Detailing Experienced Nurse Decision Making During Acute Patient Care Simulations

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Abstract

Introduction

Nurse decision making (DM) is critical for patient safety. Eye-tracking methods can effectively assess nurse DM. The purpose of this pilot study was to use eye-tracking methods to assess nurse DM during a clinical simulation.

Materials and Methods

Experienced nurses managed a simulated patient manikin who suffered from a stroke mid-simulation. We assessed nurses' gaze patterns prior to and after the stroke. DM in general was assessed by nursing faculty using a clinical judgement rubric, and dichotomously based on recognition of the stroke or not.

Results

Data from eight experienced nurses was examined. For the nurses who recognized the stroke, visual attention was focused on the vital sign monitor and patient's head, which suggest those locations were consistently examined for correct decision-makers.

Conclusions

Dwell time on general AOIs was associated with poorer DM, which may reflect poorer pattern recognition. Eye-tracking metrics may be effective to objectively assess nurse DM.

Keywords:

Nursing, Eye-Tracking, Simulation, Decision Making

1.0 Introduction

In healthcare, particularly in emergent situations, rapid recognition of patient deterioration and quick decision making (DM) is needed to escalate care and prevent adverse patient outcomes.[1] Given the extended amount of direct contact they have with patients to record and document patient status information,[2] nurses play a crucial role in recognizing patient deterioration. A recent integrative review of the literature found that regular assessment of patients (i.e., particularly vital signs and observations), familiarity with the patient and their medical history, education (i.e., education level, ongoing clinical education), and use of technology were associated with more timely recognition of patient deterioration.[2] However, another literature review found that there are several aspects to nursing knowledge and DM that impact nurses' abilities to effectively recognize patient deterioration including their understanding of clinical deterioration, lack of basic assessment skills, and use of subjective methods to highlight patient concerns. Given the impact nurse DM has on recognition of patient deterioration, it is necessary to better understand how nurses actually make these decisions in clinical settings.

Several models of DM exist, which generally define it as the process of selecting a course of action between multiple options.[4] The DM process consists of several components, including: a search for relevant information, judgement and evaluation processes, and post-decision processes to confirm the validity of a decision and adjust to the implications of that decision.[5] Differentiation and consolidation theory details this process well and identifies four stages in the decision-making process: detection of the problem, differentiating an initially selected choice from other alternatives, the decision stage, and the post-decision consolidation stage.[6,7] Differentiations, or comparison of the selection versus alternatives, help the decision maker clearly distinguish one suitable alternative from others and justify their selection.[6]

For healthcare professionals, there are several decision processes that are presented in quick succession with multiple decision choices (e.g., evaluation, diagnosis, and treatment).[8] Clinical decisions are also characterized by the multitude of dynamic variables that impact decisions (e.g., patients' physiological status), time pressures to quickly make diagnostic decisions and intervene, and the absence of sometimes critical information, which make decision problems ambiguous. A systematic review of the literature on nurse DM found that nurses' experience is influential to DM and contributed to an unconscious and intuitive DM process.[9] Furthermore, understanding and maintaining situation awareness on the patient's status allows nurses to identify patterns intuitively based on their experience. Recent research efforts have focused on better-understanding experienced nurse intuition and factors that influence their DM.[10] Experienced nurses explained that they maintain a holistic approach to information gathering that includes a comprehensive patient assessment, establishing relationships with patients and families who may share additional clinical information about the patient's status, and utilize their extensive experience to identify patient care needs and potential risks based on this data.

One common method to study DM is to define an optimal behavior and detailing why individuals arrive at that decision.[5] Rather than assuming what subjects will do in response to decision problems, taking a descriptive approach to categorize how people actually process information in order to arrive at a decision is more beneficial. Following this descriptive approach to DM research, it is possible to categorize DM and draw conclusions about the process through process tracing measures, such as evaluating individuals' information scanning and having them verbalize thought processes using think-aloud protocols.[5] However, it has been argued that think-aloud protocols increase the cognitive load of participants,[11] impede participants' standard work practice,[12] and some unconscious DM processes may not be verbalized.[13] In order for researchers to study "work-as-done" instead of "work-as-imagined" related to nurse DM, more objective methods than think-aloud protocols are needed. Given the fact that eye-tracking methods allow researchers to objectively study how users gather data from the environment,[14] eye-tracking methods may be appropriate to study nurse DM rigorously.

There have been several studies applying eye-tracking methods to study experienced nurse and nursing student visual attention and behaviors in the simulated clinical environment. In one study, researchers implemented eye-tracking with nursing and paramedic trainees during high-fidelity clinical scenarios and tracked their gaze fixations on key areas of interest (AOI).[15] The authors were able to discern how trainees prioritized patient status information based on their percentage of total fixations on the AOIs, but argue that further study is needed to understand how expert clinicians' performance is related to gaze fixations on environmental stimuli. Another group studied the differences in eye gaze patterns between experienced nurses and nursing students during a simulated intravenous injection task, and found that eye-tracking methods were sensitive to detect that experienced nurses focused more on task-relevant stimuli than novices.[16] Similarly, researchers in another study utilized a mobile eye-tracker to study the behaviors of experienced nurses and nursing students during simulation, and found that eye-tracking can be an objective assessment method to detect differences in patient care behaviors (e.g., assessments performed, treatments administered) between nurses.[17] A scoping review of the medical DM literature[18] found that fixations (i.e., relatively brief gaze point on an AOI), dwell time (i.e., the amount of time fixated on an AOI), and the time to first fixation on certain AOIs were commonly used metrics to assess what stimuli were most salient to medical DM.

