Information Layering to De-Clutter Displays for Emergency Ambulance Dispatch

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ABSTRACT
In this paper we report on a study to examine the usefulness of the MLD (Multi-Layered Display) as a device for creating physically distinct but visually overlapping information, what we refer to as 'information layering'. The technique was applied to emergency ambulance control, as a method for reducing visual clutter and information complexity in displays used by controllers. The results of the study show that participants completing simulated dispatch tasks in the MLD condition performed better on all categories of task difficulty compared to participants using a standard single layer display. However the improvements in performance were not significantly different.

Keywords
display design techniques, information layering, emergency ambulance command and control, multi-layered displays, visual clutter

INTRODUCTION
This study is part of research into developing new forms of information representations for operators in domains with high volumes of data and where the data undergoes high rates of change. One example of such a domain is emergency ambulance command and control. This research sought (i) to understand the nature of the decisions that emergency ambulance controllers make using cognitive task analysis methods such as the Critical Decision Method (Klein, 1989) and the Emergent Themes Analysis (Wong and Blandford, 2002), (ii) to identify the factors that contribute to the perceived complexity of the ambulance dispatching task and how these factors influence information extraction, situation assessment and decision making during these tasks (Hayes, et al, 2005), and (iii) to examine how appropriate information representations can improve the dispatcher's performance on the dispatch task. In this paper we will focus on the last issue.

BACKGROUND
One of the problems known to impede operator performance is that of data overload (Woods, Patterson and Roth, 2002). Whilst in many systems there is no shortage of information that is able to be presented to the operator, there are limits in regard to the cognitive resource that operators can allocate to this information. As such, although data is available, operators may not be able to extract meaning from this data in relation to their goals. With this in mind it makes sense to design information representations that avoid such problems of data overload.

According to Woods, et al (2002), one of the factors that contribute to data overload is visual clutter (i.e. a large number of display elements in a small display area). An approach to addressing this issue is simply to remove data elements from the display and allow operators to turn these on when required. However attempts to reduce visual clutter in this manner have not always proved successful. For instance an experiment conducted by Yeh and Wickens (2001) illustrated how the time cost of turning information on and off out weighed the time benefits of presenting less information. In this experiment the participants were asked to find and then answers questions about information on the displays. The authors theorised that any advantages that may have occurred from reducing the clutter on the interface were offset by the participants having to determine if they needed to consider the hidden information (adding further cognitive load).

A second disadvantage to the above approach is determining which data elements are primary information and which are secondary. Often this is dependent on the situation encountered by operators and as such information that is considered secondary in some instances may be absolutely critical in others. Consequently the risk of operators not turning on the required information and therefore overlooking critical data increases.

Such scenarios raise questions including what techniques are there to reduce visual clutter that still retain the representation of key information items and furthermore, allow these items to be viewed in context? Two such techniques are discussed in more detail below.

Fisheye Views
One approach that can be used to avoid visual clutter are fisheye views. The main motivation behind a fisheye

view is to provide a balance between detail at the focus of the users attention and context at a global level (Furnas, 1986). For instance, on a map display there may be a considerable amount of detail at the point on the map where the users' attention is focused. This information could include streets, street names, points of interest (e.g. hospitals or information centres). However at points further away from the users' centre of attention the level of detail decreases where only important features of the situation being evident (Furnas, 2006). For instance, street names and points of interest would no longer be presented and the number of streets may reduce such that only major arterial routes would be shown.

Whilst such an approach may prove useful in domains such as emergency medical dispatch, it again raises questions as to what is the most important information to present outside the user's focus of attention.

Multi-Layered Display

An alternative approach is the use of information layering on a new display device called the MLD, or Multi-Layered Display.

The MLD is a new and un-conventional display technology. It consists of two overlapping LCD (Liquid Crystal Displays) separated by a 10 mm thick transparent Perspex layer. It is designed such that data presented on the rear LCD is visible through the front LCD. This creates new opportunities for presenting information, such as information layering (as to be described in this paper), which can increase the density of information presented within the same visual field of view of an operator. An advantage of this approach is that it is not necessary for operators to turn information on or off and that information on each layer is able to be viewed in context.

While we can anticipate problems, such as poor legibility caused by presenting text over text, resulting in an un-readable display, the MLD has also led to some un-expected outcomes: certain colour pairings, of text in the foreground against a background colour that have been found to lead to poor legibility on conventional CRT monitors in past research, have been found to be just as good as good colour pairings, when tested on the MLD (Nees, 2003; Karanja, 2006).

The key characteristic of the MLD, however, is its layered LCD construction. This physical layering creates a real perception of visual depth. Another study found that in a target identification task, the participants on the MLD were 4 seconds ($p<0.05$) faster than participants using a conventional single layered display. This task involved participants identifying designated moving circles within a larger group of moving circles. For the participants using the MLD, the designated moving circles were presented on the front screen layer (Joyekurun, 2005).

