Experimental Transformation of a Cognitive Schema into a Display Structure

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Abstract

The purpose of this paper is to report on an experiment conducted to evaluate the feasibility of an empirical approach for translating a cognitive schema into a display structure. This experiment is part of a series of investigations aimed at determining how information about dynamic environments should be portrayed to facilitate decision making. Studies to date have generally derived an information display organisation that is largely based on a designer's experience, intuition and understanding of the processes. In this study we report on how we attempted to formalise this design process so that if the procedures were adopted, other less experienced designers would still be able to objectively formulate a display organisation that is just as effective. This study is based on the first stage of the emergency dispatch management process, the call-taking stage. The participants in the study were ambulance dispatch officers from the Dunedin-based Southern Regional Communications Centre of the St. John's Ambulance Service in New Zealand.

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1 Introduction

The operators, or the people who plan, control and direct the use of resources in emergency co-ordination centres or military command and control centres, are often faced with decision making conditions that are very different from laboratory-based environments. They may frequently encounter conditions of time-pressure where it is necessary to make near-instantaneous decisions; high stakes where a wrong decision could result in loss of lives; unstructured problems where it is not clear what the problems are; dynamically changing situations; and inter-dependent decisions where the outcomes of decisions made earlier in the process will influence the outcomes of subsequent decisions. The decision making that takes place under these conditions have been termed naturalistic decision making (Klein, 1990; Orasanu & Connolly, 1993).

Computer-based information systems have been introduced into these environments in order to deal with the large amount of information that operators in these centres usually have to deal with when managing real-time planning and control activities. Because time is constrained, the manner in which these systems portray task-critical information becomes important. The operator needs to be able to see the information, and quickly understand what the information is portraying about the situation being controlled so that the operator can quickly devise a plan of action. For instance, in an ambulance dispatch decision, the dispatch officer needs to know what resources he or she has available and know where these resources are. The dispatch officer would be able to make a faster decision if the information portrayed indicated the vehicles that are available rather than those in use. Alternatively, if the operator needs to make a comparison between vehicles available at neighbouring stations, the comparison can be facilitated by having the display portray information in a manner that would facilitate such a comparison (Wong, et al. 1995).

In the development of an approach for designing the way information should be portrayed in naturalistic decision making situations, one of the problems encountered is how the information requirements identified can be formally and objectively translated into a computer interface display design. This paper reports on one of the experiments conducted to formalise this translation.

2 Background to the Study

The St. John's Ambulance Service in New Zealand is responsible for managing all emergency and non-emergency ambulance operations in the country. The Ambulance Service is divided into six regions each with a dispatch management centre, called a

Regional Communications Centre (RCC), sited in a major city. The responsibility of each RCC covers both rural and metropolitan areas. This study was conducted in the Southern RCC based in the city of Dunedin. The Southern RCC is responsible for 48 ambulances deployed over an area of approximately 54, 000 square kilometres.

A cognitive task analysis (CTA) was conducted with eight randomly selected ambulance dispatch officers of the St John's Ambulance Service Southern Regional Communications Centre in Dunedin to identify their decision strategies and information portrayal requirements. The CTA interview technique employed was the Critical Decision Method (Klein, Calderwood & Macgregor, 1989). The interview transcripts were analysed using a qualitative data analysis software called NUD*IST™ (QSR, 1994).

The study is based on the notion that there will be improvement in human performance if task critical information is portrayed in a manner that supports the decision strategies invoked during that process. The study may therefore be divided into the following three components:

a. identify the decision strategies,
b. identify the knowledge requirements and hence information portrayal requirements,
c. translate these information portrayal requirements into a display design.

This report is concerned with components 'b' and 'c'. The next section will describe how the knowledge and information portrayal requirements were identified by determining the information structure required by the decision process and strategies identified in an earlier study (Wong, 1995) . The concept mapping technique (McFarren, 1987; Novak & Gowin, 1984) was initially applied but found unsuitable especially when the purpose was to make the procedure as replicable and personality-independent as possible. Geiselman & Samet's (1980) Schema Theory-based technique was then attempted and was found to have potential for determining the information portrayal structure.

