

# GUIDELINES FOR THE ON-SCREEN DISPLAY OF MEDICINES – FINAL REPORT

A partial task analysis and heuristic evaluation were carried out to provide advice on twelve questions regarding human factors guidelines for the Australian Commission on Safety and Quality in Health Care.

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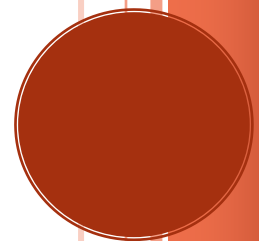
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# Guidelines for the On-screen Display of Medicines – Final Report

## Contents

Overview .....	5
Preliminary Partial Task Analysis.....	6
Processes involved in generating a prescription using computer-based prescribing software .....	6
1. Identifying the patient in the system database .....	7
2. Reviewing patient information.....	7
3. Medicine selection.....	7
4. Reviewing clinical decision support .....	8
5. Entering administering details .....	8
6. Entering dispensing details and reviewing.....	9
7. Reviewing alerts and advisories.....	10
Processes involved in administering prescribed medications .....	10
1. Check patient’s identity.....	10
2. Assess medication requirements .....	11
3. Perform any required physiological assessments .....	11
4. Locate patient’s required medicine .....	11
5. Prepare and administer medication.....	12
Key questions to be addressed by the human factors evaluation panel.....	13
Heuristic evaluation research methods .....	14
Heuristic evaluation results: Rationales for final recommendations .....	15
Question 1: How should micrograms be displayed? .....	16
Background.....	16
Option 1: MICROg .....	16
Option 2: microgram.....	16
Option 3: mcg.....	17
Option 4: Display as milligrams not micrograms (e.g. 0.25 mg instead of 250 mcg).....	17

Option 5: $\mu\text{g}$ .....	17
Option 6: MICROgrams.....	17
Option 7: microg.....	18
Option 8: micrograms .....	18
Question 2: How should “greater than” be displayed? .....	19
Background.....	19
Option 1: greater than.....	19
Option 2: > .....	19
Option 3: more than.....	19
Question 3: How should “less than” be displayed? .....	20
Background.....	20
Option 1: less than.....	20
Option 2: < .....	20
Question 4: Is it appropriate to use the “/” symbol in an expression of product strength?.....	21
Background.....	21
Option 1: /.....	21
Option 2: per .....	21
Question 5: Is it appropriate to use the “/” symbol in an expression of rate? .....	22
Background.....	22
Option 1: /.....	22
Option 2: per .....	22
Question 6: Is it appropriate to reserve the “+” symbol for separating the active ingredients in a product? .....	23
Background.....	23
Option 1: + .....	23
Option 2: and .....	23
Option 3: &.....	23
Option 4: plus.....	24
Option 5: /.....	24
Question 7: Is it appropriate to reserve the “&” symbol to separate multiple components in a multiple component pack? .....	25
Background.....	25
Option 1: &.....	25

Option 2: &.....	25
Option 2: {&} .....	25
Option 3: (&) .....	26
Option 4: and .....	26
Option 5: + .....	26
Option 6: plus.....	26
Option 7: /.....	27
Option 8: )&( .....	27
Option 9: }&{ .....	27
Option 10: }and{ .....	27
Option 11:  &  .....	27
Question 8: What term should be used for the separator label denoting quantity? .....	28
Background.....	28
Option 1: supply.....	28
Option 2: supply qty.....	28
Option 3: quantity.....	28
Option 4: supply quantity.....	29
Option 5: qty .....	29
Question 9: What formatting guidelines should be recommended for the display of product names? .....	30
Background.....	30
Option 1: Active ingredients are bold, lowercase, non-italicised. Brand names are non-bold, lowercase, italics. The first letter of every key word in the brand name is a capital (i.e. title case). .....	30
Option 2: Active ingredients are bold, lowercase, non-italicised. Brand names are non-bold, uppercase, non-italicised. ....	30
Option 3: Active ingredients are bold, uppercase, non-italicised. Brand names are non-bold, lowercase, non-italicised. The first letter of every key word in the brand name is a capital (i.e. title case). .....	31
Option 4: Active ingredients are non-bold, italics, lowercase. Brand names are uppercase, non-bold, non-italicised. ....	31
Option 5: Active ingredients are bold, lowercase, italics. Brand names are non- bold, non-italicised, lowercase. The first letter of every key word in the brand name is a capital (i.e. title case). .....	31