While the work briefly described above used abstract representations, e.g. moving circles, this study attempted to explore the use of the MLD in a more applied context. A very close replica of the actual map-based display used by the emergency ambulance controllers of the Northern Region ambulance centre, in Auckland, New Zealand, was developed and re-designed so that key pieces of information needed by the dispatch task were placed on the front layer of the MLD, while contextual information such as the map and location of secondary medical resources, were presented on the rear LCD (Figure 1). At the same time, the new display maintained a form that is still visually identical to the original dispatch map-display. Hence the only difference between the MLD and the SLD was that key pieces of information were presented on the front layer in the MLD.

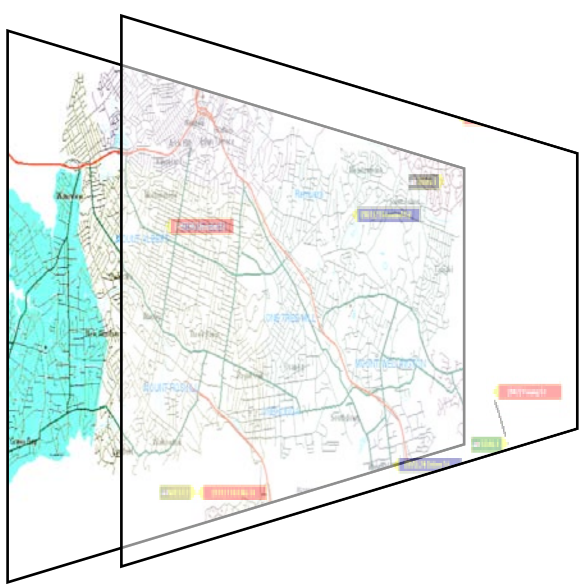

Figure 1. The MLD consisting of two overlapping LCD displays

METHODS

One of the key tasks in this study was an assessment of the current map-based dispatch display. A number of shortcomings were identified in terms of what were considered to contribute to perceived task complexity and in relation to the decision strategies that were previously identified. One of the most noticeable problems was that the display is visually cluttered, e.g. there is a large amount of information on the display relating to ambulances at destination, in transit, or on station; location of incidents and whether they have been responded to; and black lines linking ambulances to incidents. An example of a fairly cluttered map display currently used in the centres is presented in Figure 2.

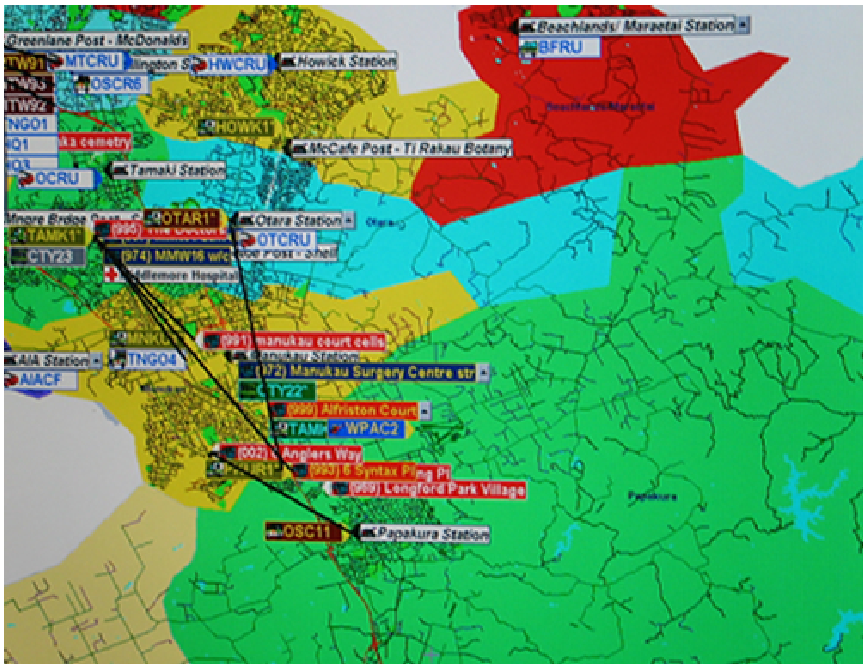

Figure 2. A photograph of the current map display in use.

The display was re-designed with the view that we can reduce some of the perceived complexity by reducing some of the visual clutter on the display. Information layering was applied as the main technique. Information layering is the process of separating and segregating relevant pieces of information across the two layers of the MLD. For example, in our study information about the incident, and ambulance resources were presented on the front layer, whilst contextual information such as the map, location of stations, and secondary medical resources were presented on the rear layer. The design decision was also guided by the Proximity-Compatibility Principle (PCP) (Wickens and Carswell, 1995), as we attempted to make the design compatible with the decision strategies and needs in order to address perceived task complexity. Hence, the visual depth information layering was used as the technique to show relationships between entities of the control environment.