These studies, however, were conducted with physicians, and few studies have attempted to study the connection between eye-tracking metrics and nurses' clinical DM.

In reference to DM, specifically, research outside of medicine has found that there is a bias in the gaze behavior of participants to direct their visual attention to the area of interest that most impacts a decision in the five seconds preceding that decision.[19] Based on differentiation and consolidation theory and the gaze cascade effect, a combined decision-making framework (Figure 1) can be used to guide eye-tracking analysis on how nurses make decisions clinically.

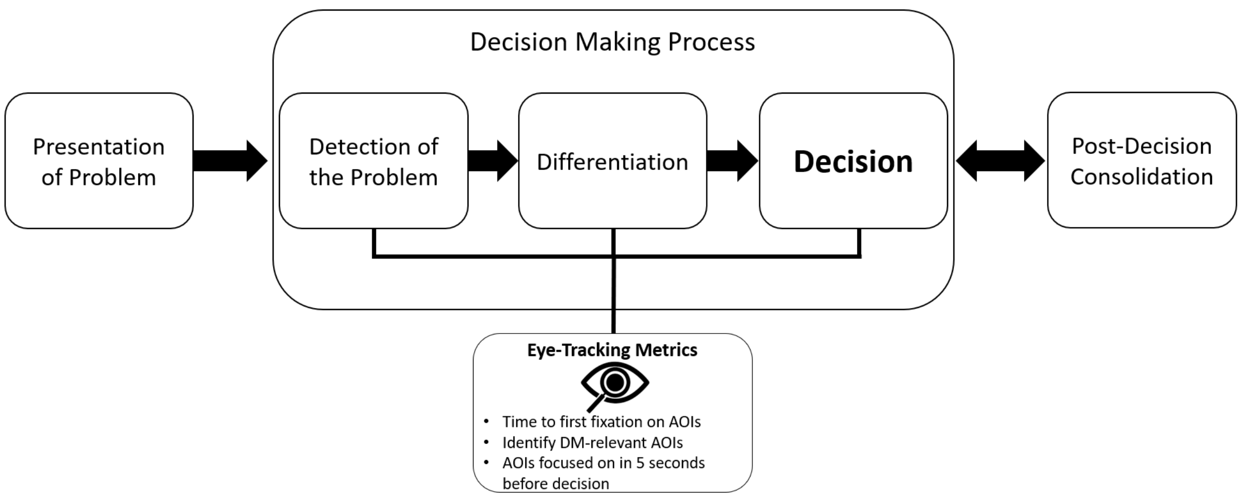

Figure 1. Differentiation Theory Framework Applied to Nursing

These studies emphasize the ability of eye-tracking methods to be effective methods to study DM and how medical professionals visually attend to clinical information and DM. However, there is a dearth in the literature on utilizing eye-tracking methods to objectively assess nurse DM. The differentiation and consolidation theory of DM that has been applied in other fields may be applicable to examine DM in healthcare. Furthermore, eye-tracking methods may be leveraged to study elements of this theory. Eye-trackers allow researchers to measure the time to first fixation on AOIs (i.e., indicating detection of the problem and salience of AOIs to the presenting problem), the time spent attending to AOIs prior to the problem and afterwards (i.e., differentiation of decision-relevant information from irrelevant information), and what AOIs nurses attend to in five seconds prior to decision. The combination of this novel application of differentiation and consolidation theory of DM to nursing, as well as the use of objective eye-tracking methods may yield new insights into nurse DM that think-aloud protocols alone are unable to provide. Accordingly, the purposes of the current exploratory pilot study were to:

1) Utilize eye-tracking methods to study specific elements of differentiation and consolidation theory (i.e., detection of the problem, differentiation, and the five seconds prior to the decision) applied to experienced nurses' DM during a validated patient-care simulation.
2) Compare eye-tracking and think-aloud process tracing methods to determine which method is more effective to explain nurses' DM.

2.0 Methods

Regulatory approval for this study was provided by the Purdue University Institutional Review Board (IRB#2020-1684). A convenience sample of full-time practicing nurses, who were known to members of the study team at the time of recruitment, voluntarily participated in this research. Inclusion criteria for participation in the study included ensuring nurses were out of training at the time of the study, registered to practice nursing in the state of Indiana, and currently in practice at the time of the study. Despite these limited criteria, our team intentionally solicited participation from nurses with extensive clinical experience.

Following their informed consent to participate, nurses were equipped with the Tobii Glasses 2 mobile eye-tracking system (Tobii AB, Danderyd Municipality, Sweden). The glasses have two infrared cameras per eye to capture pupil positioning, and a fully high-definition external camera to capture the perspective of the user. The eye-tracking system automatically overlays the user's gaze point on the video of the environment (Figure 2).

Figure 2. Overlay of participant's eye fixation in simulated environment

For each user, the eye-tracking system was calibrated per manufacturer's instructions.[20] Participants were then introduced to the simulated environment through a standardized tutorial by a member of the simulation center staff, who provided information on the patient manikin

(Laerdal Sim Man 3g), how to operate the vital sign monitor, and how to call for assistance if needed. The nurses were then instructed by a member of the study team that they should verbalize their clinical DM thought process as they performed the scenario. This think-aloud process was captured using a lapel lavalier microphone (Zoom H1n Digital Handy Portable Recorded, Zoom Corp, Tokyo, Japan), which was affixed to their scrub shirt collar. In order to assess the nurses' performance, two members of the study team (i.e., both were clinical assistant professors at our institution, and one nursing faculty member had developed the simulated scenarios) completed a DM rubric while evaluating eye-tracking videos from nurses performing the scenario. Nurses individually completed the Lasater rubric for each participant, then came to a consensus on a single score for each domain, so there were no divergent scores between the two raters.