Option 6: Active ingredients are bold, lowercase, italicised. Brand names are non-bold, lowercase, non-italicised. Only the first letter of the first word in the brand name is a capital. ....	31
Question 10: What formatting guidelines should be recommended for the display of prescription elements other than product name?.....	32
Background.....	32
Option 1: Dose value is bold; supply value is regular, non-bold.....	32
Option 2: Dose and supply values are bold .....	32
Option 3: Dose value is bold and italics; supply value is regular, non-bold.....	32
Option 4: Typical current practice: all non-drug name elements are regular, lowercase.....	32
Question 11: What human factors recommendations should be provided regarding the order in which the elements in a prescription should be presented on a computer display? .....	34
Background.....	34
Option 1: Drug name/strength, Form, Route, Dose, Frequency, Supply.....	34
Option 2: Drug name/strength, Form, Dose, Route, Frequency, Supply.....	35
Option 3: Drug name/strength, Dose, Frequency, Form, Route, Supply.....	35
Option 4: Drug name/strength, Frequency, Form, Dose, Route, Supply.....	35
Question 12: What should be the guidelines relating to when the product brand name can be used in place of the list of active ingredients?.....	36
Background.....	36
Option 1: Use brand name as sole descriptor of product only if it has 3 or more active ingredients .....	36
Option 2: Use brand name as sole descriptor of product only if it has 4 or more active ingredients .....	37
Summary of heuristic evaluation panel recommendations for each of the key questions .....	38
Future research recommendations.....	40
1. An expanded task analysis .....	40
2. Rapid prototyping of alternative software interfaces.....	40
3. Controlled behavioural experiments.....	41
References .....	42

## Overview

The Australian Commission on Safety and Quality in Health Care is developing national guidelines for the on-screen display of medicines. As part of this process, a number of key issues have been identified that require evaluation by human factors experts.

The current project was carried out by a human factors expert panel from the University of Queensland to address these key issues. The project involved:

1. Conducting a preliminary partial task analysis of processes relevant to computer-based medicine displays in order to inform the evaluation.
2. Operationalizing the key issues identified by the Commission as twelve questions for the human factors panel to address.
3. Generating potential alternative solutions for each of the twelve questions and creating simulated prescription software screenshots to illustrate each solution where appropriate.
4. Conducting heuristic evaluations on the alternative solutions for each question, in order to provide preliminary recommendations for best practice from a human factors perspective.

This report describes the outcomes of this project. First, we provide some general context for the use of prescription software and the potential errors that could occur, as generated through our preliminary partial task analysis. Then we present the twelve questions designed to cover the key issues identified by the Commission as requiring human factors evaluation. Next, we describe the heuristic evaluation methods that we used to evaluate potential alternative solutions for each question. Then we present the outcomes of the heuristic evaluations conducted on the alternative solutions to each question. This takes the form of a précis of the human factors panel's deliberations, and provides the rationales behind the final recommendations. Finally, we provide a summary of our recommendations and discuss some options for further research.

## Preliminary Partial Task Analysis

The first step in this project was to conduct a preliminary partial task analysis to better understand typical contexts in which on-screen computer-based displays of medications are used, and hence inform the heuristic evaluation process. The preliminary partial task analysis process involved: (1) reviewing the research literature; (2) interviewing system users, including nurses, pharmacists, and doctors; and (3) investigating current practice in prescription software that is commercially available in Australia at present. Note that a full task analysis would involve a far more exhaustive investigation process, including detailed observations of users' behaviour in context, but this was beyond the scope of the present project.

In this section, we present the outcomes of the preliminary partial task analysis. Some of the typical processes involved in prescribing medication using prescription software and administering prescribed medications are described, and we highlight potential errors that could occur at various stages, referring to the research literature where relevant. The aim of the exercise was to provide the evaluators with a general insight into the steps involved in typical tasks that might be carried out related to on-screen displays of medication and the associated errors that could occur.

Research has indicated that prescribing errors account for the greatest proportion of all medication errors, while drug administration errors tend to cause the greatest harm to patients (Ostini, Roughead, Kirkpatrick, Monteith & Tett, 2012). As a result, we chose to focus on the processes involved in the prescribing and administration of medications as opposed to other elements (such as pharmacist-centred tasks).

### *Processes involved in generating a prescription using computer-based prescribing software*

While computer-based prescribing may eliminate errors associated with illegible handwriting, it has also been found to introduce new types of errors (Smith, Dang, & Lee, 2009). It has been estimated that approximately 2–16% of computer-based prescriptions contain at least one error (Avery et al., 2013; Donyai, O'Grady, Jacklin, Barber & Franklin, 2008; Magrabi, Li, Day, & Coiera, 2010; Nanji et al., 2011). It has been proposed that a considerable proportion of these errors could be avoided if systems were designed in accordance with human factors principles. For instance, in a study of two e-prescribing systems, up to 42% of prescribing errors were attributed to poor system usability (Westbrook et al., 2013).

In the following section, we outline a typical procedure for creating a computer-based prescription and discuss potential sources of error at each stage of the process.

## 1. Identifying the patient in the system database

The practitioner typically retrieves an individual's record by typing the patient's details into a search field in the prescription software. A patient's surname, telephone number, Medicare number, chart number or address can generally be used to locate a record. A shortlist of potential matches is generated, with patients' ages noted.