The new display was then evaluated in an experiment that involved 40 participants with normal colour vision. The experiment was designed as a between subjects, 2 (SLD vs. MLD) x 4 (levels of task difficulty) factorial design. The four levels of task difficulty are:

- Category 1 Simple Problem where there is only one appropriate ambulance station in the area from which to dispatch an ambulance.
- Category 2 Trade Off Problem where the incident occurs within a stations area of responsibility and multiple resources are available. Participants must also match the skill of the ambulance crews to the needs of the patient.
- Category 3 Boundary Problem where an incident occurs in between two stations areas of coverage. Dispatchers must determine factors such as the resource likely to arrive at the incident the quickest and the coverage in each area.
- Category 4 Balancing Problem, a more demanding problem where the dispatcher needs to balance the ambulance coverage over an area so that there is no ‘gaps in coverage’ as a result to sending ambulances to an incident.

These categories were representative of the types of difficulties the dispatchers regularly encounter. For each level of task difficulty there were 6 test trials, making a total of 24 trials for each participant. Prior to completing the test trials, participants completed eight practice trials.

Table 1: *Mean response times for each category of difficulty.*

	Mean Response Time (msec)		
	SLD	MLD	Difference
Category 1	8454.05	7529.16	924.91
Category 2	10310.78	9789.97	520.82
Category 3	12854.43	11563.58	1290.86
Category 4	10646.36	9412.15	1234.20

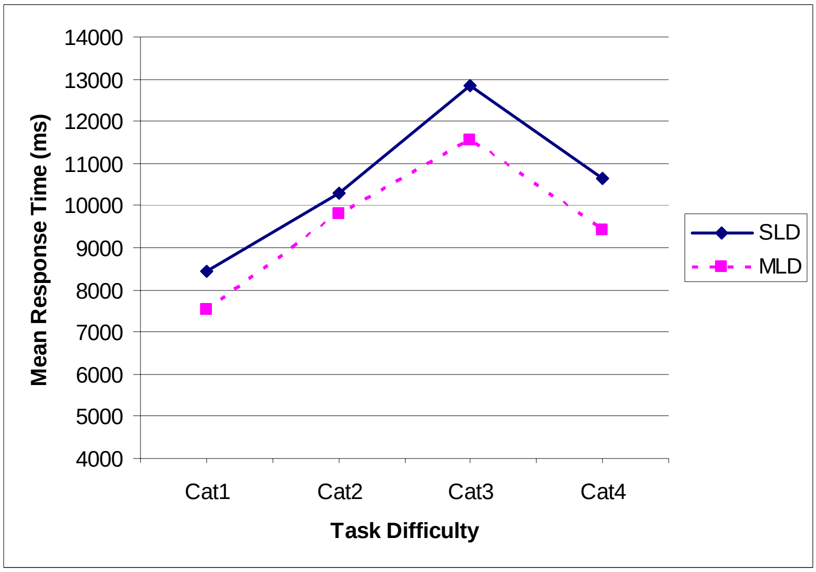

Figure 3. Plot of Dispatch Time versus Category of Task Difficulty.

PROCEDURE

At the start of each trial, the participants were presented with details of an emergency incident requiring one or more ambulances. This included information about the incident location and the patient's condition. On acknowledging that they understood the nature of the incident, the participant was then presented with a map display, either on the MLD or the SLD, showing the location of the incident and ambulances. From this display they selected and assigned the ambulance resource that they considered to be the most appropriate for the incident.

RESULTS

The unit of measure to determine difference in performance between the display conditions was the dispatch decision making time. This is measured as the time from when participants acknowledged that they understood the details of the incident, to the time the first ambulance is assigned.

An initial analysis of the data collected from the experiment showed that for almost all of the trials, participants in the MLD condition performed better than their counterparts in the SLD condition. However this difference only proved to be significant for one of the 24 trials ($t(38) = 3.366$, $p=0.002$).

A second analysis was made to determine whether there were any significant differences in performance between each condition for the different categories of difficulty. For both simpler tasks (Category 1 and 2), there are no real differences, although the mean response times seem to suggest some very small differences of between 0.5 sec to 0.9 sec. For the more difficult problem categories, the differences are much larger, Category 3 at 1.29 sec (borderline significance at $p=0.053$) and Category 4 at 1.234 sec (although, not significant). These results are presented in Table 1 and illustrated graphically in Figure 3. A more detailed report on this is available elsewhere (Hayes, 2006).

Another aspect of the experiment was the number of errors made. An error was considered to be made if the nearest ambulance was not dispatched to the incident. The total number of errors across all participants was calculated for each trial, and for each category. These results are tabulated and presented in Table 2.There were generally fewer errors made by users of the MLD.