The same two members of the study team performed content analysis of the nurses' think aloud protocols to detail general themes about their approach to identifying the clinical problem and resulting decisions following an approach detailed in the literature.[21,22] The two nurse educators coded audio transcriptions individually, independently identifying themes. After individually coding the videos, the nurse educators discussed and assimilated tentative themes. After several meetings, each educator identified the final themes. These were shared, further discussed, and refined until agreement was reached on the final themes. Also, a study team member performed a task analysis on nurses' performance during the simulation to mark the start and end times of the key phases of the scenario and annotate behaviors that nurses were observed performing during the simulation (e.g., patient assessments, calling the physician in charge, etc.).

2.1 Patient Care Scenario

Nurses were provided a handoff (i.e., in a standard Situation, Background, Assessment, Recommendation format)[23] on the simulated patient by a member of the study team portraying the role of a certified nurse assistant in the emergency department (ED). Nurses were given the background on the patient, who was admitted to the ED for a traumatic fracture of the tibia and fibula during a motor vehicle crash, and were told they were being asked to monitor the patient and administer his intravenous antibiotic prior to being moved to surgery the following morning.

In the initial phase of the scenario (i.e., entry into room until five minutes), the patient was responsive to all questions and displayed unremarkable vital signs. However, the patient's demeanor suddenly changed with the rapid onset of a stroke. The patient's blood pressure became 180/100 and they experienced cognitive symptoms including confusion (e.g., forgetting words), slurred speech, and numbness and tingling on the left side of their body. Nurses were able to perform any desired physical assessments on the patient manikin, and the scenario operator provided feedback on the patient status during assessments if needed (e.g., the patient was unable to squeeze the nurse's hand on the left side). Nurses were able to call the physician in charge to convey any concerns or discuss ordering diagnostic tests. Scenarios were concluded when nurses ordered a rapid response team to the ED to assist with stroke management. All aspects of the scenario (e.g., patient verbal responses, status, vital signs) were controlled by a preceptor in a control room that was separated from the simulator room by two-way glass. Thus, the preceptor could see all actions performed by the participant, but the participant could not see the preceptor. Unless nurses explicitly ordered a rapid response alert or indicated that the patient was suffering from a stroke, scenarios were concluded after ten total minutes (i.e., including the five minutes of initial patient assessment).

2.2 Measures

Prior to participating in the stroke scenario, nurses were asked to complete a demographic questionnaire. The questionnaire detailed their age range, gender, degrees obtained, how many years they have been in practice (post-training), areas or specialties they have experience in, bed size of current hospital, trauma level of hospital, unit where they spend the majority of time, typical # of hours worked per week, and whether or not they have received advanced cardiac life support or other advanced training.

To evaluate clinical DM, two members of the study team who are nursing faculty in the School of Nursing reviewed participants' eye-tracking videos and completed the Lasater Clinical Judgement Rubric.[24] The Lasater rubric is an 11-item measure that evaluates the quality of several aspects of nurses' DM (e.g., focused observation, making sense of data, well-planned intervention) on a four-point scale. Since the nurses did not engage in critical reflection before the end of the scenario, the evaluation/self-evaluation and commitment items were not rated. We also averaged all ratings from the Lasater rubric to derive a single score representing DM.

2.3 Eye-tracking Metrics

Using the Tobii Pro Glasses 2 eye-tracking system, participants' gaze data was captured from immediately before the patient handoff at the start of the scenario until the scenario operator ended the simulation. The Tobii Pro Glasses 2 has shown comparable accuracy and reliability in data capture at a distance of ≤2 meters to other commercially available eye-trackers.[25] Tobii eye tracking analysis software (Tobii Pro Lab, Tobii AB, Danderyd Municipality, Sweden) was used to extract metrics from the key phases: the handoff from the certified nurse assistant, the initial patient assessment (i.e., entry into the patient room until the change in patient status), change in patient status (i.e., onset of the stroke until the end of the scenario), five seconds prior to the explicit recognition of the stroke (i.e., if the nurse verbalized that they perceived the patient was suffering from a stroke), and the scenario as a whole (i.e., entry into the patient's room until the end of the scenario).

The Tobii Pro Lab software allows researchers to evaluate a multitude of eye gaze metrics. In this study, the following eye-tracking metrics were utilized: percentage of scenario phase (e.g., initial patient assessment or change in patient status) fixated on AOIs, average fixation duration on AOIs, and time to first fixation on AOIs (i.e., for specific scenario phases) in the current study, as well as percentage of visits (i.e., all fixations on an AOI before looking away) and average visit duration on AOIs. These metrics were captured for each of the aforementioned scenario phases. In the current study, relevant AOIs included the patient's eyes, mouth, head (other), torso, arms, legs, vital sign monitor, patient chart, and intravenous (IV) pump. These AOIs were selected as they relate to patient systems, particularly those included in general and focused nurse assessments, or are critical external areas that display diagnostic information (i.e., vital sign monitor) or relate to the administration of medication listed in the patient chart (i.e., IV pump). Members of our study team, including human factors engineers and nurse educators, conferred and a consensus was achieved to focus on the aforementioned AOIs. This approach of AOI selection has been reference previously in the literature.[15]

2.4 Statistical Analyses

Mean (standard deviation) was calculated for all variables. Non-parametric statistics were used since the dataset was not normally distributed (based on Shapiro-Wilk test of normality). Spearman's Rho was used to calculate correlations between eye-tracking variables and Lasater scores. Differences in eye-tracking metrics between the initial patient assessment and change in patient status were assessed using Wilcoxon Sign-Rank test. P-values less than 0.05 were considered significant. All statistical analyses were conducted with the International Business

Machines (IBM) Statistical Package for Social Sciences (SPSS) version 27 (IBM Corporation, Armonk, New York).

