

# Clinical decision-making and adaptive expertise in residency: A think-aloud study

**Maria Louise Gamborg** (✉ [gamborg@au.dk](mailto:gamborg@au.dk))

Aarhus University

**Mimi Mehlsen**

Aarhus University

**Charlotte Paltved**

Corporate HR MidtSim, Central Denmark Region

**Sigrid Strunge Vetter**

Aarhus University

**Peter Musaeus**

Aarhus University

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## Research Article

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# Abstract

**Background:** Clinical decision-making (CDM) depends on residents' learning, experience and knowledge. Previous research has used dual-process theory to explain the cognitive processes involved in how physicians acquire experiences that help them develop CDM. However, research is lacking about how CDM is shaped by the physicians' situated cognition in the clinical environment. The challenge is that novice physicians need to train their cognitive competencies as adaptable processes. The adaptive expert framework is meant to explain how novice physicians learn to make clinical decisions in demanding clinical situations.

**Purpose:** The aim of this study was to analyse how residents utilize and develop adaptive expert cognition in a natural setting. By describing cognitive processes through verbalization of thought processes, we sought to explore their CDM strategies in light of the adaptive expert framework.

**Methods:** We used concurrent and retrospective think-aloud interviews in a natural setting of an emergency department at a university hospital to query residents about their reasoning during a patient encounter. We analyzed data using protocol analysis to infer cognitive strategies from these verbalizations and compared these to the framework of adaptive expertise.

**Results:** 14 interviews were audio recorded over the course of 17 hours of observation. We coded 78 informational concepts and 46 cognitive processes. Residents who were quick to move on to hypothesis testing, tended to be more laborious in their CDM. Here a qualitative analysis demonstrated that uncertainty and differences in how informants assumed their role as a physician affected their hypothesis generation and information gathering.

**Discussion and conclusion:** In order for a resident to learn to act as an adaptive decision-maker, they relied on contextual support. The professional role was crucial in decisional competency. This supports current literature, which argue that role clarification helps decisional competency. This study adds that promoting professional development by tolerating uncertainty may improve adaptive decisional competency.

## Background

### Residents' clinical decision-making

Residents' learning of clinical decision-making is wrought with challenges due to the fundamental variability in the clinical environment coupled with residents' scant knowledge and experience (1–8). Schwartz (3) argued that it was problematic to translate decision science with a focus on heuristics and biases to medical problems, and argued that processual account was needed. This translational approach to clinical decision making has arguably led to a discrepancy between the basic scientific discoveries and applied or every day clinical decision making (3).

These challenges for residents has sparked several initiatives for residency training on how to support clinical decision making, such as technological educational aids (9), reflective interventions (10), and bias-reduction aids and strategies (5, 11–15). However, there is no clear evidence that decision aids, such as algorithms outperform unaided decision making (16) or that de-biasing strategies reduce errors (15, 17, 18). A think-aloud study focused on thinking processes, showed that junior doctors' decisions are largely motivated by senior staff, indicating that learning independent decisional competency is challenging in residency. (2)

## The adaptive expert framework

An alternative concept of developing competence in clinical decision-making can be gleaned through Hatano's (19) framework of adaptive expertise. This framework conceptualizes the acquisition of expert decision competency through a cognitive model of procedural and conceptual knowledge (19, 20), where adaptive experts shift between routine and adaptive practices (21, 22). Adaptive experts balance these routine and adaptive practices in what Schwartz called an 'optimal corridor of adaptability' indicating the progression of professional development through appropriately applying both new conceptual knowledge and innovative solutions and efficient automatic or routinized practices (23, 24).

In order to identify their knowledge gaps, physicians need to learn to position themselves as observers of their procedural and conceptual knowledge. This is called *epistemic distance* (25) and refers to the ability to flexibly monitor the adequacy of one's knowledge to solve a problem, constructing deeper understandings and develop new solutions. During this process, the expert physician *self-regulate* towards closing these gaps in knowledge, by applying metacognition and critical thinking (23). At the same time, physicians are *oriented towards new knowledge* and actively seek out learning opportunities (25–27). This competency reflects a fundamental attitude which guide the physicians in their professional development (28). This relates to their professional identity, i.e. their becoming physicians by their own and their colleagues' accounts (25).

## Adaptive expertise in residency and medical education

Residency training involves a myriad of learning situations and teachers (29). Therefore, medical educators have highlighted adaptive expertise as an important competency to learn in residency (30). Research has emphasized that adaptive expertise is a social and relational phenomenon where social and material bonds are formed, negotiated, and reshaped constantly (31). Thus, novices might unreflectively mimic routine practices, if these practices are not explicitly reinstated (32). Such awareness of residents might potentially affect patient safety (8).

Experts are characterised by their excellence in forming meaningful patterns of information with organized structures of knowledge that reflect situational variation. Experts' rapid and flexible retrieval of situationally relevant knowledge is what defines the expert and make them reliable decision-makers (33, 34). While residents may acknowledge that variability in medical practice requires more than routine knowledge, studies on their conceptual understanding of expertise has been shown to reflect a routine

approach to developing expertise, (35), which may influence their approach to learning and ability to learn adaptive expertise.

The framework of adaptive expertise has been found to be a meaningful way of developing decisional competency (36) and preparing residents for future learning (37). Yet, only limited research explores the development of adaptive expertise within resident physicians (28). Empirical research on adaptive expertise has centered on socio-cultural elements or individual predispositions which mediate development of adaptive expertise. However, in medical education, little empirical research has focused on how adaptive expert thought-processes unfolds in clinical practice (21). Hence, it is important to investigate the real-life thought processes of residents and how they reflect adaptive expert cognition, in order to understand early-career interventions which promote clinical decision-making.

## **Objective of the study**

This study sought to analyse how residents utilize and develop adaptive expert cognition during diagnostic reasoning in the emergency medical setting.

## **Methods**

### **Design**

This was a think-aloud interview study aiming to provide insight into participants' thought processes (38, 39). Two interview methods were used with each participant. Firstly, a concurrent think-aloud interview that sought to record residents' verbalization of information in their short-term memory during the diagnostic process (39). Secondly, a retrospective interview, which subsequently explored residents' rationales for their decision-making. This combination of two methods has been used in other studies to provide a comprehensive description of thought processes (40, 41). It has been argued that natural settings provide a realistic testbed for CDM (41, 42). For this reason, we used the concurrent interview during real patient encounters. Transcripts of these encounters then provided case material for the retrospective think-aloud. Additionally, the primary investigator, MLG, performed observer participant observations (43) before, during and after the concurrent think-aloud interviews.

## **Setting and case of geriatric emergency medicine**

Inclusion criteria for patient encounters were patients over the age of 60, admitted to the emergency department. It has been argued that complex cases provide the best opportunity to explore CDM (44). Geriatric emergency cases are clinically complex and they were selected because residents report lower confidence treating geriatric patients, compared to other adult groups (4, 6). Specifically elderly patients are complex due to comorbidity, social factors and communication issues (4, 45). Furthermore the emergency setting is highly unpredictable (46). Thus, residents need to develop adaptive expertise in order to handle the unpredictable and demanding setting of the emergency department (30).

# Informants

Ten volunteering residents were recruited through a chief physician from the Emergency Department (ED) at one university hospital. We aimed to recruit residents in their first postgraduate year (PGY1). In all, seven PGY-1 residents were included in the final dataset. Two residents were excluded from the dataset due to scheduling issues related to Covid-19 restrictions and one resident was excluded after the concurrent think-aloud interview, as it was not possible to perform the retrospective interview think-aloud interview.

## Procedure

The first author (MLG) conducted all interviews. Right after recruitment, residents were instructed in the thinking aloud method. They engaged in a short practice session on the day of the concurrent think-aloud interview. All staff in the ED were informed of the study before data collection. Staff were given information on the day of data collection and they were notified when they were being audio recorded.

## Concurrent Think-Aloud interview

The concurrent interviews were audio recorded during the geriatric patient encounter. The interviewer recorded second-order verbalizations of thoughts (38, 39, 47), by probing the resident to describe *what* they were thinking rather than *why* they were thinking it. Audio recording started when the resident prepared for the patient meeting. The recording would only be paused in case the resident had to take care of another patient or during long waiting periods. The audio recording was also stopped when diagnosis and treatment plan was deciphered.

## Retrospective Think-Aloud interview

The recordings were transcribed ad verbatim. This provided a case description for the subsequent retrospective think-aloud interview. The average time between interviews were 16 days (ranging from four to 44 days). Residents were instructed to think-aloud as in the concurrent interview, but also provide rationales for their thought processes as well as add any thoughts they were unable to verbalize during the patient encounter out of consideration for the patient.

