# DASHBOARD CONFESSIONAL: CO-DESIGNING A DECISION-MAKING SUPPORT TOOL TO SUPPORT RESIDENT'S TEST ORDERING

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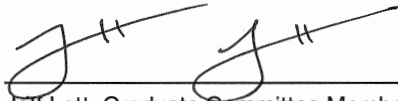of Michigan
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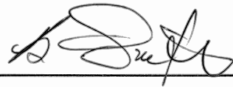
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**M STAMPS**
SCHOOL OF ART & DESIGN

UNIVERSITY OF MICHIGAN

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**APPROPRIATE CARE**

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To the real ones, the dreamers, the sad ones, the ones that see the world differently, the ones that never give up:

We are the music makers,

And we are the dreamers of dreams,

Wandering by lone sea-breakers,

And sitting by desolate streams;—

World-losers and world-forsakers,

On whom the pale moon gleams:

Yet we are the movers and shakers

Of the world for ever, it seems.

# Contents

# Abstract

Patient-centered appropriate care is complex, as each patient will be a unique situational case. Within appropriate care, "meaning the right treatment, at the right time, with the best outcome, while providing excellent service, and with minimum waste (Naylor 1998), exists the realm of appropriate testing. Testing which is not appropriate could be test overutilization (unnecessary testing or overtesting), which is "the performance of a test [where] the result has little to no effect on a patient's care," (Procop, 2018) or test underutilization (not enough testing), in which a "provider does not request a test that could positively affect patient outcomes" (Procop, 2018). This thesis seeks to understand the opportunity of a decision-making support tool to support Residents (providers) in their test ordering decisions to lead to more appropriate testing. The approach used allowed Resident end-users to play a significant role in the design of my proposed decision-making support tool. This project explores making the decision-making process of ordering a test explicit, as opposed to tacit. The project looked specifically at Hospital Medicine, a branch of Internal Medicine, with non-ICU (non-intensive care unit) Residents.
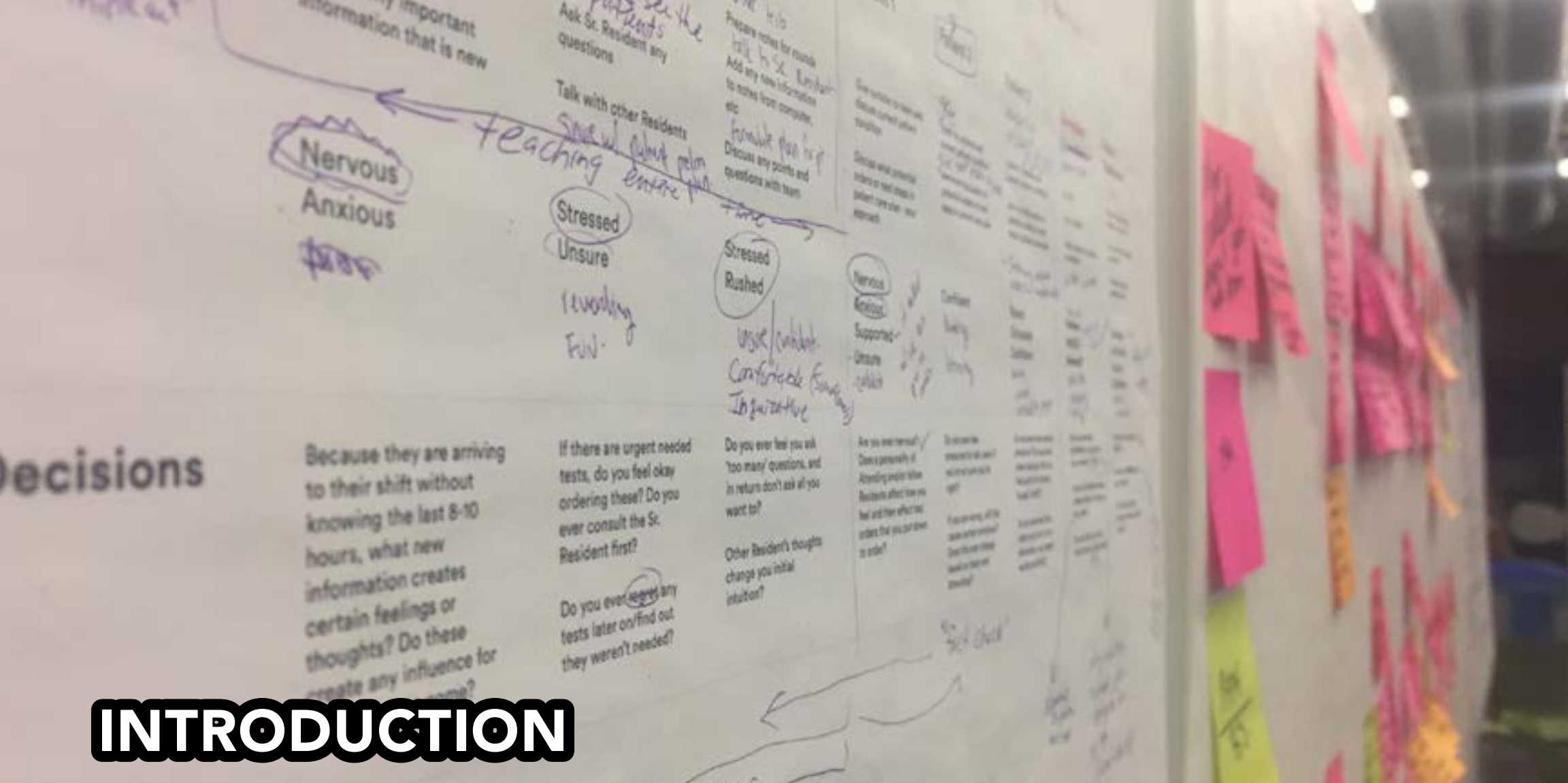
# Keywords

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# INTRODUCTION

## 1.1 Overtesting

According to Jerome R Hoffman, professor emeritus of medicine at the University of California Los Angeles, and, Hemal K Kanzaria, Robert Wood Johnson clinical scholar of the Robert Wood Johnson Foundation Clinical Scholars Program, US Department of Veterans Affairs, Emergency Medicine Center, University of California Los Angeles (2014),

"Physicians [providers] themselves mostly cite fear of legal (malpractice) claims as the primary driver of excess, but less attention has been paid to other drivers, whether at the individual or medical societal level. We believe that intolerance of both uncertainty and error—among physicians, in the larger medical culture, and in general Western culture—may be the most important reason that physicians engage in medical excess. [...] Physicians routinely assert that defensive medicine—defined as deviation from sound medical practice because of fear of liability—is the leading cause of medical excess. In a well-done survey of a random stratified sample of physicians practicing in six high-risk specialties, over 90% of 824 US physicians acknowledged engaging in defensive medicine. This primarily involved ordering unnecessary diagnostic tests and procedures (59%), prescribing more drugs than indicated (33%), and referring patients more often than necessary (52%). In another recent survey study of US emergency physicians, 97% of respondents admitted ordering advanced imaging studies that they thought were medically unnecessary, asserting that fear of litigation and fear of missing a low probability diagnosis were the primary contributors" (Hoffman & Kanzaria 2014).

Medical testing is commonly done as a means of diagnosis and for monitoring treatment. Unnecessary testing (test overutilization, overtesting) is one of many factors contributing to an increase in the overall volume of testing (Solomon et al. 1998), which is strengthened with a prominence fixed on "perverse financial incentives," which, "reinforce such behavior," and "commercial marketing efforts designed to create demand for more testing, diagnosis, and treatment" (Hoffman & Kanzaria, 2014).

Health systems, insurance companies, and patients are all impacted by extensive testing and testing costs (Kwok & Jones 2005). Overtesting has been studied to find that when testing that is not within appropriate parameters occurs, there are risk factors for patients, care providers, test processors (Pathology), and healthcare institutions. Potential

consequences are decreased patient satisfaction, unnecessary harm as a result of test overutilization or underutilization, or increased costs (Kwok & Jones 2005). Likewise, it has been shown that testing not conducted appropriately (such as defensive testing to ensure against medical malpractice) can lead to a reduction in the quality of a patient's care as it inadvertently causes a diminished health outcome (DeKay & Asch 1998). Testing, which is not appropriate, can have a far reaching impact on a health system, but this thesis began from an interest in the effect it has on Pathology. This thesis aims to achieve more appropriate testing through a design concept of a proposed decision-making support tool (as an add-on to a dashboard being created by a quality division).

## 1.2 Tackling the Wicked Problem of Appropriate Testing

I started this project during my time within the University of Michigan's Master of Design program, in the Winter 2018 semester when my cohort was looking into the problem of test overutilization in partnership with a test utilization committee, some members of which are a part of a quality division (QD) within a department of Pathology at an academic medical center. The academic medical center is part of an academic health system within a public university. I partnered with a project manager (PM) within a QD to continue to work on this project throughout the remainder of my thesis project (until May 2019). The QD is a team of quality experts, led by a Pathologist, whose goal is to provide better patient care through the lens of Pathology (PM 2019).

Appropriate care, meaning the right treatment, at the right time, with the best outcome, while providing excellent service, and with minimum waste (Naylor 1998), is an overarching goal of many healthcare systems. To arrive at the right treatment, at the right time, with the best

outcome, while providing excellent service, and with minimum waste, laboratory testing must be done in a manner that supports these desired outcomes. Appropriate testing has become an issue throughout healthcare systems seeking to adopt a patient-centered appropriate care approach and improve the quality of care that a patient receives. Some considerations which contribute to appropriate testing include the following:

• Testing that is diagnostically valuable

• Testing that is valuable for patient treatment

• Testing that would change a patient's course of care

The QD's primary reason for pursuing appropriate testing is to deliver the best care possible to patients by guiding providers to order only tests that are valuable in the diagnosis and treatment of disease (PM 2019). A test utilization committee, which is an interdisciplinary committee with representation from Pathology and Internal Medicine that involves members of the QD, is creating a dashboard. A dashboard is commonly described as a communicative tool that offers visual displays of information to users so that they can better understand relevant information in a useful way (Few 2006). The decision-support tool explored in this thesis is a proposed add-on to the QD's dashboard.

Wicked problems are complex problems that are usually entangled within multiple contexts (Rittel & Webber, 1973).

Each patient is unique, with individual needs and desires, in addition to their medical needs. The interplay between these factors can make it challenging for providers to address a patient's situation holistically and provide the most appropriate care. Achieving appropriate testing is a similarly wicked problem because not only is each patient unique, but for each provider ordering a test there might be a range of information (or gap in information) that impacts a test ordering decision. I wanted to explore what information could support Residents during the deci-

sion-making process.

## 1.3 Project Purpose

Pathology has limited resources. Time spent processing tests that are not appropriate is time that could have been allocated to fulfilling higher value tests more quickly, returning essential results to providers and patients sooner. Since the act of appropriate testing itself positively impacts facets of healthcare (e.g., patient outcomes, patient experience, financial costs), appropriate testing should remain a priority within the workflow of providers regarding their ordering. This allows for certain healthcare workflows which are impacted, to remain satisfactory for both healthcare systems and their patients, but also so that patient-centered appropriate care is reached. When the considerations that contribute to appropriate testing are not met, this leads to substantial negative consequences. Examples of testing that falls out of the bounds of what is recognized as appropriate care include:

• Unnecessary repeat orders:

    More frequent than necessary (results will not change in a given timeframe)

    Results will not change (i.e., genetic testing)

    Provider is unaware of results

• The test provides no additional value:

    Based on the results of another test

    Based on the inability to interpret due to the results of another test

    Based on patient demographics, location, time of year, sample type

Redundancy of result

• Misordered test

Technical problems (inadvertent selection, aberrant listing)

Cognitive problems (sound-alike tests, i.e., magnesium/manganese)

Misunderstanding of specific indications

Improper test menu or order set configuration

• Incomplete testing for diagnosis

• Incomplete testing for monitoring

(Procop 2018)

Within the academic medical center, many tests in Hospital Medicine units are commonly ordered by first-year Residents during rounds, which is when Resident and Attending teams discuss the condition and plans for continued treatment of each of their patients, including testing. Attendings are providers who are, "responsible for the overall care of a patient in a hospital or clinic setting [...] [and] may also supervise and teach medical students, interns, and [R]esidents involved in the patient's care" (NCI Dictionary of Cancer Terms). It is important also to understand that other testing may be ordered throughout the day by other providers as necessary. First-year Residents, along with other year-specific Residents, are Residents who have recently completed Medical School and are now working on their postgraduate residency training. Residents place test orders (via computers) at various points during rounds. While a small percentage of ordering occurs before rounds and during rounds, most test ordering typically occurs after the completion of rounds.

The QD's test utilization committee is designing a dashboard. It is intended to be utilized by unit and service leadership, such as Service

Chiefs, as a tool to help them change behavior and address the volume of tests that are currently not ordered appropriately (PM 2019). This dashboard would contain and display unit-level data of volume and cost so that a unit director can know which tests are being over-utilized in their unit, and take action (PM 2019). This would not track provider ordering data, but rather look at testing that is done within services and units so that units (and units within certain services) are able to make changes (PM 2019). The test utilization committee hopes that by providing unit leadership with certain information, it will help them make informed decisions regarding testing policies within their units, and lead to more appropriate care. However, I considered a different approach. I noticed an opportunity to add a decision-making support tool that could be an add-on to the dashboard to help Residents order tests more appropriately.

This project hypothesized that by providing more helpful and supportive information during the decision-making process of ordering a test, my proposed decision-making support tool (as an add-on to the dashboard) could better inform the decision. For instance, when Residents are trying to decide which test to order, the tool can be used as an informational resource. Similarly, it can support Residents in responding to patients. For example, a patient might request a test because of commercial marketing efforts that they had recently seen; they may be seeking reassurance if they feel they may be at risk for a certain disease, or want to know if they may have a specific condition of which they were previously unaware. During this scenario, my proposed decision-making support tool (as an add-on to the dashboard) could provide information that can then be used by the provider (which may be a first-year Resident), to reassure a patient why a test may not be necessary. The proposed decision-making support tool (as an add-on to the dashboard) can also help Residents during times when they typically need to satisfy both the real and perceived standards of the patient (patient-centered care and appropriate care), as well as the standards of their Attendings (who lead them), and defensive medical

practices (departing from normal medical practice as a safeguard from litigation) (Fortess & Kapp, 1985).

This project sought to discover what information would be most helpful and supportive to Residents for use at the moment of decision-making. I also wanted to find out what information can make Residents more aware of how they make certain decisions. Ideally, having the tool could prompt deeper reflection for Residents, and lead them to become more aware of what information might help their decision-making process.

Furthermore, I wanted to do this project because of my previous professional experience in the fields of product, UI, UX, and visual design, where I have gained various levels of experience about how to approach problems and design effective and adaptive solutions. With this project, I believe that more appropriate testing could be achieved by intervening at the time which tests are ordered (via my proposed decision-making support tool as an add-on to the dashboard) rather than intervening retrospectively, and in doing so, be able to influence future decisions to be more appropriate.

Decision-making support tools built around a supportive and desirable user experience can relay timely, actionable information to users, which ultimately affect and change their behavior, affecting future outcomes. Co-designing the decision-support tool increases the likelihood that it can support Residents to shift their behavior. The decision-support tool should be co-designed with multiple stakeholders and constituents in various roles and positions (Sanders & Stappers 2014). The process of Co-Design takes into account the engagement of all parties involved to form a more understanding relationship of roles and their associated workflows (Sanders & Stappers 2014). This has the potential to create user-agency and shared empowerment. Through the participation of diverse stakeholders, we could collectively determine the most preferred data for the decision-making support tool to display and analyze. This flow of information and expertise between all levels

of providers will afford the capture and sharing of data from expert specialists, or specialized medicine Residents to better support less experienced providers. This collaborative approach allows opportunities for Residents and other providers to feel included and supported. Co-Design and the involvement of Residents also enable the capture of unique information that the QD would not otherwise have gained access to within their process.

