on how well it fits into the day-to-day realities of healthcare settings.

Some clinical needs become visible when existing workflows are carefully studied. Challenges in practice are not always about the lack of data or knowledge—they often involve logistical, physical, or contextual barriers. For example, nurses may suffer back injuries when transferring patients, which is not just a knowledge issue but a workflow, design and physical issue. In response, prior work developed the NurseCare system to encourage safe patient transfers by involving nurses directly in the design process [8]. This example illustrates how designing tools based on real workflows and day-to-day tasks—not abstract assumptions—can lead to effective and widely adopted solutions.

Clinical tools will help when they are built on the realities of how specialists work, think, and adapt to uncertainty. Our study fills this gap by examining the workflows and decision-making processes of one group of clinical experts—neurologists who specialize in movement disorders. Rather than focusing solely on the final diagnosis, we investigate how these specialists approach the process of diagnosis: how they gather information, navigate challenges, and make decisions. We also explore how digital tools could be designed to support—not replace—this complex, expert-led process.

2.2 Clinical workflows vary but little is known about *how* specialists decide what to prioritize

Clinicians do not always strictly follow protocols because clinical work is filled with uncertainty and imperfect knowledge. When clinicians are unsure how a protocol applies to a specific patient or situation, they might prioritize tasks they can complete with greater confidence [36]. Clinicians may delay decisions until all necessary information becomes available– a strategy that some systems might misinterpret as noncompliance—when it is actually an artifact of human intelligence [19]. Clinical workflows are dynamic—they can vary not only between patients but also across visits with the same patient. For instance, the workflow of primary care providers is not always predictable and does not follow a fixed sequence of tasks [15]. Instead, the workflow is shaped in real-time by the interaction between the clinician and the patient during each encounter. Additionally, clinicians' decision-making depends on the specific characteristics of the health disorder. In the case of sepsis, for example, decision-making is fast-paced, time-sensitive, and high-stakes—where every minute counts [37]. In contrast, movement disorders specialists often work with longer timelines, making decisions that aim to improve a patient's quality of life over years [29]. These decisions are shaped by chronic care needs, longitudinal assessment, and evolving patient goals. In summary, one context demands rapid, acute decisions; the other requires careful, long-term judgment. While these studies illustrate that clinical workflows are dynamic and shaped by uncertainty, patient interactions, and condition-specific demands, they primarily focus on non-specialist contexts such as primary care [15]. There is little empirical work that focuses on how clinical specialists structure their workflows. Experts like movement disorders specialists who manage chronic and complex conditions face different kinds of decisions and constraints—such as interpreting subtle motor symptoms— yet their workflow patterns and challenges remain underexplored. Our study addresses this gap by focusing on movement disorders specialists, whose work is shaped by longitudinal care, subtle diagnostic cues, and expert clinical judgment. Additionally, our study shows *how* contextual factors actively shape which tasks are prioritized, skipped, or revisited.

3 BACKGROUND: MOVEMENT DISORDERS

Movement disorders are neurological conditions that affect body movements [6]. 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—neurologists with specialized training—play a critical role in diagnosing and managing these disorders. These conditions are defined by their clinical features—such as the type, speed, and pattern of movements—which specialists must understand or describe in detail to guide diagnosis. Most movement disorders are diagnosed clinically— based on careful observation and description of abnormal movements rather than on laboratory tests or imaging [11]. However, the diagnosis process is far from straightforward. The clinical presentation of movement disorders is often "complex, variable, and sometimes even bizarre," making accurate diagnosis difficult even for experienced specialists [1]. Many movement disorders lack definitive biomarkers, requiring clinicians to rely on subjective interpretation of subtle motor signs and patient history. This increases the risk of misdiagnosis—especially in early or atypical cases [9]. Symptoms can look very different from one patient to another and can also change from day to day in the same person, making it difficult to assess how the disorder is progressing [9]. Current assessment tools are limited in their ability to track symptom variability, and assessments often depend on clinician interpretation.

In addition to these diagnostic challenges, movement disorders specialists are scarce. 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. A recent study found that only 9% of people with Parkinson's disease receive care from a movement disorder specialist [21], despite clear evidence that specialized care leads to better outcomes. 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.

To address these care gaps, researchers and clinicians have explored digital tools—particularly those aimed at automating motor performance assessments using smartphones, wearables, or touchscreen-based tasks [21]. While these tools offer promising technical capabilities, their integration into routine clinical care remains limited [9]. Many such tools are designed without a clear understanding of how movement disorders specialists actually work, think, and make decisions in clinical settings. Existing tools often fail to align with clinical workflows or address the types of cognitive challenges clinicians navigate on a daily basis.