## Observations

MLG performed participant observations before, during and after the patient encounter. She performed ad-hoc field interviews, which was also audio recorded, when the resident was not in the presence of patients or other staff. The audio recordings were transcribed and were added in the appropriate places in the transcript for the retrospective interview, together with field notes from observations. During analysis and reporting, the interviews added clarification and rationales for actions and field notes provided rich descriptions of the environment, interactions and procedures that the residents engaged in.

## Data analysis

The analysis was two-fold. Firstly, protocol analysis aimed to identify what information residents identified, and which cognitive processes they used to do so. Secondly, we performed a narrative analysis of these informational concepts and cognitive processes, to illustrate and describe the diagnostic processes of residents, in relation to the adaptive expert framework.

## **Protocol analysis**

Protocol analysis is a well-researched method of analysis, which can be applied to think-aloud verbal data of complex decision-making in clinical settings (40). We merged the two transcripts from the concurrent and retrospective think-aloud interview into one verbal protocol for each resident, which underwent protocol analysis as described by Ericsson and Simon (47). We performed referring phrase analysis and script analysis in line with Fonteyn, Kuipers (48), Funkesson, Anbäcken (49) and Johnsen, Slettebø (50). In the referring phrase analysis, we identified the types of information (referred to as information concepts) used in their CDM, from the noun or noun-concepts in the sentences. In the script analysis, we analysed how this information was used as cognitive operators for CDM (referred to as cognitive processes). This analysis was summarized, allowing us to describe the type of information as well as the cognitive processes used in clinical diagnosing.

## **Narrative analysis**

From the protocol analysis, we mapped the progression of how residents employed cognitive processes and collapsed them into a six-step decision-making process. These were formulated based on research on diagnostic reasoning, which describe information gathering, hypothesis generation and testing (15, 51–55). Based on the data, we added the processes of confirmation and diagnosing, as they emerged as separate processes. These are described in more detail below:

1. Gathering information: verbalisations that demonstrated specific actions to gather information about the patient.
2. Generating hypothesis: verbalizations that reflected that the resident which hypothesis was investigating and what their working hypothesis was.
3. Identifying cues: verbalizations that reflected which specific information the resident acted on and noticed in regards to the working hypothesis.
4. Testing hypotheses: verbalisations, which demonstrated concrete actions taken towards confirming their working hypothesis.
5. Confirming hypotheses: verbalisations that indicated that the resident was confirmed in their working hypothesis.
6. Diagnosing: verbalisations that demonstrated a conclusion to the diagnostic process, iterating what diagnosis was confirmed and would be acted on, in regards to treatment planning.

Furthermore, we related this to the framework of adaptive expert framework (23, 25, 36, 56), which allowed us to illustrate the diagnostic process and provide rich case descriptions of each informant.

## **Reliability and validity**

The first author (MLG) collected all data and conducted the primary analysis under supervision from the other authors who were chartered psychologists (MHM and PM) and a senior resident with expert knowledge of emergency medicine (CP). Samples of data was analysed by a co-author (PM) to discuss and reach consensus on information concepts and cognitive processes. This analysis was then discussed with a second co-author (MM). The intention of collecting both concurrent and retrospective think-aloud verbal data, was to increase validity and reliability, allowing triangulation in data analysis and cross-checking with the informant during the retrospective think-aloud (41).

## **Results**

### **Informant characteristics**

The final sample consisted of seven were PGY-1 residents (4 female and 3 male) with an average of 2.5 months of experience at the time of their first interview (range = 48–111 days post graduate).

### **Data set**

Data consisted of 14 one-hour interviews with the seven informants, and 17 hours of observation of patient-resident encounters. The interviews focused on one patient encounter for each informant resident.

### **Protocol analysis**

As described in the data analysis, protocol analysis consisted of two steps: 1) referral phrase analysis, and 2) script analysis (48).

### **Referral phrase analysis**

By isolating the noun and noun-sentences in the transcripts we were able to identify what kind of information residents verbalized during their diagnostic process. From this referral phrase analysis, 78 concepts of information emerged, where the most common are described in Table 1.

Table 1  
Concepts from referring phrase analysis identified amongst all participants

Concept	Definition	Verbal data from novices
Actions	Statements related to their own behavioural actions.	The nurse has just finished her handover of the patient to Daniel: "Yes, but let's go in right away."
Patient characteristics	Patient characteristics with consequence the diagnostic process (e.g., gender or known pathology).	Casper is treating a fallen patient who reportedly suffers from dementia. During his preparation, Casper explains: " <i>often we are more generous with x-rays when they [patients] have dementia, because the physical examination can be difficult.</i> "
Anamnesis	Patient history and description of events leading up to admission.	Ellen is gaining an overview of the patient and explains while reading the electronic patient journal that the patient " <i>...has been here for outpatient control, where she was [treated] for a distal radius fracture.</i> "
Peer opinion	Opinions from other physicians, both residents and experienced.	Julie has taken over a complex patient from another resident. She has conferred the patient with the available supervising physician who is an orthopaedic surgeon, but is still unsure of the medical side of the problem. She remarks, " <i>Here it's good to talk to the tending emergency physician, as they are more attuned to the medical challenges...</i> "
Plan	Recounting the plan for receiving and treating the patient.	Mark is treating a patient who has fallen and is in severe pain. He stops the physical examination and explains to the patient that as she is in so much pain, that " <i>...we will do an x-ray first, and then I can examine you further, if there's no visible fracture.</i> "
Sign	Visible symptoms or test results related to the present diagnosis or patient state.	Christina is examining a patient of suspected fracture to the ankle. She compares the sizes of the patients' ankles and notes, " <i>there's a visible swelling here.</i> "
Value	The meaning of symptoms to the diagnosis.	During the handover from the EMTs, Mark retrospectively explains that some of the reported values puzzle him. He reflects that this affects his decision-making: " <i>I start to consider... because you shouldn't receive a random patient with a heart rate of 35.</i> "

Concept	Definition	Verbal data from novices
Referral	The referral note, which is written by the referring physician, prior to admission.	Anne has been notified that there is a patient incoming, and remarks that <i>"...I will look him up... [And] see if there's a referral note..."</i>

## All names are pseudonyms

### Script analysis

From this identification of what kind of information residents verbalized, we were able to infer how this information was used during the diagnostic process, indicating the cognitive processes employed by residents. From this script analysis we identified, in all, 46 cognitive processes amongst all resident. The most common are described in Table 2.

Table 2  
Cognitive processes identified in the script analysis

Cognitive process	Definition	Verbal data from novices
Choosing	Decision-making during the diagnostic process.	Christina is examining a patient who may have a fracture to the ankle, and is considering if it warrants an x-ray. She has acknowledged a significant swelling but decides, <i>"I actually think we should see if you can stand on it."</i>
Concluding	Summarising and concluding on rationales for choices made.	Ellen has been through the patient's electronic journal and summarize her reflections: <i>"We definitely need to take an ECG."</i>
Information seeking	Actively seeking out ways for gaining more information.	The EMTs has just finished the handover to Mark, where an unusual heart rate is reported. He explains that therefore <i>"the first think I do, is to take her hand and feel her pulse, pretty early [in the examination]."</i>
Studying	Investigating information further, seeking a better understanding in order to make a diagnostic decision.	Anne is examining a patient who has cut himself and explains that she usually repeats the patient's answers, <i>"...so they can elaborate on their story a bit."</i>

## All names are pseudonyms

An additional table file contains a complete list of the 78 informational concept and 46 cognitive process codes [See Additional file 1]

We identified several commonalities amongst cognitive processes including choosing, concluding, and information seeking and studying. All residents utilized adaptive expert cognition through similar strategies. For instance, epistemic distance defined as monitoring level of knowledge and identifying knowledge gaps (25) was observed amongst all participants.

## Residents' diagnostic reasoning

The narrative analysis of the chronology of diagnostic process of each informant was visualized into individual models of diagnostic reasoning. These models of diagnostic reasoning are illustrated in Figs. 1.1–1.7. They show a progression in thought processes and changes in hypotheses (color-coded).

Anne has been in residency for 5 months. In the observed patient encounter, she received a 60-year-old patient who had stepped on glass a week ago. The patient (Anton) is now referred to the ED with an inflammation.