At this stage, there is the risk that the prescriber could select the wrong patient either by misidentification (e.g. selecting a patient with the same or similar name) or by an inaccurate use of, say, the computer mouse (i.e. they identify the correct patient but accidentally select a different patient). Both types of errors have been documented in the literature (see Redley & Botti, 2012; Spencer, Leininger, Daniels, Granko, & Coeytaux, 2005; Westbrook et al., 2012).

## 2. Reviewing patient information

After selecting a record, the patient's basic medical details are generally displayed. From this initial display, further details can be accessed via tabs. This additional information can include records of past visits, test results, medical history, and a list of current and elapsed prescriptions (displayed to include medicine name, strength, dose, frequency, instructions, route, elapse date, PBS status, quantity and purpose). In some software packages, different text colours are used to denote which prescriptions are current, approaching completion, or elapsed.

## 3. Medicine selection

The prescriber selects the 'create new prescription' function and is taken to a medicine selection dialogue box. There are three usual methods for selecting a medicine:

- a) Typing the drug's trade or generic name (or part thereof) into a search field;
- b) Navigating a collapsible tree of hierarchically arranged classes and subclasses of drugs; or
- c) Opening a list of commonly prescribed 'favourite' medicines.

The medication options are typically listed with their strength, formulation, quantity, and PBS status. Once a drug is selected, the prescriber can view and choose from a list of available brands. Medication safety checks may appear after



confirming the medicine selection, or later in the prescribing process (see ‘Reviewing alerts and advisories’).

Searching for a drug by text input typically retrieves a list of similarly-spelled medications, which can lead to incorrect selections via false recognition (Lambert et al., 2011). Incorrect drug selection constitutes approximately 2% to 10% of all prescribing errors (Avery et al., 2013; Donyai et al., 2007; Shulman et al., 2005; Westbrook et al., 2013; Westbrook et al., 2012). Receiving the wrong drug accounts for approximately 16% of deaths caused by medication error (Mishra, 2014). This risk may be reduced by selecting medication from a list of favourites (due to the likelihood of having to choose between fewer similar names) or selecting by class (because drugs listed adjacently may have more similar functions to one another, lowering the risk of an adverse outcome). In addition, the use of Tall Man lettering for drug names may reduce misidentification by assisting visual differentiation (Filik et al., 2006). There is also the potential for a user to select the wrong drug strength or formulation at this stage. Such errors constitute between 2% and 9.5% of prescribing mistakes (Donyai et al., 2008; Magrabi et al., 2010; Westbrook et al., 2012; Westbrook et al., 2013).

#### 4. Reviewing clinical decision support

To confirm the suitability of the selected drug, clinical reference materials can often be accessed from the medicine selection window. Typical options might include ‘product information’ (supplied by the pharmaceutical company), ‘monographs’ (evidence-based reference material compiled by pharmacists) and ‘details’ (a summary of important drug information). These provide information such as indications, contraindications, precautions, interactions with other medicines and dosing guidelines. However, research indicates that prescribers access this information infrequently (Devaraj, Sharma, Fausto, Viernes, & Kharrazi, 2014; Robertson et al., 2011). Cited barriers to accessing this information include criticisms that the information is not concise, easily searchable or well integrated into the workflow, precluding review in time-poor consultations (Devaraj et al., 2014; Rahmner et al., 2012; Robertson et al., 2011).

#### 5. Entering administering details

Once the medication is selected, then dose, route, frequency and instructions need to be entered. This information is typically selected from drop-down menus, often with the option to add further instructions by free text input. According to available evidence, up to 61% of all prescribing errors involve omission of these administration

details. A number of researchers have noted that a forcing function could be incorporated into the software to prevent incomplete scripts from being printed (Avery et al. 2013; Nanji et al., 2011; Warholak & Rupp, 2009; Westbrook et al., 2012).

Prescribing an inappropriate dose is a common mistake, accounting for up to 26% of prescribing errors (Magrabi et al., 2010; Shulman, Singer, Goldstone, & Belingan, 2005; Warholak & Rupp, 2009; Westbrook et al., 2012). Approximately 40% of deaths caused by medication error are due to inappropriate dosage (Mishra, 2014).

Errors of route and frequency also occur (Avery et al., 2013; Westbrook et al. 2013). Many prescription software packages use abbreviations to denote these instructions (e.g. 'q.i.d.' for 'four times per day' or 'p.o.' for 'orally') (Nanji et al, 2011). This practice is likely to be problematic, as abbreviations are more likely to be misread, impacted by a single typographic error, or misinterpreted as compared with their unabbreviated equivalent (Dooley, Wiseman, & Gu, 2012). It was also noted that options for dose and route, and instructions in drop-down menus, were sometimes irrelevant to the chosen drug (e.g., suggesting 'two puffs' for a tablet). Filtering out irrelevant options may reduce the risk and impact of errors. Selections made from drop-down menus can also conflict with free-text instructions entered by the prescriber (e.g. if the dosage varies over the course of treatment), presenting another potential source of confusion for dispensing and administration (Nanji et al., 2011; Smith et al., 2009).

