Unlike office work, clinical decisions are collaborative activities that computer terminals that were intended for use by office workers. Available electronic CIS, for example, are typically implemented on are grounded in assumptions about hospital work. Commercially these problems have the potential to create new types of errors designs that have been copied from paper antecedents; some of changes in work practices and technology, but they have not been although this assertion has not been tested (Wears and Berg, 2005). Advocates of electronic clinical information systems (CIS) that store and present patient and treatment related data assert that these systems can reduce medical error (Bates et al., 1998, 1999; Fraenkel et al., 2003; Kohn et al., 2000; Instit. of Med., 2001), although this assertion has not been tested (Wears and Berg, 2005). Traditional paper-based CIS have evolved informally in response to changes in work practices and technology, but they have not been evaluated either. Given paper’s widespread use, it has been reasonable to assume that traditional paper chart designs that include mixed graphs, tables and free-form text should be successful when implemented in an electronic format. However, reports and problems are emerging with electronic CIS information designs that have been copied from paper antecedents; some of these problems have the potential to create new types of errors (Ash et al., 2004; Koppel et al., 2005; Morris et al., 2005; Wears and Berg, 2005).

Berg et al. (1998) argue that many of the observed problems are grounded in assumptions about hospital work. Commercially available electronic CIS, for example, are typically implemented on computer terminals that were intended for use by office workers. Unlike office work, clinical decisions are collaborative activities that depend on team members being able to develop common understandings from information they can all see (Klein, 2001; Endsley et al., 2003). Small screen sizes make it difficult for team members to analyse large amounts of information. Paper charts are typically laid out on tables where separate pieces of information can be bought together given the issues at hand. Transferred to computer screens this capacity is lost as information is fragmented across multiple screens, making relationships between pieces of information difficult to see. Finally, only one person can use single input devices (eg a mouse) thus limiting collaborative interaction among people and with information.

To address these deficiencies new frameworks and approaches to information design have been developed based on the principle that electronic CIS should reflect the work of its main users, that is, nurses and physicians (Berg et al., 1998; Burns and Hajdukiewicz, 2004; Endsley et al., 2003; Gibson, 1979; Powsner and Tufte, 1994; Rasmussen et al., 1994; Vicente, 1999; Xiao, 2005; Zhang et al., 2002). Work domain analysis (WDA) is a framework for describing the relationships among elements (eg information) in a work environment in ways that usefully guide design (Rasmussen et al., 1994; Vicente, 1999). A WDA (reported in Miller, 2004) was completed for medical Intensive Care Units (ICUs) and used as a basis for information design within the ecological interface design approach (Burns and Hajdukiewicz, 2004). The research reported in this paper evaluates the effects of two CIS designs developed using the same WDA but displayed using different media. The overall purpose of the work was to determine whether there were
differences in physicians' diagnostic agreement and nurses' ability to detect patient change when using traditional paper charts (TC) versus a WDA-based paper prototype (PP), and if so, whether these differences persisted when the PP was converted to an electronic prototype (EP). Conversion to an EP involved dividing information displayed in the PP. The EP’s design rationale was the same as the PPs and information was divided using WDA principles. Two experiments were completed as described in the following sections.

2. Method

The two experiments were conducted in two major metropolitan tertiary teaching hospitals in different Australian cities in different years; both are recognised research centres. The ICUs were comparable in terms of patient demographics and severity of illness, bed numbers, types of technology and procedures undertaken. In summary, the first experiment (Brisbane, 2002) tested role-relevant aspects of ICU nurses’ and physicians’ performance when using traditional paper charts (TC) compared to a paper prototype (PP). Subsequent funding in 2006 allowed this experiment to be extended. In experiment 2 (Melbourne, 2006), ICU nurses and physicians used an electronic prototype (EP) to complete tasks instead of the PP used in experiment 1. In both experiments the clinicians’ experimental tasks reflected their clinical roles: nurses were asked to detect parameters associated with patient change whereas physicians completed diagnostic tasks. Nurses’ data were analysed using signal detection, whereas the physicians’ data were analysed according to inter-physician agreement. Human Research Ethics Committees in both hospitals approved the protocol.