In her first hypothesis generation, Anne comments that a physician has not seen Anton before being referred to the ED. This would have been common practice with this type of patient. Thus, her thinking is part of the cue collection in her first hypothesis generation. She reads the short referral note, which states that the patient had stepped on something while swimming in the ocean. The patient's pain has increased since, and he has a hard time walking. Anne's initial hypothesis is therefore, that the foot is inflamed. Anne observes that the patient's walking is affected. However, during her clinical evaluation she rejects her initial hypothesis based on the cues that there is no swelling, redness or heat, and that he is able to lean on his foot. She therefore changes her hypothesis. To check further and evaluate her new hypothesis, she examines the wound more closely, finding no foreign bodies. This way she is confirming that the patient's pain is due to soreness from a healing wound rather than an inflamed injury. After this diagnostic decision, she goes back to look for the referral note once again. Unfortunately, she once again must realize that there is no note. Anne's behaviour shows signs of a relevant checking behaviour as evident by her retrospective comments on her rationale for checking the referral note after seeing the patient:

*I just want to make sure I have not missed something, since [the referring physician] thought he should come in [to the ED].*

The case continues with Anne becoming confused as to why the patient was referred to the ED. Anne did not deem that there was a justifiable cause, but she was not confident in acting on this due to her lack of experience.

Ellen has been in residency for almost 3 months. She is receiving a female 83-year-old patient (Mary), who reportedly has fallen in her own home. Initially the referral note suggests indications of a subdural haematoma, which Ellen settles on as her working hypothesis. Ellen thoroughly checks Mary's history and

medication in the electronic patient journal. Based on this investigation, she states that this is a rather classic case and that she is *"fairly sure"* that Mary is suffering from a subdural haematoma, based on the indication that the at home nurse has reported high blood pressure and a headache. She then goes on to examining the patient. The emergency medicine technicians inform that despite the home nurse reporting a high blood pressure, they were only able to detect a small increase in blood pressure. All other critical values are normal. Furthermore, they inform Ellen, that there are no neurological symptoms. This contradicts Ellen's working hypothesis, and from the interaction with the emergency medicine technicians, she identifies a stress response in the patient, as the emergency medicine technician reports that Mary recently broke her arm, which has influenced her independence and daily routine. In the retrospective interview, Ellen describes how her working hypothesis changed from this information, to a stress response. However, during the physical examination, Ellen routinely explores the headache and it turns out to be rather severe if slowly building. In the retrospective interview, Ellen explains that concussions can be tricky, and to be sure, she changes her working hypothesis for the third time, wanting to investigate the probability of a concussion, as she knows from the referral, that Mary hit her head, when falling. She performs a quick neurological screening, and concludes that she is uncertain if the symptoms warrant a CT scan. Therefore, Ellen chooses to seek out a supervising physician, and they discuss that the small increase in blood pressure could be white coat syndrome (fourth hypothesis), but the supervising physician agrees that a CT scan and ECG would be a good idea. Both of these come out normal and Ellen conclude that Mary's increased blood pressure is due to white coat syndrome.

Christina has been in residency for 3 months. She is receiving a female 70-year-old patient (Karen) who has twisted her ankle. From reading the electronic patient journal and referral note alone, Christina verbalize that her first hypothesis is that there is a fracture, based on the patient history, because she has osteoporosis, and has previously had fractures related to this disease. However, when Christina meets Karen, Christina becomes uncertain of this diagnosis. Thus, Karen presents with only limited swelling and no indirect pain on indicative pressure points. Based on this information, she explains in the retrospective interview, that at this point, she only expected a sprayed ankle, as none of the symptoms indicated a fracture. However, here Christina demonstrates adaptive expertise as she orders an x-ray despite this hypothesis and no indicative symptoms. She reflects that her rationale builds on the hypothesis that Karen has osteoporosis:

I usually do that if I have a patient where I'm like: should or should I not? Then I'm like: okay would I be able to go to sleep tonight without thinking about it?

This indicates a strategy of using her emotional response to scaffold self-regulation when she experiences gaps in knowledge (epistemic distance). Consequently, from this x-ray she notices a possible fracture and changes her diagnosis back to the original, and seek out a specialized physician to get her hypothesis confirmed.

It is an evening shift and Julie is taking over a male, 73-year-old patient (Karl) from the other resident, Daniel. Julie has been in residency for almost 3 months. Karl had fallen during clean up from a celebration dinner and cut himself on his lower leg, and Daniel had conferred with a supervising

physician, who said to suture the open wounds and admit Karl, as he had many comorbidities. Julie confirms that she goes with the Daniels' hypothesis that Karl has to be admitted due to his injuries, as Daniel also informs her, that Karl is suspected to be intoxicated. Daniel explains that he is tired and knows that he is providing unorganized information. Julie explains in the retrospective interview what make it particularly confusing:

Here I'm thinking that I need to see the patient... I have the feeling that I have many things in my head that is not sorted. So, I hope that when I see the patient, everything will fall into place.

By the end of the handover a supervising physician, who has a surgical specialty, is interrupting the handover, arguing that they should discharge Karl. Julie demonstrates self-regulatory practice in response to this interruption, explaining that:

"...especially with elderly patients and the very medical... it's good to talk to the emergency physician instead, because they look for the more medical problems..."

As this supervising physician continues to interrupt the handover, Julie retrospectively describes her emotional response to such interruptions:

*Then the supervising physician comes in and says that if there has been given a plan [in consultation with a supervisor], one should never 'shop around' for other treatment possibilities... but I feel like, if there have been over 12 new patients since, then I want to make a new evaluation, and then I will have to consult again*

She adds to this, describing the emotional impact on her performance:

*"So, I feel like giving up. [Like] am I alone, then? Just because [the previous resident] has already conferred the patient with another supervising physician? In addition, what if I myself make a new judgement that is not consistent with that... I feel uncomfortable backing a decision I did not make... [so I] become irritated, because it is arrogant [of her to put me in that position] ... the feeling of being a little helpless.... powerless is a good word for it."*

After this chaotic handover, Julie decides to go see Karl and from this interaction, she verbalizes in the retrospective interview that she immediately recognises that Karl is lucid, has no severe pain and she hypothesize that there is no need for admitting him as the injuries are only superficial. She seeks out another supervising physician to have him see Karl and assess the severity of his injuries. This supervising physician agrees with her diagnosis and plan for treatment (sewing and dressing the wound) and her decision to discharge Karl.

Mark is in his 5th month of residency and is treating a 75-year-old female patient (Eden). He does not have time to read up on Eden, as his priorities to get the handover from the emergency medicine technicians. Mark knows from the referral that the patient has fallen and remarks while walking to the patient room that he should always expect a fracture in the hip or pelvis area, due to the age and injury. However, during the patient interaction, he quickly recognizes that there is no indicative pain and his first hypothesis is that there is no fracture to her pelvis or elbow area (which were the areas mentioned by the emergency medicine technicians). Mark decides on performing an x-ray to be sure, due to Eden's age,

which confirms his hypothesis and he diagnose her with no fractures to the pelvis or elbow, and discharges her.

Casper is in his third month of residency and is seeing a 72-year-old male patient (Hans) with dementia. Hans has fallen and the referring physician has written that he suspects a colles fracture and that Hans's leg is rotated, which Casper mentions is a sign of such a fracture. While Casper is reading up on Hans, a nurse interrupts him several times, which he comments on retrospectively:

You become removed from your line of thoughts... the process that you are in.

As a result, Casper does not settle on a hypothesis before seeing Hans. While reading the electronic patient journal, Casper is thorough, and despite noting several relevant information that could indicate a fracture, he verbalizes that he should 'investigate' or 'be suspicious of' several different symptoms. However, Casper still does not settle on a hypothesis and several times iterates that *"we will know when we see the patient"* or *"then I know I will need to be extra thorough"* Indicating that he uses this preparation more as an overview and way of prioritizing his investigation, rather than narrowing down the hypothesis. Casper goes to examine Hans who is accompanied by a caregiver from his residential facility. In the retrospective interview, Casper comments that he initially suspects that there is no fracture based on the physical examination, but that this hypothesis is disrupted by a conflict with the caregiver. Casper informs the caregiver that he does not suspect a fracture and will possibly discharge Hans. The caregiver protests and Casper comments retrospectively:

She might be worried, because she had previously experienced that the ED overlooking a fracture of one of her other senior residents... Nevertheless, I will not order an x-ray although she is very worried... If I examine the patient and cannot find anything, [then I will not order an x-ray]. Otherwise, I could just order an x-ray without seeing the patient.

Here, Casper is mindful of a conflict of interest. But he is also aware of his role as the physician and the authority associated herewith. He initially justifies the value of his assessment through his role as a physician, which can be seen as a strategy of drawing confidence from the expected role that he is occupying:

I think it is my responsibility [to take the lead]. I'm the doctor so I'm the one in charge.