In the last sections, this paper will report how this information portrayal structure was converted into a display design.

3 Concept Mapping of Information Requirements

Initial analysis of the interview transcripts using the concept mapping approach revealed a schema (Bartlett, 1932) of the call-taking frame of knowledge, represented in Figure 1.

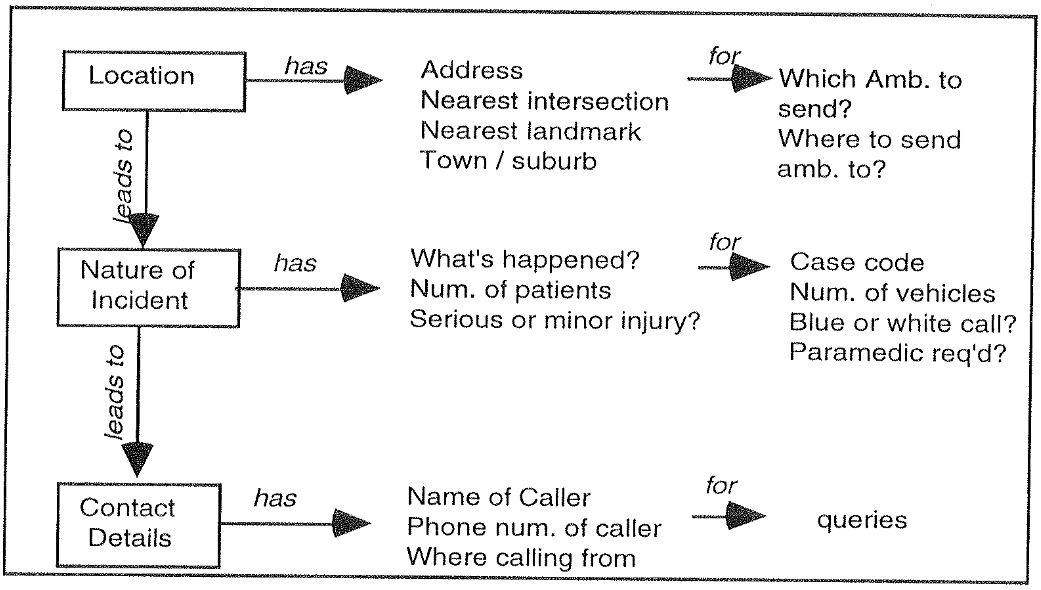

Figure 1: A concept map of the mental schema of information requirements during call-taking

The boxes on the left of Figure 1 indicate the main concepts or information entities. These entities were derived from a collation of the attributes cited during the interviews. The attributes are recorded in the centre column. The extreme right column represents the purpose each entity and attribute serves. For example, the "Location" entity is used by the dispatcher to determine which ambulance is nearest or most appropriate to send, and the location details are necessary for directing the vehicle to the incident site, especially if the site is in a rural area or out in the country.

The arrows are free to describe the nature of the relationship between entities, their attributes and the concepts that these entities are associated with, e.g. the purpose of an entity, or the reasons for which an entity and its attributes exist. In the concept map in Figure 1, the arrows represent three types of relationships:

a. The *has* arrow indicates that the entity has the attributes following the arrow.

b. The *for* arrow indicates the reasons *for* which the attributes exist or are used for during the call-taking phase.

c. The *leads-to* arrow indicates the general sequence in which the entities are used during call-taking.

This approach is less restrictive than the formal knowledge modelling notation (e.g. is-a) used in the knowledge engineering domains. The concept map is also different from the conventional entity-relationship (E-R) diagrams with which systems analysts are familiar. The concept map is also not a data model aimed at explicating the relationships for database design purposes. The concept map represents the cognitive schema of the user, which consists of the concepts that the dispatcher works with and the information that supports these concepts. It has also been used to include higher-order constraints or goals that the entities serve. These goals are indicated by the *for* arrow.

