Computerisation and decision making in neonatal intensive care: a cognitive engineering investigation

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Abstract

This paper reports results from a cognitive engineering study that looked at the role of computerised monitoring in neonatal intensive care. A range of methodologies was used: interviews with neonatal staff, ward observations, and experimental techniques. The purpose was to investigate the sources of information used by clinicians when making decisions in the neonatal ICU. It was found that, although it was welcomed by staff, computerised monitoring played a secondary role in the clinicians' decision making (especially for junior and nursing staff) and that staff used the computer less often than indicated by self-reports. Factors that seemed to affect staff use of the computer were the lack (or shortage) of training on the system, the specific clinical conditions involved, and the availability of alternative sources of information. These findings have relevant repercussions for the design of computerised decision support in intensive care and suggest ways in which computerised monitoring can be enhanced, namely: by systematic staff training, by making available online certain types of clinical information, by adapting the user interface, and by developing intelligent algorithms.

Key words: intensive care, computerised monitoring, decision support, cognitive engineering

Introduction

Computerised aids offer considerable potential for improving the quality of medical and nursing care in the hospital *intensive care unit* (ICU) [1]. However, there is extensive evidence to suggest that computerised aids in medicine are not always readily accepted or widely used by medical or nursing staff, and often fail to produce the sought-for clinical improvements [2-5]. Previous human factors research suggests, nevertheless, that computer systems have a significant role to play in patient care, provided that they are designed and implemented appropriately [6-7].

In this paper, we look at the role of computerisation in *neonatal* intensive care. We describe a series of investigations conducted in the neonatal ICU of the Simpson Maternity Hospital in Edinburgh (UK), where a PC based trend monitoring system (MARY™)[1] has been in use for more than 10 years [8]. The computerised system was generally welcomed by clinical staff at the unit, who positively valued its utility [9]. However, recent studies have shown, perhaps surprisingly, that the presence of a computerised trend monitoring system does not in itself result in better outcomes in terms of morbidity and mortality [4]. A major goal of the investigations discussed here is to identify in detail the reasons for these limitations, and to investigate techniques to increase the efficiency of computerisation in neonatal care.

We are using a *cognitive engineering* approach to address the problem [10-11]. This involves applying the theories and methodologies of cognitive psychology to gain an understanding of the working practices and cognitive processes (reasoning and decision making) of the eventual system users. The goal is to use insights about staff cognitions to evaluate the usability of the currently implemented system and to contribute to the design of computerised decision support in intensive care.

In consonance with current research in complex naturalistic decision making environments (including intensive care [12]), our approach has been to use a range of methodologies and information sources. Specifically we have conducted interviews with and observations of clinicians (physicians and nurses) working at the neonatal unit, as well as experimental work ("off-ward" simulations) in which staff were presented with data patterns recorded from previous real patients and were asked to "think aloud" during their interpretation of the data.

In this paper, we focus on those aspects of our investigations concerned with the ways in which staff use information during their clinical decision making, paying particular attention to their interaction with the computerised trend monitoring system. By looking at sources of information, we can assess the role that computerisation plays in their decision making, and determine the sort of information that may need to be incorporated into an efficient computerised aid. These investigations have involved the use of a particular computerised monitoring system for neonatal intensive care, MARY™. However the intention is to draw more general conclusions about the use of computerised monitoring rather than focus on the detailed

[1] MARY™ is a trademark of Meadowbank Medical Systems.

characteristics of this particular system, which functions for our purposes as a research tool.