2.1. Participants

The experimental design was a within-participants, 2 (control and prototype) × 4 (four patient data sets) counterbalanced design that required eight participants. Eight experienced bedside nurses from each of the two hospitals (N = 16) volunteered to participate. Only four of the six possible physicians volunteered to participate in experiment 1 (Brisbane); one physician was on sabbatical and one was on recreational leave. As a consequence, counterbalancing for the experiment 1 physicians was incomplete for the patient data sets but was complete for the designs. Eight physicians volunteered to participate in experiment 2 (Melbourne) (N = 12).

2.2. Materials

Two sets of materials were used: 1) demographic surveys and task response sheets, and 2) three information designs that served as experimental stimuli. The demographic surveys elicited information about participants' age, academic qualifications, years of ICU clinical experience, and hours of weekly patient contact. The nurses' task response sheet included tables with columns for writing the time and day of patient change events, the parameters and variables associated with the change event and the direction of the change (deteriorated or improved). The physicians' task response sheets included space for listing the name of physiological systems that had failed and for writing the patient's current diagnoses.

As part of the PP design process ten ICU patient data sets had been collected from archived records with approval from a third hospital. Data sets were selected in consultation with the ICU medical director of the third hospital ICU who considered them to be typical of complex ICU patients. The criteria used to select the data sets included ICU length of stay of at least five days, failure in more than three physiological systems, and data sets that represented a comprehensive range of ICU treatments. Four data sets were randomly selected from the original ten and put aside for use in evaluation studies; these data sets were not used in the design process. Coming from a third hospital the patients represented in the data sets were unknown to the participants. The profiles of the randomly selected patients are provided in Table 1.

Each of the patient data sets were presented in the TC design used in experiment 1 and 2, in the PP design used in experiment 1 and in the EP used in experiment 2. The three designs are summarised below (Table 2).

The TC design used in this study was based on charts used in the hospital from which the patient data sets were collected. This hospital’s chart designs were based on examples taken from other hospitals and were considered to be representative of such designs. The grouping of information was also similar to information groupings in the proprietary electronic CIS used in the experiment 1 hospital and was similar to the mixed paper and electronic system used at the time of the study in the experiment 2 hospital (Fig. 1).

The PP design, represented schematically in Fig. 2a and as an annotated photograph in Fig. 2b was based on the previous WDA (Miller, 2004). The overall information architecture mirrored the functional whole-part dimension of the WDA. Four functions were represented including 1) Neurological functions: Executive (eg consciousness, etc.); sensory and perceptual (eg vision, response to pain), and autonomic (eg temperature regulation) functions; 2) circulation and communication functions with three levels: i) system level variables, eg blood pressure; ii) organ level variables, eg heart rate and iii) tissue level variables eg blood cell analyses and other blood tissue profiles and 3) Two metabolic functions (fluid and electrolyte–renal; and gas exchange–respiratory functions). The functional arrangement in Fig. 2a is schematic to understand there are two advantages for human information processing: 1) horizontal scanning across information at the same level of functional description (eg across circulation, fluid and electrolyte and gas exchange functions at the system, organ or tissue levels) allows clinicians to quickly assess functional relationships, whereas 2) vertical scanning within each function facilitates more detailed analyses without loss of orientation to the data set as a whole (Burns and Hajdukiewicz, 2004; Vicente, 1999).
To limit variation between the PP and the EP information presented in the EP could not be manipulated. Information was displayed in a graph format, although the graphic elements used in the PP could not be transferred to the onscreen environment without reducing participants’ ability to read them. Instead, while preserving cause-and-effect relations presented in the PP, two-dimensional graphs were used that included multiple related parameters displayed on single x-y axes. Limited screen size also meant that only four instead of the six days of patient data presented in the PP were displayed.

2.3. Procedure

The purpose of experiment 1 was to test for differences in nurses’ ability to detect patient change and in physicians’ agreement about patients’ states, depending on whether the TC or PP were used. The purpose of experiment 2 was to determine whether the results obtained in experiment 1 persisted when the PP was implemented in the EP format. Thus participants in both experiments received the TC but participants in experiment 1 received the PP and participants in experiment 2 received the EP. The counterbalanced schedule in Table 3 was used to present the designs. Each participant was tested four times – twice with the traditional and twice with either the paper or the electronic prototype designs (all four patient data sets).