## 6. Entering dispensing details and reviewing

After confirming the administering details, dispensing details are, in general, entered manually. These details typically include supply quantity, number of repeats, treatment duration and anticipated treatment completion date. The prescriber can often opt to accept system-recommended default values (via a checkbox). A reason for medication can be entered in many packages, either by selecting from a searchable list, selecting from the patient's medical history, or by manual input.

The most common type of conflicting information found on scripts is a mismatch between the requested supply quantity and the treatment duration, dose, and frequency (Nanji et al., 2011; Smith et al., 2009). One potential solution to this issue would be for the software to automatically calculate supply quantity. This could remove the need for the prescriber to input redundant (and potentially incorrect) information.

## 7. Reviewing alerts and advisories

After finalising dispensing details, some systems provide alerts about drug interactions, drug-disease interactions, allergy warnings, and other contraindications. After attending to all warnings, the prescriber is typically returned to the patient record. The new prescription will then usually appear in the current prescriptions tab, from which it can be printed. The Consumer Medicine Information sheet can also usually be printed for the patient at this stage.

Prescribers report clicking through most alerts, or even disabling them, despite acknowledging the risk of missing potentially important warnings (Avery et al., 2013; Westbrook et al., 2012). The reasons given for ignoring alerts include clinical irrelevance, repetition, distrust, and time intrusion into the consultation (Devaraj et al., 2014; Rahmner et al., 2012; Robertson et al., 2011). Alert fatigue is a well-known phenomenon in human factors. Solutions that employ more judicious use of warnings may better serve patient safety (Russ, Zillich, McManus, Doebbeling, & Saleem, 2012).

### *Processes involved in administering prescribed medications*

In a study conducted at a Sydney hospital, 25% of drug administrations involved at least one clinical error (Westbrook et al., 2010). Human factors interventions may be successful in reducing errors, as they tend to arise more so from slips and lapses when reading prescriptions, medication labels and other documents, than from lack of knowledge or procedural incompetence (Keers, Williams, Cooke, & Ashcroft, 2013b; Manias, Kinney, Cranswick, & Williams 2014; Roughead & Semple, 2009). An example of a typical procedure for administering medicines in an inpatient context is as follows (noting that steps may not always be completed in this precise order or in such a linear manner):

#### 1. Check patient's identity

When possible, the patient's armband is used to check his or her identity against the information on the medication chart. In some wards, an identification photo may be used in lieu of an armband (e.g. for patients with memory loss, with mental health issues, or in children's wards). Failing to identify the patient is one of the most common procedural failures, leading to 2–19% of administering errors (Keers, Williams, Cooke, & Ashcroft, 2013a; Manias et al., 2014; Mishra, 2014; Redley & Botti, 2012; Westbrook et al., 2010).

## 2. Assess medication requirements

After identifying the patient, his or her immediate medication requirements are assessed, with consideration to the last time each drug was given. The patient's medication chart is consulted to determine the relevant medication orders (these have usually been documented by a prescriber or by a nurse in the case of phone orders). Nurses may also choose to initiate specific medications without a doctor's authorisation.

At this stage, common errors include administering a drug either too late or too early, at the wrong frequency, or not at all. In a literature review of inpatient administering errors, 80% of included studies reported timing mistakes amongst their top three errors (Keers et al., 2013b), and over half reported complete omission of medication as another significant source of error.

## 3. Perform any required physiological assessments

The nurse checks that the route of administration is safe and appropriate. For example, this might include avoiding oral medication if a patient is vomiting. The nurse also performs any necessary physiological assessments (for example, recording the patient's vital signs or checking relevant test results) and compares the results to required parameters. Both lack of experience and time pressure have been implicated in failures to perform these safety checks (Keers et al., 2013a).

## 4. Locate patient's required medicine

Once the safety of administering the medication has been established, the patient's due medications are retrieved (from an automated dispensing cabinet, medication trolley, bedside locker, storage room, treatment room, or emergency medication trolley). The supplied medicine is double-checked to determine if it matches the medication order in name, formulation and strength. The expiry date of the medication is also checked.

According to available evidence, selecting the wrong medication at this point can account for up to 17% of administering errors (Keers et al., 2013b; Manias et al., 2014; Mishra, 2014). Commonly cited causes include name confusion and packaging similarity (Keers et al. 2013b; Manias et al., 2014; Medication Safety, 2011, 2014). Errors in selecting the correct formulation and strength may also occur but are less common (Manias et al., 2014; Redley & Botti, 2012). Expired medication may also be given, as expiry dates can become illegible (particularly on foil packaging) or are not checked (McBride-Henry & Foureur, 2007; Redley & Botti, 2012).

## 5. Prepare and administer medication

The nurse performs any necessary calculations, such as determining the dosage required while taking into account the patient's weight or an intravenous infusion rate. Next, the medication is prepared by cutting, pouring, drawing up, dissolving, diluting, or reconstituting the specified dose, which is then administered via the advised route. Ideally, two nurses will be present throughout the entire procedure if intravenous drugs, restricted drugs or drugs of dependence are being administered. Finally, drug administration is recorded by initialling the patient's medication chart (with drugs of dependence also recorded in a separate register).