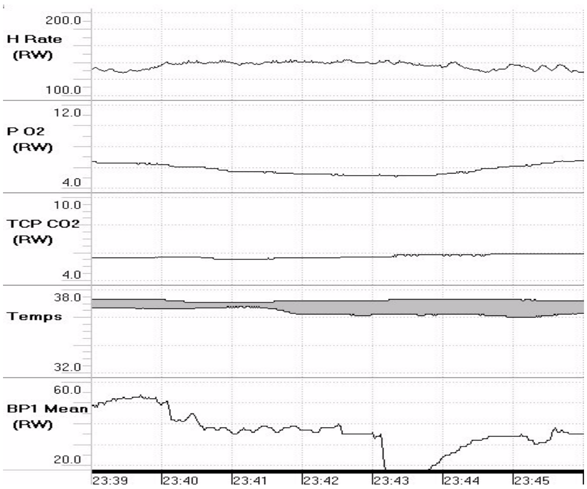

Fig.1 Sample of trend monitoring data used in the off-ward simulations

Methods

The Monitoring System

One of the most distinctive features of this system is its presentation of monitored physiological data as trend graphs. It shows physiological trends over long periods of time, in contrast with most conventional monitors which present the parameter values at a particular moment in time. Data presentation in the form of trends is deemed to facilitate the clinicians' assessment of the data and propitiate rapid and effective decision making in emergency situations [13]. The system allows continuous collection of physiological information which is automatically recorded and displayed on a PC at the cot side. It allows the display of real time and previously recorded trend data, and data from any period of the infants' monitored stay in the ICU can be retrieved. Important features of the system are the flexibility of its display and the ease with which this can be manipulated. For example, each physiological channel can easily be changed with regard to its value scale, time scale, and its relative size and position to the other displayed graphs. If desired, an auto-scaling function can be used which selects the most appropriate scale for the displayed channels. Furthermore, the user can enter information or comments in real time; nursing staff are encouraged to enter comments about procedures and tests performed, as well as about relevant clinical events. The whole system is based on menus, which the users can access using a standard keyboard. Associated with the system is a database facility which can be used by medical and nursing staff to enter information about the clinical history of an infant.

Interview procedures

Thirty-four members of the clinical staff volunteered to take part in the interviews. These included: (a) seven senior doctors (consultants and senior registrars); (b) eight junior doctors (senior house officers, registrars and staff grade doctors); (c) ten senior nurses; and (d) nine junior nurses.

The questions asked in the interviews covered the following areas: (a) position and clinical experience of the interviewees as well as their responsibilities on the unit; (b) sources of information used to decide that the condition of a baby is giving no cause for particular concern and to deal with various clinical events; (c) the ways in which staff deal with monitoring artefacts; (d) experience with computers, attitudes towards the computerised monitor, and the way of interacting with the system.

All interviews were conducted individually by a professional research psychologist (E.A.). The interviews were recorded on audio tape.

In order to assess the generality of our results, we interviewed five other consultants working in two different UK neonatal units, where the MARY™ monitoring system is in routine use. Due to space limitations we will not describe their replies in detail, but these were essentially consistent with the reports from the consultants in Edinburgh.

Observation procedures

Eight observation sessions were conducted at the neonatal unit of the Simpson Maternity Hospital. Each session lasted from one to two hours, giving a total of 13.5 hours of observation data. All the observation sessions were run by the research psychologist who had conducted the interviews. The observer sat in the same location in the neo-natal ICU for each session while using a coding scheme to record activities as they arose on the ward, noting the grade of the staff member performing each activity. Many of the members of staff who participated in the interviews were also observed on the ward. They comprised nurses taking direct care of the baby, other nurses on the ward, junior and senior physicians.

The activities recorded during the observation sessions were: (1) interact with MARY™, (2) look at baby, (3) handle baby/equipment, (4) talk to colleagues, (5) write and read paper notes (6) deal with alarm, (7) other (overview ward, interact with relatives, look at X-rays).