## 1.4 Project Setting, Environment, and Test Ordering

The academic medical center is within an academic health system. At the academic medical center, tests in Hospital Medicine units are commonly ordered after rounds, by first-year Residents, although tests can be ordered at any time before, during, and after rounds. First-year Residents are Residents who have recently completed Medical School and are now working on their postgraduate residency training. As a part of their training, first-year Residents are often responsible for ordering tests. Since Residents are commonly responsible for ordering a large number of tests, they play a crucial role in delivering on the ultimate goal of more appropriate testing. Furthermore, Residents continually rotate through various teams. They are continuously required to be learning not only new medical information but the social and working practices of new units regularly. Residents are also led by Attendings. Residents may interact with fellow Residents, Attendings, and other types of specialists (Pathologists, Gastroenterologists, etc.), while fulfilling their role as a provider. Basically, the practice of delivering care as a provider is complex, as any one person's ability to do their job is dependent on others upstream and downstream to their job. Within this complex network lies the system of Resident education and the potential for gaps in information to occur, since:

• First-year Residents have not had long-term experience;

• First-year Residents are transient (they change units or services every 2-4 weeks and are subject to frequent changes in socialization);

• First-year Residents are overseen by a different Attending (a medical provider in charge of a service unit's Resident's day-to-day work) in each unit or service

• Residents often order tests individually, either before or after rounds, when they may not have access to the input of their peers and Attending

The academic medical center commonly fosters a more dynamic (changing) style of learning by how individual teams function during rounds. Rounds are a truly vital teaching experience, with an Attending having a teaching and learning experience with Residents discussing a patient and what tests should be ordered. This is a teaching opportunity for Attendings, since they are leading rounds and getting the Residents to think about what they potentially should be doing, as well as having a discussion about what tests should be ordered. Within the academic medical center, I observed two "types" of rounds (within a Hospital Medicine unit), which I named: "table rounds" and "physical rounds." Table rounds are rounds where the lead Attending and all Residents discuss all patients that are under their care at a table in the team room. They then go together to visit select patients in their rooms. Physical rounds are rounds where the lead Attending and all Residents walk together through the unit and discuss all the patients that are under their care just outside of the patient's room and then visit the patient. Residents gain experience by rounding and working under an Attending; they are able to learn while taking care of their patients.

Attendings have permanent roles; however, Residents' roles are transient. Residents are often rotating through units and services with new groups of Residents, as well as getting the opportunity to work (learn) with new Attendings. This process exposes them to a broad range of experiences, but also places them in unfamiliar contexts and requires repeated readjustment to the norms of each Attending as they are learning to care for patients. Within the academic medical center, Residents' orders are reviewed by their Attendings. Attendings are ultimately responsible for these test orders (PM 2019). Since appropriate testing is ordering the right test at the right time and is essentially a decision-making process based on the needs of patients, determining the correct test is typically done with regard to the patients' diagnostic and monitoring needs (PM 2019). Given the complexity of a Resident's transience, I suggest that my proposed decision-making support tool (as an add-on to the dashboard) can help augment the process of decision-making for Residents. It can introduce information to help them make a more informed decision and afford them an opportunity of conscious reflection that may help to prevent them from making a test ordering decision that is not appropriate. If information can have an impact during decision-making, then I want to know what information can be supportive, and gain a better understanding of what gaps in information may exist. The Resident is still making the decision, but the process has a digital resource built-in that can be used. It is not a replacement for judgment. It is an added resource to help make a more appropriate test decision.

## 1.5 Scope, Boundaries, and Limitations

I narrowed the scope of my project down to the academic medical center's Hospital Medicine units. The project's context centered on Residents in these units, which are first, second, or third-year Residents, and their decision-making process when they are ordering tests. Residents are tasked with placing many orders as a part of their learning experience. When the decision-making process happens during rounds,

Residents are informed by the experience of being with their third-year Resident, Attending, or fellow nurses as they go through this process.

They also order many tests individually, when that support may not be present. My assumption is that this phase of learning, when Residents are gathering new experiences, is an ideal opportunity to positively impact the behavior of Residents in forming desired test-ordering habits.

Even though the context of this project focuses on first, second, and third-year Residents, Pathology receives test orders from all types of providers such as Residents, Fellows, Attendings, Nurse Practitioners, and Physician Assistants, among others who are authorized to place orders (PM 2019). Tests are then completed, and the results are sent back to providers. It is Pathology's job to perform needed testing, and their process is designed to perform those tests (PM 2019). Most of what Pathology does happens in laboratories behind the scenes in a hospital. Therefore, providers are not always aware of the logistical implications of ordering additional tests 'just in case' they might be needed. Unnecessary testing pulls resources, like technician time and testing reagents, away from more appropriate tests (PM 2019).

This project's intent was to understand the current decision-making process of Residents ordering a test so I could then understand what information would be necessary to help Residents make more appropriate testing decisions. The project demonstrated how a decision-making support tool could make helpful and supportive information more accessible to Residents, so they are more supported in making more informed decisions, leading to more appropriate testing. The decision-making process of Residents to order a test happens during all phases of rounds. My intent was to expose what is happening within these phases where decision-making occurs, what information would impact these moments of decision-making for a Resident, and how a decision-making support tool could support them. I also wanted to understand how I could Co-Design this project with Residents.

## 1.6 Research Questions

The main research questions for this project are:

Question One:

"How can I understand Residents and the context in which they make a decision to order a test?"

Question Two:

"What information would be most helpful to be shown to Residents for use at the moment of decision-making?"

## 2.1 Decision-Making

How humans make decisions is a complex process. Usually, this process is uncommunicated, unknown, and invisible – essentially implicit, and therefore, it is hard for people to describe, or even visualize. Within human brains, the limbic system is the part of the brain that processes feelings, or emotions (Mériau et al. 2006), and is responsible for all decision-making (Kuehn 2013).

"The neocortex is responsible for all of our rational and analytical thought and language. [...] [O]ur limbic brains are responsible for all our feelings, like trust and loyalty. It's also responsible for all human behavior, all decision-making, and it has no capacity for language. [...] [Y]es people can understand vast amounts of complicated information like features and benefits and facts and figures. It just doesn't drive behavior. [...] Because the part of the brain that controls decision-making doesn't control language" (Sinek 2010).

The emotional condition a person is feeling, along with the emotional subject matter itself, can influence decision-making (Dolan 2002) (Mériau et al. 2006). The making of a decision to order a test in relation to appropriate testing is therefore also complex; how tests are ordered occurs through a series of decisions made by Residents. By examining these decisions, understanding these complex moments, and then creating a decision-making support tool to be used in the decision-making process of ordering a test, we can help allow Residents to make more informed decisions within their decision-making process.

## 2.1.2 The Decision-Making Process

Within the general decision-making process, our brains naturally identify all possible outcomes of potential decisions, favorable or adverse (Tom et al. 2007) (Hsu et al. 2005). When faced with complicated, complex decisions, doubt can arise, leading us to be more likely to gamble, and "take a chance" (Doya 2008), which can lead to testing that is not appropriate. Kenji Doya, Ph.D., a Professor and Unit Head at the Neural Computation Unit at the Okinawa Institute of Science and Technology in Japan, breaks down the decision making process into four steps: "(recognize) the present situation (or state)...(evaluate) action candidates (or options) in terms of how much reward or punishment each potential choice would bring...(select) an action in

reference to one's needs...(potentially reevaluate) the action based on the outcome" (Doya 2008). However, these generalized decision-making steps, don't include all of the information or knowledge that exists within a decision-making process.

## 2.1.3 Internal and External Influences in Decision-Making

Our decisions are influenced by both internal and external factors (Doya, 2008). Influences we feel internally can be driven by emotions in an effort to avoid negative feelings or outcomes (Lerner et al. 2015). Emotions, regarded as the "deliberation preceding the action," are intuitively compared to possible decision outcomes through our own limited scope of personal knowledge and experience, leading to decisions that seldom can be considered rational and, rather, are predominantly emotionally driven (Schall 2005). Emotional subject matter can influence even the most straightforward decision (Mériau et al. 2006). External influences within the environment in which we interact (Zardo, Collie, & Livingstone 2014) can be supportive or unsupportive to the decisions we make. Both internal influences that exist within each person, as well as the various external influences that exist within a person's environment often go unnoticed or unstated. But, these influences are one part of the puzzle that must be taken into account when looking at the complex decision-making that directly affects performance (behavior which occurs) in the case-by-case appropriate care of patients, as well as the organizational goal of more appropriate testing (Endsley 2016). Hence, since decisions are influenced by internal and external factors, and this is mostly internal within us, this becomes somewhat "tacit knowledge" (Polanyi 2009).

## 2.1.4 Tacit Knowledge in Decision-Making

Tacit knowledge is used within the process of decision-making. This project refers to tacit knowledge as information that is implicit (Schön 2017), that which is difficult to speak about or visualize to another person (Polanyi 2009). Donald Schön describes tacit knowledge through "knowing in action" (Schön 2017). He speaks about knowing in action within "reflective practice" (Schön 2017), which is "the practice by which professionals become aware of their implicit knowledge base and learn from their experience" (The Reflective Practitioner by Donald Schon 2012). Knowing in action within reflective practice is also one taking time to be reflective. Schön further speaks about reflection with "reflection in action," where one thinks about their performance during that moment, along with "reflection on action," where one thinks about what has happened, and then assess the scene (The Reflective Practitioner by Donald Schon 2012). Tacit knowledge plays an important role in the process of decision-making because it directly affects actions that happen (the ordering of a test) since these actions result from decisions that are made. Therefore, it is important that any information (tacit knowledge) regarding or relating to Residents ordering is understood and visualized within my proposed decision-making support tool (as an add-on to the dashboard). This allows information to be most helpful to Residents at the moment of decision-making. Tacit knowledge within an environment is also gained from that environment's organizational goals.

## 2.2 Appropriate Testing as an Organizational Goal

There currently is successful documentation of organizations built around "creating, acquiring, and transferring knowledge, as well as modifying behavior to reflect new knowledge and insight" (Škerlavaj, Štemberger, & Vlado Dimovski 2007). Therefore, by providing Residents with access to information, including specialist knowledge, they can not only acquire this knowledge, but they can utilize it to change their behavior within their decision-making processes and make more informed decisions to achieve more appropriate testing. However, successful organizational performance must align with organizational goals, and include defined objectives, as well as the participation of all stakeholders.

The performance of individuals within an organization has a direct correlation with the goals of that organization, and "all stakeholders need to be taken into account when assessing a modern company's performance" (Škerlavaj, Štemberger, & Vlado Dimovski 2007). When an organization's goals involve all stakeholders, the acquisition of actionable information can be translated for comprehensible interpretation, creating an opportunity for changed behavior (Škerlavaj, Štemberger, & Vlado Dimovski 2007). Therefore, to reach the organizational goal of more appropriate testing, all stakeholders must not only be taken into account in the process of creation, but taken into account when deciding the most viable means that can be created to relay information, and display visualizations to be interacted with by Residents. This is an area where a communication tool, such as a decision-making support tool, can enter the environment to support the process of decision-making.

## 2.3 Decision-Making Support Tools

## 2.3.1 What is a Decision-Making Support Tool and How Do They Work?

Since the process of decision-making is complex, there has been an increase in the creation of decision-making support tools to help people who work in complex environments make better decisions (Fujita & Herrera-Viedma 2014). A specific type of decision-making support tool is a dashboard. Author Stephen Few, gives a working definition, summarizing dashboards as a "visual display of the most important information needed to achieve one or more objectives; (data) consolidated and arranged on a single screen so the information can be monitored at a glance" (Few 2006) so that users can easily comprehend the useful information (Gorcester & Reinke 2007). Dashboards are able to be used in any situation to communicate varying degrees of data in an intelligible form easily. Examples of dashboards can include the physical instruments on car dashboards or virtual data on the display of a Fitbit. So, a dashboard is one type of decision-making support tool that could display information to Residents to help them within the decision-making process of ordering a test. Dashboards tend to be displayed on some type of digital screen. While the functions of a dashboard can vary, this thesis refers to dashboards as having information with interactive capabilities that are displayed on some sort of screen. The information displayed on a dashboard comes from a database, which can have static visualization of fixed data sets or dynamic visualizations of streams of data that can change over time and adapt to new parameters (Gorcester & Reinke 2007).

## 2.3.2 Decision-Making Support Tools in Healthcare

Applications of decision-making support tools in healthcare settings are utilized for a plethora of reasons, such as patient monitoring, care processes, or imaging reports, but notably for their "decision support capability" which can aid actionable behaviors in organizational view-

points (Wang, Kung, & Byrd 2018) (Weiner, Balijepally, & Tanniru 2015). Decision-making support tools have proven to be extremely valuable due to their instantaneous response of data through visualizations, directly informing decisions made by managers and providers regarding patient care (Health Catalyst 2015). They can utilize other "hospital information systems," such as electronic health records (EHRs) to help users analyze potential outcomes of decisions (Liberty 2018) or aid in, "timely, data-driven decisions" (Rosow et al. 2003), allowing for more informed decisions through increased situational awareness (Endsley 2016). This helps to lead to improved performance and organizational communication while creating a trickle-up effect and subsequently, a reduction of financial costs (Al-Kassab 2014) by recognizing inappropriate diagnostic testing (Wang, Kung, & Byrd 2018). In summary, the advantages of a decision-making support tool can help an organization improve its performance and reach set goals through the increase of relevant information which creates awareness for providers within healthcare settings.

## 2.3.3 Utilization of Decision-Making Support Tools in Healthcare Settings

Decision-making support tools display information "with analytic tools to present complex internal and competitive information to planners and decision makers," (Negash, 2004, p. 178) which, "delivers the right information to the right people in the right format at the right time" (Zhang, Gallagher, & Goh 2011). Therefore, a decision-making support tool can help with the decision-making process regarding appropriate testing (appropriate care), "meaning the right treatment, at the right time, with the best outcome, while providing excellent service, and with minimum waste" (Naylor 1998). This can have the potential to lead to better decisions within the complex problem of appropriate care.

The benefit of a decision-making support tool in healthcare is that decision-makers can use them as an interactive tool to enable learning, review information, and then improve performance through various forms of data visualizations (Gorcester & Reinke 2007) (Wang, Kung, & Byrd 2018). Interactive decision-making support tools allow users to access visualizations of data in real-time, such as "important information about strategic objectives...to measure, monitor and manage performance more effectively" (Ghazisaeidi et al. 2015). This can allow decision-makers to decide what steps to take next – helping them make more informed decisions. Since this data is so multidimensional and complex, displaying it in comprehensible visualizations can help users better understand situations (Karami, Safdari, & Rahimi 2013); therefore, allowing them to make better-informed decisions.

The integration of EHRs within decision-making support tools can be utilized by providers to better understand the enhancement of organizational workflow communications and expertise, which can lead to more proper diagnoses and better patient care planning (Zhang, Gallagher, & Goh 2011). However, a decision-making support tool's adaptability relates to how well information is visualized (Endsley 2016). Decision-making support tools can offer desirable information, to support individuals in decisions (Few 2006); and, furthermore, assist in decision-making, leading to more appropriate testing, and inevitably, a more holistic sense of patient-centered appropriate care.

## 2.3.4 Adoption of Tools

Successful tools that are supportive and desirable are more likely to be adopted by users (Dover 2004). To achieve better adoption, a decision-making support tool created with a Co-Design process, in tandem with all users, can create more adoption (Dover 2004). This is because the tool will be created with users and their needs in mind, which will allow them to see it as beneficial. If Residents adopt the

tool, a trickle-up process among the organization is more likely to take place (Dover 2004). When support tools are valuable to users, they not only provide users with awareness of critical information but provide information which is actionable, therefore allowing users to make more informed decisions; coordinating an unintentional yet desired relation of individual performance within an organization through making the workflows of individuals or the culture within an organization visible (Dover 2004). This provides users with a foundational baseline awareness of their own actions, along with how their actions relate to the processes and responsibilities of others (Dover 2004). Decision-making support tools can aim to decrease negative consequences, behaviors, decisions, or outcomes, even if unintentional, once a decision is acted upon (Reilly & Evans 2006).