Calculation errors were noted as common in several studies (Keers et al., 2013a). For example, one study found 8.6% of total administering errors were due to miscalculation (Manias et al., 2014). In addition to mathematical error, other common causes of dosage error include missing a decimal point due to a trailing zero or omission of a leading zero (creating a tenfold overdose), or confusing units of measurement (Manias et al., 2014; Medication Safety, 2014). Wrong route errors (e.g. administering intravenously rather than orally) are less common, but still occur (Manias et al., 2014). In a review by Keers et al. (2013b), nearly half of the included studies reported dosage errors amongst the top three administering errors.

## Key questions to be addressed by the human factors evaluation panel

Following the preliminary partial task analysis, we reviewed the key issues raised by the Commission as requiring human factors expert input. In order to facilitate the evaluation process, these issues were broken down into the following twelve questions for the human factors panel to address.

Question 1: How should micrograms be displayed?

Question 2: How should “greater than” be displayed?

Question 3: How should “less than” be displayed?

Question 4: Is it appropriate to use the “/” symbol in an expression of product strength?

Question 5: Is it appropriate to use the “/” symbol in an expression of rate?

Question 6: Is it appropriate to reserve the “+” symbol for separating the active ingredients in a product?

Question 7: Is it appropriate to reserve the “&” symbol to separate multiple components in a multiple component pack?

Question 8: What term should be used for the separator label denoting quantity?

Question 9: What formatting guidelines should be recommended for the display of product names?

Question 10: What formatting guidelines should be recommended for the display of prescription elements other than product name?

Question 11: What human factors recommendations should be provided regarding the order in which the elements in a prescription should be presented on a computer display?

Question 12: What should be the guidelines relating to when the product brand name can be used in place of the list of active ingredients?

## Heuristic evaluation research methods

For each of the twelve questions that we identified, we created a number of display solutions to be subjected to heuristic evaluation. These display solutions were chosen as plausible alternative recommendations relevant to each of the key questions. The task of the heuristic evaluation panel was to decide which solution or solutions ought to be recommended as best practice (or to recommend that a different approach ought to be taken with respect to a particular guideline).

A number of example prescriptions were provided by the Commission to allow us to illustrate each of the display solutions. We generated simulated screenshots of each of the display solutions to inform the heuristic evaluation panel's deliberations.

Solutions for questions involving the on-screen display of full prescriptions were illustrated via two alternative display formats. These two formats were chosen because, between them, they were considered representative of how prescriptions are typically displayed in prescription software that is currently commercially-available in Australia. We defined the first format as the "column format" (in which medicine information is arranged into columns) and the second format as the "dash format" (in which medicine information is separated by dashes).

Options for questions involving how product information should be displayed when a user is searching a list of medicines were illustrated using a list format that is typical of most commercially-available prescription software currently available in Australia.

The alternative solutions were presented as part of a series of simulated on-screen interface screenshots. We used actual screenshots from currently available prescription software to provide a plausible background context for each of the solutions, so that evaluators could make their judgements taking into account the effects of factors such as the overall visual clutter of the display. Note that we have not included examples in this report for copyright reasons.

A team of five heuristic evaluators inspected all of the alternative solutions for each question and provided individual written reports regarding their recommendations for best practice. In addition, for two of the questions (7 and 12), evaluators reviewed lists of medicine names (see heuristic evaluation results for details). To help focus their evaluations, evaluators were also provided with relevant extracts from three sets of published heuristics for user-interface design (Gerhardt-Powals, 1996; Nielsen, 1994; Zhu et al., 2005).

All five heuristic evaluators had prior experience in medical human factors research. The panel included three associate professors, a senior research fellow, and a research assistant. Discrepancies between evaluators' judgements were resolved through discussion.

## Heuristic evaluation results: Rationales for final recommendations

In this section, we present a précis of the heuristic evaluation team's reports on the advantages and disadvantages of each of the alternative solutions for all twelve of the research questions described earlier. These accounts provide the rationale for our overall recommendations regarding each of these questions.

For each question, we first discuss the question's context and then list each of the alternative solutions considered by the panel with a summarized account of the panel's reports is provided.

For ease of explanation, the potential solutions for each question have been re-ordered to present the preferred option first (which is also denoted with a tick). The remaining alternative solutions are presented in no particular order. A summary of our final recommendations follows this section.




## *Question 1: How should micrograms be displayed?*

### Background

Two units of mass frequently used in prescriptions are milligrams and micrograms. Milligrams are usually denoted as mg and micrograms are typically denoted as mcg. There were concerns that these two abbreviations are not sufficiently distinct from one another. Further, while most products are described only with respect to one or the other of these terms, there are products where both can be used. This suggests that it is likely to be important to minimize the chance of confusing the two terms. We evaluated eight alternative terms to denote micrograms.