To allow a direct comparison between the observation records and subjective reports, the activities used in the above scheme were also topics for the interviews, which took place at a different time. Interviewees were asked to order the set of

Table 1. Sources of information used to decide that a baby's condition is giving no cause for concern

	ALL (N=34)	Senior Doctors (N=7)	Junior Doctors (N=8)	Senior Nurses (N=10)	Junior Nurses (N=9)
Observation of baby	**100%**	100%	100%	100%	100%
Computerised monitor (MARY™)	**88%**	100%	75%	100%	77.50%
Information from colleagues	**76.50%**	85.50%	87.50%	50%	89%
Other monitor(s)	**73.50%**	85.50%	50%	80%	77.50%
Examination of baby	**56%**	71.50%	37.50%	60%	55.50%
Paper notes	**32%**	28.50%	12.50%	40%	44.50%
Other	**12%**	28.50%	--	10%	11%

activities in terms of the frequency with which they believed that they conducted them on the ward.

Off-ward simulations

The purpose of the experiments was to further investigate the decision making procedures of neonatal staff. The participants were shown, off ward, a series of 14 sets of trend graphs (traces) on the computer screen from babies that had previously been on the ward. Some of those trends were uneventful, some showed normal events, and some showed developing pathology. The participants were asked to point at the abnormalities or artefacts that she/he detected and, if possible, to interpret any of those abnormalities. The participants were also instructed to think aloud while looking at the traces, reporting everything that went through their mind.

Each trace was shown on a computer screen as a series of seven minute blocks of data (see Fig. 1); subsequently, the trace was shown again on a different time scale, namely as two 1.5 hour blocks of compressed data. The experimenter had full control of the manipulation of the computer display. The participants were allowed to ask the experimenter to scroll back and look at what had happened earlier, but the experimenter would never scroll forward to the next block of data until the participants had said all they wished to say about the trace to that point. At that point they could ask for more information which would be given to them if it would have been available at that time clinically. Prior to the presentation of each trace, the participants were shown basic information about the baby from whom the trace was recorded.

The simulations were conducted with a total 25 members of staff comprising 6 senior physicians, 9 junior physicians, 5 senior nurses and 5 junior nurses. All sessions were recorded on video to capture the participant's voice and interaction with the computer display.

The resulting videotapes were transcribed and the resulting verbal protocols were segmented into statements. The segmented protocols were analysed using common protocol analysis techniques [14], as a result of which an coding scheme was developed. This scheme was used to categorise the types of reasoning or behaviour involved in the protocol statements (e.g., whether a statement includes a *description* or *interpretation* of a data pattern, whether it contains a *hypothesis* or a *request for extra information*, whether *artefacts* are noted, etc.). Subsequently, those statements which contained requests for extra information were analysed in detail. The purpose was to identify the sources of information that neonatal staff may need to complement the information provided by the computer system.

Other detailed analyses conducted on the simulation data are reported elsewhere [15].

Results

Sources of information

Less than half of the interviewed staff reported that they would ever use the computerised monitor as a primary source of information (see Table 3, item number 5). In fact, many reported that their decision making frequently relies on the combination of various sources of information used in conjunction; they would rarely use a single source in isolation.

The most common sources of information reported by the interviewees were the following: (a) observation of the baby; (b) examination of the baby; (c) computerised monitor; (d) other monitors; (e) information from colleagues; (f) case notes.

Table 1 shows the proportion of people out of the total number of interviewees that mentioned each source of information (see column two), as well as the proportion of interviewees within each staff group who reported each of them (see columns three to six). Clearly, the most commonly reported source of information is "observation of baby", which was mentioned by all the interviewees.

The second most frequently reported information source was the computerised monitors, especially for senior doctors and senior nurses. The computerised monitor is closely followed by "information from colleagues" and by the "other monitor(s)".