This study aims to understand how specialists work by providing a human-centered understanding of how movement disorders specialists approach diagnosis. By understanding their real-world workflows and decision-making processes, we seek to inform the design of tools that better complement expert clinical work. To guide this investigation, we: (1) examine the current workflows that movement disorder specialists follow; (2) identify the challenges they encounter in clinical practice and how they manage them; and (3) explore how digital tools can be designed to support their work.

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. 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 [12], starting with professional colleagues and contacts and asking them to share our recruitment materials within their networks. The 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 experiences with patients, decision-making processes, and current assessment methods for motor performance. 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 [20] and manually reviewed each transcript to ensure accuracy. We analyzed the data using an inductive thematic analysis approach [30]. The first author coded the transcripts using atlas.ti [2], exported the codes into Miro [17], and used affinity mapping to group them into broader themes. The first author progressively discussed codes and themes with the two authors to synthesize themes to answer the research questions.

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

From these findings, we derived a set of design claims—reasoned insights about where and how technology can better support clinical expertise. These claims informed a set of design possibilities for future tools, including opportunities to support remote motor assessments, assist activities of non-specialists with early detection, and enhance communication between specialists, patients, and their families.

5 RESULTS

Our study examines how movement disorders specialists work, the challenges they face in clinical practice, and how technology might support their decision-making. We have organized our findings around workflows, challenges, and design possibilities.

1. First, we describe specialists' workflow by highlighting specific tasks and context-specific adjustments **(RQ1)**
2. Next, we present the major challenges they face and, where applicable, how they respond to them **(RQ2)**
3. Finally, we synthesize insights from both sections to identify design possibilities for future tools that align with specialists' needs and decision-making **(RQ3)**

5.1 Specialists' Tasks: Observation, gathering patient history, conducting physical examination, and clinical diagnosis

Movement disorders specialists described four tasks that guide their approach to patient care: observation, gathering patient history, conducting physical examination, and clinical diagnosis.

5.1.1 Observation: Forming 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 what might be wrong. They 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, 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)
>
> *"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: Narrowing down 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, 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 that I ask the patient 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?', 'Is there a tremor?' Yes, no... Then I'll go through my*

> *non-motor questions. 'Do you have sleep issues?'... then I'll do the standard H and P, you know, past medical history, medications, allergies, family history, things like that."* (P6)

In **gathering patient history**, specialists request patients—and often caregivers—to speak freely to understand what patients are most concerned about. 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, both from just patients, allowing them to speak on what their concerns are... asking questions that I want to know the answers to ruling in or out certain disorders."* (P6)

5.1.3 Conducting physical examination: Confirming or refining 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 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)

> *"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?"* (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.

> *"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. 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: Synthesizing findings from previous tasks to make a diagnosis. 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** gives insight into motor and non-motor symptoms, along with contextual factors like medications and family history, all of which help narrow down possible conditions and identify patterns.
- **Physical examination** allows specialists to check for movement abnormalities and confirm or adjust their thinking.

Specialists described using formal diagnostic criteria when available to match this combined information, while also using clinical judgment to interpret signs and symptoms.

> *"Most of our movement disorders diagnoses are based on criteria… for example, for Parkinson's, the movement disorder society has a criteria that says, if someone meets this checklist, then they have Parkinson's disease."* (P1)
>
> *"We diagnose many of the diseases... based on the phenomenology, based on what we see the patient doing in clinic, we examine the patient, the patient has tremor, the patient has, let's say, bradykinesia, the patient has rigidity. We say, Okay, this is a form of Parkinsonism. And then through a related process, we say, okay, of all the possible types or causes of Parkinsonism, we think this patient is more likely to have, let's say, Parkinson's disease, as opposed to another disorder in that family."* (P4)

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.

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
	Optional 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

5.1.5 Contextual factors that shape workflow. Although observation, patient history, physical examination, and clinical diagnosis are central to clinical encounters, 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. These include: (1) Diagnostic certainty or uncertainty, (2) Resource constraints, (3) Administrative needs, (4) Patient or family behavior. These factors not only shape how clinicians perform core tasks, but also help explain why they sometimes skip certain tasks marked as optional in Table 2. We share how these factors influence how clinicians prioritize, sequence, and carry out their tasks.