### Option 1: MICROg

The panel preferred this option for a number of reasons. First, it is shorter than some of the other options that were regarded as potentially safe and hence would not take up significant screen space, especially for products with multiple active ingredients (where longer options may force other safety-critical information off of the screen or else create unnecessary visual clutter). Second, this option strongly emphasizes “micro” (the key element needed to distinguish micrograms from milligrams) and the term is visually much more distinct from “mg” than many of the other options below. Third, the capitalisation separates "MICRO" and "g" into two sub-units. That is, even someone who has never seen any abbreviation for micrograms other than  $\mu\text{g}$  or mg would be expected to immediately understand that the first part of the word is "micro". In contrast, for the similar alternative "microg", the default pronunciation rhymes with "my frog" (i.e. the word is read as a single unit rather than two sub-units) and therefore provides a weaker cue as to its meaning. However, the evaluators noted some potential concerns with MICROg. First, it is relatively novel compared with some of the other options (however, we would argue that it nonetheless should be obvious what it means, especially when used in context). Second, the use of Tall Man lettering could mean that some people read it as a drug name, such as microgynon (however, we would argue that this is unlikely given there are other cues that it cannot be a drug name, such as its placement after the actual drug name. On balance, the panel still preferred this option, where these concerns were considered low risk in the context of the potential safety advantages of the term.



### Option 2: microgram

Reviewing the examples, the panel thought that the use of “microgram” (and similarly long terms in the other options below) might lead to product descriptions that were too long for the displays. That is, it could contribute to safety-critical information not fitting on a single page, even with a full-size computer display. This

would be an issue particularly when a product contained more than one active ingredient. Even if all of the safety critical information could fit on a single page, this term could add unwanted visual clutter (increasing task workloads and hence potentially increasing the likelihood of error). A secondary issue was that the term was likely to be inappropriately singular most of the time.

### Option 3: mcg

While this option is currently widely used in prescription software, the team thought that it was too similar to “mg” to be considered safe. Specifically, it might be too easy for users to only notice the first and last letter of the term.

### Option 4: Display as milligrams not micrograms (e.g. 0.25 mg instead of 250 mcg)

One problem with this option is that the use of a decimal point is likely to increase errors (e.g. 0.25 is read as 25). Another is that it will result in mismatches between the prescription and the labels on medication packaging (which would use micrograms or milligrams) requiring the person administering the drug to convert in their head (thus increasing cognitive load and the chance of an error, and also not matching the task of a key user). While this option has the benefit of possibly avoiding errors from the confusion of two types of unit (by only having one type of unit), the concerns described above were considered to make it a risky option overall.

### Option 5: µg

This option has the advantage of being short while also already being standard scientific notation for micrograms. However, there are a number of concerns that led the panel to reject this option, specifically: (1) its widespread use may lead to handwritten versions of the µ symbol being misinterpreted because a hand-written µ might look like an “m”; (2) it has the same number of characters as mg and hence may not be as visually distinct from mg as some of the other options; (3) the meaning of µ may be unclear to a substantial proportion of users and consumers; (4) and there may be input issues (that may become relevant in certain circumstances) as µ is not mapped to a single key on a standard keyboard (i.e. the procedure for inserting a character like µ is not intuitive on most systems).

### Option 6: MICROgrams

One issue with “microgram” is that it still looks quite similar to “milligram” (while acknowledging that mg will probably be used for milligrams). This option is one way to address that issue, by highlighting the difference between the two using capitalisation. The panel however choose to reject this option due to the amount of space required. The space issue is likely to be problematic, especially for products with multiple active ingredients.

### Option 7: microg

The advantages and disadvantages of this option are discussed in conjunction with Option 1 above.

### Option 8: micrograms

It could be argued that there may be an advantage in having software that is sensitive to whether the amount is (a) 1 microgram or (b) greater than 1 microgram – which can then display the label as singular or plural as appropriate (i.e. it provides an extra cue as to the amount). Whether this is likely to map onto significant differences in error rates in practice is another issue. It could be argued that, even if this label is not sensitive to whether the amount is singular or plural, plural amounts are more likely anyway. That is, this option is likely to be grammatically correct most of the time. Having said that, the favoured option (MICROg) avoids this issue altogether. The panel rejected this option on the same basis as similar options above – namely that it is too long (especially if a product contains more than one active ingredient).

## *Question 2: How should “greater than” be displayed?*

### Background

“Greater than” is often abbreviated to the symbol “>” in prescriptions. However, the question is whether this abbreviation should be considered risky.

### Option 1: greater than

This option was considered to be the safest out of the alternatives. It was considered less likely to be confused with “less than” compared with the “>” symbol (and less likely to be mistyped). It was also considered less problematic than “more than” (see below). However, the panel noted that “greater than” does read awkwardly in some cases (e.g., “if fever lasts greater than 4 hours”), where a more appropriate alternative would be “longer than”. So, while we considered “greater than” to be the safest option for generic use across all contexts, a better solution would be to use terms that were specific to context (e.g. “longer than” for durations and “more than” for doses).