Table 2. Objective records and subjective reports about the frequencies with which staff conducted activities on the ward

a) OBSERVATIONS		b) SUBJECTIVE REPORTS	
Nurses		**Nurses (N=17)**	
Handle baby/equipment	26%	Look at baby	1.06
Talk to colleagues	21.50%	Deal with alarm	2.41
Deal with alarm	18%	Handle baby/equipment	4.76
Write/Read paper notes	16%	Talk to colleagues	5.47
Look at baby	7%	Interact with MARY™	6.00
Other	6.50%	Write/Read paper notes	7.76
Interact with MARY™	5%	Other	8.67
Junior Doctors		**Junior Doctors (N=6)**	
Handle baby/equipment	35%	Talk to colleagues	3.67
Talk to colleagues	25%	Write/Read paper notes	4.00
Write/Read paper notes	17%	Look at baby	4.33
Look at baby	8.50%	Handle baby/equipment	5.17
Deal with alarm	6%	Interact with MARY™	6.83
Interact with MARY™	4.50%	Deal with alarm	8.00
Other	3.50%	Other	8.28
Senior Doctors		**Senior Doctors (N=7)**	
Talk to colleagues	32%	Talk to colleagues	2
Handle baby/equipment	21.50%	Look at baby	2.43
Look at baby	16%	Interact with MARY™	4.143
Interact with MARY™	13.50%	Other	4.38
Other	10.50%	Handle baby/equipment	6.35
Write/Read paper notes	5.50%	Write/Read paper notes	7.78
Deal with alarm	1.50%	Deal with alarm	9.28

"Examination of the baby" was reported by roughly half of the interviewees, and paper notes were the least frequently reported. Alternative sources of information mentioned by staff were: laboratory information (reported by one senior doctor), information from parents (mentioned by one senior doctor, and two nurses); and manual charts (reported by a junior nurse).

Observation data provided an interesting contrast with the reports in the interviews. This is highlighted in Table 2. Column (a) in the table shows observation data for each of the three staff groups considered in the observation sessions: nurses, junior doctors, and senior doctors. For each staff group, the table shows, in decreasing order, the proportion of times each type of activity was recorded throughout the 8 observation sessions. Column (b) shows, for each of the staff groups the average ranking given by interviewees to each of the activities. Again, these are listed in decreasing order of frequency for each staff group (note that a low score indicates a high estimated frequency).

All staff groups reported interacting with the computerised system ("Interact with MARY™") more often than they were actually seen using it during the observations. In fact, "Interact with MARY™" was one of the least frequently conducted activities by nurses and junior doctors. The small percentage in Table 2a (4.5%) indicating use of the system by a small number of junior doctors accounts for all the interactions with the system that occurred in the observation sessions. In six of the observation sessions junior doctors were never seen interacting with the computer monitor in any way.

In contrast with the interview data, the activity "look at baby" was recorded for nurses and junior doctors on relatively few occasions during the observations. However, an action was marked as "look at baby" only when staff were observing the baby independently from any other activity. Naturally, while performing other activities (e.g., while handling the baby and often while interacting with relatives), staff would be looking at the baby as well. On the other hand, "handle baby/equipment", a very frequently recorded activity during the observations, was reported during the interviews to be an infrequent activity.

The observation data suggest that information from colleagues ("talk to colleagues") plays a more important role in staff decision making than suggested by the interviews. However, it is worth noting that not all the verbal interactions involved an exchange of clinical information, with some natural casual conversation.

Another interesting discrepancy between interview and observation data concerns the use of paper notes. Although, according to the observations, staff (especially nurses and junior physicians) spend a lot of their time writing and reading paper notes, this source of information was very seldom mentioned during the interviews.

The graph in Fig. 2 summarises the results of our analyses of clinicians' requests for extra information during the off-ward simulations. We focused on data from physicians: senior doctors (SD) and junior doctors (JD). The graph shows, for each staff group, each type of extra information requested as a proportion of the total number of information requests throughout all the traces viewed in the study.

Consistent with interview and observation data, the results of the simulations suggest that the senior physicians were the staff group who interacted most frequently with the computerised monitoring system and were most familiar with its features. The most frequent requests by senior doctors were to change the displays on the monitoring system (see "monitor" in Fig. 2); and they requested this kind of information considerably more often than did junior doctors.

