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Dynamic modeling of patient and physician eye gaze to understand the effects of electronic health records on doctor-patient communication and attention

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Abstract

Objective—The aim of this study was to examine eye gaze patterns between patients and physicians while electronic health records were used to support patient care.

Background—Eye gaze provides an indication of physician attention to patient, patient/ physician interaction, and physician behaviors such as searching for information and documenting information.

Methods—A field study was conducted where 100 patient visits were observed and video recorded in a primary care clinic. Videos were then coded for gaze behaviors where patients' and physicians' gaze at each other and artifacts such as electronic health records were coded using a pre-established objective coding scheme. Gaze data were then analyzed using lag sequential methods.

Results—Results showed that there are several eye gaze patterns significantly dependent to each other. All doctor-initiated gaze patterns were followed by patient gaze patterns. Some patient-initiated gaze patterns were also followed by doctor gaze patterns significantly unlike the findings in previous studies. Health information technology appears to contribute to some of the new significant patterns that have emerged. Differences were also found in gaze patterns related to technology that differ from patterns identified in studies with paper charts. Several sequences related to patient-doctor- technology were also significant. Electronic health records affect the patient-physician eye contact dynamic differently than paper charts.

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Authors' Contributions

All authors provided: 1) substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; 2) drafting the article or revising it critically for important intellectual content; and 3) final approval of the version to be published.

Statement on Conflicts of Interest

The authors have no competing of conflicting interests to report.

Conclusion—This study identified several patterns of patient-physician interaction with electronic health record systems. Consistent with previous studies, physician initiated gaze is an important driver of the interactions between patient and physician and patient and technology.

Keywords

Health Information Technology; Communication; Primary care encounter

INTRODUCTION

To improve health systems outcomes such as cost, efficiency, and access to patient information [1], there is national support for the widespread implementation and adoption of electronic health record systems. However, little research has evaluated the effects of these technologies on interactions between the patient and physician using dynamic methods. Several studies found that computers and health information technologies do affect physicians' communication quality [2], cognitive functioning [3] and the ability of patients and physicians to build rapport and [4] establish emotional common ground. However, while the results from these studies indicate that there may be negative consequences that are the result of electronic health records, EHRs, the methods used to study the interactions do not provide enough evidence to describe exactly how the EHRs affect patient- physician interaction or what design guidelines for EHRs should look like. The study described in this paper illustrates the use of a dynamic analysis of patient and provider interaction with EHRs to answer key research questions 1) What is the nature of patient/ physician communication when electronic health records are used and 2) What is the influence of EHR use on patient-physician communication dynamically? To study these questions gaze, or where an individual looks or focuses the direction of their eyes, is used to understand communication between patients and providers, and their attention to the EHR.

Gaze is used to understand communication for two purposes, first gaze provides a more objective and measureable indication of attention and communication, and second gaze is an attribute that can inform design guidelines. Many health communication studies focus on verbal communication to understand interactions between patients and physicians. These studies often focus on information flow [5] and comprehension, and emotional variables such as empathy [6]. Nonverbal communication is more recently being explored as an important aspect of communication. From a system design perspective, nonverbal communication is very useful for understanding important variables related to designing user or human-centered systems. For example, posture and body language can provide indications of comfort or satisfaction, facial expressions can provide more objective assessments of satisfaction or emotional state, and eye gaze can illustrate attention to people or other artifacts. Another benefits of exploring nonverbal communication is that findings related to some nonverbal behaviors can inform design guidelines. For example, technologies can be designed to afford pre-described levels of visual attention that might be necessary for optimal human performance or communication outcomes. If we find that physicians should make eye contact with patients for at least 50% of a clinical visit to influence care outcomes such as patient satisfaction, perception of physician empathy or comprehension of information, we should be able to design technologies that do not inhibit the physician's ability to make eye contact at that level.

Many studies focus on how the clinician's nonverbal behavior affects the patient's perspective, such as patient satisfaction [7]. However, there is a growing awareness of the value of nonverbal communication; more and more studies have focused on quantitatively evaluating nonverbal behavior. Coding system for nonverbal interaction have been developed, such as Nonverbal Communication in Doctor-Elderly Patient Transactions (NDEPT) [8], Nonverbal Accommodation Analysis System (NAAS) [9], Relational Communication Scale for Observational Measurement (RCS-O) [10], and instruments used in studies of the effects of physician gender on nonverbal behavior [11]. Although several coding system have been made, developing a validated methods and reliable analysis tools are still needed to evaluate nonverbal communication in clinician-patient relationship [12].

While understanding the threshold of visual interaction needs is important, it may be that nonverbal communication is better understood dynamically rather than in terms of thresholds. Using the example above, it may be that patient's need to receive physician eye contact at certain intervals or in response to certain behaviors rather than simply 50% of the encounter. By understanding the important interactions, redesign may be in the form of design requirement for technology and/ or in the form of training. With an observable state such as emotion, it is less common for an individual to have a single emotion for an entire encounter; also individuals can often influence another individuals’ emotional state either positively or negatively by expressing emotion during moments when the other individual would likely be most receptive. In these cases, to understand emotion, you would want to understand when the emotional state changes and the events that trigger the change, the events that influence the emotion are also the points that can lead to redesign or training. The study described in this paper focuses on gaze, but similar approaches can be used to understand the effects of other interactions that contribute to patient outcomes such as emotion.