The utilization of information to benefit these decision-making moments of intuition within environmental workflows helps "to fill a void in both the literature and practice..." (Erdem, Kizilelma, & Vural 2016). Residents within the academic medical center have access to a plethora of resource tools and literature. However, most of these resources are external and do not relate to a specific part of a process or a specific environment. It is this information, exclusive to the academic medical center's patients and providers, that can be accessed within their own work environment via a decision-making tool so that they can be supported in their decision-making process. If a decision-making tool can display personalized information, such as a patient's EHR, it can have an even greater impact on the decision-making process.

Furthermore, adoption of a decision-making support tool within the social, cultural, and personal aspects of Resident culture within the academic medical center, means the inclusion of specialist knowledge and supportive information at critical points within employee workflows to allow for it to be used as an integrated means of communication or for personal assessment (Dover 2004). Users' needs, responsibilities, and roles that occur regularly, "from decision making

perspectives," should be taken into account for graphical informational elements to be "actionable information needed for decision making" (Zhang, Gallagher, & Goh 2011); and, therefore desirable and supportive. If a decision-making support tool is created to be used by Residents within their decision-making process to order a test, and it is to be successful, it must be used. To be used, it must be desirable and supportive. By having an array of information that is desirable and supportive, the decision-making support tool is likely to be adopted by Residents and will create a trickle-up effect on its use and the outcomes regarding appropriate testing.

## 2.4 Decision-Making Support Tool Case Studies: Examples in Healthcare Settings

Rosow et al. investigated a range of healthcare decision-making support tools and report some of the advantages and disadvantages of decision-making support tools. The following decision-making support tool examples were selected because they were created within healthcare settings. Some of the most valuable examples of decision-making support tools were the Bed Management Dashboard, the iDashboard, and the BioBench.

**(1) Bed Management Dashboard (BMD)**

*Hartford Hospital, Hartford, Connecticut*

When looking at an example of a healthcare decision-making support tool in use, let's first look at the BMD healthcare dashboard. This real-time dashboard provides information to individuals about "process improvement and decision-support" (Rosow et al. 2003). The system is accessed continuously throughout a patient's entire care by all hospital staff that is "admitting, transferring, and discharging patients" (Rosow et al. 2003). BMD specifically coordinates the complex process of as-

signing patients "specific bed locations" within the hospital – eliminating overcrowding while making system tasks easier to perform (Rosow et al. 2003). The BMD consists of a "user-defined process," offering user-interactive displays of active data visualizations, which enable communication between applicable individuals or groups (Rosow et al. 2003). The status of a decision can be observed to flag problems to stakeholders and users (Rosow et al. 2003). The advantages of this dashboard include it being accessible to all types of users throughout a patient's entire journey. By allowing providers access to patient's personal health information along with the hospital systems information, it allows this complex process to be easily comprehensible but also accomplish their goal of eliminating overcrowding. However, the disadvantages of this dashboard are that the software might not take into account patient desires, which may lead to less appropriate care of patients.

**(2) iDashboard**

*St. Joseph Mercy Oakland Hospital (SJMO), Pontiac, Michigan*

Another decision-making support tool, the iDashboard, created with a third-party IT company based in Michigan, "achieve(s) strategic alignment and enforce(s) accountability" (Weiner, Balijepally, & Tanniru 2015). Created with a diverse group of stakeholders, the iDashboard at SJMO uses data from various outlets for hospital staff of all levels to access statistical data relative to their individual job routine (Weiner, Balijepally, & Tanniru 2015). The iDashboard presents visually displayed "action items," represented through a system of color-coding (Weiner, Balijepally, & Tanniru 2015). Outcomes of the dashboard included a boost in responsibility, obtained goals from the ability to observe their performance (individual or team), and (through the use of the dashboard's drill-down approach), making, "root cause(s) of various problems" visible to administration (Weiner, Balijepally, & Tanniru 2015). The advantages of this dashboard are how the use of visualization and

specific elements can be used to help easily relay information to users. By including a categorization of color, especially well-known colors of "red as stop or danger," "yellow as caution," and "green as good or completed," users are even more easily able to comprehend information.

**(3) BioBench (Virtual Instrument (Dashboard))**

*National Instruments, Austin, Texas*

The healthcare virtual instrument BioBench was created by Premise Development Corporation, based in Hartford, Connecticut, for "physiological data acquisition and analysis" (Rosow et al. 2003). Co-Designed by software engineers, biomedical engineers, researchers, and providers, BioBench acts as a depository for physiologists or biologists to preserve obsolete data equipment while allowing for visualization of analysis (Rosow et al. 2003). Outcomes include the opportunity for individuals to "create their own computer-based data monitoring systems in the form of virtual instruments" (Rosow et al. 2003). The advantages of this dashboard were to have all stakeholders involved in a Co-Design process to better get at a desirable dashboard that meets the needs of all end-users. Building a dashboard through a user-centered design framework can ensure a highly increased likelihood of successful usability (Al-Kassab et al. 2014).

## 2.5 User-Centered Design

This project uses a User-Centered Design (generally considered to be interchangeable with or related to human-centered design or user-driven development) approach and involves the inclusion of end-users (alongside organizational and developmental teams) in the creation of the design, using various methods throughout (Abras, Maloney-Krichmar, & Preece 2004). It is important to understand that the UCD process does not follow a single linear path, but is an iterative

process. Every project will include distinct goals, users, and objectives (IDEO 2015). Because UCD is not linear, each project will utilize varied pre-existing methods (tools) — the selection of which is mostly unknown at the beginning — from a toolkit (IDEO 2015). UCD grew out of "socio-technical systems design" (Emery & Trist 1960), which "describe systems that involve a complex interaction between humans, machines, and the environmental aspects of (a) work system" (Ritter, Baxter, & Churchill 2014). Don Norman, in his book The Design of Everyday Things (Norman 1988), highlights the importance of exploring the needs and yearnings of users who will actually use the product and involving those users within their own environment during the creation process, as, "their involvement leads to more effective, efficient and safer products and contribute[s] to the acceptance and success of products" (Preece, Rogers, & Sharp 2002). To help choose the most beneficial and relevant methods, designers conduct an exploration of which potential methods could best achieve insights leading to the next steps. Although the need for user participation will vary during the process, it is crucial that they are involved during the entirety of the project and beyond (Abras, Maloney-Krichmar, & Preece 2004). Therefore, it is critical that users not only think of this regarding their needs but, given the core of UCD, that users be involved in every single step throughout the process, even if the need of a user seems insignificant. The development of the support tool within this project follows UCD guidelines and principles as well.

## 2.5.1 An Overview of User-Centered Guidelines and Principles

Ritter et al. (Ritter et al. 2014), provides UCD guidelines to serve as recommendations for designers (Ritter, Baxter, & Churchill 2014). These guidelines discuss that the designed product should be functional, us-

able, learnable, efficient, and reliable (Ritter, Baxter, & Churchill 2014). Mica Endsley (2016), provides us with three UCD principles: (1) arrange the product around goals, proficiencies, and tasks of the user, (2) the product should be based on how its users acquire information and how decisions are made, and (3) the product allows for the user to have system control and awareness (Endsley 2016). A UCD support tool must be created, or "Co-Designed" with all stakeholders and end-users, while the information should be effective in the decisions that are made through the awareness the information of the product produces.

## 2.5.2 Co-Design: An Aspect of User-Centered Design

The process of Co-Design within UCD allows for a superior transfer of information between humans themselves and the creation of systems within their environment (Pea 1987). Co-Design is unlike traditional processes of design, where users commonly do not participate in the creation of the design. Co-Design includes participation from users, designers, and non-designers during the entire process – anyone centralized to the product (Sanders & Stappers 2014). Co-Design usually includes a group of individuals consisting of stakeholders, partners, and constituents; primary, secondary, or tertiary users, or any other person who has an interaction or presence within the environment of the product being developed (affected). Co-Design includes continuous iterative making (generative) and assessing (evaluative) of prototypes to reach a product (Sanders & Stappers 2014). Many Co-Design activities are structured around research, understanding the requirements, strategy, set objectives, and usability testing (Sanders & Stappers 2014). Therefore, the design of a decision-making support tool for Residents' decision-making process should be created with a Co-Design approach to ensure that the product can be iteratively tested. The participation

of individuals on all organizational levels in the Co-Design process is crucial to identify stakeholder goals, while users' needs and process workflows are taken into account – the hallmark focal point of a decision-making support tool; the right awareness to situations, to support critical decision-making moments, creating an opportunity for performance behavior change. When identifying and selecting end-users of a product that will be designed in a UCD process, it is important to think about how you will involve the users in the process – the users using the product or those who will be affected by the downstream effects within decision-making (Abras, Maloney-Krichmar, & Preece 2004).

## 2.5.3 User-Centered Design is Key to Creating Adoptable & Usable Decision-Making Support Tools

There is no doubt that decision-making support tools can support decision-making processes by useful displays of data and information, but the process of how they are created remains key. UCD places, "greater emphasis on the user and less of a focus on formal methods for requirements gathering and specification — a move from linear, rigid design processes to a more flexible iterative design methodology," — and the involvement of end-users ensures a deepened satisfaction with a product since said product suits their needs (O'Grady & O'Grady 2017) (Pea 1987). To achieve greater satisfaction, research is integrated throughout the process of product creation, producing beneficial insights into the "needs, behaviors, and expectations of the target audience" (O'Grady & O'Grady 2017), so that the process revolves around the design of a pleasant, effective, and useable experience (Garrett 2010). When UCD is utilized to create a product, users are involved, the product is built around their needs, and in return, the design becomes

pleasurable to use, leading to desire, and adoption.

# METHODOLOGY
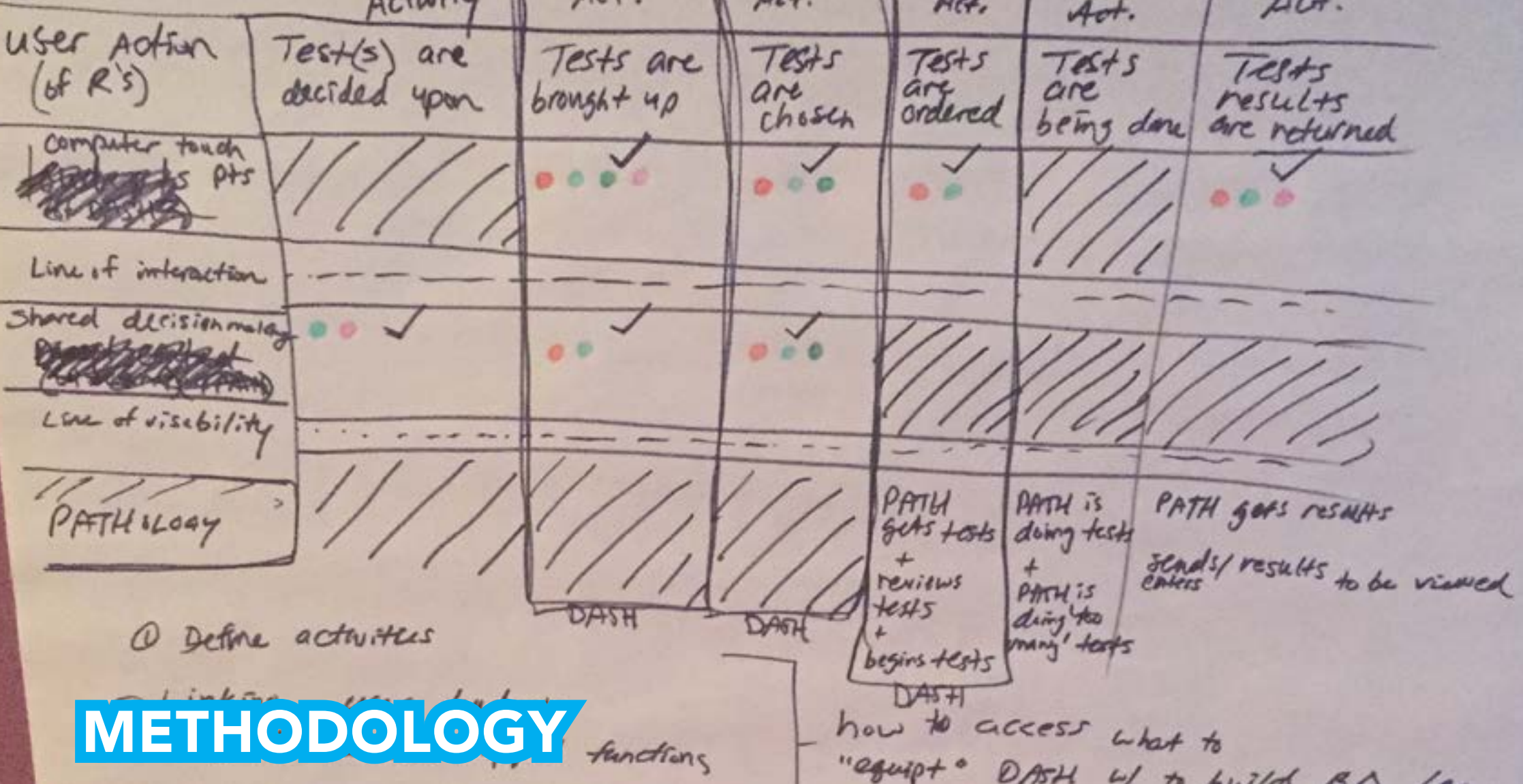
## 3.1 Project Approach

I chose a User-Centered Design approach because I wanted my proposed decision-making support tool (as an add-on to the dashboard) to be supportive, desirable, and adaptable by users so that they would use it. User-Centered Design is appropriate to this problem because it is necessary to understand the current decision-making process of how Residents order a test. Co-Design activities are structured around

research, understanding the requirements, strategy, set objectives, and usability testing. By working with Residents, Service Chiefs, Attendings, Expert Specialists, and Nurses, I could then understand what information would then be necessary to provide to Residents to help them make more appropriate testing decisions through the application of a Co-Design process. Through this Co-Design process, my proposed decision-making support tool (as an add-on to the dashboard) would present information correlated to the very moments it would be most helpful to Residents to make more informed decisions and therefore more appropriate testing decisions.

## 3.2 Project Process: Co-Design

Since I wanted to ensure that my proposed decision-making support tool (as an add-on to the dashboard) was adaptable, and could lead to more appropriate testing, it was relevant to Co-Design with Residents, because they are the ones who commonly order a lot of tests.

## 3.3 Project Methods

### 3.3.1 Observations

To understand how Residents are making decisions, I first needed to understand how decisions are made. The data-gathering method of observation is derived from qualitative research (Merriam 2002) and involves studying people in their normal environments (Curedale 2012). By conducting observations as a designer, I was looking at a group of individuals and their daily processes, and aiming to understand the interactions between various providers, such as Residents, Service Chiefs, Attendings, Expert Specialists, and Nurses as they make test-ordering decisions. By allowing researchers to gain first-hand

knowledge of their subjects' behaviors, observation has the power to "uncover the gap between what people say and what they do" (Dailey et al. 2018). Through observation, I was able to see what types of information Residents encounter in critical moments during their decision-making. Using observations within Hospital Medicine allowed me to gain an overall understanding of critical points in the process of their decision-making.

## 3.3.2 Semi-Structured Interviews & Conversations

Since it was not possible to truly know what someone may be thinking when observing them, I found it crucial to use other methods to further learn information from healthcare workers about what they were thinking about or feeling during moments of making a decision to order a test. Semi-structured interviews and conversations are a direct method of collecting information to form an intimate understanding (Dailey et al. 2018), to "uncover tacit knowledge... (which they) may not be consciously aware of" (Curedale 2012), and thereby help to evaluate and pinpoint problems, or opportunities (Curedale 2012). It was necessary to conduct these interviews and conversations so that I could actually understand what Residents are thinking during the process of their work, but especially what they are thinking in the decision-making moments of ordering a test. Another method could be structured one-on-one interviews, but, semi-structured interviews allow for a more personalized and spontaneous approach that allows exploration of interesting points that come up in conversation with each subject/interviewee (Cohen & Crabtree 2006).