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 shift their focus to more informative tasks. In such scenarios, they may prioritize gathering a thorough patient history or engaging the patient's family to understand the context of the symptoms rather than physical exams.

> *"...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 increase diagnostic uncertainty. 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."* (P2)

In essence, specialists prioritize and carry out tasks based on the level of diagnostic certainty. When specialists are more certain about their suspected diagnosis, they tend to rely on pattern recognition and streamline their approach. 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.

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)

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]... 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.

> *"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, delegating, or streamlining—reflect how clinicians flexibly manage resource constraints.

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)

Patient and family behavior: Specialists adapt their workflow based on how patients and their families engage during the clinical encounter. 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..."* (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.

5.2 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 the ways in which specialists respond to some of them—offer insights into their cognitive processes. This section highlights how they think through complex, uncertain, and evolving clinical situations.

5.2.1 Diagnostic challenges. Diagnostic challenges refer to the difficulties clinicians face when working toward a diagnosis. These include: (1) diagnostic dilemma, (2) subjectivity in assessment, and (3) limitations of diagnostic tools.

(1) **Diagnostic dilemma:** One of the key challenges specialists highlighted was the diagnostic dilemma—uncertainty in arriving at a clear diagnosis.

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

This dilemma often arises because the path to diagnosis can be unclear in movement disorders, especially in early or atypical presentations. Movement disorders often present gradually, and many disorders share similar motor features such as tremor, stiffness, or slowness. This makes it difficult to determine a clear diagnosis from a single encounter—especially in older patients, whose symptoms may overlap with normal aging.

> *"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)

In some cases, patients exhibit symptoms that suggest a disorder but do not fully meet formal diagnostic criteria. This is especially common in the early stages of disease, when key signs may not yet be fully present. In addition to this uncertainty, diagnostic criteria are limited, as they do not always account for every patient's unique experience or presentation.

(2) **Subjectivity in assessment:** Diagnosing movement disorders often relies on subjective visual interpretation. Specialists interpret subtle motor signs—like tremor amplitude, slowness, or rigidity—using what they see during short clinic visits. But these 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)

This variation is a product of clinical judgment being applied to symptoms that do not always present clearly. Even similarly-experienced clinicians often disagree on whether a symptom is subtle, abnormal, or normal.

> *"We have situations where 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, but specialists still interpret them slightly differently. Such tools depend on what the clinician sees and estimates, especially for features like tremor size.

> *"…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 this variation is the heavy reliance on visual estimation. Clinicians judge features like tremor amplitude with the naked eye, using informal comparisons rather than measurements. Tools for precise assessments do not exist.

> *"... 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)

Also, some movement patterns are hard to assess. Specialists explained that observation alone can fall short in difficult cases, especially when movements are subtle or unusual.

> *"... 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)

(3) **Limitations of diagnostic tools:** Specialists noted that no single diagnostic tool can offer a definitive diagnosis for most movement disorders. Instead, diagnosis relies on clinical judgment and often happens 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 detection. Most clinical diagnoses are still based on observable motor symptoms, which often appear after substantial neurological damage has occurred.

> *"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… And then, 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 so much time and effort that it was only feasible for a few select cases.

> *"He would spend at least an hour with the patient, if not longer, and then interpreting the data afterward… also took so much time and effort... it was something he didn't really like to do very often, and 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.

Using ancillary tests: Clinicians use ancillary 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)

Giving the case more time: Another common strategy is giving the case more time. Specialists may delay diagnosis in order to re-evaluate the patient over time, watching for new symptoms or changes that bring clarity. This approach allows clinicians to revise or refine the diagnosis as more information becomes available.

> *"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)

Consulting with colleagues: Specialists also collaborate with colleagues to help resolve difficult cases. This may involve formally consulting with more experienced clinicians, informally asking for opinions, or bringing the case to formal grand rounds or team discussions in their movement disorders division.

> *"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."* (P2)

> *"... 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)

Drawing on clinical experience: Finally, many participants noted that clinical experience plays a major role in managing diagnostic uncertainty. Specialists described how 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)

5.2.2 Disease-related challenges. Specialists described challenges that stem from the nature of movement disorders themselves.

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.

5.2.3 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 encounter. 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.

5.2.4 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)

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

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)

5.3 How can we design tools to augment experts' work?

To answer this research question, we create design claims about how and where technology could intervene. Then we generate design possibilities—concrete instances of these design claims that are situated in specialists' work.