### Option 2: >

This option was rejected by the evaluators because “>” is easily confused with “<”.

### Option 3: more than

The term “more than” was considered to be ambiguous when applied to hours. Specifically, “more than 4 hours” could be taken to mean “5 or more hours” (rather than “any duration over 4 hours”).

### *Question 3: How should “less than” be displayed?*

#### Background

“Less than” is often abbreviated to the symbol “<” in prescriptions. The panel evaluated whether this practice could be considered unsafe.

#### Option 1: less than

The panel considered the term “less than” to be safer than the “<” symbol across all contexts (despite its greater length). However, as with “greater than”, the panel agreed that a better solution would be to use context-specific terms. For example, there are likely to be contexts in which “fewer than” would be more appropriate. In the specific case of heart rate, “under” or “below” would save more space and be just as clear. However, these words might not be an appropriate replacement for some other uses of “less than”.



#### Option 2: <

As with “>” in Question 2, the problem with this option is that “>” and “<” are easily confused.

***Question 4: Is it appropriate to use the “/” symbol in an expression of product strength?***

**Background**

The “/” symbol is typically used when describing product strength (e.g. 200 mg/100 mL). The panel investigated whether a written alternative (per) might be safer in this context.

**Option 1: /**

In this situation, the panel favoured the symbol (e.g. 200 mg/100 mL) over the written form (e.g. 200 mg per 100 mL) because the symbol is unambiguous in this context (i.e. it clearly indicates a ratio) and takes up less room on the screen. Evaluators also considered the symbol easier to read than the written version.



**Option 2: per**

Evaluators thought that “per” is more cumbersome to read in this context (e.g. 200 mg per 100 mL) than the “/” symbol (i.e. it is longer and potentially less clear).

***Question 5: Is it appropriate to use the “/” symbol in an expression of rate?***

**Background**

The “/” symbol is also typically used when describing a rate as part of a prescription (e.g. 1 L/hour, 1 L/12 hours, 500mL/12 hours, 320 mg/20 minutes). A written alternative (per) was considered by the panel (e.g. 1 L per hour, 1 L per 12 hours, 500mL per 12 hours, 320 mg per 20 minutes).

**Option 1: /**

The panel thought that this was another situation in which the “/” symbol was preferable to the written alternative (“per”). The context makes it clear that the expression refers to a rate (i.e. there is a duration after the “/”). This option was also considered to separate the two elements of the rate expression clearly.



**Option 2: per**

This option was considered to be less familiar than the symbol form, and may be harder to read in this context than the symbol. Also, “per” is longer than “/” and so takes up unnecessary room.

## ***Question 6: Is it appropriate to reserve the “+” symbol for separating the active ingredients in a product?***

### **Background**

The Commission is proposing to reserve the “+” symbol exclusively as a separator between multiple active ingredients in a product (e.g. **perindopril arginine** 10mg + **amlodipine** 10mg). The panel considered another four possible options to assess whether this proposal could be regarded as best practice. Note that Option 5 below was included to address the question of whether it is appropriate to use the “/” symbol to separate strengths for multi-ingredient products (this is another option that the Commission is considering).

### **Option 1: +**

The panel favoured the “+” option as best practice in this context (e.g. **perindopril arginine** 10mg + **amlodipine** 10mg). It was considered to provide the clearest perceptual separation between each grouping of drug name and strength. While in other situations, the symbol ‘+’ may be misread as the number 4, in the context of separating active ingredients, this sort of confusion was considered to be unlikely. The panel therefore concurred that it would be appropriate to reserve the “+” symbol for this specific purpose.



### **Option 2: and**

The panel thought that this was a situation where the symbol “+” was better at visually separating the elements than the word “and” (e.g. **perindopril arginine** 10mg and **amlodipine** 10mg) because the symbol “+” is more distinct from the surrounding words and the word “and” makes the product description appear as a single chunk of text.

### **Option 3: &**

While the panel considered the “&” to do a reasonable job at perceptually separating each group of product name and strength (e.g. **perindopril arginine** 10mg & **amlodipine** 10mg), it was not considered to be as effective as “+”. This could be because of the form of the symbol itself (“&” is visually a more complex and hence clutter-inducing symbol than “+”).



#### Option 4: plus

The panel rejected this option (e.g. **perindopril arginine** 10mg plus **amlodipine** 10mg) on the same grounds as Option 2 above. It was not considered to provide clear perceptual separation between each grouping of active ingredient and strength.

#### Option 5: /

The “/” symbol is already used for other purposes (e.g. strength and rate; see above). Hence, it was considered better to reserve it for these other uses to avoid possible confusion. While the panel agreed that this option provided some perceptual separation between each grouping of active ingredient and strength (e.g. **perindopril arginine** 10mg / **amlodipine** 10mg), it was not as effective as + in any case.