3.0 Results

Twelve experienced nurses (100% female) completed the study. Due to system connectivity issues and poor gaze sampling quality, four eye-tracking files were excluded from the analysis. Thus, the remainder of this section will report results from the remaining eight participants.

3.1 Demographics

All remaining participants were currently in practice at the time of the study (13.5±11.3) years in practice), and the majority of nurses (88%) were working 36 hours or more and were trained in advanced cardiac life support at the time of the study. There was an even distribution of participants in the following age ranges: 18-29 years (n=2), 30-39 years (n=2), 40-49 (n=2), and ≥ 50 years (n=2). All participating nurses had obtained a Bachelor's of Science in Nursing, and 25% had obtained Master's of Science in Nursing.

3.2 Detection of the Problem

Key results from problem detection, differentiation, and decision phases can be found in Figure 3. Following the onset of the patient's stroke, nurses' time to first fixation was lowest for the patient's eyes (8.1 seconds±8.7).

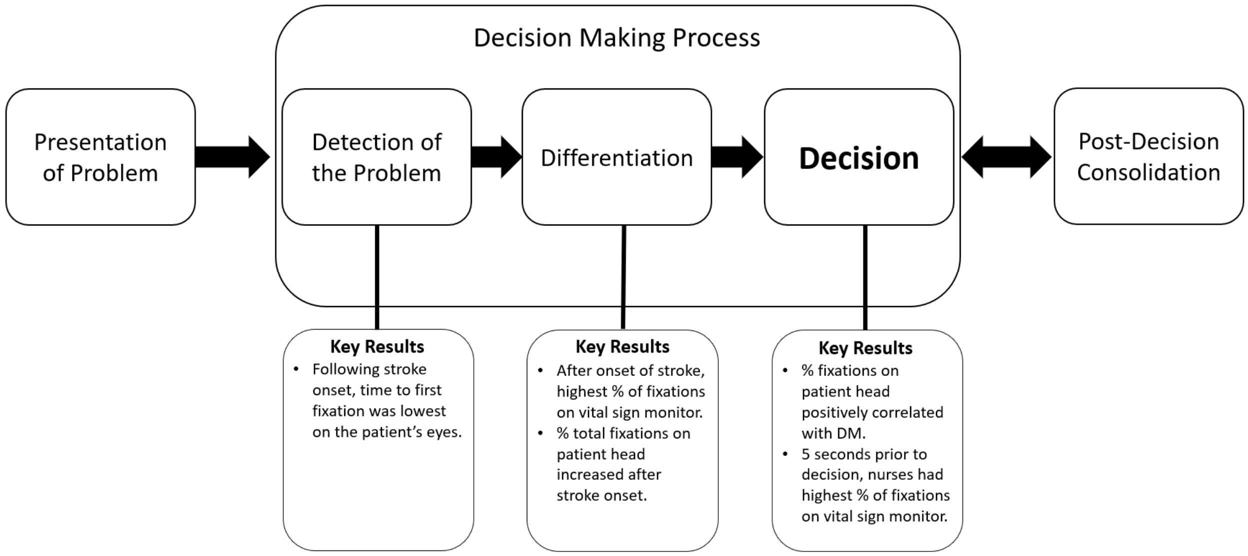

Figure 3. Key Results by Decision Phase

3.3 Differentiation of Task-Relevant Stimuli from Irrelevant Stimuli

During the initial patient assessment, nurses had the highest percentage of total fixations on the vital sign monitor (Figure 4). Similar to the initial patient assessment, participants had the highest percentage of fixations on the vital sign monitor following the onset of the stroke (Figure 5).