However, as the caregiver continues to question his decision, Casper gives in to this pressure and orders an x-ray. This x-ray confirms Casper's initial hypothesis and his diagnosis of with no colles fracture, and therefore discharges Hans.

Daniel is in his fourth month of residency and is receiving an 83-year-old female patient (Lisa). The referral note suggests a luxated hip. Daniel goes to greet Lisa in order to get a handover from the emergency medicine technicians before reading her patient journal. The emergency medicine technicians explains that Lisa has had an increasing pain and that she can walk, but that they assess that she has a high pain tolerance. When examining the patient, Daniel identifies low mobility, and despite Lisa describing low pain, his first hypothesis is that she has a luxated hip, as Lisa also informs him that she had a hip replacement surgery fifteen years ago. As seen with Mark, Daniel also reflected upon his role

and were cognizant of his inexperienced disposition in this regard. Lisa asks Daniel if it could be due to her hip replacement, and he responds: *"I have to be honest and say that I don't know [about the risks of 15-year-old hip replacement surgeries,]"* adding in retrospect that: *"I shall in no way pretend I know more than I do. It does not serve me, nor the patient."*

Daniel chooses to order an x-ray to confirm his hypothesis, but when the x-ray presents atypical, he seeks out a second opinion from one of the other residents, Ellen, who happens to be in the room with him. Here, Ellen explains that she has seen it before, and that it looks like a luxation. However, Daniel is still not sure and therefore chooses to confer an online medical handbook and look closer into typical treatment plans for a luxated hip. He settles on the hypothesis of a luxated hip, despite retrospectively reflecting that:

...because we fail to look at the x-ray picture of the side profile, where we would expect that the hip joint was outside of the socket, we mistakenly think that it is a luxated hip.

Explaining that after consulting Ellen he:

...has blind faith in her, because she is very convincing and has seen patients with luxated hips before... I haven't seen it before... she has seen it before, took a look at the picture and said 'it clearly looks like it's luxated' and I jump on that.

Daniel continues to plan the treatment and routinely goes to confer his decision with the supervising physician to get confirmation of his diagnosis and plan. Here, Daniel shows the x-ray pictures to the supervising physician, who disagrees with Daniel's diagnosis. He asks to see the side profile and identifies that the plastic liner of the artificial hip socket has broken. Daniel explains in the retrospective interview: *"I have never heard of a plastic liner before he mentioned it"*. The supervising physician calls to consult an orthopaedic specialist and is confirmed in the hypothesis and they settle on this diagnosis. Lisa is then transferred to the orthopaedic department for further examination.

## **Adaptive expertise and diagnostic reasoning**

Setting this organization of the residents' diagnostic process in perspective of the adaptive expert framework, we were able to identify how adaptive practices were temporally distributed in the diagnostic process as illustrated in Fig. 2:

Here, epistemic distance would often occur during information gathering, generating hypotheses and identifying cues, where residents would become aware of gaps in knowledge. Self-regulation was then seen primarily during the hypothesis testing process where residents whom applied adaptive expert cognition were able to identify this discrepancy between their existing knowledge and the problem at hand, redirecting their attention back to gathering more information. Furthermore, the general attitude of orientation to new knowledge was also observed as a continuing process amongst some residents, as also illustrated in Fig. 2.

## **Discussion**

This study sought to explore how adaptive expertise permeated diagnostic processes within medical residents in encounters with geriatric emergency patients. Results showed that all residents displayed adaptive cognitive practices during the diagnostic process, arguing that novices are capable of adaptive expert cognition, thus extending the understanding of the development of expertise (33). Adaptive expertise has been conceived as a learnable output of training, using the rhetoric 'becoming an expert' (34). By integrating the adaptive expert framework in diagnostic decisional processes, looking at how adaptive expert cognition was temporally distributed throughout, this study showed that novices sometimes were able to utilize adaptive expert cognition similarly to experts (33), but that they did not do so consistently. This suggests that adaptive expertise may be an available potential, but not yet a consistent and reliable competency within novices. Results also showed that some novices were more prone to being affected by their context, like peers' suggestions and opinions, or uncertainty, as when they were questioned on their authority. This finding suggests that the development of adaptive expertise is also fostered by individual predispositions and is in line with previous research (21, 57, 58) showing that attitude and professional identity inherently affects the development of adaptive expertise. The study discusses how these factors become important for novices.

**Key point 1: Epistemic distance and self-regulatory processes are a part of hypothesis generation, and hinder premature closure.**

As seen from the figures 1-7, some residents identified fewer cues before the patient meeting, which made them liable to changing their hypothesis several times before collecting adequate information to confirm their hypothesis. Some residents (Christina and Daniel) prematurely tested their hypothesis, and they were forced repeat the whole cycle when proven wrong. On the other hand, when residents collected more cues in their initial information gathering process (Daniel) or when the patient case was relatively simple (Mark), fewer shifts in hypothesis were necessary before confirming their diagnostic hypothesis. Arguably, when comparing these two methods of arriving at a diagnosis, premature closure on informational cues led to a more laborious diagnostic process for these informants.

Another possible reason might be that residents are primed by reading the patient journal, as we have seen that some residents prematurely anchor to one specific diagnosis and need thorough discouragement (e.g., x-ray) in order to put this hypothesis away, despite seeing the patient.

In the case with Mark, he does not have the time to read the patient's journal before examining her, and quickly arrives at the right hypothesis from the examination and handover from the emergency medicine technicians. In this case, Mark is scaffolded by his environment to be more open to information, but strategies for avoiding premature closure was seen in Casper, who explicitly states that he is gathering an overview, but withhold hypothesizing before seeing the patient.

These differences detected in cue collection impacted hypothesis generation. Residents who were less epistemically aware in their initial hypothesis generation, were prone to premature closure on a hypothesis, making them more prone to the need of changing hypothesis and this rapid hypothesis generation has been shown to entail risk of errors (8). However, while Elstein and Schwarz (59) argue that

novices struggle with generating hypothesis and planning because they have difficulty moving beyond data collection, this study indicates that the residents were able to move beyond data collection, and in some cases, rapidly change and develop hypotheses. Results showed that the challenge resided in the quality of hypotheses, as also argued by Elstein and Schwarz (59). This could suggest that the observed residents had enough experience to move beyond data collection and enough knowledge to form a hypothesis. However, the sometimes-low quality of the hypothesis could indicate that at this point in their professional development, they have not been trained to reflect on their knowledge and experiential acquisition.

Results indicated a lower tolerance for information load amongst residents, as illustrated by Casper, who wards off a nurse when preparing for his patient, saying: *"I cannot handle more patients right now"*, explaining retrospectively *"it's difficult to have it all in your head"*. Critical thinking skills, metacognition has been argued to improve cognitive efficiency through the reconstruction of knowledge, which is needed to free mental capacity to perform adaptive expertise (60). Here, context specificity helps increase the residents' tolerance of information load (60). This might help residents free mental capacity to 'slow down' and improve their diagnostic reasoning (56).

While we have at this point argued for the primarily individual nature of these cognitive competencies, research within the framework of adaptive expertise, also points to a collaborative nature of CDM (31, 60).

## **Key point 2: Emotional responses and uncertainty influence resident performance**

The results indicate that residents under some conditions are able to apply epistemic distance, but was seemingly affected by residents' confidence in their hypothesis. Christina only acted on her epistemic distance, due to her expected negative emotional response, whereas Daniel expressed his lack of knowledge on the patient's problem and made several attempts at self-regulatory behaviour in seeking out information and peer feedback. This could also be an indication of uncertainty present amongst many of the residents. When residents were uncertain and timid about their knowledge and competencies, they required additional reassurance of their assessment before taking action. The actions they took included weighing risks, conferring guidelines or inquiring about the patients' need or peers' opinions. These can be seen as epistemic behaviours. However, checking behaviours were also recorded and they seemed often to be initiated by an emotional response such as fear of missing a diagnosis, as seen in Anne's case.

Disturbances could add to this uncertainty. The case about how Casper was affected by pressure from his context illustrates how residents take on their role through their actions in the clinical setting and what the clinical setting allows. As described in his case, he retrospectively justifies and solidify his authority by the role that he has as a physician in the department, but when pressed by the caregiver, gives in and becomes unsure of his initial hypothesis.

As described in the results of the protocol analysis some residents viewed their role as a physician as tied up with their strategies used to harness epistemic distance. Instances such as described in Julie's emotional response, impacted residents' experienced learning culture in the department. Consequently, Julie did not feel comfortable with the available support from the first supervising physician, and sought out another physician to consult for small corrections to the diagnostic process throughout. This demonstrate the reciprocity of cognition and emotion (61) and underscores the importance of considering emotional regulation and identity in professional development.