## 3.3.3 Journey Mapping

To make sense of information gathered in observation and conversations, I made a journey map to showcase the visual timeline of Residents' actions and experiences, including what they think and feel (Stickdorn et al. 2011). Journey maps present a user's "journey" to help illustrate experiences, interactions, and emotions (Stickdorn et al. 2011) – making the invisible, visible. Once a user's journey is identified, their actions can then be broken down into "touchpoints" (Stickdorn et al. 2011). These touchpoints display a user's experience, along with their actions, impacts, or emotions, in its totality (Stickdorn et al. 2011). Journey maps allow a direct examination of the influence of a user's decision about a problem or situation (Stickdorn et al. 2011). By utilizing a journey map to visualize the process of Residents ordering tests, I was able to start to see what Residents think, feel, and do in the process of ordering a test. Another method I could have done was "Day in the Life" (Think Design 2020), which is a method where you spend time following someone throughout their day while speaking with them. This method could have been useful because I would have been able to spend an entire day understanding their workflow through verbal communication of what a Resident is doing, thinking, and feeling. But because of the limited time in which Residents were available (they didn't have an entire day) a journey map was an efficient way of mapping the process.

## 3.3.4 Affinity Clustering

To better understand the gathered information, the method of affinity clustering was used to "classify ideas into natural groups on the basis of similarities" (Curedale Design Methods 2 2012), allowing for patterns to be found and arranged (Luma Institute 2012). This created an opportunity for mutual awareness around previously known or unknown evidence within the problem space (Luma Institute 2012). By doing an affinity clustering, I started to understand the groupings of information

I had so that I could see patterns that emerged.

## 3.3.5 Card-sorting

To gather information on what Residents consider when ordering a test, the method of a card sort was a way to help identify the relative importance (O'Grady, Visocky, and O'Grady 2009) of what Residents consider when ordering a test, and therefore what they could potentially consider or identify as appropriate. I conducted a hybrid card sort, where participants are allowed the opportunity to add absent or additional concepts while also being presented with already given information (Olsen-Landis 2017). Through the utilization of a card sort, subjective opinions are obtained to understand better (O'Grady, Visocky, and O'Grady 2009) audience preference (or about confirming assumptions) so that common project goals could be established in the design process (O'Grady, Visocky, and O'Grady 2009). By utilizing a card sort method, I better understood what first-year Residents, as well as other Residents, think is important to consider when ordering a test. Other methods of card sorts could have been an open or closed card sort. An open-sort allows participants the opportunity to add absent or additional concepts, while a closed-sort forces participants to put the cards into pre-arranged groupings, not allowing the opportunity to add concepts (O'Grady, Visocky, and O'Grady 2009) (Olsen-Landis 2017).

## 3.3.6 Paper Prototyping

Throughout the process of design, paper prototyping can be used as an, "...effective way to make ideas tangible, to learn through making, and to quickly get key feedback from the people you're designing for" (IDEO 2015). Prototyping is the creation of rapid iterative concepts to gain feedback on what initial designs should consist of, allowing for

testing potential developments, and making iterative assessments (IDEO 2015). Prototypes can be simple sketches or fully fleshed-out digital-mockup versions of an idea, solution, or product. Paper prototyping focuses on how a concept is portrayed, as the objective is less about the usability of the design and more about discovering the goals and needs of users. This allows the insights gathered from these low-fidelity, relatively quick, and cheap prototypes to inform higher-fidelity, more time-consuming, digital prototypes. I quickly made various paper prototypes to gauge information that Residents see and feel (supported, aware, consider, etc.) to then be able to know what information would support them, but also be desirable to them.

## 3.4 Partner Stakeholder & Target Population

I selected my partner, a PM within the QD, by continuing to work with him on this thesis project as a further extension of my cohort's partnership. This partnership was an extension of my first year within the program, when my cohort and I worked with him and the QD on test utilization. It was beneficial that I had already established this relationship, and it made the most sense to continue this relationship for this project, but also because I was interested in the topic of appropriate testing. When starting with the QD, they were building a dashboard to display evidence-based data, particularly volume and cost, to be used by administrators to track and evaluate test-ordering decisions and habits of units within a service level. It made sense to continue working on this project because of my prior experience working on dashboards as decision-making support tools. I continued to seek Resident access throughout my project, which was granted to me through an Attending, who is a provider in the Hospital Medicine units and services of the academic medical center.

## 3.5 Site Access, Solicited Participation, Participant Responses & Determination

Initial access to the academic medical center was granted and arranged by the QD and was first granted to the Trauma Burn ICU, Internal Medicine ICU, and the Division of Gastroenterology non-ICU between December 2017 - May 2018. Between August 2018 - May 2019, access to the academic medical center's Hospital Medicine unit was granted and arranged by the QD and an Attending.

## 3.6 Data Collection & Procedures

Data was collected mostly by myself, within Hospital Medicine, through a hand-written note or "informed consent" ("Informed Consent Guidelines & Templates." n.d.) recordings through hand-held recording devices. Methods were conducted one-at-a-time or simultaneously in the following steps: (1) observations, semi-structured interviews & conversations, journey map; (2) affinity clustering; and (3) card-sort, paper prototypes.

## 3.7. Timeline of Methods

I chose to start my project using observations and semi-structured conversations and interviews to understand better what Pathologists do, think, or feel. I then did the same with Residents, while also creating a journey map to get a better understanding of Residents' test ordering process. Taking the information I gathered, along with the journey map of Residents Ordering Journey, I then created an affinity clustering to be able to analyze all data collected, before conducting a card sort to see how information could have an impact during the decision-making process when ordering a test. Finally, I created paper prototypes

to understand what information Residents would find supportive and desirable and ultimately help achieve more appropriate testing.

## 3.8 Methods

### 3.8.1 Observations

Observations were conducted in two separate durations of time over the course of a year and a half of this project. The first set of observations, consisting of all five students in my MDes cohort, spanned January - April 2018. Observations took place within the Trauma Burn ICU, Internal Medicine ICU, and the Division of Gastroenterology non-ICU, where the cohort spent a combined total of over 40 hours. Proper procedures, including volunteer paperwork and vaccinations, along with training courses, were completed before observations began. During this same timeframe, we were also able to have the opportunity to tour the Pathology lab at the academic medical center. It was here where we were able to observe and understand the daily workflow of fulfilling lab tests and dispensing results. The goal of these observations was to identify a gap between what people say they do and their actual actions.

Within the first set of observations, the interest lay in the realm of better understanding the problem space around appropriate testing, and an understanding of the general test-ordering system, but also the process of a Resident ordering a test. We specifically looked at where and how tests were ordered, who was doing the ordering, when tests are ordered, and what happens before and after ordering, to allow us to better understand Residents themselves. We were also interested in learning about how specimens are processed and results are generated in Pathology. Pathology at the academic medical center is largely split into two parts: Anatomic (tissue samples from surgery) and Clinical

(samples of body fluids).

Pairs of students went to various units and services at each observation. To better immerse ourselves in the understanding of the space, we would take turns observing all units and services multiple times each. This first set of observations were conducted through the use of fly-on-the-wall or the POEMS framework (which is observing people, objects, environment, messages, and services in the space). Some of the cohort members observed as "observer as a participant" and engaged in light conversation about any noticeable moments that happened. Through this first set of observational interactions, our cohort was able to start to form a level of initial trust with many of the subjects.

The second set of observations, which continued for this project, spanned January - May 2018, and took place within a Hospital Medicine unit. During the second set of observations, my interest lay in understanding a Resident's workflow. This included better knowing the context of the entire ordering process and the phases that existed. In partnership with the QD, I looked specifically at the phases of the test ordering process for Residents, and how Residents experience their ordering journey.

As I conducted the second set of observations, at times, I would participate with light interactions among Residents and their lead Attending. Observations were conducted within two areas of the unit. Observations would first start within the team rooms, essentially an office-type room where Residents do most of their daily tasks, such as ordering tests. From here, observations would continue, depending on the various Attendings (and their type of rounds), to the hallways outside of multiple patient rooms.

### 3.8.2 Semi-Structured Interviews & Con-

## versations

Semi-structured interviews and conversations took place for the entirety of this project, spanning January 2018 - April 2018 and September 2018 - April 2019. The first set of discussions were conducted by all five students in the cohort at various days and times within and around the Trauma Burn ICU, Internal Medicine ICU, and the Division of Gastroenterology non-ICU. Access was arranged for us by the QD. We completed over eleven (11) interviews with providers and specialist experts: Pathologist Residents (2), Senior Residents (2), Residents (3), Nurses (1), Pathologists (6), and Specialist Providers (3). These semi-structured interviews and conversations were routinely conducted at a medical school building, a department of Pathology, the MDes Graduate Student Facility (MDes GSF), the academic medical center, or via telephone call (1). Interviews or conversations varied from several minutes to several hours. Most consisted of one participant at a time. However, several situations consisted of multiple participants. These conversations were transcribed through written notes, or audio recording; all were done with verbal consent and unconditional anonymity for participants. The goal of utilizing this method was to gather information from various people and their perspectives in the most suitable form.

During the first set of discussions, we sought to gain a better understanding of the problem space around appropriate testing, and again, an understanding of the general test-ordering system, but also the process of a Resident ordering a test (from both Resident ordering perspectives and other non-Resident provider ordering perspectives, such as how ordering is done in different units like that in ICU settings). We specifically spoke about where and how tests were ordered, who was doing the ordering, when tests are ordered, and what happens before and after ordering, to gain detailed information from all various provider job roles.

As this method unfolded, we also started to discuss: workflows of individual providers, what factors they consider when determining the appropriateness of a test, and what information could have an impact during the decision-making process. We also discussed if ordering is monitored (it is not monitored; however, every test is approved by each Resident's Attending) and if feedback is provided, Resident's perceptions about patient's needs and expectations, the level of communication with patients about testing, what is considered to be the challenges of appropriate testing, and how they would increase the appropriateness of testing.

The second set of discussions followed during the time frame of September 2018 - April 2019, mostly within the domain space of a department of Pathology (largely including the QD) and Hospital Medicine. Access was arranged by the QD, an Attending, and a Hospital Medicine Resident. There was a total of thirteen (13) semi-structured interviews: Senior Residents (3), Residents (5) Pathologists (2), and Specialist Providers (3). Conversations totaled to more than thirty (30) discussions occurring at various points in time: Residents (10), Pathologists (1), Specialist Providers (2), and other Providers (4). Again, interviews and conversations were either transcribed through my own hand-written notes, or audio recorded; all done with verbal consent and unconditional anonymity for participants.

During this second set of discussions, I sought to gain a more accurate understanding of the test ordering process of Residents and how Residents perceive their ordering journey. This included a discussion around a major theme. It was around the context of the decision-making process of ordering a test and what information is currently known or used. Both sets of discussions were conducted during the timeline of this project. These interviews and conversations were conducted to help further uncover research to help myself answer my own research questions as well as uncover tacit knowledge from participant subjects, allowing me to validate what I had observed or discussed.

## 3.8.3.a Journey Map

While observations, interviews, and conversations helped me to understand the Resident Ordering Journey in a general sense, I still needed to understand what I had seen and interpreted during this process. By creating a visual journey map, I was able to bring the visual aspect of this journey to the attention of Residents for validation, but to also help me understand what gaps in information may exist. The goal of developing a journey map was to: (1) accurately identify the phases of a Resident's Ordering Journey, (2) accurately identify what Residents go through at each point during this journey, (3) to start to get an idea of what information impacts their decision-making process to order a test. By creating a visual journey map showcasing Residents' actions and experiences, as well as what they think and feel, I was able to have Residents themselves further comprehend the Resident Ordering Journey (what they go through and how to see this can help make them more aware). Furthermore, by understanding the ordering journey from the perspective of Residents, I started to understand how and where a decision-making support tool could be utilized, along with what potential features can best support Residents.

## 3.8.3.b Journey Map: Identifying and Validating the Phases of the Resident Ordering Journey

The first version of the journey map featured a visual grid. Across the top of the grid (see figure 1), reading horizontally, were the three steps in the ordering process: "pre-rounds," "rounds," and "post-rounds." The left-hand side of the grid, reading vertically, was labeled "does," "feels/thinks," "influences on decisions" ( regarding their decision-making).



Figure 1. Grid of Resident Ordering Journey Version 1.



Figure 2. Grid of Resident Ordering Journey Version 2.

For this method, the journey map was presented as a physical-paper format, where it featured the three phases of rounds on top, along with sub-phases within each phase, while the left side featured what Residents do, feel or think, the influence this may have on their decisions. The method was described to Residents as a visualization of the daily rounds journey, and they were asked to help verify, correct or add information to the journey map so that the journey map could be as accurate and validated as possible (within the context and scope of this project). The goal was to document their workflow to be able to understand not only individual experiences, but team experiences as well, and start to understand what information may impact their decision-making process when ordering a test. I had six (6) Residents in total review the journey map and describe to me their feelings and thoughts, along with other overall feedback.

## 3.8.3.c Journey Map: Identifying the Accuracy of the Resident Ordering Journey

The second version of the journey map (see figure 2) featured the same grid, but this time with the iterative addition of collected information and three phases (which were defined by myself): building your case, making your case, and employing your case. This version was again presented to Residents in a physical-paper format. The goal for the second iteration of the journey map was to further validate the accuracy of the additionally collected information, as well as the three defined phases of the Resident Ordering Journey.

It was important to understand not only what happens during the Resident Ordering Journey but to understand what information may impact their decision-making process. It is also valuable to map the Resident Ordering Journey to pinpoint potential moments when information, such as Specialist or peer-to-peer knowledge, could be used

and presented via my proposed decision-making support tool (as an add-on to the dashboard).

## 3.8.4 Affinity Clustering

An affinity clustering method was utilized during November 2018, after completion of the above methods, first to dissect, then to arrange, in order to better understand all research gathered to date. The goal of this method was to be able to create smaller clusters of information so that the research as a whole could be better understood in order to spot any correlated patterns of information. These small correlated groupings of research make information easier to process, therefore enabling me to create an overview of all of my research to better analyze it.

The method of affinity clustering was conducted by assigning gathered research onto an assortment of multi-colored sticky-notes to allow for easier arrangement. The sticky-notes were then coded by two different techniques: color for the setting where the research was gathered and with a letter-code for the type (title) of person relaying or doing the information. There were five (5) colors in total (see figure 3), representing the QD and related individuals in green, Attendings in orange, Residents in light pink, and a technology team in blue. My own observations were in hot pink. Each sticky-note contained a letter-code to identify the source for the information: "DM" for dashboard meeting, "Pre-R" for pre-rounds, "R" for rounds, "Post-R" for post-rounds, "A" for Attending meeting, or "M" for miscellaneous (miscellaneous information was only gathered in phases of rounds; pre-rounds, rounds, and post-rounds). Each sticky-note was sorted into clusters based on the topic or general theme of information which it featured. This allowed me to identify situations or issues that may impact or influence decision-making.

Figure 3. Affinity Clustering method.

## 3.8.5 Creation & Iteration

During my project, information was collected and analyzed through the methods of observations, semi-structured interviews and conversations, a journey map, and affinity clustering. Now that there was a better understanding and definition of the problem space, I was then able to look at what could be created to better get at what information would be displayed on my proposed decision-making support tool (as an add-on to the dashboard).

## 3.8.6 Card Sort

A Card Sort method was conducted during three (3) separate occasions of this project between November 2018 - January 2019. I was granted access by an Attending, and interactions with Residents were facilitated by a Hospital Medicine Resident. The card sort method was performed in the Hospital Medicine unit and was a physical paper card sort, with each criteria card being a piece of a paper. The goal was to identify what Residents consider when ordering a test.