5.3.1 Supporting collaboration between specialists. Specialists may consult with expert colleagues when they come across complex or uncertain cases. Often, they discuss case details by describing symptoms and clinical observations, like abnormal movement patterns. However, such descriptions can lack essential details about symptom characteristics like tremor frequency, regularity, or triggers [11].

"A need for more case details" leads to our *Design Claim 1*: **Case discussions can improve using the design principle of *"show, don't tell"*.** Rather than relying solely on spoken accounts or memory, specialists could benefit from tools that provide visual and quantitative representations of motor symptoms.

One *design possibility* is a tool that shows visual representations of tremors along with quantitative data about tremor frequency, amplitude, and path deviation. Such tremor representations can be added to specialist conversations and in-person or Zoom meetings like grand rounds. A tool's data combined with specialist's initial assessment can yield more grounded conversations for better decisions.

5.3.2 Remote assessment of motor symptoms. In telehealth settings, 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 are harder to evaluate remotely, such as tremor amplitude, slowness of movement, or muscle tone.

> *"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)

"A need to observe fine motor details remotely" leads to our *Design Claim 2*: **Clinicians may assess motor symptoms more effectively in tele-visits when supported by a tool designed for remote assessment**.

One *design possibility* is a tool that enables patients to complete brief, structured motor tasks remotely—such as finger tapping, drawing spirals, or following movement prompts on a touchscreen. The tool would then extract and display quantitative features (e.g., tremor amplitude) that specialists can review before or during the appointment. This would enhance the clinician's ability to make informed judgments, even when physical presence is not possible.

5.3.3 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.

This leads to our *Design Claim 3*: **Supporting non-specialists in making diagnostic or referral decisions can reduce delays in accurately diagnosing movement disorders**.

One *design possibility* is a tool that helps non-specialists identify fine motor symptoms that suggest movement disorders, aiding in diagnosis and referral decisions. The tool could guide patients through simple motor tasks, such as finger tapping and analyze real-time movement patterns. By highlighting features such as reduced amplitude, the tool could provide non-specialists with actionable insights that suggest whether a referral to a movement disorder specialist is needed.

5.3.4 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.

This leads to our *Design Claim 4*: **Patients and their families are more likely to accept a clinical diagnosis when they can see and understand objective data supporting it**.

One *design possibility* is a tool that helps specialists communicate their diagnostic reasoning more effectively by presenting visual and quantitative representations of motor symptoms. For example, the tool could show traces of a patient's tapping patterns alongside clinical markers such as tremor frequency, path deviation, or decreased amplitude. These representations could be shared during the clinical encounter to help illustrate the basis for the diagnosis, making it easier for patients and families to follow the clinician's thinking.

6 DISCUSSION

In this section, we reflect on how our findings shed light on the flexibility specialists demonstrate in their diagnostic workflows and decision-making processes. We then present two tool ideas that build on our design claims, illustrating how our findings can inform design in concrete ways. 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 flexibility they demonstrate in clinical workflows

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. The main tasks in specialists' workflow include: observation, gathering patient history, conducting physical exam, and clinical diagnosis. However, in practice, this sequence is not rigid [15, 38]. Specialists shift the order, depth, and focus of tasks based on contextual factors—such as diagnostic certainty (or uncertainty), resource constraints, administrative needs and patient/family behavior. In initial steps— when observing or hearing the chief complaint from patients/caregivers, specialists form a working idea of the concern. When confident, they proceed to evaluating that hypothesis, using focused exams or more detailed history to confirm or rule out their hypotheses. If this initial hypothesis fails, they revisit earlier steps or consider alternatives [1, 11, 24].

Tools need to support flexible, nonlinear workflows, rather than making rigid assumptions about how clinicians work [15, 31]. Our results suggest that specialists should be able to skip, revisit, or expand steps only when needed. For instance, tools need to allow clinicians to begin wherever it makes the most sense—whether that is logging a likely diagnosis, entering a key symptom, or uploading a video of patient movement.

6.1.2 Expertise shapes how deeply clinicians engage with each task. Over time, specialists shift from step-by-step methods taught in medical school to more strategic, personalized approaches. 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 [11, 22]. 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. Experts' work is an external representation of their underlying cognitive processes [22]. These processes include two key phases in diagnostic work: *hypothesis generation* and *hypothesis evaluation* [22, 24, 37].