Residents who verbalized their role as physicians would pick up on cues in their context that were not directly related to their diagnostic reasoning. This would be seen in instances involving conflicts of interest or disturbances. As a result, they would continuously check the appropriateness of their diagnostic reasoning and become more uncertain. Research has shown that uncertainty tolerance does reduce errors (62-64) and being able to tolerate unpredictable circumstances in an adaptive expert manner, helps residents engage in learning opportunities (57, 65). Research also suggests that the main concern for educational interventions should concern rational failure, which are caused by both individual affective and cognitive biases. Workplace factors increasing cognitive load and limited resources further increase the risk of such biases (46, 66). Researchers argue that critical thinking and metacognition reduce affective biases (67, 68), and reduce errors in diagnostic processes (69). Our data showed that critical thinking and self-regulation were processes that residents actively engaged in. However, conceptually, these are not commonplace competencies, and researchers in medical education argue that these must be cultivated through education (57, 65).

While all residents in this study utilized critical thinking, only one resident reflected on her emotional response and how emotions influenced her decision competency. This suggests that affective biases are not recognized in this particular setting, in that verbalization of emotional responses are not cultivated. Therefore, how the environment take part in cultivating critical thinking and reflective practices which encompass emotional features and how they affect residents, could help reduce the mortal consequences of biases in diagnostic reasoning.

### **Key point 3: How residents assume their role in the ED affect their cognitive strategies**

Results showed that while all residents reflected on their professional role, they were often verbalized through cultural expectations of their role as a physician in general, and not specific to their emergency context. Their decisional competency was extended through this negotiated general authority. This suggests the need for investigating settings that allow residents to acknowledge knowledge gaps, without feeling that their professional identity and authority is being challenged. While uncertainty is often interpreted as a sign of incompetence (70), this study suggests that supporting residents to develop a professional identity which allows knowledge gaps could scaffold adaptive expert cognition. At the same time, results indicate that clarifying their professional role and expected competencies could promote this, which is in line with current research (29, 71).

Our results showed that residents tended to rely on contextual cues in order to prompt their adaptive expert cognition. Previous research has shown that this strategy can increase mental load (46, 60). Results suggested that some residents required contextual structures like structured examinations to scaffold their ability to employ adaptive expert cognition, which has not previously been described in the literature on adaptive expertise.

In summary, residents used a range of informations and cognitive processes during diagnostic decision-making. All informants demonstrated adaptive expert cognition, but the chronological approach to analysis, showed how these were interspersed with routine practices and that disturbances and attitude impacted their diagnostic reasoning process. Results indicated that adaptive expert cognition was exerted at different times throughout the diagnostic process, indicating that the cognitive features of the adaptive experts' framework are imbedded in the process differently.

### **Strengths and limitations**

Introspection is a much researched and discussed methodology (47) and we acknowledge that observing first-order thoughts through verbalization is not wrought with difficulty (72). The method of Think-Aloud interviews were chosen in order to access second- and third-order verbalizations of thoughts (39). As such, the choice of including both concurrent and retrospective interviews served to obtain data as close to thought-processes as possible (40, 41).

### **Changes and differences in concurrent and retrospective interviews**

The choice of using both concurrent and retrospective think-aloud interviews had both strengths and some limitations. The use of both served to check for the reliability of the findings, by having time to transcribe and make initial analytical interpretations before the retrospective interview, which could then be confirmed or denied by the informant. Furthermore, the retrospective interview provided more thorough and unaffected insights to the informants' reasoning, while allowing for minimal invasion during the concurrent interview. This was especially worthwhile in the natural setting, as the concurrent interview did not interfere with flow management too much. However, during the retrospective interviews, some participants would express that "I should have done this..." or "it is probably because I thought...", indicating firstly, that the retrospective reasoning might not reflect the actual thinking processes during the patient encounter, but rather their procedural knowledge. It is arguably important to discuss this problem with introspection when using this methodology, as this might reflect automatic responses to a diagnostic task that were later analysed to reflect adaptive expert cognition, but may not have been actual adaptive expert cognitive processes during the diagnostic process. Secondly, a bias in the data may arise from the fact that we had no means of assuring that the reasoning that the informants provided during the retrospective interview, reflected their actual reasoning in the natural setting, and was not just a consequence of prompting retrospective verbalization of their thoughts. This point has previously been discussed of the think-aloud procedure and was the reason for including bot concurrent and retrospective think-aloud interviews. However, this study found that this limitation was still present, despite performing both, and as the method of including both is immensely time-consuming and

demanding of the researcher, it is reasonable to discuss the cost-benefit of using this methodology in opposition to common think-aloud methods or even interview methods. To this point, we found that performing concurrent think-aloud interviews was feasible and when asked in the retrospective interview, the informants in this study did not find it constraining, nor did they add types of information that was not addressed during the concurrent think aloud interview.

### **Future directions for research**

This study adds to the research on residents' cognitive decision-making processes. However, given the relation between residents' diagnostic reasoning and their adaptive expert cognition, future research might focus on applying the adaptive expert framework in relation to training diagnostic reasoning. Specifically, how do we train to reduce uncertainty, by means that are not mere knowledge acquisition? Experience is not sufficient to rid novice residents of uncertainty and give them the tools to act adaptively. Therefore, future studies could operationalize findings in this study of the possible positive effects of learning to accept knowledge gaps as a natural part of medical practice, and methods of slowing down in the initial hypothesis generation.

## **Conclusion And Implications**

This think-aloud interview study showed that resident CDM and adaptive expert cognition are closely related. They are both affected by uncertainty and professional role, in how residents assumed confidence in their authority by either the cultural expectation or their own merits as an ED physician.

The concurrent and retrospective data established that residents who were less able to detect their knowledge gaps, too quickly settled on a hypothesis. This not only meant that they were forced to revise the initial hypothesis during the patient encounter, but also reflected a tendency to forego adaptive expert practices, in change for decisional action. Research on adaptive expertise needs to be able to explain how residents' thoroughness in hypothesis generation is a consequence of their confidence and tolerance of restrictions in knowledge and uncertainty. Results showed that residents could apply adaptive expert cognition during diagnostic reasoning, and that epistemic distance was aligned with the information gathering process, whereas self-regulation applied to the hypothesis testing process. Furthermore, results underscored the importance of professional role, attitude and beliefs during the entire diagnostic process, and their openness and orientation towards learning opportunities.

## **Abbreviations**

ED  
Emergency Department  
PGY-1  
Postgraduate year 1  
CDM

Clinical Decision-Making  
EMT  
Emergency Medical Technician

## **Declarations**

### **Ethics approval and consent to participate**

This study was approved by the “Danish Data Inspectorate” (j.2016-051-000001, case 1487). The study was exempted from ethical approval, which was approved by the “Central Denmark Region Committees on Research Ethics” (j.1-10-72-1-19).

All methods were carried out in accordance with the Declaration of Helsinki. During recruitment, all residents were provided with oral and written information about the project, and written informed consent was obtained from all participants. Audio-recorded verbal informed consent was obtained from all patients, relatives and healthcare professionals. Anonymization was done during transcription, leaving out identifiable information and replacing all names with pseudonyms.

### **Consent for publication**

Not applicable

### **Availability of data and materials**

The raw datasets analysed during the current study are not publicly available due to General Data Protection Regulation in respect to the participants and patients but anonymized raw data are available from the corresponding author on reasonable request. Anonymized accumulated data are included in this published article.

### **Competing interests**

The authors declare that they have no competing interests.

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### **Authors' contributions**

MLG designed the study, collected and analysed all data and was the main author of the manuscript. MM and PM helped design the study, analyse the data and were major contributors in writing the manuscript.

CP helped design the study and provided continuous feedback on the manuscript. SS transcribed all interviews and helped analyse the data. All authors read and approved the final manuscript.