Nurses and physicians had different experimental tasks. According to Miller and Sanderson (2005), nurses’ dominant use of clinical information is tactical monitoring and patient change detection; highly detailed analyses over relatively short time-frames. Thus, nurses were asked to identify parameters associated with patient change. In contrast, physicians’ dominant use of clinical information is strategic; including a broader range of information over larger timeframes, and so they were asked: (1) to name the organ systems that had failed for each patient, and (2) to diagnose the patient’s condition on the last day of the presented data; which was not the last day of the patients’ admissions. All information about patients’ diagnoses, other than the patient’s admission history, had been omitted from all designs. (It should be noted that strategic and tactical distinctions are relative not absolute tendencies; highly experienced nurses may take a more strategic orientation whereas inexperienced physicians may tend to be more tactically focussed. Irrespective of who assumes these roles, both high-level diagnoses and detailed monitoring need to be supported.)

Following an initial briefing, each participant was given a 10 min orientation to the TC or PP/EP design; no other training was provided. Using a demonstration display, the briefing included a verbal description of the display space including the location of key groups of physiological and treatment information and the structure of the display elements. During this time participants could ask questions about the design’s structure and could manipulate the EP hyperlinks if needed. The researcher then read the admission history for the first patient, and participants had 20 min to complete their respective tasks. The process was repeated for the second patient using the same

Table 2

Comparative summaries of each of the designs

<table>
<thead>
<tr>
<th></th>
<th>Traditional paper charts (PC)</th>
<th>Paper prototype (PP)</th>
<th>Electronic prototype (EC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical dimensions</td>
<td>1 x 1.2 m</td>
<td>1.2 x 1.4 m</td>
<td>30 x 38 cm Computer screen</td>
</tr>
<tr>
<td>Design composition</td>
<td>Composed of mixed graphs and tables with free-form text commentary. Grouping of information reflects the original data source eg biochemistry results presented on biochemistry department forms, drugs presented on drug chart.</td>
<td>62 Three-dimensional graphs with annotations. Information grouping reflects whole-part dimension of the WDA including neurological, circulatory, respiratory and renal functions. Within each function patient information (sensed information) is grouped with relevant treatments (effectors) and goals were represented with the sensed information and treatments.</td>
<td>Two-dimensional graphs with annotations were presented on each of four functional screens (neurological, circulatory, respiratory, and renal). The sensed information, treatment and goal groupings from the PP were preserved. Only the functional division of information and its 2-dimensional graph representation was different.</td>
</tr>
<tr>
<td>Temporal representation</td>
<td>One day of data is displayed on each page. Five pages were presented per patient.</td>
<td>Five days of data were presented on one page per patient.</td>
<td>Five days of data were presented on each of five screens representing five physiological functions.</td>
</tr>
</tbody>
</table>
design, and was followed by a 10 min briefing in preparation for the second design. The same process ensued for the remaining two patient data sets. The same overall procedure was used in experiment 2, except that the participants were given 14 instead of 20 min to complete tasks because four instead of six days of data were presented in the electronic prototype.

2.4. Data collation

2.4.1. Detecting patient change

In consultation with physicians who did not participate in the study, a patient change event was operationally defined as an episode where: 1) at least one parameter deviated from a previous state (not necessarily a state within the ‘normal’ range) within a specifiable time range, ie if the timeframe over which the variable changed from start to resolution was 5 h then any time nominated within that frame was considered valid if the remaining criteria were also met; 2) at least one parameter reached a value differing by more than 20% of its preceding value; and 3) the new state was sustained or required intervention. Using these three criteria a coding scheme was developed for each day of each patient’s admission represented in the designs. A ‘day’ was defined as the period between 0001 and 2400 h.