The "neat" schema is probably due in part to an existing computer fill-in form which dispatchers use during call-taking for data capture. It is believed that dispatchers use this fill-in form screen as a framework for their recall of what happens during call-taking. The interview data however does not indicate a total reliance on these data because the sequence in which the data is reported is not consistent in many cases.

While the existence of the fill-in form may challenge the usefulness of the procedure to develop the schema, it serves as a useful check to test the accuracy of the method to develop a schema. This issue is further discussed later.

While providing a quick solution, the approach used above to derive the mental schema has several problems:

a. It does not take into account the variability of the sequence in which individuals report the occurrence of the information. One dispatcher had reported that the piece of information, "nearest intersection" is the first piece of information that is used or needed, while two others have reported it as the second piece of information, and yet others have suggested that the same piece of information is the third item used in the process.

b. It does not take into account the fact that not every individual reported the occurrence of each piece of information. For example, only three of the eight dispatchers reported the use of the information "nearest landmark", yet it is accorded the same level of importance as "nearest intersection" which is reported more frequently (seven of the eight dispatchers).

c. The method used to derive the schema in Figure 1, while effective, is unfortunately somewhat intuitive and based largely on the judgement of the researcher and on the experience he had gained from studying the dispatchers as they worked in the control centre.

Thus, it is not possible to predict whether another researcher, given the same data, would be able to replicate the results. For this reason, another approach is required.

4 The Geiselman and Samet Schema Theory-based Approach

Geiselman and Samet (1980) applied Schema Theory to quantitatively derive a schema of intelligence officers' use of military information. Their method required the identification of the information used by intelligence officers when making a situation assessment of a simulated wartime incident. The relative positions or sequence of the identified information entities and attributes were then worked out for each officer. The median relative positions of each piece of information for the entire group were then calculated.

Another factor was also calculated. This was the inclusion rate. This value represented the percentage of officers who had cited the use of a particular piece of information. The higher this percentage, the greater the salience as it indicates that more people thought it significant enough to cite it.