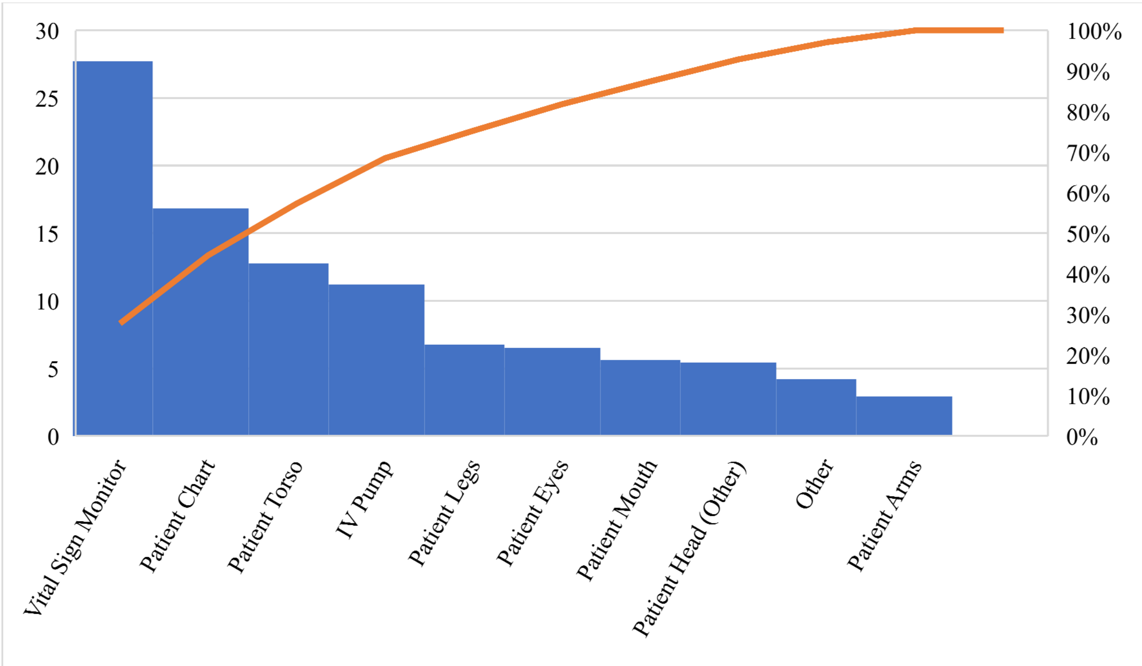

Figure 4. Percent Total Fixations during Initial Patient Assessment

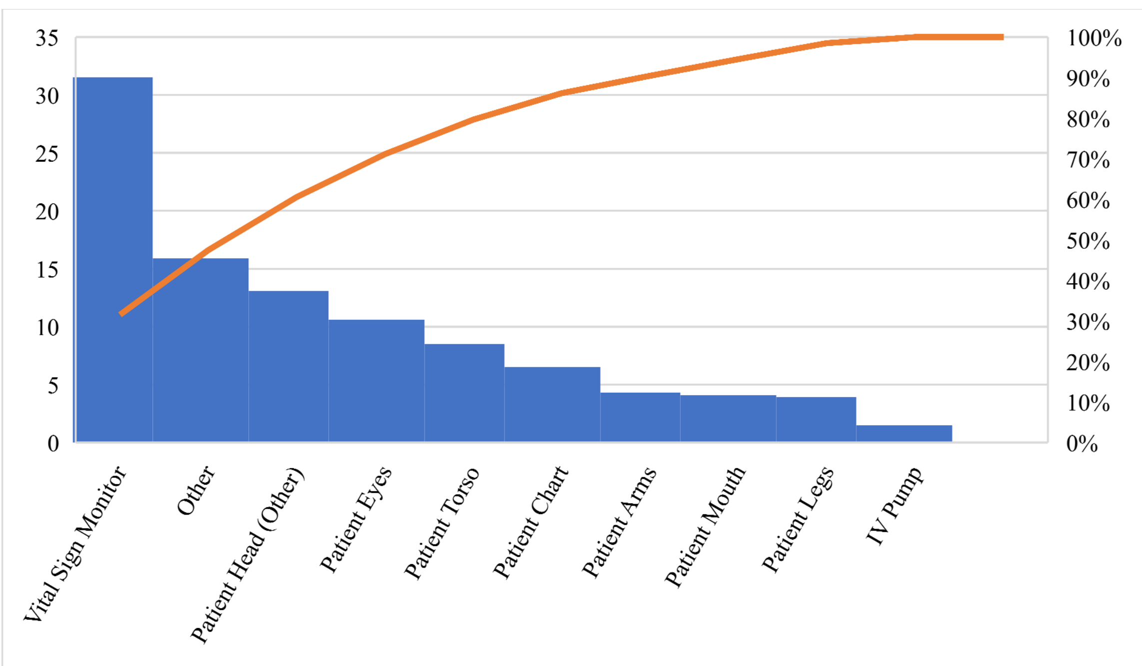

Figure 5. Percent Total Fixations after Change in Status

In order to determine how experienced nurses' visual fixation changed over the course of the scenario, eye-tracking metrics were compared between the initial patient assessment phase and the change in status phase directly. We found that nurses' percentage of visual fixations on the patient head significantly increased over time (5.46±3.77 vs. 13.14±13.15, $p = 0.04$). Similarly, we found that the percentage of visits significantly increased from the initial patient assessment to the change in status on the patient's head (5.79±4.07 vs. 12.2±14.87, $p = 0.04$) and mouth (1.4±1.7 vs. 3.51±2.78, $p = 0.04$), specifically. Conversely, percentage of visits on the patient chart significantly decreased over the scenario (18.75±15.65 vs. 5.89±6.44, $p = 0.04$). Lastly, average visit duration significantly increased during the scenario on the patient's mouth (0.29±0.19 vs. 0.42±0.25, $p = 0.046$) and torso (0.24±0.08 vs. 0.61±0.43, $p = 0.03$).

3.4 Decision

For those nurses that did explicitly recognize the patient's stroke (i.e., N = four nurses out of eight), the highest percentage of total fixations from the change in the patient's status to recognizing the stroke were focused on that patient's vitals (Figure 6). Furthermore, for those nurses that explicitly recognized the stroke, the highest percentage of total fixations within five seconds of indicating the patient was suffering from a stroke was on the vital sign monitor (Figure 7).