Eye gaze patterns have not been dynamically evaluated in primary care settings where health information technologies are used. Lag sequential analysis is an appropriate method to assess eye gaze patterns dynamically, this approach has been validated in previous studies with patients and care providers [13]. In these studies doctor-patient eye gaze patterns in paper-based clinical settings were evaluated [13]. The results showed that doctor's gaze patterns are followed significantly by patient gaze patterns, for instance if doctor gazed at the patient, the patient gazed back at the doctor. However, the study also showed that there were no significant associations between patient gaze patterns and doctor gaze patterns when gaze was initiated by the patient. In other words, when the patient gazed at the doctor, it was unlikely that the doctor would gaze back to the patient. In the referenced study, the encounters were all new patient visits- there was no prior relationship between patients and doctors- and there was no computer (EHR) in the clinic room. In the present study, we will evaluate doctor-patient eye gaze patterns in computerized settings, where EHRs are used, to understand the effects of the EHR on doctor-patient eye gaze patterns.

The purpose of this study was to better understand the effects of health information technology (HIT) use on physician-technology, patient-physician, and patient-technology interactions. This study used field research methods with quantified ethnographic techniques, where observational data from video were reduced to codes of behaviors. Data from codes were used to build sequential models where hypotheses could be tested. The results are in the form of sequential models of patient, physician, and HIT interaction. The primary research questions for this study were: 1) How is the doctor's gaze related to the patient's gaze in computer mediated health encounters? and 2) How is the patient's gaze related to the doctor's gaze in computer mediated encounters?

METHOD

Sample (Participants)

One hundred patients and ten doctors participated in this study. Patients who received care in primary care clinics with their primary care doctors were invited to participate in the study. Visits were recorded using three high-resolution video cameras. Each camera was placed at a different angle—one wide angle and two close-up views of patient and physician faces respectively. All three videos were synchronized (by video and sound) and combined to form one single multichannel video. This multichannel technique was used to accurately capture gaze and avoid ambiguity of the gaze direction caused by a single camera angle. Furthermore, several steps were also taken to minimize Hawthorne effect, which is the possibility of altering behaviors of participants due to the being observed or video recorded. The video cameras were set up unobtrusively, and participants were told to behave as naturally as possible during the visit. These steps also diminished possible Hawthorne effect in our study. It was also reported in the literature that video cameras have been shown to influence participant behavior far less than a human observer, so video method limits the Hawthorne effect (Pringle 1990, Penner et al. 2007). Pringle [14] also found out that there was no significant difference in doctors' behavior between video recorded and unrecorded consultations.

Participants were recruited in five different primary care clinics in the Midwestern region of the United States. Informed consent was obtained from all participants, both patient and doctor participants. The study procedure and activities were approved and monitored by university and clinic Institutional Review Boards (IRB). Health Insurance Portability and Accountability Act (HIPAA) regulations were fulfilled. Doctors' participation involved agreeing to have their visits with patients video and audio recorded. New patients were not recruited for this study, to mitigate the potential effects of first time encounters and the differing processes that are used for new patients as opposed to existing patients. After physicians provided consent, their patients were invited to participate a week prior to the data collection data. All patient participants received a letter from their primary care provider and the project PI inviting them to participate. The letters also included an opt-out postcard that could be mailed to the research team should the patient decline participation and request that they not be contacted for research studies when they arrived for their appointment. On the day of their visit, patients provided informed consent, and their entire clinical visit was recorded.

Demographic characteristics were collected from doctors and patients. Patient ages ranged from 18-65 (M 45.21, SD 13.3) and were relatively dispersed across age groups with 19 participants ages 18-29, 14 ages 30-39, 20 ages 40-49, 31 ages 50-59, 15 ages 60-65, and one who did not provide an age. 56 male and 44 female comprised the patient group. Patients' reported having a relationship with their physicians from 1 to 37 years. Due to language barriers, participants who did not speak English during the visit or who preferred to speak another language with their care provider during the visit were not recruited, so all visits were conducted in English. Participants who discussed or planned to discuss socially stigmatizing conditions such as substance abuse, illegal activity, abortion or mental illness were also excluded from participating in the study and were not recorded. Six male and four female doctors volunteered to participate in the study (mean [M] = 47.6 years old) and had been practicing family medicine for 5 to 37 years. The recruited doctors reported using computers in clinical consultations for 3 to 10 years. The same EHR systems were used in all 100 visits; in addition paper charts were also used in 76 of the 100 visits. We used 10 different exam rooms for video recording in total, since each physician uses a different room for their care process. However, all of the exam rooms had similar settings regarding the location of the EHR, physician seat and patient seat. All EHRs' screens are located on the wall between patient and the physician and facing towards them. All the screens also have the ability to be moved around by the physicians.