Another interesting pattern in Fig. 2 is the high frequency with which the junior doctors requested information about procedures conducted on the baby; in contrast with the senior doctors, who did not request this information quite so often (see "procedures" in the figure). Arguably, this was because conducting procedures on the baby is an important part of a junior doctors' job on the ward (see Table 2a), and they were more sensitive to this type of information than were the senior doctors. Additionally, the second most frequently requested type of information by the junior doctors was information about the baby (see "baby" in Fig. 2). These data patterns seem to suggest that, when making decisions on the ward, the junior doctors are more likely to rely on the information obtained from direct contact with the baby than on other sorts of information (e.g., the information provided by the computerised monitor). In contrast, senior doctors seem to rely more heavily on the data provided by the monitor.

In contrast with interview and observation data, information from colleagues was the least frequently reported source of information during the simulations (see "colleagues" in Fig 2). Nevertheless, one could argue that many of the types of information categorised under other labels in Fig. 2 (e.g., "procedures", "tests", "calibration", etc.), would have been obtained from other members of staff present on the ward in a real clinical setting. Therefore, although rarely noted explicitly, the information from colleagues was arguably an implicit source of information in many of the participants' information requests.

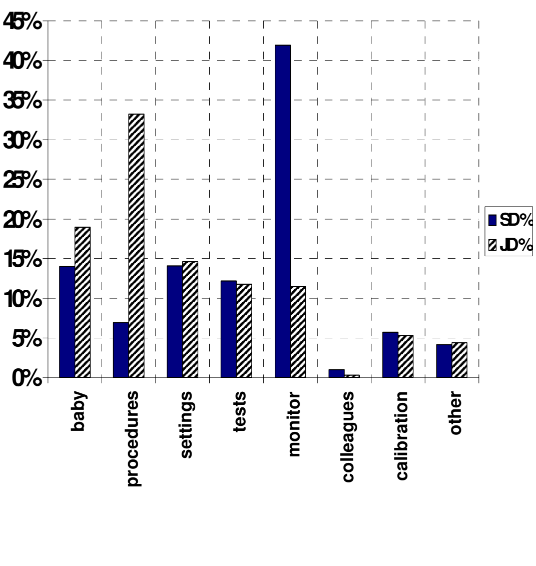

Fig. 2. Types of requests for extra information during the off-ward simulations

The role of the computerised monitor

Many of the questions in our interviews were specifically aimed at assessing the role that clinical staff attribute to the computerised monitoring system in their decision making. We asked interviewees about their attitudes towards the computerised monitor, about the way in which they interact with it, and the role that they believe it plays in a variety of clinical situations. Table 3 shows the proportion of people (out of the total number of interviewees and within each staff group) who gave particular replies. From the table it is clear that the general attitude towards the computerised system is very positive. The majority of interviewees seemed to find the system helpful and, at least, reasonably easy to use, and many of them reported using it very frequently. Most of the interviewed staff (particularly more senior staff) agreed that the computerised system represents an improvement compared to conventional monitoring methods (item 6 in Table 3).

The great majority of the interviewees reported that the most useful feature of the system were "the trends", that is, the system's ability to show the changes in physiological parameters over time (item 7 in Table 3). Other useful aspects of the system mentioned by the interviewees include: (a) ability to show simultaneously the changes in more than one physiological parameter (mentioned by 15% of staff); (b) the educational function of the system, e.g., on the ward rounds (at least four interviewees mentioned this feature); (c) the ease of use of the system, and the reliability and accessibility of the information that it provides (reported by two interviewees); (d) the possibility of manually inserting comments to indicate procedures or events of particular relevance (two people suggested this feature).