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## Figures

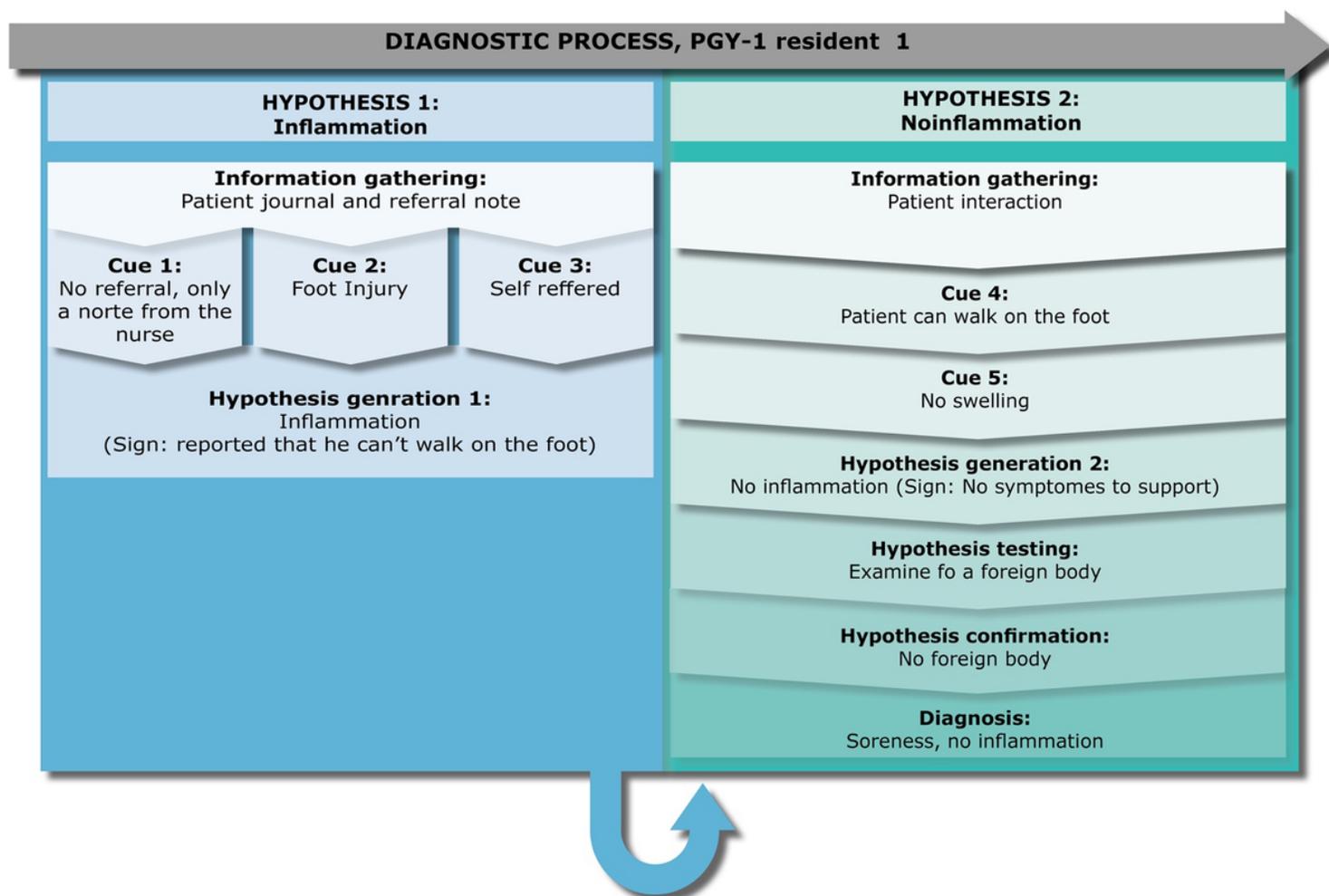


Figure 1

Figure 1.1: PGY-1 resident 1, "Anne"

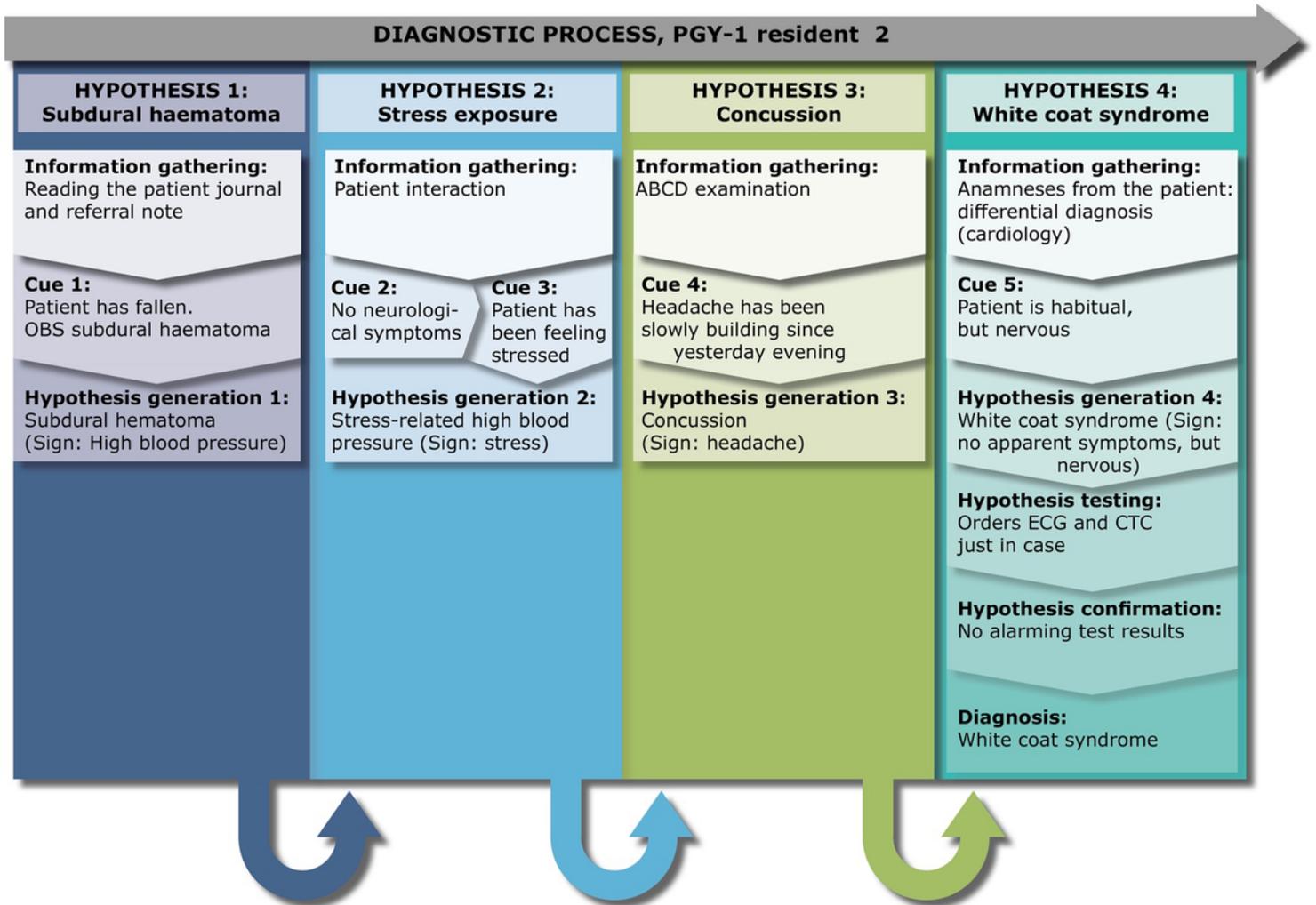


Figure 2

Figure 1.2: PGY-1 resident 2, "Ellen"