Coding doctor-patient eye gaze patterns

Coding is the process of reducing complex data into measurable units; in this study the complex data were human-human and human-technology interactive behaviour from videos. A coding scheme was adapted from a previous study [13] and modified to explore eye gaze behaviours in the current study. The coding scheme included doctor-gaze-patient (DGP), doctor-gaze-EHR (DGT), doctor-gaze-chart (DGC), doctor-gaze-other artifacts (DGO), doctor-gaze-unknown (DGU), patient-gaze-doctor (PGD), patient-gaze-EHR (PGT), patient-gaze-chart (PGC), patient-gaze-other artifacts (PGO), and patient-gaze-unknown (PGU). The behaviors by the same subject (doctor or patient) were mutually exclusive. In the coding scheme, "chart" referred to documents with information about the patient or notes written by the clinician during the encounter. "Other artifacts" were the objects in the room, including chairs, exam table, sink, medical tools, magazines, etc. "Unknown" included two situations: (a) the coder could see the subject's eyes but was not able to specify the object (this also includes situations when the subject is moving and looking somewhere while thinking), and (b) the subject gazed at part of the patient's body that was not the face, such as the foot, or back.

Each video was coded temporally for the entire visit length (see figure 1 for an example). Doctors' and patients' eye gaze behaviours were coded separately, meaning coders coded the video in its entirety for patient behaviours and then again for doctor behaviours. Start and stop times for each code were annotated using the software Noldus Observer XT, which calculated the start and stop times, duration, and simultaneous occurrence of codes (i.e. codes that occurred at the same time). For instance, the behaviour "patient gazing at doctor" was coded using the patient's behaviour of when the gaze began and ended temporally. However, variables, such as eye contact were the combination of patient gaze and doctor and doctor gaze at patient, these combination variables were calculated in the software. The physical exam component of the visit was not included in the analysis.

Each coder was trained with seven practice videos in total. Coding a video is time demanding, as it takes 1-1.5 hours to code a single video (typically 15 minutes). When the coder achieved at least a 0.60 Kappa reliability score, they were allowed to code research data. According to the literature, a Cohen's Kappa value of 0.60 is standard and above 0.75 is considered an excellent value [15]. To maintain inter-rater reliability all coders coded a single reliability video each week. A lead coder would evaluate videos for reliability using a conservative threshold of one second (meaning any code that deviated by one second or more from another coder was not counted as congruent and thus the reliability was reduced). At the end of the week, the video was discussed in detail and reliability scores were compared to maintain a reliability value score above 0.60. The average value of Cohen's Kappa coefficient of all the reliability – check videos was between 0.60 and 0.79.Inter-rater reliability scores were calculated conservatively at one-second levels. Throughout the coding process videos were randomly checked by members of the research team to assess reliability.

Behavior Patterns and Contingency tables

Behavior patterns were identified and analyzed based on the research questions. The first group of behaviors was doctor–initiated patterns (i.e., the doctor's gaze preceded the patient's gaze). The second group of behaviors was patient-initiated patterns (i.e., the patient's gaze preceded the doctor's gaze). Each group had six sequential behaviors patterns (Table 1).

To identify the gaze behavior patterns in the encounters, lag sequential analysis was used [16, 17]. This approach has two different methods- event and time based methods, which were both used in this study. The first step was to generate contingency tables based on each method. For the event-based method, the coded behaviors were considered discrete events that occurred at their start time with durations ignored. After transforming the coded data to reflect this approach, contingency tables were generated by counting the frequency of behavior pairs. For example, if DGP (doctor gaze at patient) is considered an initial behavior, then the frequency of PGD (patient gaze at doctor) as a response behavior (which happened right after DGP) could be counted. The aim of generating the event-based lag contingency table was to determine the frequency of sequential behaviors. Each individual encounter has two event-based contingency tables; patient's behavior following the doctor's behavior, and doctor's behavior following the patient's behavior. All one hundred encounters were pooled into one contingency table for both doctor initiated and patient initiated patterns. Finally, there are two event-based contingency tables for all data.

For the time-based method, two pooled contingency tables were generated (patient initiated and doctor initiated). For these two tables, we used six-second time intervals, which are typically used for averaging human interaction data [18]. In other words, Lag 0 represented the moment the initial behavior occurred and Lag 1 represented the first gaze behavior of the other participant that occurred 0 seconds to 6 seconds after Lag 0. Therefore, there were two main contingency tables for time- based lag analysis for all data. In the case of time-based

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contingency tables, a new behavior category was added to the table—“no action,” which meant that no behavior was recorded for the target participant during that time period [13].