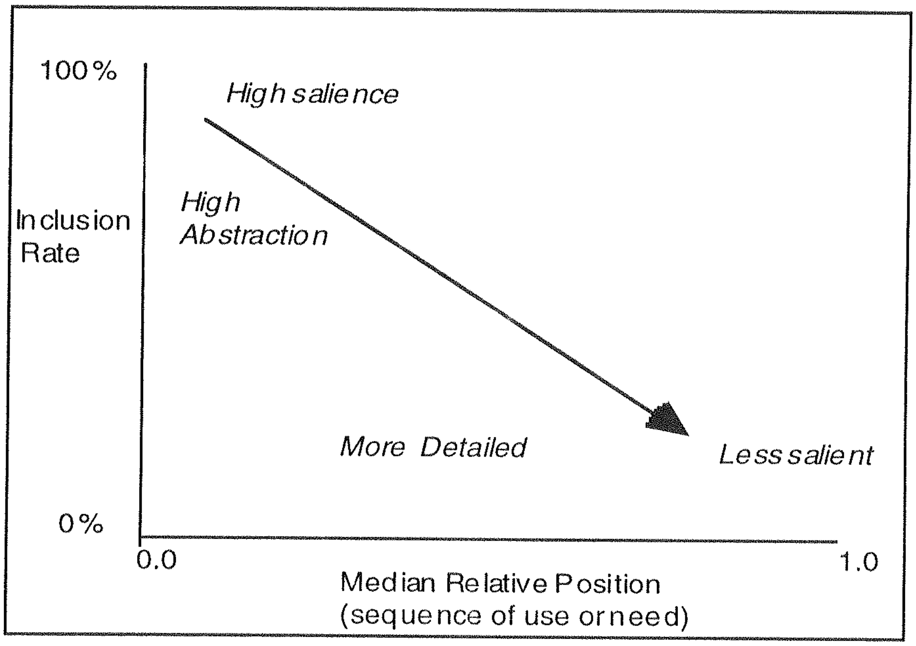

Figure 2: Interpreting a median relative position vs inclusion rate graph

By plotting the median relative positions against the inclusion rate, a visual representation of the relationship between the stage a piece of information is used and the significance of that piece of information is created. Information items that have high inclusion rates and are used earlier in the process, may be considered to be of high importance or are more salient, while those with low inclusion rates and are used later in the process indicate a lower level of importance or are less salient. This relationship is depicted in Figure 2.

This method appears to be more rigorous than the earlier experience-based approach. Also, given the same data – interview transcripts or written situation assessments – the results will be replicable. Furthermore, it would also address the problems of variability in the relative positions and will also account for the rate of inclusion, giving an indication of the considered importance. The next section will report on the procedure used to derive the chart of relative median position and inclusion rate for the current study.

5 Procedure Adopted in the St. John's Study

The specific steps in deriving the above graph were not explicitly reported in Geiselman and Samet's (1980) paper. However, guided by that paper, this study devised and adopted the following steps to analyse the St John's interview data.

5.1 Identify Absolute Position

a. Using NUD*IST™, the interview transcripts were analysed and the information used or needed during the call-taking phase of a '111' call was identified and collated.

b. For each dispatcher, the identified information was organised in the order they were reported to be used or needed during the process. This gave each piece of information its absolute position for a particular dispatcher e.g. "Location" information was reported as number two on the list for Dispatcher#4.

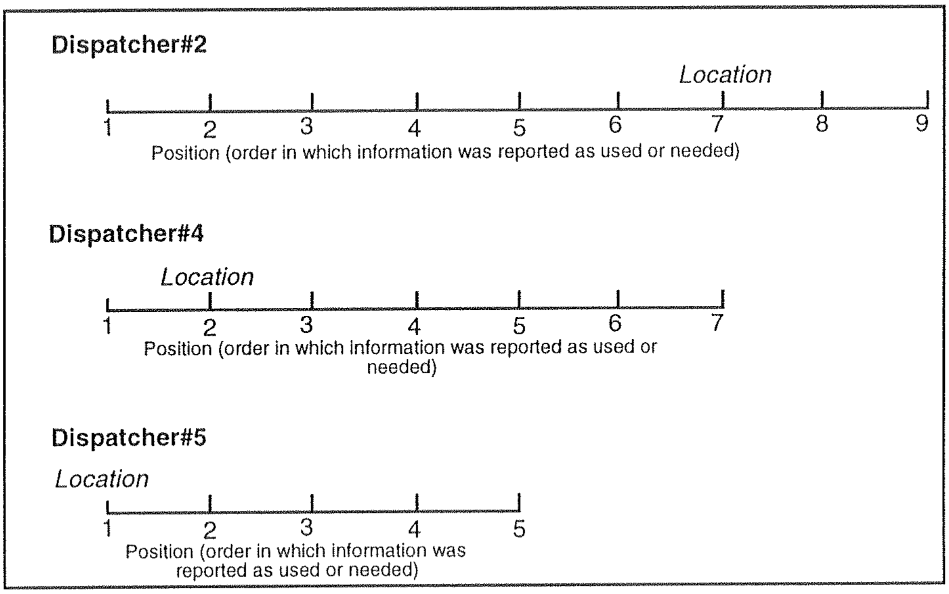

Figure 3: Reported positions of the information "Location"

5.2 Normalise the Absolute Positions

a. Because not all dispatchers reported the same number of items, there is a need to "normalise" the values of the positions so that the positions can be compared between dispatchers. This normalisation can be done by dividing the reported position by the number of items reported by each dispatcher. This then provides a common measure of the information's relative position which allows easy comparison of relatively where in the sequence the information was reported. This is illustrated in Figure 4.