Signal Detection Theory (SDT) was used to calculate scores for each nurse (Green and Swets, 1966; Proctor and van Zandt, 1994). SDT is a useful method to assess real-world detection situations because it adjusts a person’s correct responses for their false positive responses. Some people readily identify changes, that is, they have a liberal response bias. Such people have a large number of correct responses but also have more false positive responses. A person with a conservative response bias may identify fewer correct responses but will also identify less false positives. In patient care, conservative response biases may lead to nurses under-reporting patient change, whereas nurses with liberal response biases may lead to over-reporting; both could lead to patient harm. The ideal response is one where people correctly discriminate meaningful information from random variation. SDT measures this form of discrimination using two values. $d'$ (d-Prime, or sensitivity) is a participant’s normalized correct responses minus his or her false positives, and $\beta$ (beta, or response bias) is the ratio of normalized correct responses to false positives. $d'$ and $\beta$ were calculated for each nurse when using the TC and the PP or EP.

2.4.2. Diagnostic agreement

Continuity of patient care requires that strategic patient goals continue across shifts. However, physicians must first reach agreement about what the patient’s situation is; hence, physicians’ responses were analyzed using inter-participant agreement. This approach was also taken because the patient data sets were incomplete and because the physicians who would have been asked to provide standard diagnoses met criteria for participation in this study. Given that all participant physicians were experienced, all of their responses for each patient data set were pooled and used as a standard inventory of responses. Physicians exposed to the same patient data sets in the same design were paired. The proportions of agreed inventory responses were then collated for each pair using the traditional and prototype designs.

3. Results

3.1. Participant characteristics

Table 4 summarises the demographic characteristics of experiment 1 and 2 participants. The profiles for physicians represent a relatively homogenous sample.

The demographic and performance data were screened and tested for effects related to different gender proportions in experiment 1 and 2 nurses, for differences in nurses’ years of experience and their hours of patient contact, for patient data set effects and for learning effects (the difference in performance between the first and second presentations of a design). No statistically significant
3. Two partially annotated design elements:
- light bars are sensed patient data
- dark bars (except pH) are treatment related variables

Approx scale 1:10mm
Variations in background colour are a consequence of the non-uniform reflection of light off plastic laminate that was used to protect the quality of the prototypes during the study.

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differences in performance were identified depending on nurses’ gender, experience, hours of patient contact, nor were patient or learning effects observed.

3.2. Patient changes detected by nurses

3.2.1. Experiment 1: paper prototype (PP) compared with traditional charts (TC)

Two-tailed matched sample t-tests (Howell, 2002) were used to test the hypothesis of no difference between the mean d’ and β for changed parameter detection using the PP and TC designs. Nurses identified more correct changed parameters (mean d’ PP = 1.94 ± 0.24 vs TC = 1.71 ± 0.24: \( t_{(df=6)} = 2.4, p < 0.05 \)), and reported fewer false positives due to a more conservative response bias (mean β PP = 138.19 ± 59.6 vs TC = 76.88, ±50.75: \( t_{(df=6)} = 2.86, p < 0.05 \)) when using the paper prototype.

3.2.2. Experiment 2: electronic prototype (EP) compared with traditional charts (TC)

One-tailed matched sample t-tests (Howell, 2002) were used to test the hypothesis that changed parameter detection by nurses remained significantly improved using the EP compared with TC. It was also hypothesised that the more conservative response bias observed when using the PP compared to the TC would also persist when using the EP. Nurses using the EP identified more correctly changed parameters (mean d’ EP = 2.9 ± 0.38 vs TC = 2.35 ± 0.45: \( t_{(df=6)} = 3.14, p < 0.01 \)), and also reported fewer false positives due to a more conservative response bias (mean β EP = 204.51 ± 68.08 vs TC = 135.53 ± 89.15: \( t_{(df=6)} = 1.943, p < 0.05 \)).

3.2.3. Experiment 1 and 2: paper prototype (PP) compared with electronic prototype (EP)

Hypotheses of no difference between experiment 1 and nurses who used the PP (mean d’ PP = 1.94 ± 0.24 vs EP = 2.9 ± 0.38: \( t_{(df=6)} = 5.96, p < 0.001 \)). There were no significant differences between the response biases for experiment 1 and 2 nurses using either prototype.