Data analysis

Lag-sequential analysis is a technique for finding which events follow others at specified times and frequencies greater, or lower, than chance [13, 19, 20]. Lag sequential analysis methods are comprised of several statistical techniques, such as the likelihood ratio chi-square test and fitting a general log-linear model to the contingency tables [21]. An initial likelihood ratio chi-square test was conducted for each generated table to determine whether the cell behavior values were independent or not. The significant value represents the dependency of the sequential behaviors to each other. Once the chi square test is significant, the next step was to calculate conditional probability and adjusted residuals for each table cell. This step identified specific behavior pairs that show a strong association in terms of initial-response sequence and then conditional probability were calculated using the observed value [13]. Adjusted residual parameters, which compare the observed value with the expected value, were used to identify whether the sequential behavior was significant or not, assuming independence. An adjusted residual above 2.58 ($\alpha = .01$) was used as a critical value indicating significant association between the initial behavior and the response behavior [13]. In other words, a cell with an adjusted residual above 2.58 was considered significant. We were not interested in significant negative residual values (or values less than negative 2.58) as we were only interested in positive linkages between the behaviors. As a last step, Yule's Q [22] was used to estimate the strength of the association between the behavior pairs. Yule's Q value ranged from −1 to 1, with negative values indicating negative association of the two behaviors (i.e. the response behavior is not likely to happen given the initial behavior), zero indicating weak association (i.e. the occurrence of the two behaviors is random), and positive values indicating positive association (i.e. the response behavior is likely to happen given the initial behavior) [22].

RESULTS

Overall Duration of eye gaze behaviors

Percentages for each behavior patterns investigated in the study are illustrated in table 2. Visit length was defined as the total length of visit time excluding the physical exam period. Physical exam period includes hands on activity of doctors at patient table and had minimal use of EHRs and minimal amount of communication (eye gaze patterns), and physical exam period time might vary based on the visits. To have more accurate percentage values and focus on communication time, we excluded the physical exam period in our calculations. In table 2, the eye gaze behaviors were depicted in terms of percentage in the visit length period (%). Table 2 represents the average measures of one hundred visits for both duration and frequencies of the behaviors. The potential effect of patient age on patient gaze at computer behavior was explored, since there are a wide range of patient age (18-65). The results showed no significant relationship between patients’ age and patient gaze at computer ($p=0.608$).

Event-Based Lag Sequential Analysis

The likelihood ratio chi-square was 2018.52 (df = 25) for the doctor-initiated table and 543.44 (df = 25) for the patient-initiated table. Both estimates exceeded the 0.01 critical values of 21.67, so cell values in both tables were not distributed by chance and were significant. The event-based lag sequential analysis results are illustrated in Table 3, highlighted values indicate significant association. In doctor-initiated patterns, all the initial response behaviors indicate significant connection. Interestingly, the patient-initiated patterns also showed some significant eye gaze patterns, which differs from previous studies [13]. PGU (patient gaze unknown), PGO (patient gaze other artifact) and PGC (patient gaze chart) have significant association with proposed sequential behaviors (DGU-doctor gaze unknown-, DGO-doctor gaze other artifact-, and DGC-doctor gaze chart). In addition, there is an effect of technology on eye gaze patters (PGT-DGP and PGD-DGT sequences are significant). Yule Q values for each behavior patterns are illustrated in figure 2.

Time-Based Lag Sequential Analysis

The likelihood ratio chi-square test was significant for both doctor-initiated and patient-initiated patterns (1139.30, 491.87, respectively). Table 4 indicates the values estimated for both doctor-initiated and patient-initiated patterns within 0-6 s. For doctor-initiated patterns, similar significant eye gaze patterns were obtained as in event-based lag analysis. However, in the patient–initiated patterns, a new significant pattern emerged which is different than event-based analysis (PGT-DGT). In other words, doctor gaze at EHR significantly followed patient gaze at EHR within the first 6 seconds.

Discussion

The results in table 2 report overall eye gaze durations per visit. Doctors gazed at patients for 46.52% (SD: 17.3%) of the visit length; however patients gazed at doctor for 50.37% (SD: 18.8%) of the visit length. Table 2 also illustrates that both doctors' and patients' gaze at the EHR; doctors spent 30.70% (SD: 16.8%) of the visit length gazing at the EHR, while patients gazed at the EHR 11.52% (SD: 12.2%) of the visit length. It is important to note that there are several "0 %" patient gaze at EHR cases.

These results show that doctors spent approximately one third of the visit length interacting with EHRs. Doctors also used paper charts during 79% of the visits; "doctor gaze chart" occurred 8.75% of the visit length on average. Patient gaze unknown accounted for 28.69% of the visit length. The unknown gaze might occur in several situations; a) when the doctor uses the computer the patient might disengage eye contact with the doctor and the gaze would therefore be coded unknown, b) some patients do not gaze at the doctor while talking to doctor and instead gaze at an unknown object or wall while talking. Furthermore, the frequencies for each eye gaze pattern are reported (Table 2). Frequencies represent the number of times the gaze occurred regardless of the duration of the gaze.