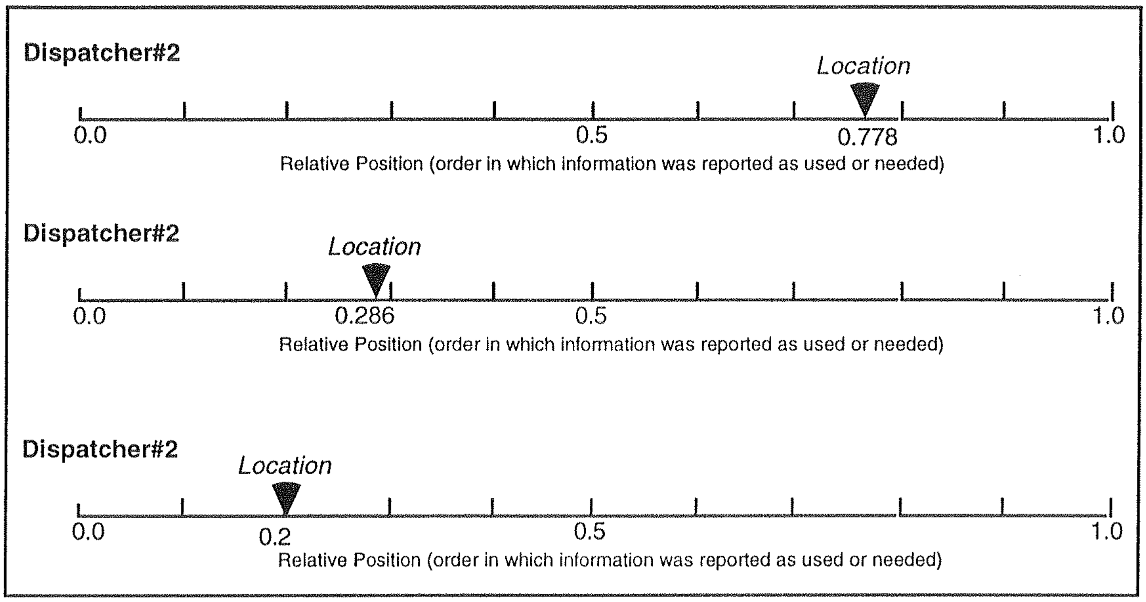

Figure 4: "Normalised" relative positions

b. A median for the relative positions can then be worked out for the given sample (the median is the value where half the values in a sample reside). In Figure 4, the median relative position for the three dispatchers is 0.286. The same can be worked out for the remaining entities. Hence each piece of information would have its own median relative position.

5.3 Calculate Inclusion Rate

a. The next step is to calculate the *inclusion rate.* The inclusion rate is the percentage of dispatchers who cited a particular piece of information during their interviews. A 100% inclusion rate means that everyone in the sample had considered that piece of information important enough to talk about it. A 60% inclusion rate implies that a piece of information is not that important.