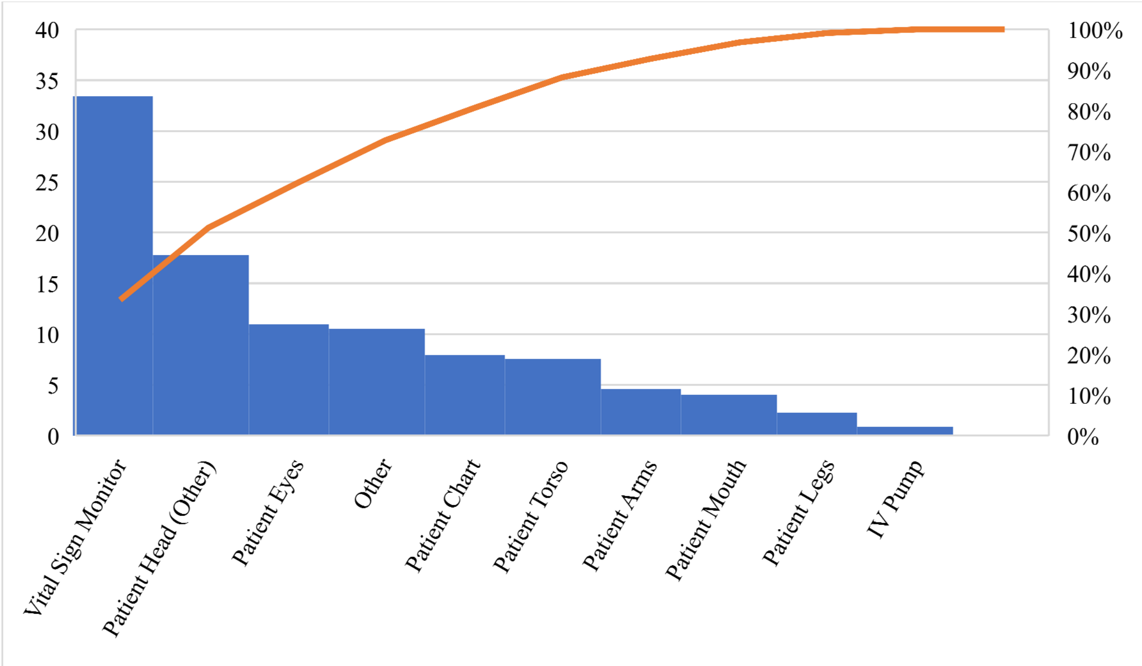

Figure 6. Percent Total Fixations Recognition of Stroke

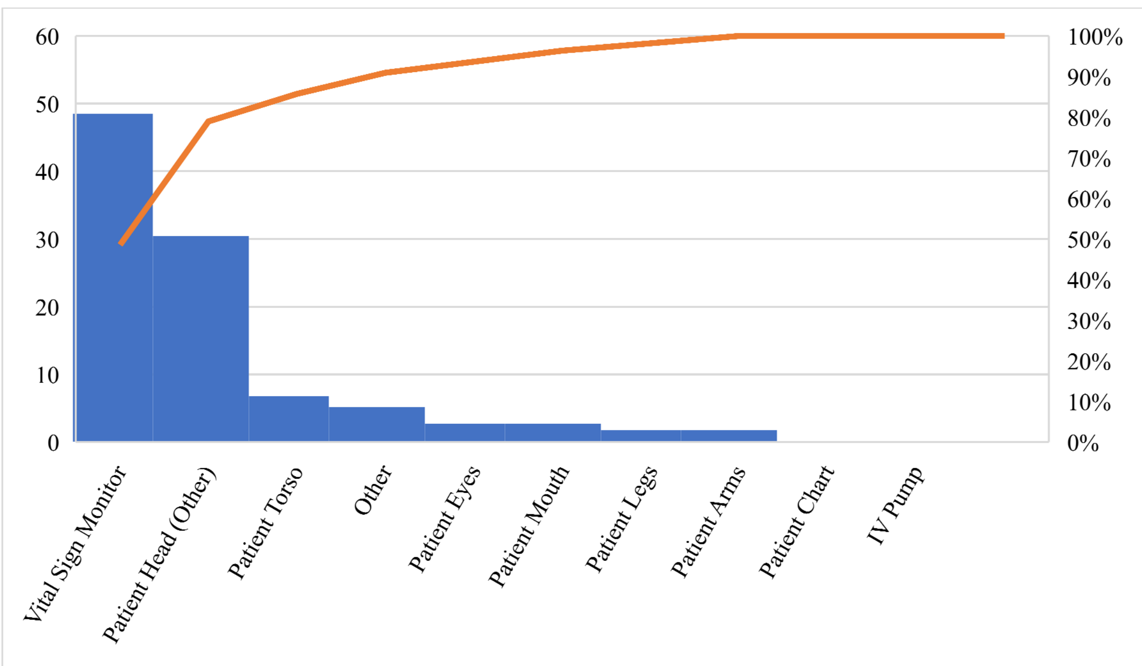

Figure 7. Percent Total Fixations -5s Prior to Stroke Recognition

Furthermore, we found several significant correlations between eye-tracking metrics and Lasater clinical judgement rubric ratings. Importantly, during the initial patient assessment, average visit duration on the patient mouth had a significant negative correlation with overall

Lasater scores (i.e., DM) (Table 1). After the onset of the stroke, the percentage of fixations on the patient head had a significant positive correlation with overall Lasater scores, and the percentage of fixations on the vital sign monitor had a significant negative correlation with Lasater scores.

Eye-Tracking Metric	Lasater Rubric Element	R, p-value
Average visit duration patient mouth	Average score pre-stroke	R = -0.9, p=0.006
Percent of fixations on patient head	Average score post-stroke	R = 0.77, p=0.03
Percent of fixations on patient vitals	Average score post-stroke	R = -0.75, p=0.03

Table 1. Eye-tracking and Lasater rubric correlations

3.5 Think Aloud Themes

The study team members who reviewed audio transcripts from nurses' "think aloud" protocols during the scenario found several themes related to experienced nurses' DM. First, experienced nurses were adept at anticipating patient complications related to their symptoms and treatments and spent time considering and preparing for possible eventualities in patient care. One nurse exemplified this by commenting "If he hit on impact and he did go forward, he could have hit his head… he's on warfarin already. So he is more likely to have a brain bleed, especially with the actual hit and the way the car accident happened."