I formed the card sort in collaboration with my partner, a PM, and the rest of this project's thesis committee. After reviewing the clusters from the affinity clustering method, we deemed a card sort to be most beneficial in exploring how Residents understand appropriate testing. We felt that this interim goal could assist regarding the objective of creating a decision-making tool to help Residents test more appropriately. We took the clusters of the affinity clustering method and dissected all data gathered, including but not limited to words and phrases, which were then pulled out and combined to formulate more concise and definable terms for what factors contribute to appropriate testing. This was done on a whiteboard, using black dry-erase markers to allow for an iterative process, which was an advantage in terms of being able to iterate these criteria with my thesis committee more easily.

Criteria for each card, sixteen (16) in total, was collaboratively decided upon as the following:

1. Build a case for treatment

2. Pre-test probability

3. An Attending's preference

4. Ensuring a positive patient outcome

5. Ensuring against a negative outcome

6. Risk of false positives

7. Senior Residents' advice

8. Physical discomfort for the patient

9. Relieve doubt

10. Test turnaround speed

11. Patient anxiety

12. Satisfying curiosity

13. Ordering Process

14. The financial cost to the patient

15. More test information is always better

16. The financial cost to the academic medical center

The first round of card sorting took place during November 2018 and was conducted with Hospital Medicine Residents, as well as the QD team members and Pathologists, and a Specialist Physician. All Resident card sorts took place in-person within various team rooms at the academic medical center, while the other card sorts were conducted through a third-party online card sorting software. The first round of card sorting consisted of a total of nine (9) participants: (2) Senior Residents and (3) first-year Residents, (1) the QD team members, (2) Pathologists, and (1) Specialist Physician. The second and third rounds of card sorting took place between December 2018 - January 2019 within Hospital Medicine. A total of eight (8) Residents participated: (3) Senior Residents, (3) second-year Residents, and (2) first-year Residents. This brought a combined total of thirteen (13) Resident participants and four (4), non-Resident participants.

Each Resident subject's participation in the card sort was completed within their team room at the academic medical center. Subject Residents performed the card sort at a table, individually, after receiving background information about the method and associated instructions. Participant subjects were given sixteen criteria cards, three blank cards, a pen, and a piece of paper containing the question "what do you consider when ordering a test?", along with two pieces of paper featuring the categories "matters" and "doesn't matter." The participant subjects were asked to place the criteria cards into one of the two categories and then to rank the criteria in each category from highest to lowest (highest indicating what matters and lowest what least matters). The choice of terminology was to enable easy comprehension as well as focus participants toward the question and categorization of the criteria cards with minimal explanation. Two (2) of the thirteen (13) participants used one blank card each to write new criteria. At the end of the card sort, participants were thanked and released with further assurance that all participation would remain anonymous.

Each of the QD subject's participation in the card sort was conducted virtually by a web browser application. Each participant received background information about the method and associated method instructions; again, all before the activity began. Participant subjects were given sixteen criteria cards, three blank cards, and the statement question, "what would you consider when ordering a test?" In having people associated with the QD respond to what they thought Residents should think matters when ordering, I was then able to understand what the QD hoped Residents would consider in their decision-making.

The goal of this method was to understand what was considered, by people in various roles, when ordering a test and how much they align. An additional advantage of this card sort method was to be able to see how aware each person was of tacit knowledge regarding the test ordering process in relation to appropriate testing. I intended to utilize the information from the card sort to better understand what sort of initial information to start with for the first set of prototype iterations for my proposed decision-making support tool (as an add-on to the dashboard).

## 3.8.7 Paper Prototyping

The method of prototyping was conducted from January 2019 - March 2019. I was again granted access to Residents through an Attending, with interactions facilitated by a Hospital Medicine Resident. Prototyping was conducted in the Hospital Medicine unit. Subject participants included a total of (8) participants: (3) Senior Residents, (3) second-year Residents, and (3) first-year Residents. The goal of the prototypes was to visualize the information related to the unconscious process of Residents when they are making tradeoffs in deciding which tests to order. The information presented in the prototypes came from the previous card sorting method regarding what Residents consider when ordering tests. These criteria were produced from all previous methods until this point regarding the factors associated with appropriate testing.

The prototypes were constructed physical-objects that consisted of various four-part combinations of information (out of twelve (12) parts of information total). Each paper prototype presented a "screen" view of a personal mobile phone, displaying four different pieces of information. Each participant was asked to consider a series of three prototypes, which they received one at a time in order: prototype one, prototype two, and prototype three. The participants were given a scenario when receiving the set of prototypes to help better situate their understanding and formulation of feedback.

The scenario for participants was as follows:

Imagine you've just returned from patient rounding, you are now back at your team room here. First, you sit down at the computer and are looking over notes you have recorded. You are pretty sure that patient one has condition A, and you start to consider the test you need to order. Then, you pull out your mobile phone and open a new app resource tool that a fellow Resident has suggested.

(participants are given prototype one)

You put in the test you are considering to order, and this information comes up. Can you please tell me how you feel or what you think about this information after you have entered the test you are considering to order?

(Residents discuss prototype one, notes are recorded, and then the prototype is removed from their line of vision)

Now, instead of the information you have just seen, imagine it would be this information that comes up instead after you enter the test you are considering to order.

(participants are then given prototype two)

Can you please tell me how you feel or what you think about this information after you have entered the test you are considering to order?

(Residents discuss prototype two, notes are recorded, and then the prototype is removed from their line of vision)

Now, please imagine you could open the app resource tool and have any type of information come up, can you please tell me what information you would want to see or have?

(participants are given prototype three, along with eight (8) cards with information that was previously shown in the first two prototypes, along with four (4) new cards with information and two

(2) blank cards, where participants are encouraged to write down anything they desire, even if it seems unrealistic)

Please choose as many or as few card items as you would like to include. There are also a few blanks with a pen in case there is any information you would want to be included that is not given here.

(Residents discuss prototype three, notes are recorded and documented, and then their prototype is removed from their line of vision)

The first prototype (prototype one) featured information including (see figure 4):

• 3 Days - This test is a send-out test and takes 3 days for results to come back

• 80% - The Internal Medicine unit does not order this test appropriately 80% of the time.

• $300 - This test will cost the academic medical center $300

• 4x in 12 Hours - This patient has been poked 4x in the last 12 hours

The second prototype (prototype two) featured information, including:

• Best Practices - Understand when to order this test

• Send Out - This test is a send-out test and takes 3 days for results to come back

• 3:30am - The last time a patient was awoken for a test

• DRG (Diagnosis Related Group) - Be able to calculate a patient's DRG to understand what they will be billed, and see if you can refer them to outpatient

The information displayed on the first and second prototypes (prototype one and prototype two) was coordinated so that each contained similar information even though the information was structured differently (i.e., the first prototype included "3 Days" where the second prototype included "Send Out," both versions contained content referring to a test that requires three days to be sent out for fulfillment).
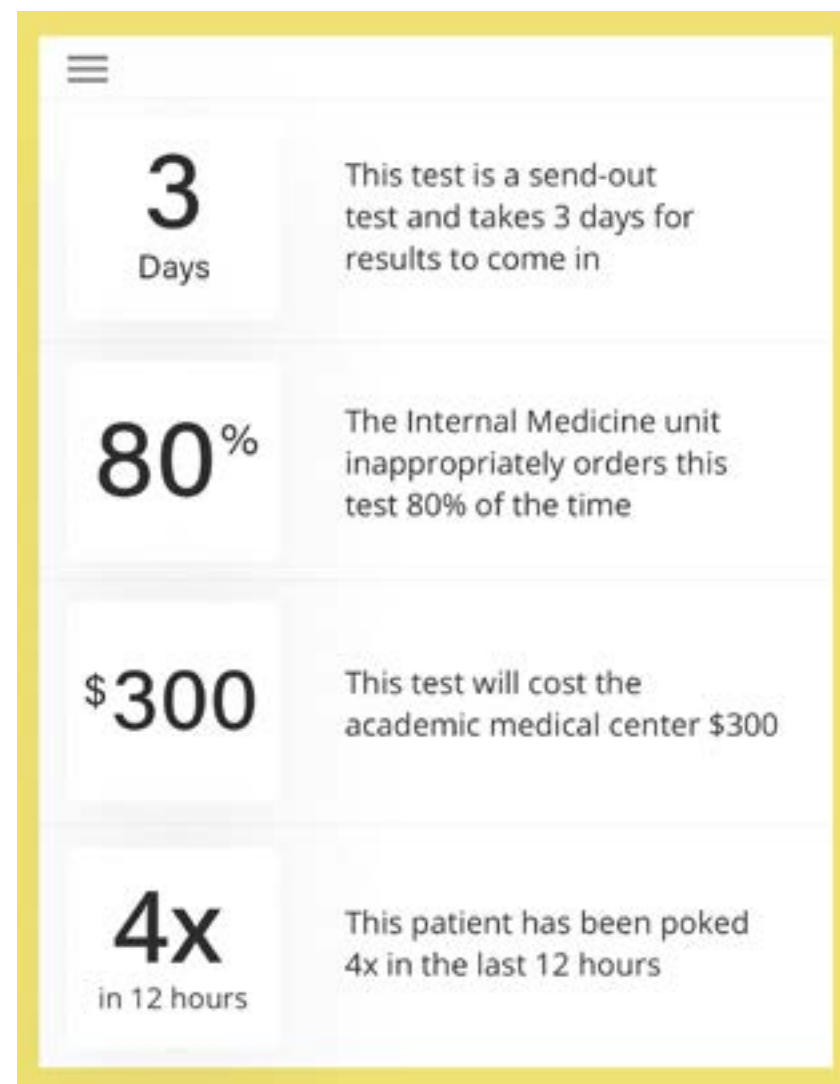


Figure 4. Prototype one.

The third prototype (prototype three) featured no information, and instead, participants were asked to build their ideal decision-making support tool with as many features as they would like – including the use of blank cards for the inclusion of information that wasn't present in the given options, but they felt would be desirable for them to know.

The third prototype (prototype three) included these twelve pre-printed cards:

• 3 Days - This test is a send-out test and takes 3 days for results to come back

• 80% - The Internal Medicine unit does not order this test appropriately 80% of the time.

• $300 - This test will cost the academic medical center $300

• 4x in 12 Hours - This patient has been poked 4x in the last 12 hours

• Best Practices - Understand when to order this test

• Send Out - This test is a send-out test and takes 3 days for results to come back

• 3:30am - The last time a patient was awoken for a test

• DRG (Diagnosis Related Group) - Be able to calculate a patient's DRG to understand what they will be billed, and see if you can refer them to outpatient

• Pre-Test Probability - Access to the sensitivity and specificity of a test

• Patient Preferences - Access to a patient's EHR or previously known information gathered about their preferences of care

• Speak with Nurse - Have the opportunity to speak with the patient's Nurse about how the patient has been doing physically, mentally, or emotionally

• 4-6 Hours - This test is estimated to take 4-6 hours for fulfillment and for results to be returned

The goals for creating these prototypes with the above information included the desire to understand:

• What information would Residents want to see?

• What information are Residents aware of and concerned about?

• What information are Residents unaware of or not concerned about?

• What supportive information could my proposed decision-making support tool show to Residents?

• What are Residents' opinions on the information shown in these prototypes related to appropriate testing?

• What type of information do Residents value when considering whether to order a test?

• How could the use of EHRs inform Residents who are considering whether to order a test?

## 3.9 Implication, Outcomes, & Limitations

## 3.9.1 Implications & Outcomes

The beneficial value that my proposed decision-making support tool (as an add-on to the dashboard) will bring to the academic medical center is to prompt behavior change that can lead to appropriate testing. This will happen by supporting Residents in making more informed decisions and therefore reducing testing that is not appropriate (i.e., overtesting and unnecessary testing). Health care costs continue to rise, as there was a 3.9% growth in healthcare spending in the U.S.

alone (GPD of 17.9%) (NationalHealthAccountsHistorical, 2018). Es-
sentially, healthcare costs a lot, which is a problem, and unnecessary
testing contributes to that problem (PM 2019). A decision-making
support tool that leads to more appropriate testing can also lead to
better patient health outcomes, and therefore create more positive
experiences for patients. However, a potential implication is that Resi-
dents may need to be trained on how to use (or best use) my proposed
decision-making support tool (as an add-on to the dashboard).

## 3.9.2 Limitations

My partnership and research for this project were within the con-
text of the academic medical center Hospital Medicine units, where
I interviewed a variety of providers and stakeholders that are part of
a specific demographic, and may not be representative of the entire
provider community either within the United States or other countries
globally. Most providers that were spoken with were recruited from an
Attending or similar within Hospital Medicine units. I acknowledge that
all providers have come from various medical schools and have varying
amounts of years of experience. Research for this project took place in
Hospital Medicine unit settings. Though I researched through various
methods some of the information which would be helpful, I was not
able to research all the information that would be necessary to imple-
ment my proposed decision-making support tool (as an add-on to the
dashboard). I identify that this is a primary limitation within this study.
Methods used within this project to collect data were selected primarily
by myself with the support of my thesis committee, and may not be
the correct sampling for decision-making support tools outside of this
project and context.
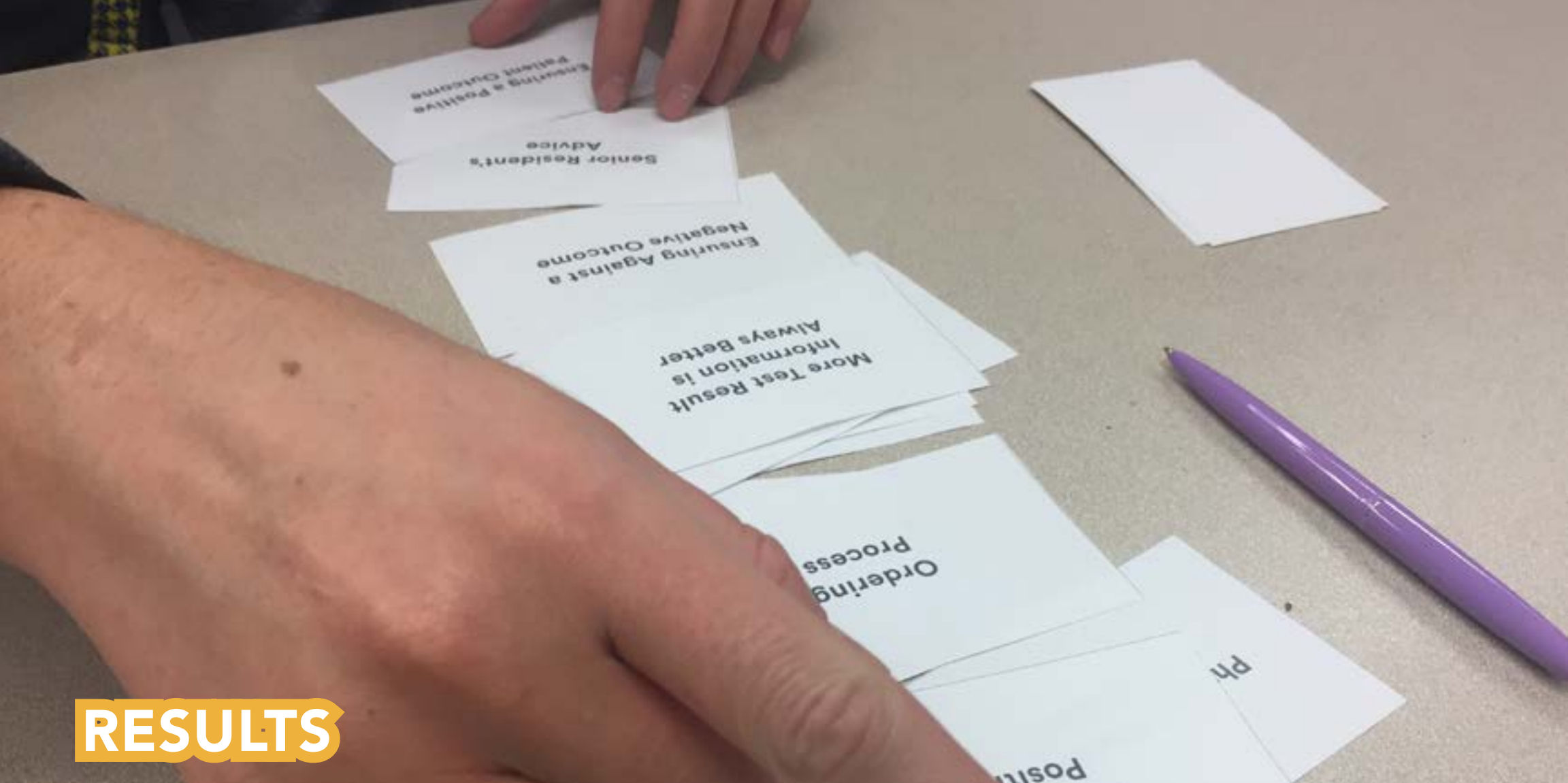
# RESULTS

Results were gained throughout the entirety of this project. These results arose from the methods I used during my Co-Design process. Throughout the process, I communicated all findings with my partner, varying stakeholders, faculty, fellow students, the general public, and my thesis committee. This was done not only to continue a collaborative Co-Design process but also to collect broad iterative feedback and ideas from varying perspectives throughout the timeline of the project.