3.3. Diagnostic agreement among physicians

3.3.1. Experiment 1: paper prototype (PP) compared with traditional charts (TC)

Student’s t-tests of equal sample variance were used to test hypotheses of no difference in agreed organ systems failure and current state diagnoses, depending on whether the PP or TC were used. There were no significant differences in agreement about failed organ systems. However, physicians using the EP achieved greater mean proportions of agreement about the patients’ current state diagnoses than they achieved using the TC (mean PP = 0.59 ± 0.07 vs TC = 0.36 ± 0.09: \( t_{(df=3)} = 4.1; p < 0.01 \)).

3.3.2. Experiment 2: electronic prototype (EP) compared with traditional charts (TC)

Based on data from experiment 1, a two-tailed Student’s t-test for matched samples (Howell, 2002) were used to test the hypothesis of no difference in physicians’ mean proportions of agreement about patient’s failed organ systems depending on use of the EP or TC designs. Contrary to experiment 1 Physicians using the EP achieved greater proportions of agreement about patients’ failed organ systems than they did using the TC (mean EP = 0.51 ± 0.11 vs TC = 0.36 ± 0.14: \( t_{(df=6)} = 3.14, p < 0.01 \)). Also contrary to experiment 1 there were no significant differences in physicians’ mean proportions of agreement about patients’ current diagnoses regardless of whether the EP or TC were used.

3.3.3. Experiment 1 and 2: paper (PP) compared with electronic prototype (EP)

The data from experiment 1 and 2 were analysed using two-tailed Student’s t-tests of no difference for independent samples of

Opening Page
Access to all functional systems is provided by hyperlinks across the top of the page.
Hyperlinks are presented on all pages in the prototype so that all functional systems could be accessed from all other functional systems.
Where parameters were relevant to more than one functional system hyperlinks from the parameter to the related system(s) were also provided within the screen.

Neurology
Top table presents data related to executive and sensory/perceptual functions in the patient.
Above this table any goals related neurological function are listed.
Drugs and drug doses intended to effect executive or sensory functions are presented in the Table below

Circulation
The top graph presents heart rate. Beneath the graph other indicators (CO CI) as well as relevant electrolytes (K, Ca, Mg) are presented with replacement doses and cardio-active drugs.
Similarly, beneath heart rate are blood pressure, related indicators and drugs and beneath this are pulmonary pressures where relevant.

Respiration
The top graph presents oxygenation indicators and associated treatment options (FiO2).
Acid-base indicators are represented below oxygenation and beneath this are patient and mechanical ventilation parameters.
Below these are examination and chest x-ray reports with relevant drugs.

Renal
The top two graphs present fluid inputs. The third graph shows the cumulative and cumulative daily input/output balances.
Urine output is presented in the fourth graph.
Beneath this are kidney related electrolytes (Urea, creatinine, Cl, etc) and drugs.


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equal variance. When using the EP physicians achieved greater mean proportions of agreement about the patients’ failed organ systems compared to when using the PP (mean EP = 0.51 ± 0.11 vs PP = 0.27 ± 0.08: t(df=10) = 3.14, p < 0.01), and physicians using the PP achieved higher mean proportions of agreement about the patients’ current state diagnoses than they achieved using the EP (mean PP = 0.59 ± 0.07 vs EP = 0.31 ± 0.2: t(df=10) = 2.23; p < 0.02).

4. Discussion

This study compared clinically relevant aspects of physicians’ and nurses’ performance when using traditional charts (TC) compared with two versions of a WDA-based prototype design (paper, PP, and electronic, EP). Findings suggest that as clinical information on paper charts is transferred to electronic media, traditional chart designs are unlikely to yield optimal physician/nurse performance. Specifically, results indicate that the presentation of information affects diagnostic agreement among physicians and nurses’ ability to detect patient change events. New approaches to design that integrate rather than fragment information would appear to improve these aspects of clinical performance. However, performance improvements were not uniform across the professional groups; design changes that enhance ICU nurses’ performance may adversely affect physicians or vice versa.