Table 3. The role of the computerised monitor: Staff's attitudes towards and interaction with the system

		All (N=34)	SD's (N=7)	JD's (N=8)	SN's (N=10)	JN's (N=9)
1.	Had previous experience with computers	**50%**	57%	75%	20%	55.50%
2.	Computer monitor is helpful for decision making	**97%**	100%	100%	90%	100%
3.	Computer monitor is "reasonably easy", "easy" or "very easy" to use	**94%**	86%	100%	100%	89%
4.	Computer monitor used "constantly" or "most of the time"(vs. "frequently", "occasionally" and "rarely")	**65%**	57%	75%	60%	66.50%
5.	Would ever use computer monitor as a primary source of information	**40.50%**	66%	57%	40%	11%
6.	Computerised monitor is an improvement compared to older methods	**85%**	100%	62.50%	100%	78%
7.	Trend monitoring is a useful feature of the system	**94%**	100%	100%	90%	89%
8.	Would change the time scale	**88%**	86%	87.50%	90%	89%
9.	Looks at monitored data retrospectively (past trends)	**91%**	100%	87.50%	90%	89%
10.	Would change the physiological channels	**61%**	71%	25%	70%	78%
11.	Can detect, at least, some artefacts by just looking at the computer monitor	**69%**	100%	33%	75%	71%

Items 8 to 11 in Table 3 refer to various aspects of people's interaction with the computerised system. These indicate level of familiarity with system functionality and the role that each function plays in decision making. A majority of the interviewees replied that occasionally they would change various aspects of the monitoring display to suit their decision making needs (items 8 and 10 in Table 3). Additionally, most of the interviewees noted that they would not only look at data as they appear (real-time data) but would also look at the past and developing trends (item 9 in Table 3), that is, they would benefit from the advantages of trend monitoring. Trend monitoring was seen as particularly useful for dealing with physiological changes that evolve progressively; the changes detected on the trend monitoring system can alert staff as to the potential onset of such conditions. In contrast, when the physiological changes are acute and very obvious, staff have to act immediately and cannot spend their time looking at the monitor.

A large proportion of the interviewed staff (especially senior doctors) reported that they would be able to recognise at least some monitoring artefacts by simply looking at the system, that is, without using any other information sources (item 11 in Table 3). There seems to be a set of artefact patterns that are fairly frequent and distinctive, and that can be potentially recognised by someone who regularly interacts with the computerised system.

If we look at the differences amongst the four staff groups in Table 3 (e.g., items 10, 11, and 6), we may infer that junior doctors have more difficulties than other staff members when interacting with the system. This is supported by the observation and simulation data, but not by the interviews. Paradoxically, junior doctors were the most computer literate group amongst the interviewees (item 1 in Table 3), and were the ones who were most likely to report that they used the system very frequently, and that they would use it as a primary source of information (items 4 & 5).

Human factors issues

The interviews explored the opinions of clinical staff on issues relating to the design of the existing computerised system and its implementation on the ward.

An interesting finding revealed by the interviews is that, currently at the neonatal unit, there is not an in-depth formal training programme to introduce staff to the system. Only 25% of the interviewees reported that they received some training on the system, usually consisting of information sheets, brief introductory talks, or demonstrations by more senior staff. In general, new staff seem to be first introduced to a few basics on the system as they arrive on the ward, but then learn the different functionalities as they go along. This does not seem to be sufficient. Junior staff, in particular, seem to have the feeling that there is much more to the computerised monitor than they can use. A typical answer, given by a junior doctor, is: "I still don't feel I can get all the information out of it on the monitoring". Interestingly, all the interviewed junior staff (both nurses and doctors) reported that they would have liked to have some training on the system (or more than they actually had). In fact, the lack of training was one of the main problematic issues raised by junior staff (particularly nurses) regarding the use of the system at the unit. Also a high proportion of senior staff reported that they would have liked to have more training on the system (60% of the senior doctors and 75% of the senior nurses).

One of interview questions referred to the number of channels displayed on the computer screen. As noted earlier, no more than five channels can be shown simultaneously. We asked staff if they thought that having five channels on display was sufficient for them to make decisions. Less than half of the interviewees (about 45%) replied that five channels were sufficient. Some felt that generally five channels were ample on most occasions although sometimes more channels would be helpful. Several of the interviewees reported that it would be difficult to assimilate all the information if more than five channels were available.