## 4.1 The Resident Ordering Journey

In order to understand the general process of ordering a test, I used observations and semi-structured interviews and conversations to create a journey map of the Resident Ordering Journey (rounds). Through these methods, I was able to determine that a Resident Ordering Journey consists of six parts that occur in three phases. These phases were not explicitly known or verbalized, so I first had to create my own labelling system before refining the language through multiple iterations, verifying its accuracy throughout with Residents. The three phases and the six parts that occur during the Resident Ordering Journey are (1) Pre-Rounds – Chart Review / Pre-Rounding on Patients / Prepare for Rounds; (2) Rounds – See Patients; and (3) Post-Rounds – Game Plan at Team Room / Patient Treatment.

To better understand what happened in each stage, I spoke with Residents to learn more. Pre-Rounds consisted of Residents being able to review any updates on patients (Chart Review) or see patients (Pre-Rounding on Patients) and prepare for rounds (Prepare for Rounds) (see figure 5). Rounds consisted of seeing patients (See Patients) and reviewing the patient's condition and status as a team. Post-Rounds consisted of Residents going back to the team room, where all Residents are stationed for their period of Residency in Hospital Medicine, to order tests (Game Plan at Team Room) and continue to monitor their patients and their treatment throughout the rest of the day (Patient Treatment). From my observations and discussions with Residents, it also seemed that this was another area where potential gaps in information can arise since some tests are ordered by Residents at various computers in the Resident team room (or even not in the team room). Other tests may be ordered through the day by providers as well. From my research, I speculate that my proposed add-on to QD's dashboard could help to support Residents in their decision-making. From my observations and discussions with Residents, it seemed that this was a moment where potential gaps in information could arise.



Figure 5. Resident Ordering Journey Map - pre-rounds, rounds, and post-rounds.

## 4.2 Gaps in Information

In the next phase of my research, my main goal was to dig deeper into the Resident Ordering Journey to see what potential gaps in information exist that I could uncover. I continued to use methods of observations, semi-structured interviews, and conversations to review and iterate on the journey map I created, and start to understand how Residents think and feel in each part of each stage during rounds; spotting areas where potential gaps in information exist. After being able to visualize the Resident Ordering Journey through a journey map, I then asked Residents to review the journey map and tell me if it was accurate, or, if not, tell me why, while also explaining more about each stage in further depth (see figure 6). It is important to note that I noticed that all Residents I had shown this to and spoke with about, had never seen this process visualized before, so they were all very curious about how I arrived here (which I explained each time). I believe this is because no visualization of the rounds process currently exists, and therefore, this process can be interpreted very differently by each Resident (or provider, as well as anyone within the academic medical center), especially in a subjective sense.

One can imagine how internal and external environmental influences can impact decision-making, especially for a first-year Resident; transient, limited long-term experience. I saw an area here where potential gaps in information exist; where an under-identification of information exists that impacts decision-making. I speculated that if these potential gaps in information didn't exist, then more appropriate testing would already be occurring. So, to try and figure out what information might not be currently available to Residents, that could support them in their decision-making, I wanted to try to start finding out what this information could potentially be. Through my observations, semi-structured interviews, and journey map, I was able to understand that this decision-making process of ordering an appropriate test may
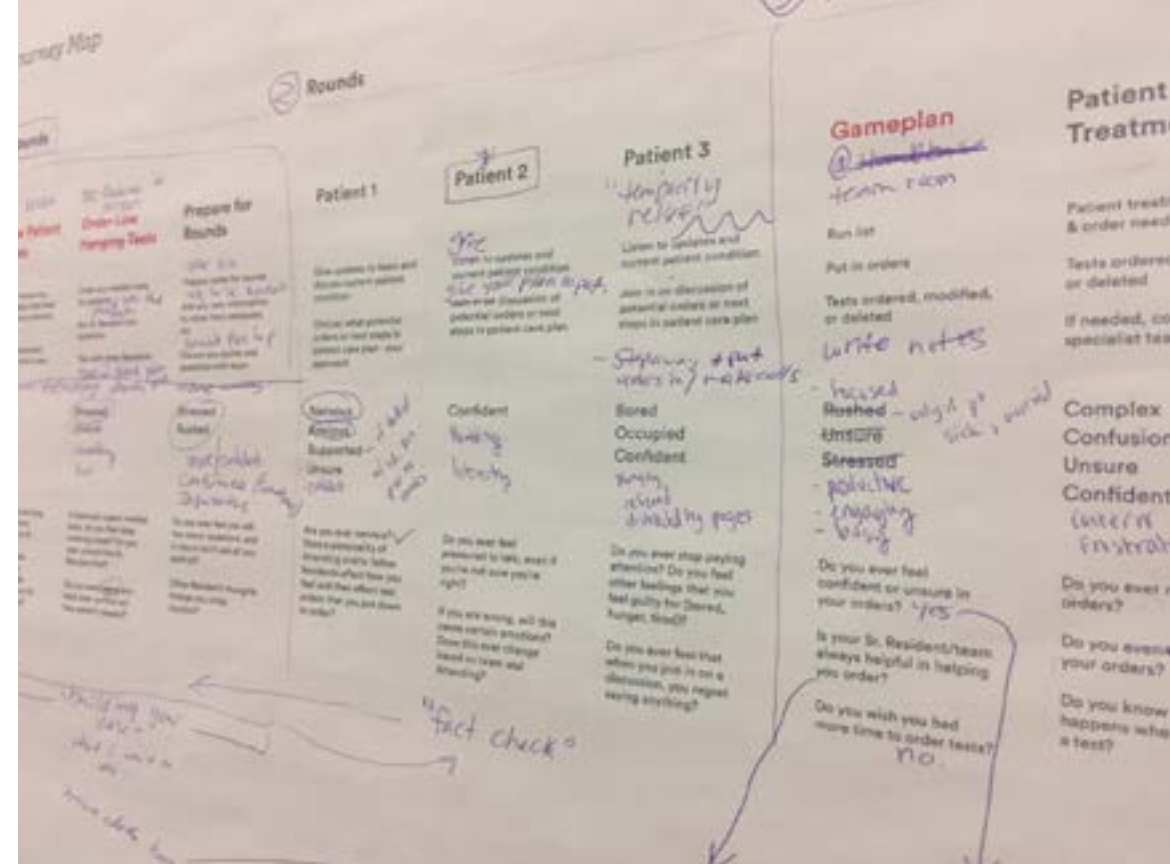


*Figure 6. Resident Ordering Journey Map - Resident influences.*

be difficult (especially for a first-year Resident), so here is where I wanted to insert my proposed decision-making support tool (as an add-on to QB's dashboard), to provide Residents with a resource which I speculate can help them to order more appropriately. I noticed during this that here was this expertise of information in Pathology about appropriate testing and currently there wasn't necessarily a way to connect this information to the people who commonly do a lot of test ordering. And, since some first-year Residents spoke that they feel more uncertainty when ordering a test since they are still learning, this proposed tool can help to bring this expertise to the point where an order is made while offering another way to learn. My proposed decision-making support tool (as an add-on to the dashboard) can be used by Residents

in these moments of decision making to support them.

To give more insight and understanding for my journey map, there are four columns of information on the left side of the journey map grid that aim to better identify what they may feel. I was able to find an array of information on what Residents think and feel which included: feeling nervous, feeling anxious, thinking about stress, thinking about being hungry or bored, feeling distracted, feeling engaged, feeling busy, thinking about concerns (see figure 6). This research was found through conversations with Residents. This method of visualizing the Resident Ordering Journey was valuable in helping uncover the gap between what people say they do in these moments that are visible (what they are aware of or consider) and what people actually do in these moments that may be invisible (what they may not be aware of or consider). This brought clarity around what potential information I should try to further prototype around.

## 4.3 What Residents are Solving For & Discovering What Information Would Help and Support Residents at the Moment of Decision-Making

Through observations, interviews, and journey mapping, it became apparent that Residents are crucial providers to patients within the academic medical center. I was able to learn this early on during observations and semi-structured interviews and conversations, specifically by understanding the Resident Ordering Journey. By noticing the three phases of rounds that happen during the Resident Ordering Journey, I was then able to rename these three phases as: Building Their Case (Pre-Rounds), Making Their Case (Rounds), and Employing Their Case



Figure 7. Resident Ordering Journey Map - building your case, making your case, and employing your case.

(Post-Rounds) (see figure 7). By doing this alongside Residents, and having them verify this language (the renamed phases), I was able to discover (from my point of view) that Residents seemed to be focused on trying to solve the medical issue of a patient (verses always focusing on patient-centered care or appropriate care of a patient). I then conducted a card sort with Residents (first through third-year) to find out what Residents consider when ordering a test. By knowing what they consider when ordering a test, and then putting these results alongside my journey map, I was able to see a clearer view of what Residents (or the ones involved in this project within Hospital Medicine) consider "appropriate," and therefore what information Residents may find to be most useful to be accessed through my proposed tool. The results, sequenced by how many Residents felt a factor a "priority" in their decision-making process, were as follows:

Build a case for treatment (13)

Pre-test probability (13)

Attending's preferences (13)

Ensuring a positive patient outcome (12)

Ensuring against a negative outcome (12)

Risk of false positives (12)

Senior Residents advice (12)

Physical discomfort for the patient (11)

Relieve doubt (10)

Test turnaround speed (9)

Patient anxiety (8)

Satisfying curiosity (7)

Ordering Process (7)

The financial cost to the patient (5)

More test information is always better (3)

The financial cost to the academic medical center (1)

Ease of obtaining a test* (1)

If it will change my management* (1)

*indicates a blank card was utilized*

In doing this card sort I realized that (1) Pathology has a lot of specialist knowledge (expertise) that could help Residents improve their test ordering, and (2) that designing a proposed decision-making support tool could have the potential to create a future state where Residents can make more informed decisions, leading to more appropriate testing.

After taking the results from the card sort, I then had to go through the information to understand: (1) what Residents are aware of, (2) what Residents aren't aware of, (3) what Residents consider, and (4) what Residents don't consider when ordering a test. Once I had gone through the information, I then created paper prototypes so I could start to figure out what information would be helpful, supportive, and even desirable to Residents in the moment of decision-making so that my proposed decision-making support tool (as an add-on to the dashboard) would be adoptable. I then asked Residents to respond to these different paper prototypes. I did this to find out how the information featured in my proposed decision-making support tool (as an add-on to the dashboard) could be beneficial by regarding Resident's goals or tasks within their role (job role and duty as a medical provider) of their overall care of a patient, and what information would align with decisions they currently made, and then how aware or desirable this information was.

## 4.4.1 How Residents Regard Information

Following analysis of the card sort, I was interested to see if the paper prototypes I created would be helpful and supportive, as well as desirable to Residents. Residents' feedback regarding the information displayed in the first two prototypes indicated a range of opinion about its usefulness. Some respondents felt the information was relevant even if they had not previously considered this information on their own (i.e., when a patient has last been tested in a 12-hour period or if a test must be sent out for fulfillment). Once the information was shown to them in these prototypes, they acknowledged it as a factor they would potentially take into account. Some of the information displayed was not considered useful by all respondents.

Some quotes gathered during prototype sessions from Residents about the information displayed is as follows:

• In regard to the "3:30am" information:

"This is a good dose of reality. If I knew (my patient) was woken up (for a test), it might change my decision." - 1st-year Resident

• In regard to the "Best Practices" information:

"...(I'm) not going to click on this personally, because I would have already talked to my

Attending on why I'm ordering this test." - 2nd-year Resident

• In regard to the "3 Day Send Out" information:

"If I knew it'd take X consecutive days for (a test) to come back, I might not order that test - especially if my patient was nearing discharge." - 3rd-year Resident

• In regard to the "$300" information:

"I couldn't see cost being a determining factor in ordering a test." - 1st-year Resident

*For further information gathered in the prototype sections, please see Appendix.*

Based on this small sample of responses, it suggests that cost is not a great driver in decision-making for Residents despite its importance to administrators. Test speed is somewhat significant. Building a case and treating a patient's health issue seems to be of primary importance. Residents are mostly ordering on their knowledge (facts, figures, benefits, information), based on their learned experience, such as their various Attending's preferences. As they progress to a third-year Resident, they take these learned experiences, this knowledge, along with their intuition, and the information which impacts them at the moment of decision-making, with them, and then proceed to further interact, teach, and presumably instill their manners and preferences in new first-year Residents. Third-year Residents helping and overseeing first-year (as well as second-year) Residents allows knowledge and best practices to be shared, but can also pass on manners or preferences that do not adhere to best practices (which may come from their own previous experience or gaps in information). The uniqueness of each patient could be clouded by a generic approach to solving for common medical issues. The card sort results indicate that Residents are focused on solving the medical issue in question. This narrow focus creates the potential to lose track of a more holistic sense of patient care. Residents are still going through their medical training; they may care deeply about adhering to their team Attending's standards, which, in turn, can create a gap in information and influence their ordering behavior in many ways.

## 4.5 Where My Proposed Decision-Making Support Tool Could Be Highly Beneficial

During this project, I focused on decision-making within the "pre-pre-analytic" phases of diagnostic testing (National Academies of Sciences, Engineering, and Medicine, 2016). Diagnostic testing consists of five phases: (1) "pre-pre-analytic," which "involves clinician test selection and ordering, has been identified as a key point of vulnerability in the work process due to the large number and variety of available tests, which makes it difficult for nonspecialist clinicians to accurately select the correct test or series of tests;" (2) "pre-analytic," "'involves sample collection, patient identification, sample transportation, and sample preparation;" (3) "analytic," "the specimen is tested, examined, or both;" (4) "post-analytic," "includes the generation of results, reporting, interpretation, and follow-up;" (5) "post-post-analytic," "the ordering clinician, sometimes in consultation with pathologists, incorporates the test results into the patient's clinical context, considers the probability of a particular diagnosis in light of the test results, and considers the harms and benefits of future tests and treatments, given the newly acquired information" (National Academies of Sciences, Engineering, and Medicine 2016). My project explored the moment of decision-making occurring in the pre-pre-analytic phase of diagnostic testing, where I was able to understanding the Resident Ordering Journey and the phases that happen within: building your case, making your case, and employing your case.

During this project I explored what information could have an impact during the decision-making process. Furthermore, the decision-making process can vary from person-to-person (e.g. because of their experience, the gaps in information that may exist, etc.). Now, even though I found that most of the decision-making process occurs during rounds, during which a discussion is had with the entire team, and an Attending ultimately ends up approving an ordered test, decision-making still happens throughout rounds (before, during, and after) when Residents are building, making, and employing their case. This is where I plan to have my proposed decision-making support tool (as an add-on to QB's

dashboard) , to be used by Residents to help inform and support them in making more informed decisions; more appropriate testing.