5.4 Chart the Relationship between Inclusion Rate and Relative Median Position to Identify Clusters

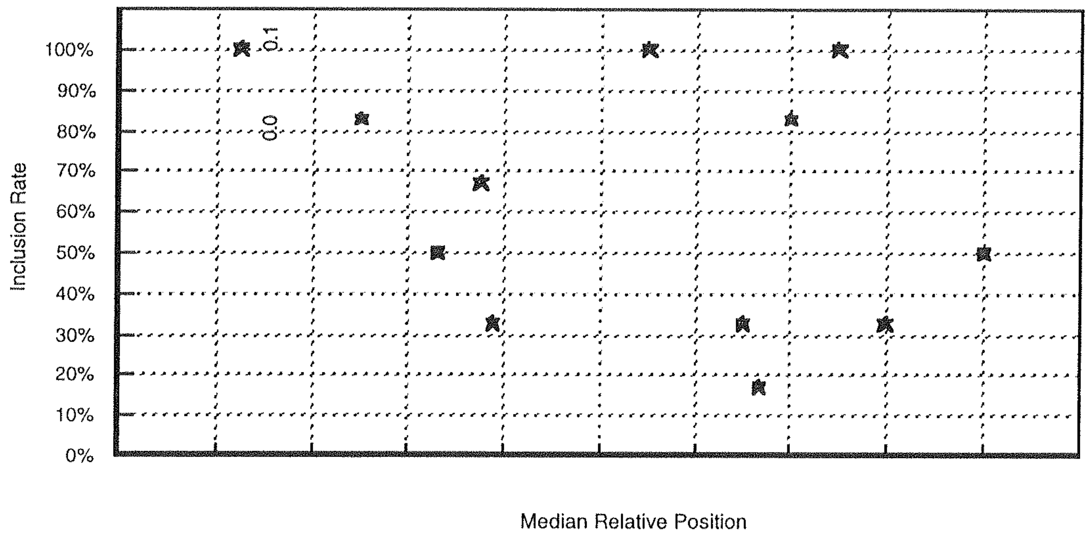

Figure 5: Chart showing the median relative positions vs inclusion rate

a. Having worked out the values for the median relative positions and inclusion rates for each piece of information, the data is then plotted. The graph in Figure 5 shows actual values derived from the interview data.

6 Is the Chart Valid?

The chart is useful for visually determining the relationship between each item and the time an item is needed or used during the process. Clustering the data based on their physical proximity with one another resulted in the following chunks:

a. Location and Intersection,

b. Town, Suburb and Landmark,

c. What happened? Phone, and Name of caller,

d. Serious/Minor?, Number of patients, [where] Calling from? and Equipment.

While the chart does not include the semantic associations needed to logically structure the information, the resulting chunks demonstrated meaningful associations. Furthermore, despite the variability encountered in the reported positions and inclusion rates, the resulting chunks very closely resembled the information structure or deep structure of the existing system display used during call-taking. As explained earlier in this paper, the comparison of the resulting information structure with an existing display structure is not a self-fulfilling activity. Instead, the comparison with an existing display was found to be useful in evaluating the validity of this approach. This finding suggests that if the analysis has been correctly performed, this chart is a valid representation of the information structure.

The next stage is to translate this information structure into a display structure

7 Translating the Information Structure to a Display Structure

An analysis of the chart in Figure 5 indicates that items with high values for inclusion rates represent items that are more significant and salient than items with smaller inclusion rates. Items with large inclusion rate values may be considered *key information*, and items with lower inclusion rates may be classified as *ancillary information.*

The median reported positions provides another clue to the sequencing of the items. Items reported early in the interviews should be portrayed early in the sequential order of a new display design. These basic guidelines can then be used to map the structure of that schema across to a display format.