Specialists do not always need to follow a full protocol [36]—especially when hypothesis generation and evaluation happen quickly. Our results suggest that supporting clinical work at appropriate depth is important for any task with which clinicians engage more. This idea complements the one presented above which suggested supporting different tasks in a dynamic order decided by the clinician. Tools need to allow clinicians confirm a working hypothesis when they feel confident, while also supporting deeper investigation when uncertainty remains. For example, a specialist might glance at a visual summary showing tremor frequency and immediately recognize a likely diagnosis of Parkinson's when other evidence matches up as well. In contrast, when the diagnosis is unclear, the same tool could expand to highlight relevant details from patient history or prompt relevant questions.

6.1.3 When uncertainty arises, specialists perform extra steps. Although certain cases may seem routine, diagnostic work is often shaped by uncertainty. In response, 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 [33, 35].

Building on these insights, digital tools need to support 1) flagging of ambiguous cases for future review: allowing clinicians to tag uncertain cases, highlight unusual trends and revisit them when more evidence becomes available; 2) longitudinal tracking: allowing clinicians to re-evaluate symptoms over time; 3) collaborative review: enabling features like video annotation or integrated case review spaces to allow specialists consult colleagues on complex cases.

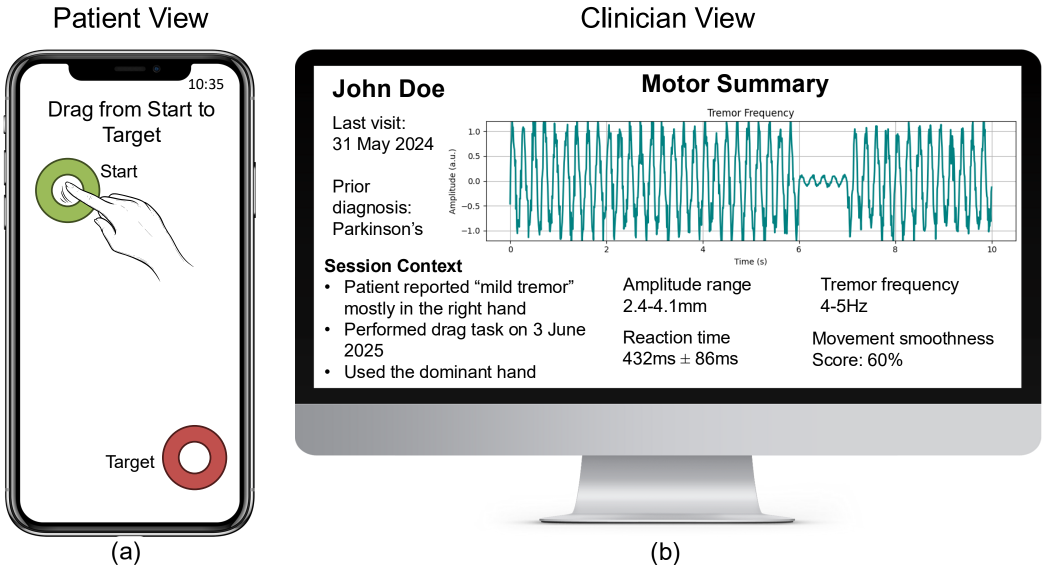
6.2 Evaluating and building on design insights: Two tool designs that draw on our findings

To turn our design possibilities into tools that might assist specialists, we share the designs for two novel tools. Each tool idea deepens our understanding of how digital tools can fit into clinical decision-making and workflow. For each tool idea, we provide a scenario and description of the tool's functionality.

6.2.1 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. We simulate a scenario where a specialist conducts a follow—up video visit with a patient who reports mild hand tremors and slowed movement. Because the video quality is poor, the specialist struggles to observe details like tremor or slowed movement. To improve this situation, we suggest a tool "MotorLens" that a patient uses on their phone before the visit.

Our proposed tool "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—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?

6.2.2 Showboard: A collaborative case review tool for shared decision-making. 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.