Nurses also prioritized the "ABCs" of patient care, which stands for airway, breathing, and circulation. For example, one nurse explained this to the patient by saying "You are going to be in isolation due to your COVID. We will be monitoring your heart. And if you experience any shortness of breath, you need to let us know. We will be watching for your O2 sats." Once the main problem was identified with a general patient assessment, nurses focused on the primary problem area. In general, it was found that experienced nurses utilize multiple sources of information to guide their patient care, primarily relying on patient cues to guide their assessment processes. Based on these patient cues, nurses ask patients relevant questions, look at relevant elements of their history, and progressively focus on problem/chronic conditions. They can also adapt their approach to patient care and respond to changes as needed. Finally, they are confident in their actions and did not always rely on the physician's orders to initiate needed assessments. For instance, upon detecting the signs of the patient's stroke, one nurse exclaimed the following "Okay, so I'm going to do a total NIH assessment and I'm going to call the rapid response nurse and I'm going to get a new set of vitals."

4.0 Discussion

In this exploratory pilot study, we aimed to use eye-tracking methods to study elements of differentiation and consolidation theory of DM when applied to nurse DM, and compare eye-tracking and think-aloud process tracing methods to determine which method can be used more effectively to study nurses' DM. According to differentiation and consolidation theory, there are several elements of an individual's DM process, which include detection of the problem, differentiation of problem-relevant information from task-irrelevant information, which ultimately lead to the decision.[6,7] Eye-tracking methods can give insights into these DM elements, as they allow researchers to study the time to first fixation on AOIs after presentation of the problem, identify AOIs participants fixate on most after presentation of the problem, and what participants attend to in the five seconds prior to the decision (i.e., the gaze cascade effect).[19] Accordingly, these are the eye tracking factors our team utilized to study nurse DM in this pilot study.

4.1 Detection of the Problem

In order to measure experienced nurses' detection of the stroke, we measured the time to first fixation on patient (e.g., torso, eyes, mouth) and diagnostic (e.g., vital sign monitor) AOIs. Following the onset of the stroke, nurses' visual attention focused on the patient's eyes first. This indicates that nurses likely examined patients for common stroke symptoms (i.e., detailed in the National Institutes of Health (NIH) stroke scale[26]) such as facial asymmetry or engaged patients in conversation to better understand their status change, as opposed to focusing on vital sign information. Thus, the primary means of stroke detection resulted from patient-related factors.

4.2 Differentiation

In regards to differentiation of decision-relevant information and irrelevant information, we studied the AOIs nurses fixated on most following the onset of the stroke and compared eye-tracking metrics from the initial patient assessment to the change in status. We found that nurses who explicitly verbalized their concern for a stroke primarily fixated primarily on the vital sign monitor, and the patient's head (i.e., in general) and eyes. Thus, these variables may be integral to nurse DM related to stroke recognition. Indeed, in addition to physical displays of stroke symptoms (i.e., facial asymmetry), the NIH stroke scale emphasizes the assessment of neurological factors such as pupillary reaction and eye movements, which may be indicative of a stroke. Additionally, the vital sign monitor presents critical diagnostic information such as increased blood pressure.

We also found that from the initial patient assessment to the change in status phase (i.e., onset of the stroke until the end of the scenario), the percentage of nurses' fixations on the patient head increased significantly over time, and the percentage of visits similarly increased significantly on the patient's head and mouth. We also found that the average visit duration increased significantly on the patient's mouth and torso during the scenario, whereas the percentage of visits on the patient chart decreased significantly. Based on this data, we have further evidence that experienced nurses narrowed their scope of assessment upon recognition that the patient's status had changed. Again, increased focus on the patient's mouth may be related to nurses gather information by asking the patient questions, and increased focus on the head in general was likely related to performance of NIH stroke scale assessments. Nurses' assessment of factors such as the vital sign monitor, patient eyes and mouth may be critical to differentiate the presentation of a stroke compared to other possible diagnoses.

4.3 Decision

Prior research on DM has suggested that a visual bias exists within five seconds of making a decision, where an individual will visually attend to the sources of information that are most salient to that decision.[18] For those nurses that explicitly verbalized their perception that the patient was suffering from a stroke, the AOIs they were focused on five seconds before their decision included the vital sign monitor and the patient head. These AOIs are critical sources of information for the recognition and differentiation that the patient is experiencing a stroke. The vital sign monitor provides critical system information that the patient's pulmonary status has changed significantly, and the patient head provides neurological status information.

In order to better understand nurses' DM process, we also assessed the correlation between eye-tracking metrics and DM. Interestingly, we found that greater focus on the vital sign monitor and the patient's mouth after the onset of the stroke had a significantly negative correlation with DM. Prior to better understanding the meaning of this finding, it is necessary to consider the nature of these AOIs. Vital sign monitors and asking information of the patient are common general sources of diagnostic information that nurses utilize to inform their DM.[10] While these AOIs certainly provide indications related to the onset of a stroke (e.g., increase in blood pressure, or the patient reporting feelings of numbness), they may also present irrelevant data that must be filtered through. Longer dwell time on these AOIs may represent inefficiency in visual scanning to identify relevant data, or poor understanding of what data means in the scope of the presenting problem. Literature has shown that a longer dwell time on an AOI may indicate that learners require more cognitive processes for data emanating from that source.[27-29] Furthermore, another study found that longer dwell time was associated with higher cognitive load when solving geometry problems, and those participants who were unsuccessful in solving the problems had higher dwell times than their successful counterparts, even on crucial sources of visual information.[30] The authors hypothesized that this difference was related to pattern recognition and encoding of visual information. Other researchers have also found that fixation duration increases as cognitive workload increases.[31,32] In the current study, it is possible that longer dwell time on the vital sign monitor and patient mouth may be related to recognition of a problem, but lack of comprehension that the problem was indicative of a stroke. Therefore, nurses spent more time reviewing vitals and communicating with the patient to gather further information.