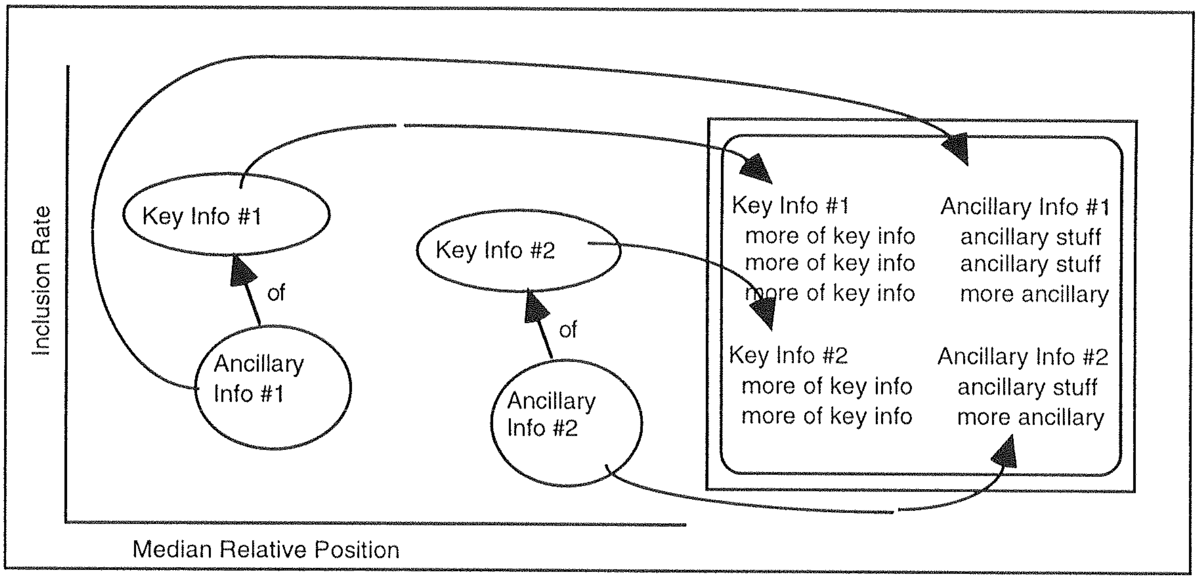

Figure 6: Transposing structure to display

One suggestion to transpose the schema represented in the chart to a display format is suggested and is illustrated in Figure 6.

In English-speaking cultures, normal reading practice dictates that people read from left to right and top to bottom. Hence, the more salient and significant information and the information used early on in the process should be displayed to the top left of a screen.

Therefore the chunk "Key Info #1" would be portrayed on the top left, and the chunk "Ancillary Info #1" would be portrayed on the top right. The next chunk "Key Info #2" and its associated "Ancillary Info#2" will be displayed lower to indicate its use later in the process.

To determine if this approach will work, the procedure was applied to the actual data. Figure 7 shows the existing data entry screen used during call-taking.

```
------------------------------ NEW JOB ------------------------------

Location      O/S 29 MACANDREW RD
Intersection  ATKINSON ST                         Suburb SthDn
Remarks       FALL IN STREET
Phone         4761234      Caller   MR THOMSON    Case Code  54
Paramedic     N            Response B             Despatcher 1
```

Figure 7: Existing screen used for data-entry during call-taking

The "Location" field in the existing screen is used to capture both the location and town information. The "Remarks" field in the existing screen is used as a catch-all field to type in the details of the incident, or the "What happened?" entity identified in this study. The remaining items - 'Case Code', 'Paramedic', 'Response', and 'Despatcher' - may be classified as derived information, i.e. their values are derived from the information collected from the caller. For instance, a paramedic is only required if the accident has resulted in serious injury.

Interestingly, while the "Landmarks" entity was identified in the study, it has no place in the existing screen. This has been included in the re-designed screen (Figure 8). The re-designed screen also features more white space between logical chunks to act as separators to delineate the respective chunks and thereby improve visual predictability and hence visual search (Tullis, 1990) .

```
------------------------------ NEW JOB ------------------------------
Location       O/S 29 MACANDREW RD
Intersection   ATKINSON ST                            TownSub SthDn
Landmarks      NEAR THE WAR MEMORIAL

What happened FALL IN STREET
Caller    MR THOMSON          Phone 4761234           Case Code  54

Paramedic     N               Response B              Despatcher 1
```

Figure 8: Re-designed call-taking screen based on proposed procedure

8 Conclusion

In this paper, we have proposed and briefly discussed a formal procedure of how information (content) can be formally structured, and then transposed from the derived structure into a display. Part of this discussion was based on data obtained through an analysis of the interviews with St John's ambulance dispatch officers. The information used represents the first one to two minutes of the call-taking phase of a '111' call.

It should be appreciated that while the process described here is still somewhat rudimentary and that a significant amount of refinement is still envisaged, it has served the purpose of clarifying the rather intuitive nature of translating information requirements into a display format.

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