4.1. Professional differences

Physicians and nurses have different training regimes, different accreditation, remuneration and organisational structures. In practice their roles are highly interdependent. They often share information displays albeit for different reasons. Physicians are primarily responsible for diagnoses, medium to longer-term care planning and treatment prescription. Bedside nurses are primarily responsible for identifying and reporting patient change and for monitoring the effects of prescribed treatments that they are often responsible for administering (Miller and Sanderson, 2005). This study assessed the effects of information presentation on limited but important aspects of healthcare team performance.

Supporting their change identification role (Miller and Sanderson, 2005), nurses were better able to identify changed parameters correctly using either prototype compared to the traditional charts (TC), and the electronic prototype (EP) better supported change detection than did the paper prototype (PP). Effective patient monitoring and change detection depend on nurses being able to closely track patient variables in the presence or absence of treatment interventions. Both PP and EP prototypes directly linked these variables, whereas the traditional design did not. The EP may have further enhanced change detection performance because the separation of data into the four functional areas helped nurses narrow their scanning focus to details within specific functions. This explanation could be tested using eye-tracking technology to analyze the focus of nurses’ attention. Confirmation would provide further evidence for the need to better link patient and treatment variables in design.

The electronic (EP) and paper (PP) prototypes had opposite effects on physicians’ diagnostic agreement. Physicians achieved the highest levels of diagnostic agreement when using the PP: performance using the EP degraded to no better than that when using the TC. The diagnosis and care planning of ICU patients typically involve assessment across multiple physiological functions. The integration of information in one display space as in the PP may have enhanced patient assessments and inter-participant agreement through one or more of the following mechanisms (Endsley et al., 2003): 1) reduced short-term memory requirements (short-term memory quickly becomes overloaded and degrades when searching multiple screens), 2) improved search time and efficiency may free cognitive resources that can be used for other interpretive or planning tasks and 3) laid out in one space, complex patterns in the information may be more readily apparent. The advantage afforded by the integrated PP design was lost when it was divided functionally in the EP.

The EP appeared to better support agreement among physicians about organ systems that had failed. Like nurses’ change detection tasks, identifying failed organ systems required a more detailed assessment of a narrow range of functionally related information. Dividing information according to physiological functions may have better supported this task because each physiological system could be assessed in isolation. However, while physicians were better able to identify failed physiological systems using the EP, they did not integrate these diagnoses overall and hence agreement decreased.

4.2. Clinical implications

Continuity of patient care involves the transfer of information, including goals and plans, from one person or group to another across work shifts. Agreement about the meaning and significance of patterns in treatment and patient variables is the basis for agreement about the directions and goals of care. Information designs that integrate rather than divide clinical information appear to enhance diagnostic agreement whereas interfaces that divide information appear to reduce it. The results of this study suggest that information displays that enhance agreement among individuals about current states may better support continuity of care across personnel and across work shifts.

Table 3

<table>
<thead>
<tr>
<th>Part 1 Design presentation</th>
<th>2nd Design presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 1 and 2 nurses and experiment 2 physicians</td>
<td>T (Pt 1, Pt 2)</td>
</tr>
<tr>
<td>1</td>
<td>T (Pt 1, Pt 2)</td>
</tr>
<tr>
<td>2</td>
<td>T (Pt 3, Pt 4)</td>
</tr>
<tr>
<td>3</td>
<td>T (Pt 2, Pt 4)</td>
</tr>
<tr>
<td>4</td>
<td>T (Pt 1, Pt 3)</td>
</tr>
<tr>
<td>5</td>
<td>P (Pt 1, Pt 2)</td>
</tr>
<tr>
<td>6</td>
<td>P (Pt 2, Pt 4)</td>
</tr>
<tr>
<td>7</td>
<td>P (Pt 2, Pt 4)</td>
</tr>
<tr>
<td>8</td>
<td>P (Pt 1, Pt 3)</td>
</tr>
<tr>
<td>Experiment 1 physicians</td>
<td>T (Pt 1, Pt 2)</td>
</tr>
<tr>
<td>1</td>
<td>T (Pt 1, Pt 2)</td>
</tr>
<tr>
<td>2</td>
<td>P (Pt 1, Pt 2)</td>
</tr>
<tr>
<td>3</td>
<td>P (Pt 1, Pt 2)</td>
</tr>
<tr>
<td>4</td>
<td>T (Pt 1, Pt 2)</td>
</tr>
</tbody>
</table>

T = traditional design, P = prototype design (paper for experiment 1 OR electronic for experiment 2 participants); Pt = patients 1, 2, 3 or 4.