DIAGNOSTIC PROCESS, PGY-1 resident 3

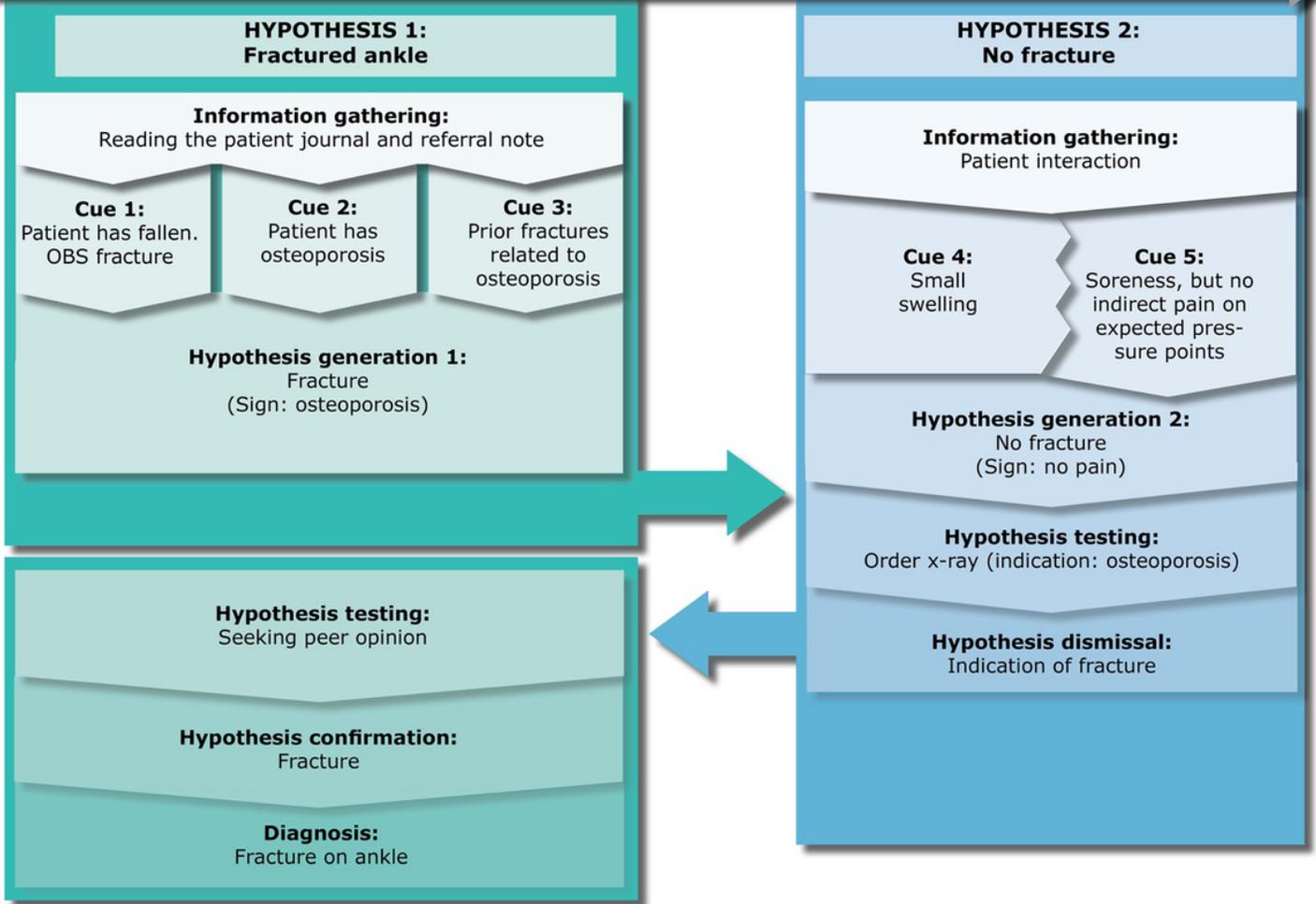
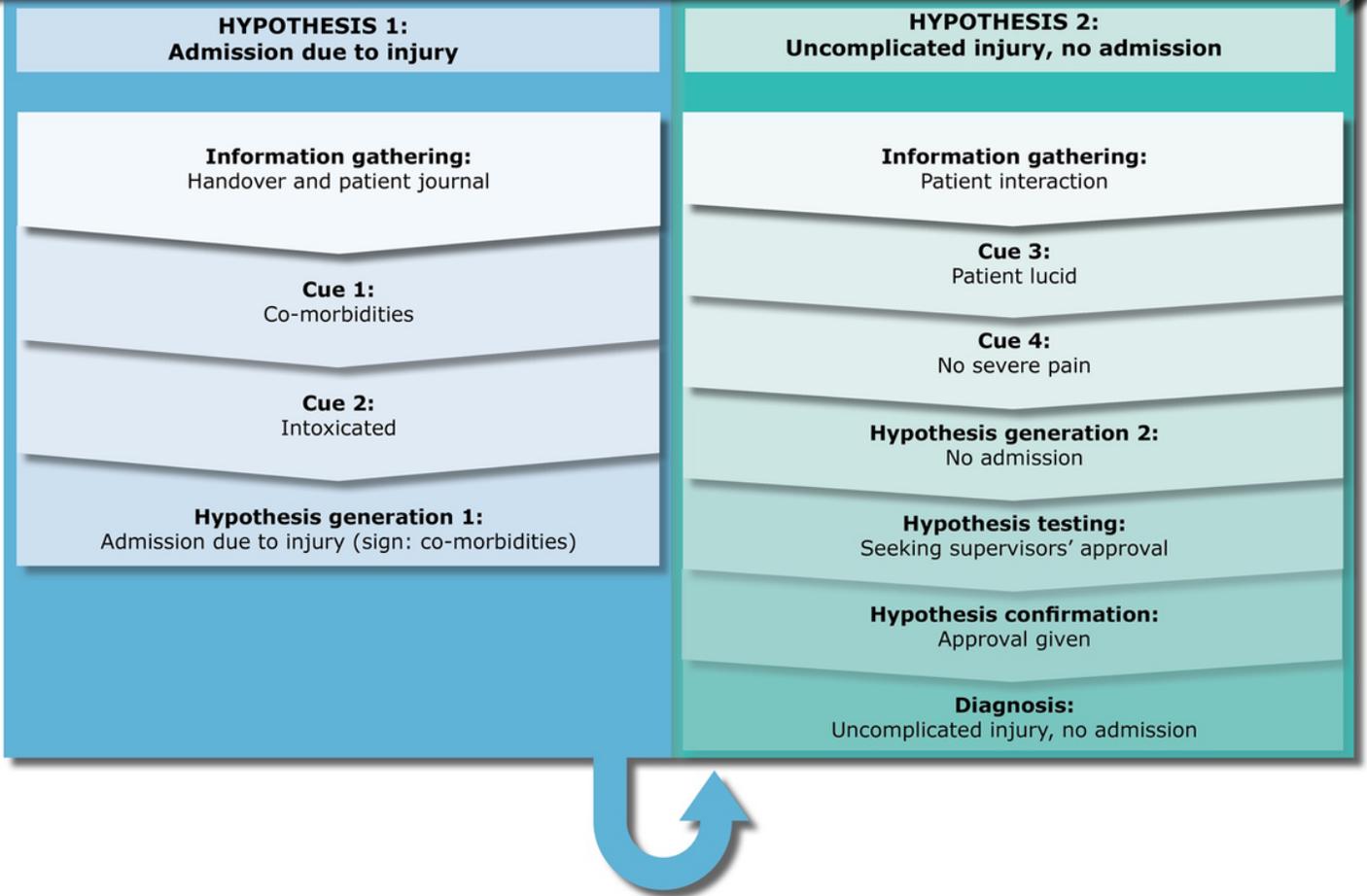


Figure 3

Figure 1.3: PGY-1 resident 3, "Christina"

**DIAGNOSTIC PROCESS, PGY-1 resident 4**



**Figure 4**

*Figure 1.4: PGY-1 resident 4 "Julie"*

**HYPOTHESIS 1:**  
No fractured pelvis and/or elbow

**Information gathering:**  
Referral and patient journal

**Cue 1:**  
Fall, OBS fracture

**Information gathering:**  
Patient interaction

**Cue 2:**  
Patient in no severe pain

**Cue 3:**  
No indirect pain

**Hypothesis generation 1:**  
No fracture

**Hypothesis testing:**  
X-ray (indication: age)

**Hypothesis confirmation:**  
No fracture

**Diagnosis:**  
No fracture

Figure 5

Figure 1.5: PGY-1 resident 5, "Mark"