In the event based lag analysis, all doctor initiated patterns with the same modifier were significant and were significantly followed by patient eye gaze patterns, in other words patients always followed the doctor gaze, for instance, if doctor gazed at a modifier, patient also gazed at the same modifier which indicates that doctors' behaviors lead patients' behaviors in the interaction. Similar results were found in previous studies, where patient gaze and eye contact between patients and doctors are influenced by physician-initiated interactions [13]. This indicates that interventions such as redesign or training directed at the physician are likely to be successful in influencing patient behaviors and the dynamics of the encounter [23]. Doctor initiated behaviors were also significantly followed by patient gaze behavior when technology was included in the interaction; when the doctor gazed at the EHR, the patient also gazed at the EHR (regardless of whether or not the patient could see or understand the presented information). This may indicate that doctors can efficiently engage patients in activities such as screen sharing by simply looking at the screen from an angle where patients can also see the screen. Alternatively, without EHR designs that are intuitive for patients to follow the information or understand, these interventions are not likely to be successful in increasing patient understanding or common ground with the physician. In previous studies of patient-physician gaze dynamics [13] the patient initiated eye gaze behavior were not significantly followed by doctor's eye gaze behavior, however in this study with electronic health records several sequences are significant: PGD-DGT (patient gaze doctor-doctor gaze technology), PGT-DGP (patient gaze technology-doctor gaze patient), PGC-DGC (patient gaze chart-doctor gaze chart), PGO-DGO (patient gaze other artifact- doctor gaze other artifact), PGU-DGU (patient gaze unknown-doctor gaze unknown).

The sequence patient-gaze-doctor and doctor-gaze-technology may indicate that doctor interactions with technology are prioritized over interactions with the patient (such as eye contact). This sequence could also indicate the process of patients asking questions from the doctor and the doctor retrieving the answer from the EHR or documenting information in the EHR. In the latter example, we would expect to see patient gaze at doctor and then doctor gaze at patient, then doctor gaze at technology.

The sequence patient-gaze-technology and doctor-gaze-patient is also unexpected because we typically expect either the patient to gaze at the technology and the doctor to also share in that interaction by gazing at the technology as well. However, patient gaze at technology followed by doctor gaze at patient may indicate a failed opportunity to use the EHR as a shared artifact. Some potential interpretations of these results are that doctors, 1) do not notice that patients are looking at the EHR, 2) do not see value in inviting patients to look at the electronic record or 3) are actively preventing patients from looking at the EHR. Few studies exist to explore physician behaviors regarding sharing information with patients using the EHR. For instance, a study indicated that when physicians share information visually from the EHR monitor, patient satisfaction and patients' involvement in the decision-making process improves [24]. Furthermore, interestingly, we see the pattern we would expect with PGC-DGC or patient gaze chart- doctor gaze chart. In this pattern, the doctor's gaze moves to the artifact the patient is gazing at (the chart). This may indicate differences in the electronic interface that prevent doctors from engaging in shared interactions with the EHR in the same ways they would with a chart. Similar patterns are found when patients gaze at other artifacts; PGO-DGO is also a significant sequence, and when patients gaze at other artifacts, the doctor's gaze follows.

Another explanation for the significantly followed patient initiated gaze patterns is that the physicians in this study had a prior relationship with their patients and may have been more aware of and responsive to patient nonverbal communication cues. Similar significant patterns for doctor-initiated behaviors were found using the time based lag analysis. However, with time based analysis (the only addition is that events occur within 6 seconds) DGU-PGD is significant, where doctors gaze unknown and patients gaze at the doctors. With the patient-initiated time based analysis, another interesting finding is that PGT-DGT (patient gaze technology-doctor gaze technology) and PGT-DGP (patient gaze technology-doctor gaze patient) are significant. This may indicate that while the immediate significant sequence for PGT-DGP, physicians may subsequently gaze at the technology as well. In this case, patients may look at the technology, then doctor looks at the patient and then they both engage in shared gaze at the technology.

There have been studies of patient-physician interaction and primary care physician communication patterns in paper-based primary care settings [25-27] [5]. These studies report the importance of physicians' communication skills and indicate that physicians with strong communication skills are able to better understand patient problems and better able to develop the therapeutic relationship necessary for its management [28]. One study in paper based environment also showed that when the physician looks at the patient for a greater percentage of appointment time, this is associated with greater patient satisfaction [25]. While the results of this study did not look specifically at patient reported outcomes such as satisfaction, our findings do show that physician gaze is associated with objective patient behaviors such as gaze at physician and patient engagement with the electronic medical record. Increasing patient behaviors such as eye contact and engagement with electronic records, may serve as a mechanism for outcomes such as patient understanding, relationship building, and satisfaction.

The integration of computer into the primary care exam room has also created opportunities to compare physician-patient communication in paper based and computer based environments. One study indicates that computers may change the ways doctors communicate with patients, decrease the amount of eye contact with patient and influence the doctor's body posture towards the patient [29]. Our study validated these findings by indicating that EHR use does affect nonverbal communication patterns that doctors may use, but also patient nonverbal communication patterns. On the other hand, Karsh et al. (2004) found that EHR users have higher satisfaction with their medical records than paper record users, although computer use might serve as an interruption that negatively affects clinicians' ability to actively attend to patients [30]. Our study illustrates that EHRs may serve as an interruption for physicians, but it may also serve as an opportunity for shared engagement when shared with patients. Another study also indicates that there is still paper record use persistence to complete the work by health care providers in institutions, which have adopted computerized systems, and this study listed several factors that contribute to health care providers use of paper records instead of EHRs [31]. Our results illustrate the persistence of paper, as 79% of encounters involved some form of a paper record. The continued use of paper records can contribute to inefficient system workflows and may also be an indicator of EHRs that are not effectively designed with the care provider's needs in mind.