John Doe

Last visit:
31 May 2024

Prior diagnosis: Parkinson's

Motor Summary

Session Context

- Patient reported "mild tremor" mostly in the right hand
- Performed drag task on 3 June 2025
- Used the dominant hand

Amplitude range
2.4-4.1mm

Tremor frequency
4-5Hz

Reaction time
432ms ± 86ms

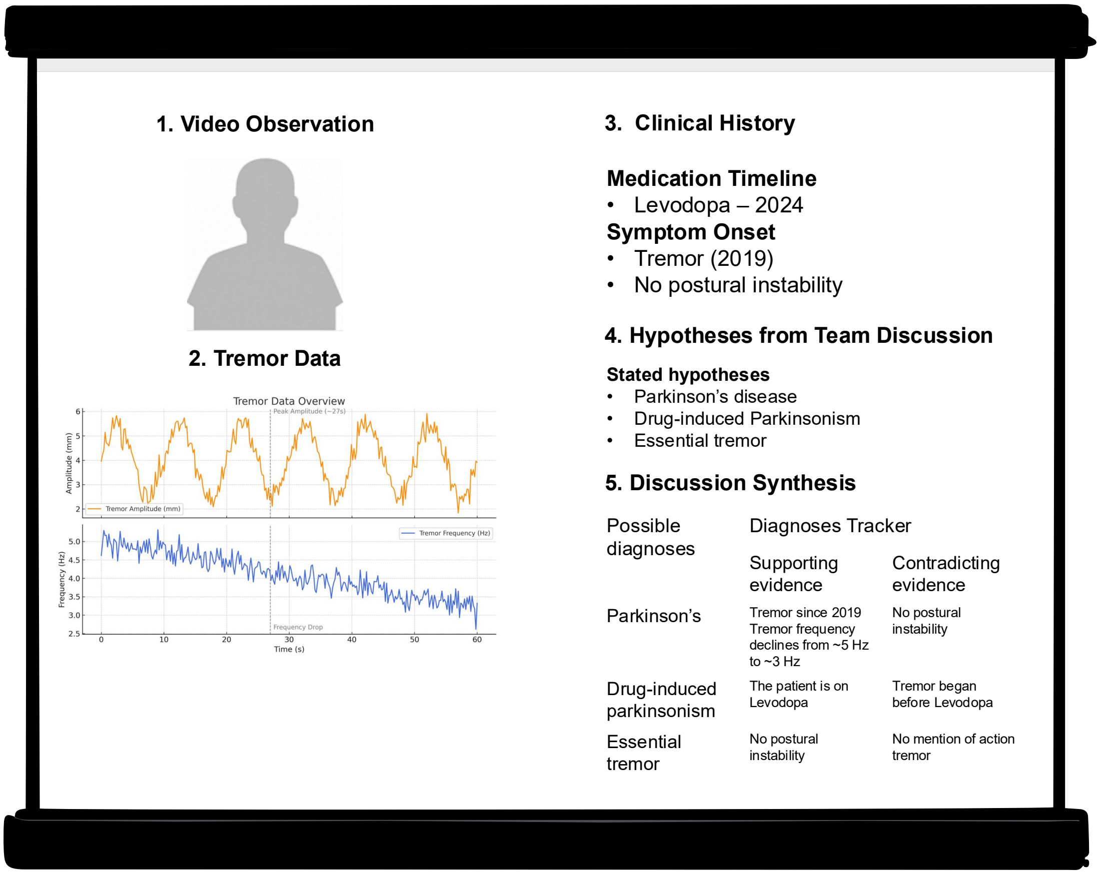
Movement smoothness
Score: 60%

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. It builds on *design claim 2*: specialists rely on observation, but telehealth 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.

Our proposed tool "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. *Showboard* builds on design claim 1: *"show, don't tell"*. 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?



1. Video Observation

2. Tremor Data

3. Clinical History

Medication Timeline
- Levodopa – 2024

Symptom Onset
- Tremor (2019)
- No postural instability

4. Hypotheses from Team Discussion

Stated hypotheses
- Parkinson's disease
- Drug-induced Parkinsonism
- Essential tremor

5. Discussion Synthesis

Possible diagnoses	Diagnoses Tracker	
	Supporting evidence	Contradicting evidence
Parkinson's	Tremor since 2019 Tremor frequency declines from ~5 Hz to ~3 Hz	No postural instability
Drug-induced parkinsonism	The patient is on Levodopa	Tremor began before Levodopa
Essential tremor	No postural instability	No mention of action tremor

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. Building on *design claim 1*: "show, don't tell", 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 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 [23]—who also influence decisions. Future work should 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 [5, 37]—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 [21]. 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 [21]. 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 [31]. 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 [10]. 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. Next steps in research include developing early-stage prototypes and testing them in simulated or real environments to see how they fit into existing workflows and support decision-making.

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, we developed *design claims*— ideas about how digital tools could support specialists' work—and *design possibilities*—which are concrete examples of how these tools might work in practice. By first understanding how specialists think and work, this study provides a foundation for 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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