I was able to come to this conclusion of my tested concept through journey mapping, card sorting, and paper prototyping. This helped me indicate what information Residents believe would be most useful to be accessed through my proposed tool (as a dashboard add-on). I investigated a means of helping Residents make more-informed decisions through my proposed tool. By using my proposed tool as an add-on to the dashboard during this phase, it can be an additional resource for Residents when ordering a test, and during an Attending's external discussion to order a test. The Resident is still making the decision, and the Attending is still going to verify the test ordered, but the process now has an additional digital resource (my proposed decision-making support tool to be used as an add-on to the dashboard) that can be used to help Residents make more appropriate testing decisions, by also offering various information from the standpoint of medical issues, Specialist information, and also patient-centered appropriate care.
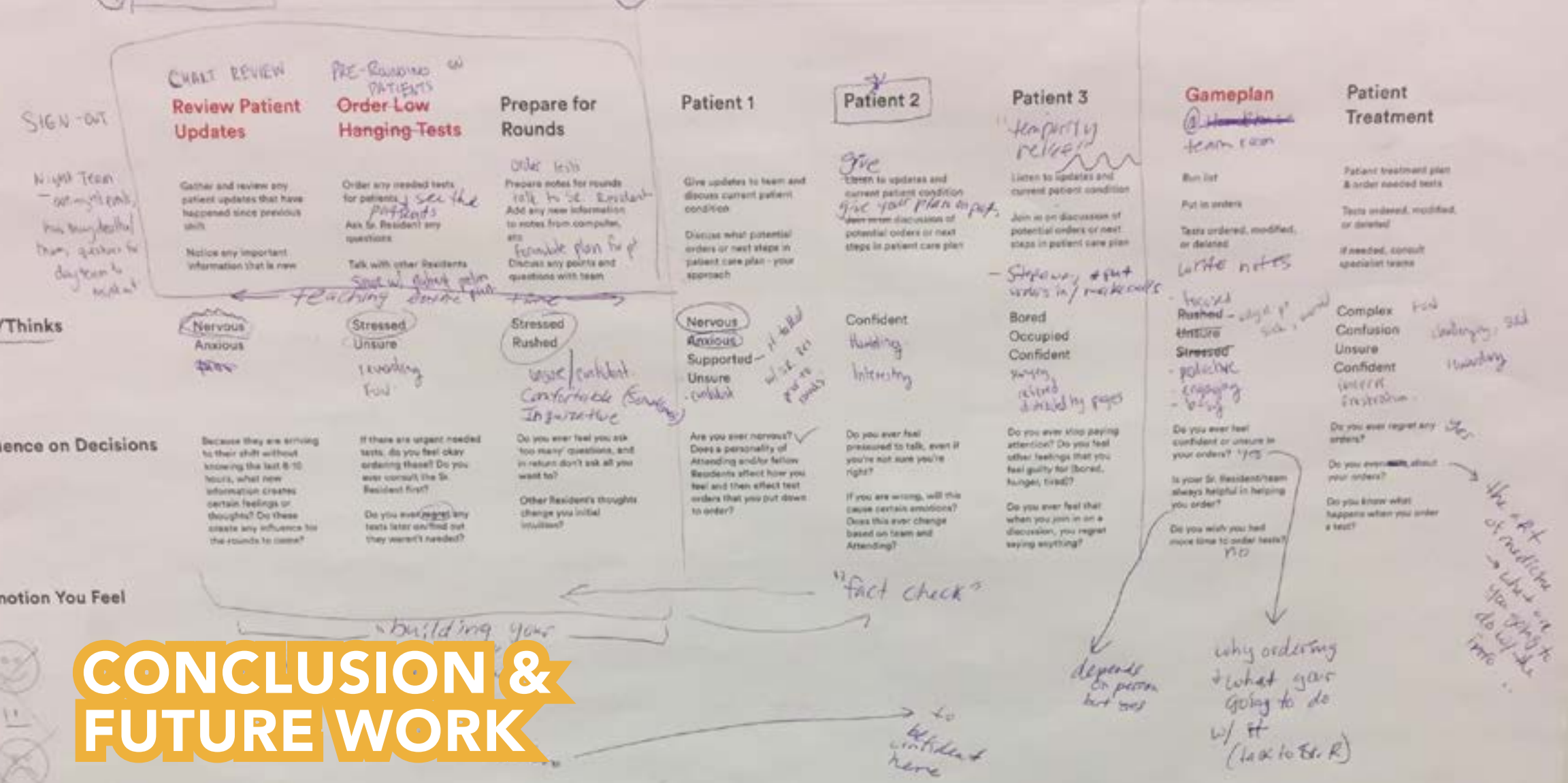
## 4.5.1 Bringing Patient-Centered Appropriate Care to the Forefront

My proposed decision-making support tool (as an add-on to the dashboard) could be created to be utilized within the decision-making process to enable a culture of open collaboration among Residents, Attendings, and Specialists, including Pathologists and other Administrators, as a means to bridge communication and share expertise to better allow for more informed decisions to be made. This also enables Residents to test more appropriately in tandem with other various providers' workflows and more appropriately overall. This not only makes various information more known, or even known at all, but also can lead to a broader understanding of other workflows and processes

that may be currently invisible to Residents. Furthermore, the tool can be made with Residents so that the (helpful) information featured is specific to them, allowing them to adopt my proposed tool.

## 4.5.2 A Decision-Making Support Tool Created in Tandem with Residents is a Desirable Tool

By incorporating residents needs into my proposed decision-making support tool, as an add-on to the dashboard, it can support them in their test-ordering decisions by allowing the Residents, as users, to have system control, and awareness, of the type of information that is to be displayed and they might find most applicable. Displaying information related to specific details about patients or test details, some of which they are aware of and/or even favor, allows for the arrangement of the tool to be around the goals and tasks of Residents, allowing my proposed decision-making support tool to be desirable and more adoptable. Furthermore, including information that they are not aware of, or don't necessarily desire, although important (helpful, supportive), my proposed tool (as an add-on to the dashboard) can then be utilized as a supportive tool to lead to more informed decisions when ordering tests. This is because it would be a proposed tool designed to allow users (Residents) to easily acquire accessible information during this moment of decision-making, and therefore create more appropriate testing, and, more importantly, align with the academic medical center value of patient-centered appropriate care.

**CHART REVIEW** — **Review Patient Updates**

**PRE-ROUNDING on PATIENTS** — **Order Low Hanging Tests**

**Prepare for Rounds**

**Patient 1**

**Patient 2**

**Patient 3**

**Gameplan**

**Patient Treatment**

SIGN-OUT

/Thinks

ience on Decisions

notion You Feel

# CONCLUSION & FUTURE WORK

## 5.1 Conclusion

To affect outcomes, it is critical to understand the behavior of Residents and the gap of information that exists during the decision-making process before an outcome can be effectively created, especially since the limbic system in our brains, which is responsible for our feelings, controls our behavior and is responsible for our decision-making. Once a process is understood, one can identify the most relevant point

in the process that needs to be examined, supported, and transformed. Furthermore, identifying this crucial moment of the process so that it can be changed can only happen when the people within this process are first understood; their needs, wants, and desires. By truly understanding these users – their workflows, roles, environment, how they think and feel, what their experiences are, and exactly what information may impact their decision-making process when ordering a test, so that my proposed tool can then be made to be supportive and desirable so that it becomes adoptable, motivating changed behavior which will then have an impact on the outcomes.

Within this user-centered approach and Co-Design process, I was able to indicate a need for the many ways in which we can get at the complex, wicked design problem of appropriate care through appropriate testing. In my approach, I regarded Residents as people, with anxieties and fears, that work within stressful environments, and saw the impact of how my proposed decision-making support tool (as an add-on to the dashboard) could affect outcomes by looking at how information can impact moments of decision-making, and I saw an opportunity where my proposed decision-making support tool (as an add-on to the dashboard) could be of value. Because of my UI/UX background experience, I was able to provide my partner with valuable insights that would have never been known if I had not done this project. This is because I had access, time, and design knowledge, to share with Residents within Hospital Medicine at the academic medical center.

This information and the interaction I had throughout this project with my stakeholders, Residents, professors, thesis committee, etc. all benefited my project regarding the identification of what information can be shown within my proposed decision-making support tool (as an add-on to the dashboard) to be useful in making Residents better at ordering tests appropriately. This partnership was aimed at having all stakeholders understand each other's needs, roles, and goals so that each can bring a unique perspective to what features would be

most usable – supportive and desirable to align on the overall goal of appropriate testing. This is necessary to initiate conversation amongst multiple stakeholders, employees, and administration across various units and services – allowing for workflows and specialist knowledge to become explicit through awareness, and using my proposed decision-making support tool (as an add-on to the dashboard) not only as a resource to enable more appropriate testing but also as a means of communication for enabling facilitation within processes that are difficult or are often unknown (e.g., Residents knowing the processes and workflows of Pathology).

## 5.2 Future Work

Currently, I am working on the creation of a manual that describes my project, design approaches to take, which methods to use and why, examples of research and insights found, and the next steps to take. This manual can serve as a sort of blueprint for the QD to use in further exploration of their dashboard while also documenting my process and insights I found or the information which may prove useful for future iterations of the dashboard or my proposed decision-making support tool (as an add-on to the dashboard). This manual will be able to live on its own, separate from this thesis, to serve as guidance for any individual who is familiar or unfamiliar with User-Centered, Co-Design, or other integrative design approaches to problems.

Implicit within this integrative design process is the production of a user-centered Co-Design model which can be continued by the QD or replicated by other individuals within the organization, or even other healthcare institutions. This approach enables collaboration and supports the inclusion of the user(s) within the design process. My working with Residents to identify what would be desirable led to the process of Co-Design being used in the design of the dashboard as well. This Co-Design process acted as an approach to help bridge the

gap in communication, understand where, how, and why decisions take place, enable decisions to be made together, and make tacit knowledge explicit – increasing the likelihood of adoption of my proposed decision-making support tool (as an add-on to the dashboard) and creating a model that can be replicated across the academic medical center. Future work must include an ongoing iterative process to keep identifying more information that makes my proposed decision-making support tool (as an add-on to the dashboard) desirable for all users and stakeholders. Iterative designing and testing must be ongoing as well. This can help to build a tool to help Residents regulate, support, and learn from experience, not only through their actions but through the actions of others around them so that they are able to have more confidence in their decision making.

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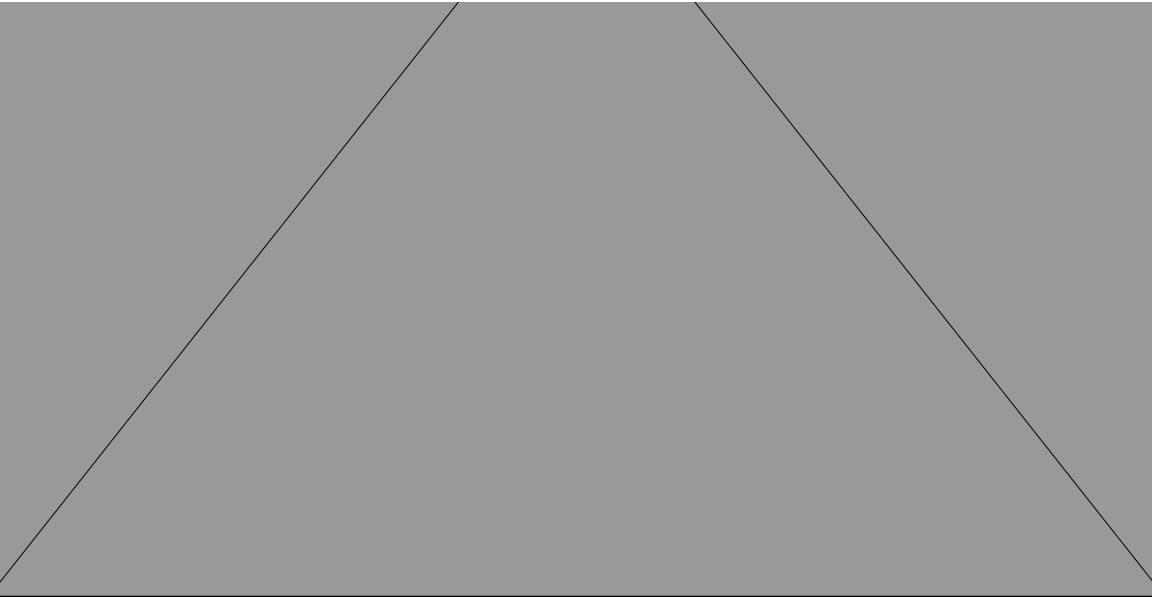
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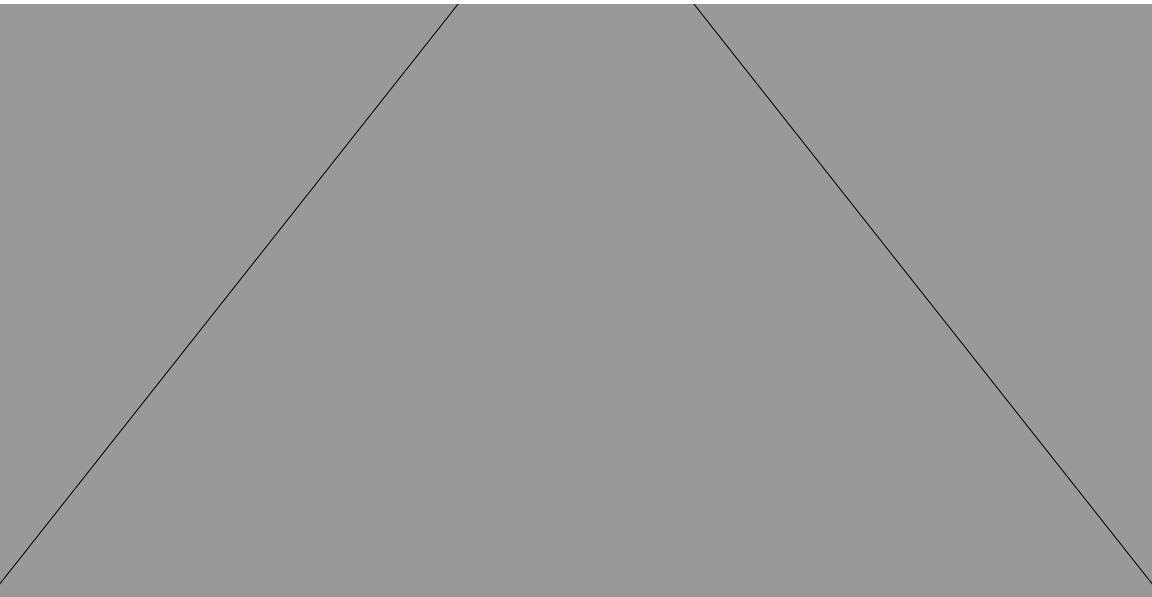Zhang, Xiaoni, Kevin P. Gallagher, and Samuel Goh. "Bi Application: Dashboards for Healthcare." In AMCIS. 2011.
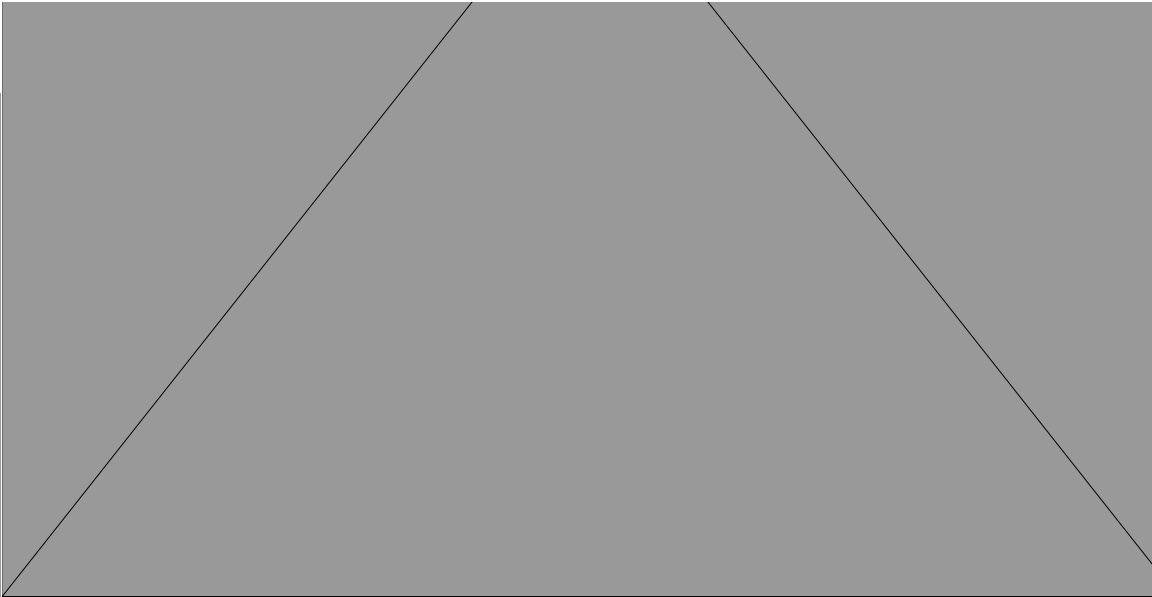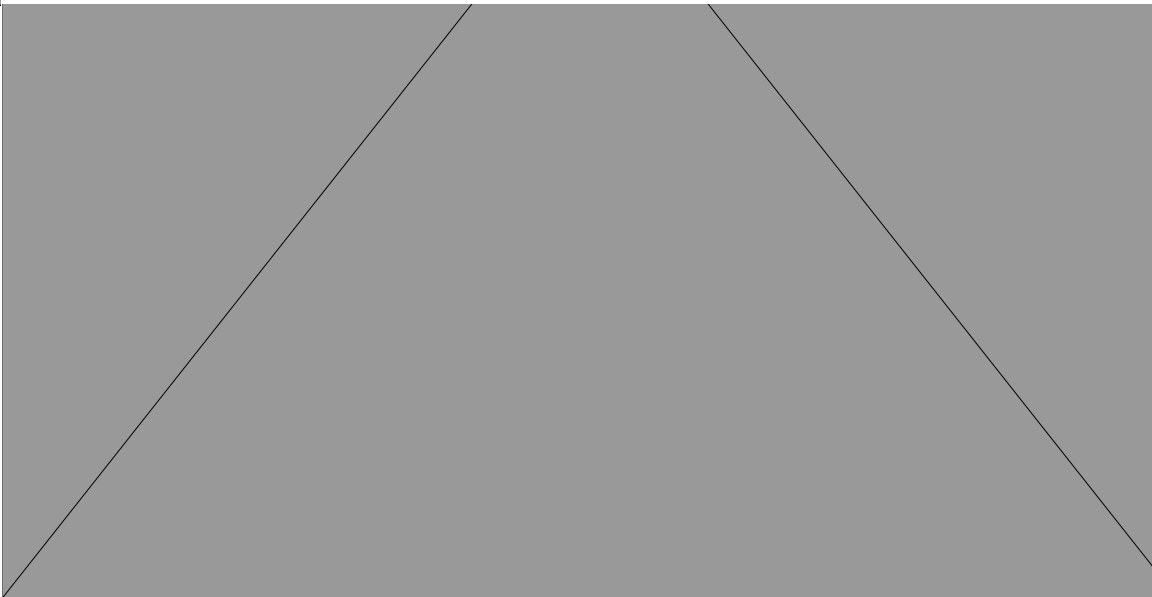
# APPENDIX