Limitations

This study has several potential limitations that should be noted to improve future studies. First the study was conducted with care providers who all used the same EHR system, different results may be found with other EHR systems. The study was conducted with a relatively small sample of physicians; future studies should consider increasing the sample of providers. Visits where sensitive topics may have been discussed were excluded from the study per human subjects and privacy concerns. Visits where topics such as depression, or socially stigmatizing behaviors have been discussed may have very different interactive dynamics.

Conclusion

This study identified several patterns of patient-physician interaction with electronic health record systems. Consistent with previous studies, physician initiated gaze is an important driver of the interactions between patient and physician and patient and technology. For example a qualitative study of patient physician computer interactions found that when computers are introduced in clinical settings, physicians integrate these into their existing ‘good; or ‘poor’ communication strategies [32]. This provides some support to the potential power of simply training physicians to induce desired gaze behaviors for the patient and the dynamic of the encounter. Training approaches might also encourage patients to view their information in the EHR, but care should be taken to provide interfaces that will benefit patients (e.g. that they can see the information and understand its meaning in their care).

These results also show that patient-initiated gaze behaviors are significant in certain circumstances, particularly when technology and charts are used. This may indicate that patient initiated initiatives to generate common ground or information sharing might also be effective when artifacts are used. More research is needed in this area, as despite assumptions patients still not as active in encounters (e.g. speaking, asking questions) as expected [33]. These results provide some support for the potential utility of information and screen sharing to be included in the patient/ physician/ technology communication dynamic.

Physician gaze largely influences patient gaze in the primary encounter, which means that any intervention that influences physicians to focus on technology will subtract from patient-physician eye contact and any intervention to increase eye contact, or EHR information sharing, will likely need to be targeted to the physician. These findings illustrate the importance of designing work systems that allow and encourage physicians to be patient centered.

Glossary

Doctor	Patient	Code definition
Doctor gaze patient (DGP)	Patient gaze doctor (PGD)	Gaze at the other person in the encounter either the doctor or patient.
Doctor gaze chart (DGC)	Patient gaze chart (PGC)	Gaze at “chart”, which are documents with information about the patient or notes written by the clinician during the encounter.

Doctor	Patient	Code definition
Doctor gaze other artifact (DGO)	Patient gaze other artifact (PGO)	Gaze at “other artifacts” which are the objects in the room, including chairs, exam table, sink, medical tools, magazines, etc.
Doctor gaze unknown (DGU)	Patient gaze unknown (PGU)	(a)the coder could see the subject's eyes but was not able to specify the object, or (b)the subject gazed at part of the patient's body that was not the face, such as the foot, or back.
Doctor gaze technology (DGT)	Patient gaze technology (PGT)	Gaze at the computer or electronic health record.

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Highlights

- Electronic health records (EHRs) affect doctor-patient gaze differently than paper.
- Differences occur between doctor-initiated and patient-initiated gaze patterns.
- Understanding eye gaze patterns contributes to future EHR designs which can create more effective doctor-patient interaction.
- Eye gaze effects on patients can be written into physician training guidelines.

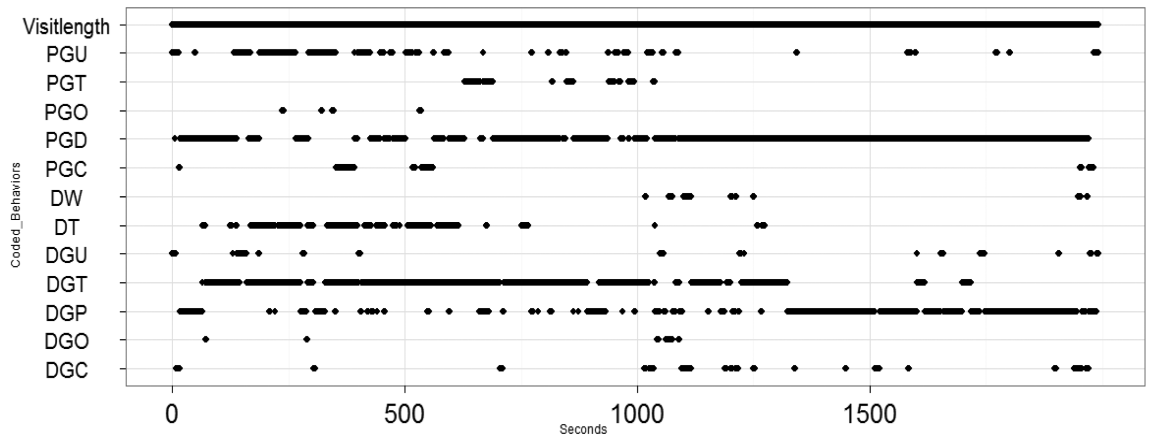
Summary Points

What was already known on the topic?

- The EHR is a tool in health care which has the purpose of enabling health care workers to provide more effective, efficient, coordinated care.
- The EHR in the exam room affect physicians' communication quality, cognitive functioning and the ability of patients and physicians to build rapport, and establish emotional common ground.
- Eye gaze provides a more objective and measureable indication of attention and communication, and is an attribute that can inform design guidelines.
- Lag sequential analysis is an approach to identify how behavior pairs follow each other significantly.