Figure 4. The situation presented in Trial 24.

However, in one specific trial, Trial 24, participants using the MLD, made 10 times more errors than users of the SLD. The errors were made by 50% of the participants in the MLD group. On closer examination, we find that the incident was located mid-way between two ambulance stations, one at Mt Wellington and the other, across a harbour, at Howick. Both stations, in terms of a straight line, were equidistant from the incident. However, because of the intervening river and the road system, an ambulance travelling from the Howick station to the incident would take much more time to get to the incident location, something that was not widely picked up by the participants. This is illustrated in Figure 4.

On the MLD, the map and other contextual information are presented on the rear LCD, and only key incident-relevant information on the front screen. The high error rate arising from this incident may be possibly due to some form of attention tunnelling. Participants were so focussed on the incident and resource information that was presented on the front layer of the display, they failed to recognise that there is a harbour in between as presented in the rear layer, which is not the focus of attention.

DISCUSSION

Has the MLD design reduced visual clutter? What are the issues raised or learnt about information layering as a design technique for reducing clutter?

(1) Although the difference between the mean dispatch decision response times of users of the MLD and the SLD are not statistically significant except for the Category 3 problems, where the *p* was borderline (p=0.053), there are some indications that the MLD could provide benefit in helping the user focus on relevant information, and in that way, provide a means for reducing visual clutter while still retaining all the information necessary for maintaining an awareness of the overall situation. In our earlier work on identifying decision strategies and key difficulties and complexities, reported elsewhere (see Hayes, 2006), the need to maintain a good awareness of developments in the overall situation (a collection of incidents in a region), rather than just individual incidents, is a major challenge. One approach to filtering out information is to turn on or off information as needed, or to drill down into more detail as needed. However, studies by Yeh and Wickens (2001) suggests that in such approaches, the cost of turning information on and off out-weighed the benefits of using such approaches to de-clutter the interface. The operator has to consider, remember or know that there are additional relevant pieces of information that have to be turned on or accessed in a decision. Other research have also shown that when the information access cost is high, such as when one has to refer to a manual when one is under significant time pressures, people are likely to do without that information (Vessey, 1994). The MLD, however, through its physically distinct layers, provides an alternative capability of being able to present all necessary information at the same time, while visually segregating the needed information on the foreground layer. However, in this study, the results on this issue are not conclusive, possibly because we still have yet to learn about designing across two overlapping and transparent displays. This avenue of research continues to be investigated in the near future.

(2) The errors encountered in Trial 24 highlights a different problem. Deciding in advance what

information is needed and to then segregate them across the different layers, in principle, is a good way of de- cluttering the interface. In practice, as we have seen, this can lead to problems associated with attention tunnelling. The information on the foreground is more salient than information in the background, such that the operators attend to the more salient pieces of information, reinforced by the information being located in the foreground of the visual field of view, to the extent that they over-look less obvious but important information. In our example, that there is a harbour separating the ambulance station and the incident location. This problem of saliency is not new (Wickens, et al, 1998), e.g. visual objects can be made erroneously salient by portraying them in bright or bold colours, or as flashing objects or texts, resulting in important information being over-looked or taking more time to attend. While this problem of saliency could have been anticipated, it was not obvious. The very feature of the MLD that gives it its distinctive capability, the visual depth feature, can work against itself. In learning how to design for it, we will need to understand how to avoid the saliency problem, while not sacrificing the capability to segregate information, and to present important informational and ecological relationships. This is to be investigated in future work.

Table 2. *Number of Errors for Each Trial by Dispatch Category*

	Trial #	SLD	MLD	Total
Category 1	1	3	3	6
	5	1	0	1
	9	0	0	0
	13	3	3	6
	17	0	0	0
	21	2	0	2
	Total	**9**	**6**	**15**
Category 2	2	0	0	0
	6	1	0	1
	10	0	0	0
	14	0	0	0
	18	2	4	6
	22	2	0	2
	Total	**5**	**4**	**9**
Category 3	3	3	3	6
	7	3	3	6
	11	0	0	0
	15	3	2	5
	19	0	0	0
	23	1	1	2
	Total	**10**	**9**	**19**
Category 4	4	3	1	4
	8	3	3	6
	12	6	1	7
	16	1	2	3
	20	1	0	1
	24	1	10	11
	Total	**15**	**17**	**32**
Overall Total		39	36	75
% of total		8.1	7.5	7.8

CONCLUSIONS

There are indications from this and previous studies that the MLD has potential for increasing operators' abilities to extract information in high information density and high rates of change. This capability needs to be exploited, but designing the information visualisations as it if were a conventional single layered display will not allow us to take advantage of the distinct physical depth. Further work is being carried out to assess the utility of the display as well as to understand the information design techniques needed to exploit this capability.

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