**7.1 Insights from Card Sort:**



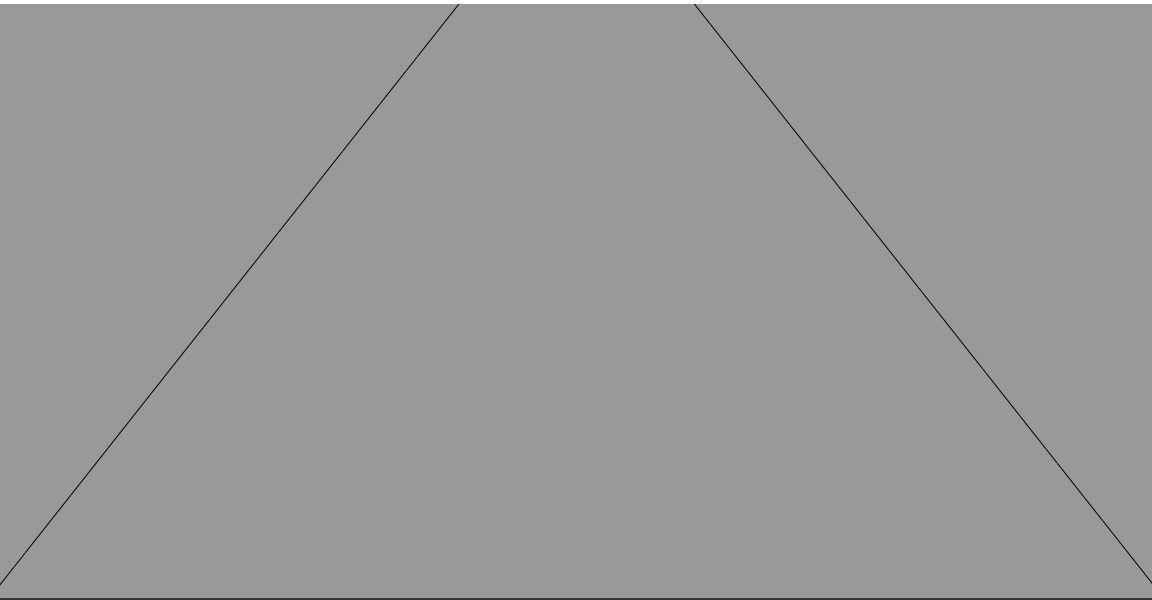**7.2 Insights from Card Sort:**



**7.3 Insights from Card Sort:**



**7.4 Insights from Prototype Sessions:**

**7.5 Insights from Prototype Sessions:**



**7.6 Insights from Prototype Sessions:**

Resident A: 3rd Year

I: Yes

3 days - Tell me how long tests are going to take, so it's helpful.

80% - If this is a test I'm not familiar with, knowing the test performance would be helpful. If we do inappropriately order it, sensitivity and specificity and price would help to determine if I should

II: Maybe/No

DRG - I have no idea what a DRG is

Best Practices - This takes more thinking, especially with Best Practices because I'd have to click on it

3:30am - Knowing how many times this patient has gotten lab draws

in 24 hours would be more helpful than say the time of 3:30

Send out - Send out is harder to read than the previous where it said 3 days

III: Their Dashboard

3 Days

Pre-Test Probability

$300

4x in 12 Hours

Best Practices

"Last time this lab was drawn on the patient"

3 days - 3 days is helpful to know

4-6 hours - I like this format for the time period

$300 - I like cost because you usually have to go find that

Last time this last was drawn on patient - Maybe the last time lab was drawn on the patient, so if it's a send out, or it has been done, it would alert us to that

Pre-Test Probability - Test performance would be good to see instead of "pre-test probability" to see what would affect a test (medicine) or see sensitivity vs. specificity


Resident B: 2nd Year

I: Maybe/No

3 days - I think this information is helpful

80% - I don't care too much about this info, because I'm trying to

order something appropriate, knowing what people do doesn't help me. This is least helpful because I'd hope I'd be in the 20%.

$300 - Cost is intriguing, I could be interested

4x - I would know this already, because people would complain, however, I think it'd be good to keep in mind.

II: No

Best Practices - Not going to click on this, but I would have already talked to my Attending why I'm ordering this test

Send out - This is good, similar to other one

3:30am - This is very hard information to know, I'm not sure how it would be updated. If it's possible to know, I'd rather know the poking one. If they didn't get sleep, they're going to say that.

DRG - This seems abstract. I would want to know of all the tests we've done so far, and then it do the math in the background, which would be intriguing.

III: Their Dashboard

Send Out

I wouldn't want this app separate. I'd want it less on my phone and more on Epic and ingrained with the software, so I wouldn't have to open another external thing. However, if it's integrated into Epic, and my phone, that would be fine. If it was through phone, how would I cross-reference, and thinking about EHRs and security?

Send out - If it showed cost expense, or see potential delay, know what tests don't come back by the time people are discharged that would be good to know ahead of time, which could change my ordering "if 80% of patients get discharged before the test comes back" that would be good.

80% - I don't know if it would affect patient satisfaction scores, but it would be nice for us to think about patients more. It doesn't matter to me as a Resident; my job doesn't depend on them being satisfied. However, I'm not actively trying to hurt anyone; I'd like them to have a good experience.


Resident C: 3rd Year

I: Yes

3 days - Send out tests tend to come back pretty quickly, but tacro levels take days and days to come back, and it's useless at that point.

$300 - Cost is fine, every now and then I get surprised by how much a test costs.

4x - The pokes, it's fine for a reality check.

80% - I mean, who is really judging what is appropriate and not appropriate. I feel like I look at this, and someone is deciding this by algorithm, and they're not actually deciding what's appropriate or not appropriate.

II: Maybe

Best Practices - As far as best practices go, in theory, it's fine. We do this at the [other hospital] whenever someone needs a vaccine, and recommendations pop up. I would want to know, but I feel like the information is not as useful for the time, like if they are paragraphs. The times when I might have this situation, I click on it wherever and it's too long to read.

Send out - This we already talked about.

3:30am - Same thing as I said earlier, how many times they're poked, but I try not to order things at 3:30am, to begin with.

DRG - I don't really know what a DRG is.

III: Their Dashboard

4-6 Hours

3 Days

Pre-Test Probability

$300

4-6 Hours - This number and cost would be good to look at.

3 Days - When I can expect to hear back with a test is key.

Pre-Test Probability - I'd use time, the pre-test probability, if they were showing some sort of metrical numbers.

$300 - If the cost was for the patient, I would put it in my clinical judgment; if someone is stable, I feel more comfortable about doing the handful of things more common and delay the other tests. If I think everything is stable, and I'm not thinking about cost, I won't think too much about it. The non-sick patients are the ones who really would make me think about cost versus a sick patient.


Resident D: 2nd Year

I: Yes/Maybe

3 days - If I knew it'd take that many consecutive days for it to come back, I might not send the test out. Especially if the patient was nearing discharge.

80% - Why and how is anyone even telling other providers what is appropriate?

$300 - Sometimes I just wait and look at pre-test probability more

than cost, and also wait to see how they do clinically more.

4x - I am generally good at knowing how much I'm poking a patient per day.

II: Maybe/No

Best Practices - This is confusing. How would you know this? Or what would this information be?

Send out - This would be good, but I like the other one with the total of days or some sort of time indicator more. It's easier to understand.

3:30am - This is just a good form of reality. If I knew someone was getting woke for it, it'd be good to know.

DRG - I kinda think I know what a DRG is, but I'm not totally sure, so this wouldn't be helpful to me.

III: Their Dashboard

3 Days

Pre-Test Probability

3:30 AM

Speak with Nurse

Pre-Test Probability - It would be cool to be able to put results in and have it give you something about post-test probability. Like how likely is your patient have these conditions now that you got the test back?

3 days - This might be interesting in the setting of critically ill people, to know if it's something to know about timing.

Speak with Nurse - We do talk with nurses and other staff, but maybe having something like access to more information could help us understand the patient more, perhaps.

Resident E: 2nd Year

I: Maybe

3 days - I love this one. This information isn't really known all that much, so this would be helpful.

80% - I don't really care if a test is ordered incorrectly a certain amount of time. I'm still going to order it if I need to.

4x - It is good to explain this more; for instance, if in the critical care unit patients are actually getting these pokes versus a central line.

II: No

Best Practices - This would be neat. There's a resource used in Radiology that is pretty valuable.

Send out - Same with this one as the 3 days, but I'd rather see it in the other format.

3:30am - This would be helpful, but I don't know if it would make a huge difference.

III: Their Dashboard

Pre-Test Probability

3 Days

4x in 12 Hours

Best Practices

Pre-Test Probability - If I was trying to figure out what to order, data around sensitivity and specificity, and data around conditions or something, or what are you trying to rule out, something like that would be interesting.

Best Practices - We have different stuff for Radiology, like "what's the

best scenario for ordering this test?" you could pull some of this in too. It's called ACR - appropriateness criteria. They say like this is what you should do, that would be helpful. People have resources, but they are all in different places, so if there was like one place. One short blurb though we're just all these things could combine.


Resident F: 1st Year

I: Yes

3 days - I don't currently have any indication that says if it is a test that is one that is sent out but if it showed, but it would be beneficial to understand just basic information regarding that test.

80% - I would want to make sure I am testing in the 80% group, but could I see where I stand with previous orders of this test?

$300 - Cost isn't that much of a determination in my ordering

4x - This would be beneficial to see as well; however, if I need to order a test, then I'll always order it.

II: Maybe/No

Best Practices - This would be helpful as some sort of 'refresher' of things learned in medical school.

Send out - Same as the other 3-day one on the previous card.

3:30am - I've never seen any information like this, and I'm not sure if it would necessarily affect my ordering, but it might still be beneficial to see.

DRG - I'm not sure what this is.

III: Their Dashboard

Best Practices

Pre-Test Probability

4x in 12 Hours

3 Days

Best Practices - I know there are lots of resources out there, but if this could be some condensed version of those, this would be great.

Pre-Test Probability - This would be great to know more around a tests' individual sensitivity and specificity. It might help me at times when I'm contemplating ordering a test for a patient.

4x in 12 Hours - I'd love to know this in general, but if I need to order a test and I have to poke a patient again, then it's just going to happen.

3 Days - I am not aware of most test times but also if they are tests which are sent out for processing. Knowing this would be super helpful.


Resident H: 1st Year

I: Yes/Mybe

3 days - This is vital because it lets me know how long a test is going to take if it needs to be sent out.

80% - I'm not really sure about this information. I don't think I'd know what to really do with it without some more explanation or data.

$300 - Knowing the cost of a test might be a good idea, it could possibly help me to learn more about the cost of tests if I ever need to know.

II: No

Best Practices - This would be great if it could be useful or to help me at times when I am unsure about the conditions to order a test or conditions a patient is presenting

Send out - I'd rather see the 3 days or the time of a test than only know if it is a test which gets sent out to a lab.

DRG - To me, this wouldn't be super helpful, but I'm not sure.

III: Their Dashboard

3 Days

Pre-Test Probability

$300

Pre-Test Probability - This would be good to combine with some information from best practices, I think.

$300 - I would always have in the back of my mind I'm not sure what the cost means, is it a negotiated price, is it for the patient, for the hospital.


Resident J: 1st Year

I: Yes

3 days - This is good. I'd love to see a breakdown potentially of all tests on a chart like this and what their general information is.

80% - This is alright, maybe. I don't know if it would translate to me even knowing what to do with this information and the next steps I could take.

$300 - To me, I don't think this would really matter.

4x - This is good to know so I can be conscious of my patients and their needs.

II: Maybe

Best Practices - This would help me choose a test that I might be un-

sure of or have other questions about if there are no other resources helping me in that moment, or I am feeling any sort of pressure from the Senior Attending.

Send out - This would be great to have to help understand just more about tests that I order, especially common ones.

3:30am - Wow, to know this would help me be more understanding of when to order tests.

DRG - Eh.

III: Their Dashboard

4-6 Hours

3 Days

Pre-Test Probability

$300

Best Practices

4x in 12 Hours

3:30am

Patient Preferences

Speak with Nurse

4-6 Hours

3 Days

Pre-Test Probability - Some combination with Best Practices all in one.

$300 - I like seeing the cost. They have this at the [other hospital] - the medication comes up with a cost next to it.

Best Practices - Same as before. Anytime that I am unsure.

4x in 12 Hours

3:30am

Patient Preferences - I try to always make sure my patients are happy, but at times it's hard, especially depending on their condition.

Speak with Nurse - Very enjoyable to know as I like to know all I can before doing something.