What has this study added to our knowledge?

- EHRs affect physician–patient eye gaze patterns differently than paper chart visits.
- There are differences in doctor initiated gaze patterns and patient initiated gaze patterns in the visits involving EHRs.
- Understanding dynamic nature of eye gaze patterns contributes to future EHR designs which can create more effective doctor-patient interaction.
- Understanding physicians' eye gaze patterns and their effects on patients can contribute to more effective provider training guidelines.



Legend: DW = “doctor writing” DT = “doctor typing”. **Note:** Time duration is in “second” unit.

Figure 1.

DW = “doctor writing” DT = “doctor typing”. **Note**: Time duration is in “second” unit.

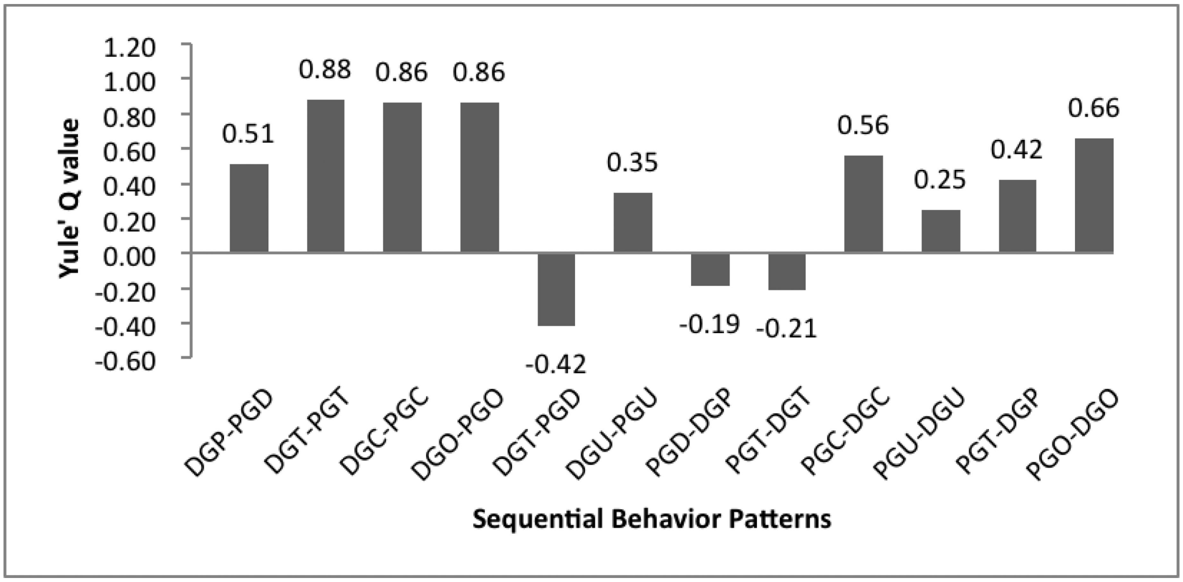


Figure 2.
Yule's Q for sequential behavior pairs.

Table I

Behavior patterns investigated in this study.

Pattern	Sequential behavior pair	
	Initial Behavior	Response Behavior
Doctor initiated patterns	Doctor gaze patient (DGP)	Patient gaze doctor (PGD)
	Doctor gaze chart (DGC)	Patient gaze chart (PGC)
	Doctor gaze other artifact (DGO)	Patient gaze other artifact (PGO)
	Doctor gaze unknown (DGU)	Patient gaze unknown (PGU)
	Doctor gaze technology (DGT)	Patient gaze technology (PGT)
	Doctor gaze technology (DGT)	Patient gaze doctor (PGD)
Patient initiated patterns	Patient gaze doctor (PGD)	Doctor gaze patient (DGP)
	Patient gaze chart (PGC)	Doctor gaze chart (DGC)
	Patient gaze other artifact (PGO)	Doctor gaze other artifact (DGO)
	Patient gaze unknown (PGU)	Doctor gaze unknown (DGU)
	Patient gaze technology (PGT)	Doctor gaze technology (DGT)
	Patient gaze technology (PGT)	Doctor gaze patient (DGP)

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Table II

Estimation of eye gaze parameters per visit.

	Patient's Behavior					Doctor's behavior				
Average Gaze	**PGD**	**PGT**	**PGC**	**PGO**	**PGU**	**DGP**	**DGT**	**DGC**	**DGO**	**DGU**
Percentage	50.3%	11.5%	5.9%	3.5%	28.7%	46.5%	30.7%	8.7%	2.9%	11.1%
Frequency	84.9	14.8	9.81	7.0	54.8	64.2	49.4	16.4	7.1	15.6

Note: Percentages have been calculated as the ratio between duration of behavior and visit length

PGD = Patient gaze doctor

PGT = Patient gaze technology

PGC = Patient gaze chart

PGO = Patient gaze other artifact

PGU = Patient gaze unknown

DGP = Doctor gaze patient

DGT = Doctor gaze technology

DGC = Doctor gaze chart

DGO = Doctor gaze other artifact

DGU = Doctor gaze unknown

Table III

Observed frequencies, conditional probabilities and adjusted residuals based on event-based lag sequential analysis.