Table 4

<table>
<thead>
<tr>
<th>Number</th>
<th>Gender (%)</th>
<th>Age (%)</th>
<th>Years in current position (%)</th>
<th>Years post-ICU graduated (%)</th>
<th>Hours of work per week (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>&gt;20–29</td>
<td>30–39</td>
<td>&gt;40</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>4</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>37</td>
<td>100</td>
<td>63</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Gender (%)</td>
<td>63</td>
<td>25</td>
<td>37</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Age (%)</td>
<td>12</td>
<td>25</td>
<td>25</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Years in current position (%)</td>
<td>25</td>
<td>75</td>
<td>38</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Years post-ICU graduated (%)</td>
<td>13</td>
<td>25</td>
<td>25</td>
<td>60</td>
<td></td>
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<tr>
<td>Hours of work per week (%)</td>
<td>88</td>
<td>50</td>
<td>25</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Nurses</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Physicians</td>
<td>20</td>
<td>20</td>
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<td>20</td>
<td></td>
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</tbody>
</table>

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The results of this study also suggest approaches that may be used to further assess the real-world effects of CIS. Nurses using both prototypes had fewer false positives. False positives are problematic for several reasons. First, for nurses and the physicians with whom they work, false positives unnecessarily interrupt and divert attention from important tasks while adding to overall work load. Second, false positives may increase the risk of unnecessary interventions that can adversely affect the quality and cost of care. Hence, false positives attributable to poor information design may have direct and measurable outcomes in the ICU. Pronovost et al. (2003) note that it is often difficult to establish causal links between team-based interventions and common patient outcome measures, such as length of patient stay. With further verification false positives may provide a direct link between CIS implementation, interruptions and broader indicators of care quality such as patient outcomes.

4.3. Implications for design

CIS are used by and need to support teams whose members have different information uses. Physicians tend to use clinical information to diagnose patient states and prescribe interventions. Nurses tend to use information to monitor and respond to change in patient status. These uses suggest that physicians need more global, integrated views of information, whereas, nurses need detailed information views that highlight cause-and-effect relationships; members of both professions use the same information but they use it for different reasons. Thus functionality that allows team members to ‘zoom in and out’ of different levels of detail is needed in future CIS designs.

Goals represent physicians’ plans for patient management, and they are the criteria by which nurses monitor cause-and-effect relations. Clinical goals, therefore, connect tactical monitoring to strategic care planning and are likely to be a key component in maintaining continuity of patient care delivery. The integrated presentation of information should ideally integrate goals directly with treatment and patient-related information and should also represent these relationships over time. Further investigations are needed to determine how clinical goals are developed, tracked and handed over from one work shift to the next and how they should be represented in design.

The types of screens used to display clinical information also need to be considered. Standard office-sized computer screens and current graphic models do not allow the concurrent presentation of large volumes of information across physiological functions, as was possible in the paper prototype and has been the norm in many traditional chart designs that were spread over medium sized tables. This may mean moving towards much larger screens with higher resolutions, and innovative presentations of clinical information.

4.4. Limitations

The limited sample size in this study is common to studies involving professional participants. Alternatively, the generalizability of results from a larger pool of typically students to experienced practitioners is questionable. A ‘within subjects’ counterbalanced experimental design reduces this problem by allowing multiple measures on single individuals. Learning effects and individual differences are distributed evenly across all experimental conditions and thus act as constants.

4.5. Conclusion

In conclusion, new approaches to clinical information design can enhance nurses’ ability to detect patient change and physicians’ diagnostic agreement. The important aspects of design appear to be the integration of information according to physiological functions and the association of cause-and-effect relations. However, the effects were not uniform. In this study differences in performance resulted from constraints on design that were imposed by computer screen sizes that are better suited to office work. Clearly, software design is only one aspect of system design; platform issues are also important and further research is urgently needed to better optimise computer platforms for the collaborative work that occurs in the ICU.

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References


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