When asked about ways in which the system could be improved, not all interviewees were able to provide an answer; in particular, the more junior staff.

The improvements to the system suggested by interviewees (both senior & junior) could be summarised as follows:

(a) To endow the system with some form of "intelligence", for example the automatic interpretation of the monitoring data and detection of evolving events, the ability to generate useful warnings to the user, and the ability automatically to summarise relevant events in the history of the baby and highlight them in an accessible way.
(b) To make the system more "user-friendly", by facilitating access to different kinds of information.
(c) A more sophisticated, complex, and flexible representation of the monitored data. (This feature was suggested only by senior doctors).
(d) To increase the amount of clinical information available online, for example blood results and bilirubin (e.g., in the form of charts); X-rays stored as graphic files; more specific information about blood gases (e.g., about pH tests); ventilator settings; "oxygen requirements" or FIO_2; and, in general, all information about the history of the baby and the mother, as well as nursing and medical notes, to get rid of paper notes altogether. In fact, a great deal of the information requested during the simulations coincided with these suggested requirements (e.g., information requests categorised as: "procedures", such as drug administration; "tests", such as X-ray and arterial sample results; and "settings" of the incubator and the ventilator).

The is apparent confusion as to what information is recorded online and what information should be recorded on paper. Similarly, a junior nurse complained about the lack of uniformity in the screen displays. As noted earlier, the representation of monitored data in the MARY^{TM} system is fairly flexible. Therefore, in practice, the time scale, the number and nature of the parameters displayed, and the axis scales can vary greatly from time to time and from baby to baby, depending on the personal preferences of the senior staff who have altered them (often junior staff do not see themselves as entitled or able to modify them). This lack of uniformity may lead to confusion amongst more junior staff. Note this is an important contrast with suggestion (c) above.

Other concerns from staff were: the lack of training on the system (as noted above); the fact that the system is not available for all babies in the intensive care unit; and problems with the calibration of some of the monitored physiological parameters (e.g. the blood gases, O_2 and CO_2).

A surprising finding revealed by the observations was the relatively high frequency with which the activity "deal with alarm" was conducted, especially amongst the nurses; but it was also conducted by the junior doctors more often than several other activities, and it took some time from the senior doctors. Dealing with the alarm merely involves turning it off. It does not normally lead to other care activities because, in most of the cases, it is not an indication that something seriously wrong is happening to the baby. The fact that alarms go off so often (and hence need "dealing with") can be partly explained by the fact that the alarms currently implemented in neonatal ICUs had been originally designed for adult intensive care patients. But a neonate has different care needs and many false alarms are generated in the neonatal unit. Although dealing with the alarm is a brief activity which does not require a lot of effort or time from staff, it is nevertheless a frequent and irritating aspect of the work environment.

Discussion and Conclusions

We have presented the results of various empirical procedures investigating the decision making of clinical staff, with a view to assessing the role of computerisation in neonatal intensive care. Findings were not always consistent across the different methods. Important discrepancies were found, for example, between the interviews and the observations regarding staff use of the computerised system. Such discrepancies reinforce the importance of using an approach involving a mixture of methodologies. By combining information from subjective reports, observations, and experimental approaches we obtain a richer picture of people's working habits and decision making procedures.

Overall, our findings indicate a positive attitude from clinical staff towards computerisation in general, and towards the currently implemented computer monitoring system, in particular. Most interviewed staff reported that trend monitoring (one of the most distinctive features of the system) was very helpful.

The staff who seemed to benefit most from the contributions of the computerised monitoring system were the senior doctors. However, as regards junior doctors' and nurses' routine decision making, the role of the computerised monitor is not so clear. Nevertheless, our observations showed that some junior staff did actually use the trend monitor, even if not very frequently. Our data suggest that an important function played by the computerised monitor in everyday working practices of junior staff is that of reinforcing their decision making. Rather than using the system to identify developing events on a baby, junior doctors and nursing staff seem to turn to the computer system as a way of finding supporting evidence for the decisions they have made after consulting other sources of information. Therefore we should not necessarily expect the system fully to replace traditional sources of information, or even to be the main source of information on which staff rely.