Initial Behavior	Response Behavior				
	PGD	**PGT**	**PGC**	**PGO**	**PGU**
	1627	92	115	84	966
DGP	**56.40%**	3.19%	3.99%	2.91%	33.48%
	(22.459)	−20.42	−8.023	−5.83	−1.74
	629	**727**	71	85	795
DGT	27.23%	**31.47%**	3.07%	3.68%	34.42%
	−15.96	**(32.101)**	−8.841	−2.759	−0.312
	211	37	**251**	24	235
DGC	27.84%	4.88%	**33.11%**	3.17%	31.00%
	−7.576	−7.053	**(30.148)**	−2.081	−2.245
	74	13	15	**95**	93
DGO	25.52%	4.48%	5.17%	**32.76%**	32.07%
	−5.342	−4.415	−1.184	**(23.139)**	−0.95
	247	12	24	28	**255**
DGU	43.64%	2.12%	4.24%	4.95%	**45.05%**
	1.534	−8.039	−2.601	0.321	**(5.412)**
	DGP	**DGT**	**DGC**	**DGO**	**DGU**
	1322	**1033**	334	145	379
PGD	39.11%	**30.56%**	9.88%	4.29%	11.21%
	−3.379	**(5.338)**	0.456	−0.665	1.549
	512	181	59	26	26
PGT	**55.41%**	19.59%	6.39%	2.81%	2.81%
	(9.429)	−5.842	−3.665	−2.601	−8.261
	188	82	**115**	22	22
PGC	42.82%	18.68%	**26.20%**	5.01%	5.01%
	0.724	−4.317	**(12.041)**	0.577	−3.939
	106	106	14	**48**	35
PGO	37.46%	37.46%	4.95%	**16.96%**	12.37%
	−1.299	−1.299	−2.764	**(10.397)**	0.974
	779	583	164	74	**288**
PGU	38.39%	28.73%	8.08%	3.65%	**14.19%**
	−3.019	1.355	−2.939	−2.102	**(6.189)**

Note: Values in parentheses are adjusted residuals. Highlighted cells show statistical significance, $\alpha<0.01$.

Table IV

Observed frequencies, conditional probabilities, and adjusted residuals based on time based sequential analysis.

Initial Behavior	Response Behavior					
	PGD	**PGT**	**PGC**	**PGO**	**PGU**	**NA**
	2163	470	272	189	1507	2179
DGP	**31.90%**	6.93%	4.01%	2.79%	22.23%	32.14%
	(7.331)	(−7.282)	(−5.215)	(−3.326)	−0.174	−0.885
	1236	**749**	121	124	1025	1789
DGT	24.50%	**14.85%**	2.40%	2.46%	20.32%	35.47%
	(−8.272)	**(18.284)**	(−10.455)	(−4.205)	(−3.815)	(6.857)
	455	82	**299**	34	327	503
DGC	26.76%	4.82%	**17.59%**	2.00%	19.24%	29.59%
	(−2.015)	(−6.159)	**(24.951)**	(−3.246)	(−3.075)	(−2.037)
	203	34	41	**113**	172	158
DGO	28.16%	4.72%	5.69%	**15.67%**	23.86%	21.91%
	(−0.426)	(−3.983)	−0.786	**(18.887)**	−1.122	(−5.814)
	494	57	65	66	**464**	380
DGU	32.37%	3.74%	4.26%	4.33%	**30.41%**	24.90%
	(3.189)	(−7.377)	(−1.501)	(2.266)	**(8.16)**	(−6.056)
	DGP	**DGT**	**DGC**	**DGO**	**DGU**	**NA**
	1872	1515	475	223	480	2498
PGD	26.50%	21.45%	6.73%	3.16%	6.80%	35.37%
	(−2.304)	−0.504	(−1.777)	(−0.979	(−0.496)	(3.33)
	520	**450**	79	37	46	542
PGT	**31.06%**	**25.88%**	4.72%	2.21%	2.75%	32.38%
	(3.553)	**(5.943)**	(−4.054)	(−2.665)	(−7.106)	(−1.46)
	283	145	**197**	28	56	232
PGC	30.07%	15.41%	**20.94%**	2.98%	5.95%	24.65%
	−1.894	(−4.533)	**(16.991)**	(−0.593)	(−1.193)	(−6.23)
	190	134	36	**85**	61	165
PGO	28.32%	19.97%	5.37%	**12.67%**	9.09%	24.59%
	(−0.541)	(−0.840)	(−1.813)	**(13.85)**	(−2.282)	(−5.25)
	1373	1045	315	139	**425**	1818
PGU	26.84%	20.43%	6.16%	2.72%	**8.31%**	35.54%
	(−1.103)	(−1.792)	(−3.289)	(−2.900)	**(4.836)**	(2.88)

Note. Values in parentheses are adjusted residuals. Highlighted cells show statistical significance, $\alpha<0.01$.