4.4 Comparison of Eye-Tracking and Think-Aloud Protocols

Our findings of the relationship between eye-tracking metrics and DM are further supported by our qualitative analysis of nurses' think-aloud protocols. Experienced nurses initially assess patients generally and follow a standard assessment framework of the patient's airway, breathing, and circulatory systems. However, once the presenting problem is identified, nurses attend specifically to this problem and perform more focused assessments. Thus, upon recognition of the change in the patient's status during our simulation, nurses with higher DM focused their assessments on the patient's neurological status and completing tasks on the NIH stroke scale. These qualitative findings were supported by our comparison of how fixations and visits changed over the course of the scenario. Thus, it appears both eye-tracking metrics and think-aloud protocols may be effective to assess naturalistic DM like that in healthcare. That being said, several participants in the current study neglected to verbalize their thought processes about what factors were contributing to their diagnosis (e.g., neglecting to verbalize what indications led them to perform neurological assessments or call a stroke alert). This is a common limitation of think-aloud protocols, particularly among experienced workers who leverage their wealth of experience when engaging in habitual, unconscious DM processes.[13] Since eye-tracking metrics provide granular data on what sources of information are most-relevant to DM and are not subject to the same biases as think-aloud protocols, we contend that eye-tracking is a more effective way to measure nurse DM in clinical simulations.

The major limitation in our current study was our small sample size that was further exacerbated by technological impediments that led to a loss of 33% of our eye-tracking data. Technological issues with wireless sensors dependent on stable wireless fidelity connectivity are an unfortunate limitation of conducting human field studies, as simulated encounters cannot be interrupted to reconnect sensors due to potentially compromised fidelity. Furthermore, given the time constraints of experienced, full-time nurses, we did not want to stop scenarios in the event of disconnection. In some cases, our small sample size may have led us to experience a type II error in our data analysis. That being said, we still observed several significant correlations between eye-tracking metrics and Lasater clinical judgment scores, as well as significant differences in gaze variables between phases of the scenario. Another limitation to our study was our convenience sampling approach, which can introduce bias, as our sample may not be representative of the population. However, this was an intentional decision by our study team, as we desired to recruit nurses with experience in direct patient care to better understand how high performing nurse make clinical decisions. Also, despite our small sample size, the results of this pilot study are robust, and offer insights into the various phases of nurse DM.

Lastly, we acknowledge that despite the patient manikin used in our study (SimMan 3G) is among the highest fidelity patient simulators available, there are elements of stroke-related visual cues that are unable to be translated well (i.e., facial asymmetry). This factor could have been a limitation in our study, as for any ambiguous visual information, nurses were instructed to ask the preceptor for further details and could not rely exclusively on visual information for all diagnostic information. This is an acknowledged limitation of patient simulators in the literature.[33] Accordingly, our team utilized best practices in simulation to familiarize participants with the capabilities of the patient manikin to display physiological signals, instructed them to perform all assessments that they would on an actual patient, and only ask the preceptor to clarify information only after they performed a relevant assessment.[34] Despite not displaying facial asymmetry, the patient head remained a source of important information on their status during the scenario through communication and physical interactions as they simulated performing their assessment activities. Moreover, since the participants were volunteers, we believe our sample likely complied with simulation instructions and did their best to simulate real patient interactions as they would in their practice. Also, the incidence of facial asymmetry in stroke patients ranges from approximately 40-60% of patients,[35,36] so the lack of visual indicators of facial asymmetry displayed on our patient manikin is realistic. Based on these factors, we can be confident that the visual attention nurses directed to the AOIs we defined were comparable to their assessment of actual stroke patients.

4.5 Practitioner Summary

The findings from this study may be utilized by nurse educators to inform training of nursing students. By leveraging eye-tracking methods to assess students' visual attention during clinical simulations, educators may be able to determine how quickly they are able to detect patient problems, differentiate salient AOIs from irrelevant AOIs, and what AOIs are ultimately informing their decisions. The objective data derived from eye-trackers may allow educators to provide more effective feedback to students on how to better approach similar clinical situations in the future. Furthermore, it is possible that objective data from eye-tracking may inform real-time, sensor-based DM support tools.

5.0 Conclusions

Our team found that eye-tracking metrics provided several insights on experienced nurse DM. Nurses attend to general assessments to initially inform their DM and progressively narrow their scope of assessment to salient areas to further inform the diagnostic process. We found that dwell time on more general AOIs was associated with poorer DM, which may be related to poorer pattern recognition. We also found that nurses' visual attention in the five seconds before their clinical decisions may be important insight on what factors influence nurses' clinical decisions. Compared to think-aloud protocols, eye-tracking metrics could be more useful assessments of nursing student DM and understanding, and help educators identify whether or not students are attending to critical sources of information for an adequate amount of time or if they are dwelling too long on irrelevant sources of information.

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