Our investigation suggest ways in which the implementation and design of the computerised monitoring system can be enhanced to ensure that junior doctors and nursing staff can and do use the system more frequently and effectively. Specifically, our findings suggest that the following issues should be addressed: (a) staff training on the system; (b) the maintenance of parallel records; (c) the nature of the information available online; (d) the user interface; and (e) the incorporation of "intelligent" warnings. Each of these issues is discussed in some detail in the following paragraphs.

An important aspect of the implementation of the system in the unit is the *training* of the staff. Few interviewees reported that they received training on the computerised system. Furthermore, several nurses and junior doctors actually mentioned the absence (or shortage) of training as one of the main problems associated with the system. Previous research has in fact shown that ongoing formal training is an essential requirement for the successful implementation of a computerised system in an intensive care unit, as it may affect acceptance and subsequent usage of a system by staff [3].

Parallel recording may also affect the acceptability and usability of a computerised system. We noted that manual nursing charts are still being kept in the neonatal unit. A great deal of the information provided by the system is already accessible from other sources, hence the computerised monitor is partly redundant. Furthermore, as suggested by previous literature [3], parallel recording often leads staff to perceive the computerised system as an addition to their workload rather than as a helpful tool. We found that this does not seem to be the case with most of the clinical staff we interviewed; they all reported that they found the system helpful. In fact, with the exception of the odd "technophobe", most of the interviewed staff seemed to be quite keen on the prospect of having online all of the clinical information about the babies. In practice, however, computerised aids do not normally replace conventional sources of information [16]. Moreover the total replacement of paper records is not usually possible in most hospitals for legal reasons.

The interviews and the off-ward simulations provided insights about the *sorts of information* staff would like (or need) to have online to take better advantage of the trend monitoring provided by the computer system. However, comprehensive information in the computer may not be the best option to support effective work. In a decision making environment such as the ICU, the interactions amongst members of staff are crucial. It is therefore arguable whether all the required information should be available online, or whether at least some of the data should be retained in more conventional methods to encourage exchanges of information among staff members, and so guarantee human communication.

As regards the *user interface*, several members of staff reported during the interviews that currently it is not sufficiently flexible, or that much of the information provided by the system is not easily accessible. However, only the senior doctors requested more flexible interfaces. In contrast, the nurses and the junior physicians (the end users of the system) tended to be concerned with the lack of consistency which arises from use of an interface that is already flexible. It seems thus desirable to tailor the balance between flexibility and consistency of data presentation for different grades of staff.

Finally, a desirable feature of a computerised aid is the use of *"intelligent alarms",* that avoid the frequent false alarms experienced on the ward, yet which rapidly inform staff as to the nature of the problem. Various members of staff (in particular, senior doctors) suggested the potential value of a computer system that can recognise and interpret monitored physiological patterns, and consequently warn the staff working at the cot side about the possible onset of relevant clinical events. The development of "intelligent" software (in the form of computerised decision support) is precisely one of the main goals of the studies described in this paper. We are investigating the ways in which data from our simulations can be used to inform the design requirements of such software [15]. We intend to combine these results with research in AI, currently in progress, on the use of *trend templates* for the automatic interpretation of monitored data [17]. Furthermore, we are looking at the literature on alarms in intensive care [18] in search for suggestions on how to implement intelligent warnings.

In summary, our studies have provided insights into clinical decision making in neonatal intensive care, and the impact (or lack of impact) of computerised monitoring in that decision making. The use of a variety of psychological methodologies has allowed us to elucidate how physicians and nurses with different degrees and types of expertise make use of the different information sources available in the neonatal ICU including. Our results are helping to identify precisely the kind of help that junior physicians and nurses would require from a computerised aid in intensive care.

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