DIAGNOSTIC PROCESS, PGY-1 resident 6

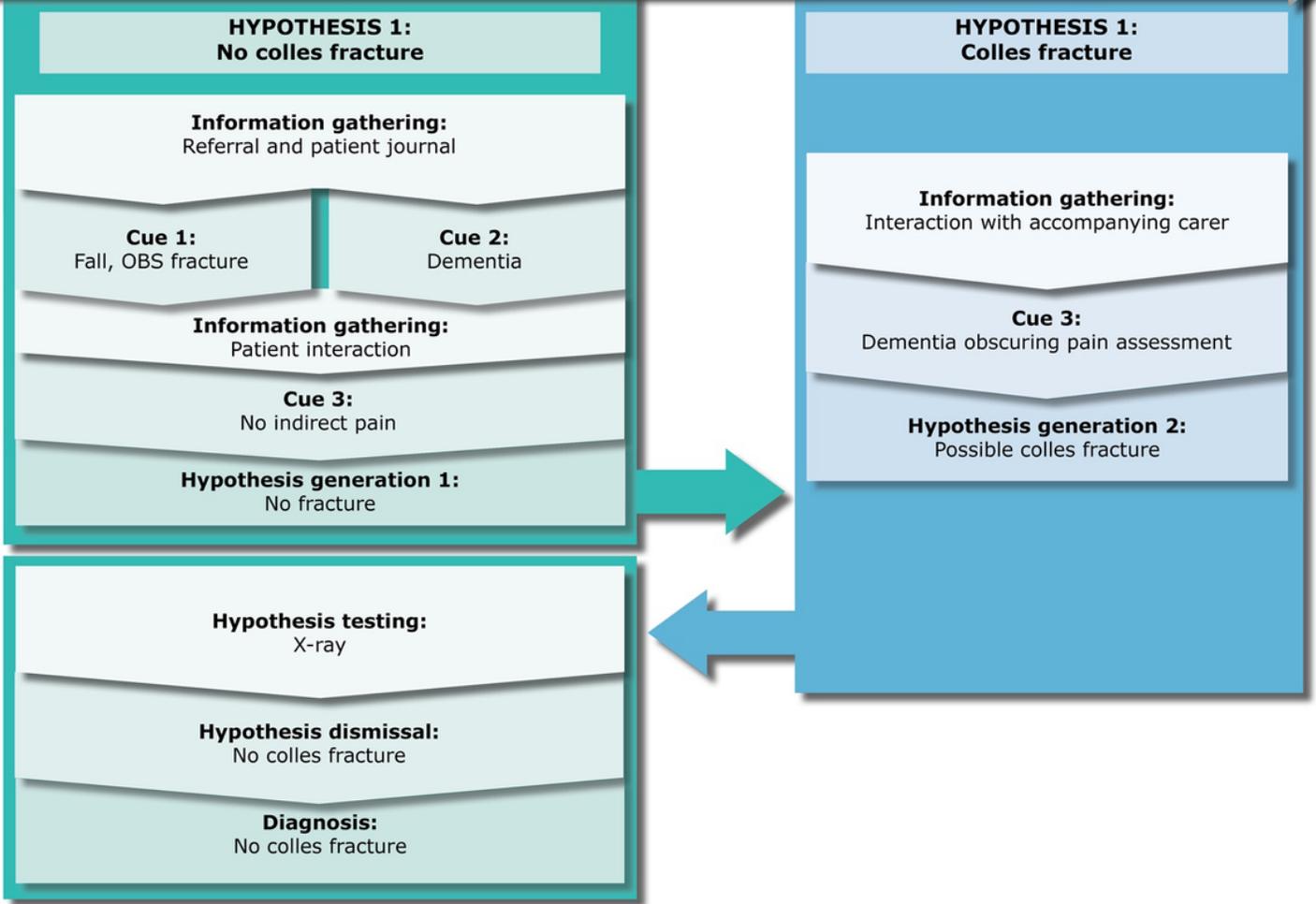


Figure 6

Figure 1.6: PGY-1 resident 6, "Casper"

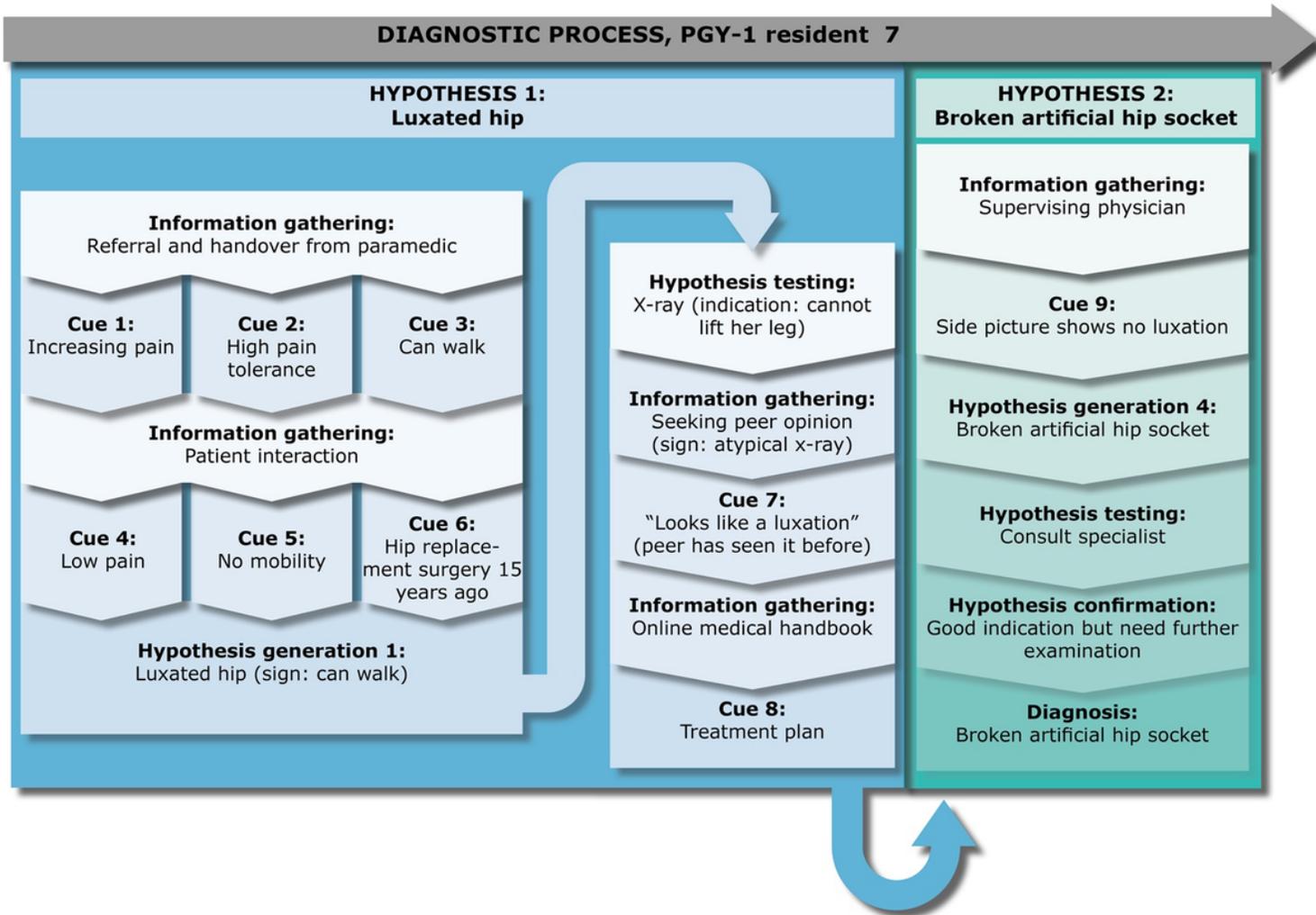
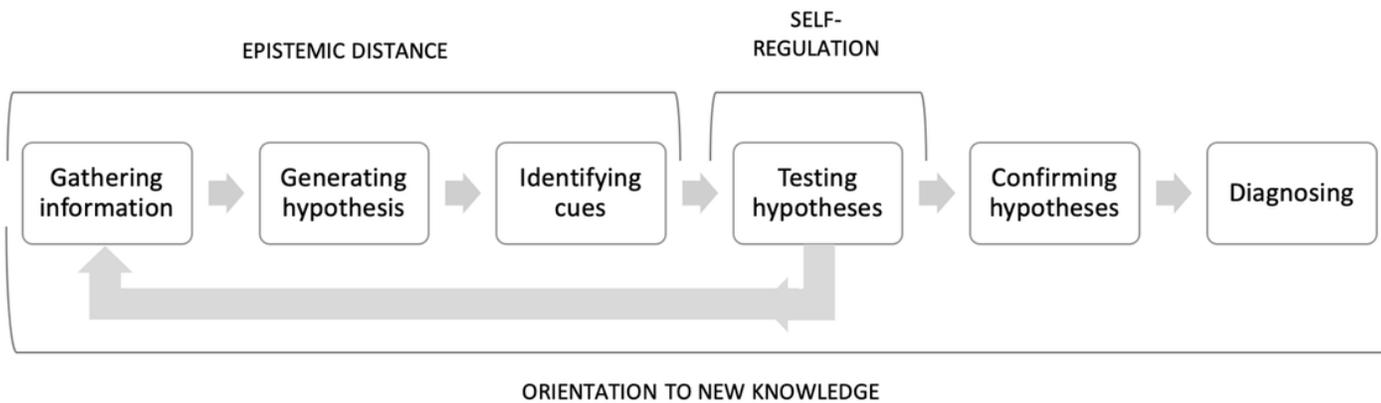


Figure 7

Figure 1.7: PGY-1 resident 7, "Daniel"



## Figure 8

Figure 2: Adaptive expert cognition as embedded in the diagnostic process

## Supplementary Files

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