## ***Question 7: Is it appropriate to reserve the “&” symbol to separate multiple components in a multiple component pack?***

### **Background**

This question refers to the situation in which there is more than one product in a single pack (where each product may have multiple ingredients). That is, “component” refers to an overall product not its active ingredients. The Commission is proposing to reserve the “&” (ampersand) symbol for this purpose.

### **Option 1: &**

The panel favoured this option (bold ampersand; e.g. **esomeprazole** 20 mg tablet: enteric [14] **& clarithromycin** 500 mg tablet [14] **& amoxicillin** 500 mg capsule [28 capsules], 1 pack). It was thought to provide reasonable perceptual separation between the components. Examples incorporating this option had the advantage of appearing less cluttered than most other alternatives (by virtue of using only a single character as the separator), and the bold formatting helps this symbol to stand out from the surrounding text.



The panel was also of the view that none of the options performed exceptionally well at providing separation between the components. It could be that proper separation might only be achieved by, for example, putting each component onto a separate line (e.g. formatting the product as a bullet point list). However this might require a more radical redesign of the software interface to accommodate.

### **Option 2: &**

This option (non-bold ampersand; e.g. **esomeprazole** 20 mg tablet: enteric [14] **& clarithromycin** 500 mg tablet [14] **& amoxicillin** 500 mg capsule [28 capsules], 1 pack) was thought to provide some perceptual separation between the components. As per Option 1, examples incorporating this option had the advantage of appearing less cluttered than most other alternatives (by virtue of using only a single character as the separator). However, it was considered less effective at separating the components than the bolded “&”.

### **Option 2: {&}**

The evaluators considered this option (e.g. **esomeprazole** 20 mg tablet: enteric [14] {&} **clarithromycin** 500 mg tablet [14] {&} **amoxicillin** 500 mg capsule [28 capsules], 1 pack) to provide the best perceptual separation of the different components out of the options assessed involving brackets. This option was considered to be slightly more distinct than “(&)” because rounded brackets are used elsewhere in the examples that were evaluated, but these brackets are not.

However, the reason that this option was not favoured was that the use of three characters in the separator adds some visual clutter compared with options with fewer characters. Also, the use of brackets in this context does not make sense from a punctuation point of view.

### Option 3: (&)

This option (e.g. **esomeprazole** 20 mg tablet: enteric [14] (& **clarithromycin** 500 mg tablet [14] (& **amoxicillin** 500 mg capsule [28 capsules], 1 pack) was also considered to provide reasonable perceptual separation between components. However, having the ampersand in brackets arguably gives off a slightly odd or unclear message (i.e., it would make more sense for the other elements to be inside brackets – especially when components have several listed ingredients – and for the ampersands to be outside of the brackets). Like Option 2, it uses more characters than “&”, which leads to more clutter. However, it is also a bit more visually dominant than the unbolded ampersand, and hence potentially a better separator.

### Option 4: and

The panel rejected this option (e.g. **esomeprazole** 20 mg tablet: enteric [14] and **clarithromycin** 500 mg tablet [14] and **amoxicillin** 500 mg capsule [28 capsules], 1 pack) on the basis that “and” does not provide clear perceptual separation between components (i.e. the components of the description are perceived as a single block of text). It allows the “+” symbol (used to separate different active ingredients within the same product) to become the dominant separator, when this is inappropriate. Also, “and” is likely to be used for other purposes within prescriptions (i.e. it might be difficult to reserve it exclusively for separating components in a multicomponent pack). However, it was acknowledged that “and” may make the examples faster to read (although this is not necessarily desirable).

### Option 5: +

This option was rejected by the panel, assuming that our recommendation to reserve “+” for separating different active ingredients within the same product is followed. That is, it becomes difficult to differentiate the separate active ingredients within a single component from the separate components in a multicomponent pack.

### Option 6: plus

The panel rejected this option on the same grounds as Option 4 above.

### Option 7: /

The panel rejected this option on the basis that it is already being used for a number of different functions (e.g. rate and strength).

### Option 8: )&(

Options 8 to 10 were created on the premise that it might make more sense to bracket the components themselves rather than the separator term. However, a problem that all of these “reverse bracket” separator options have in common is that they would result in the first and last components only having brackets at one end (where presumably it would be more difficult to have them bracketed properly, as opposed to just adding a different string of characters as the separator). However, if bracketing of the first and last component was possible then this might lead to a reassessment of these options. Of these three options, Option 8 was thought to look too much like an error, and Option 10 takes up more space and is a little less distinct as a separator between components. Hence, Option 9 was the preferred option out of these three, but overall, evaluators considered the likely lack of bracket completion for the first and last components to be too problematic.

### Option 9: }&{

See comments for Option 8 above.

### Option 10: }and{

See comments for Option 8 above.

### Option 11: |&|

This option was an attempt to avoid the implication that the “and” is in brackets (where, grammatically speaking, it is unclear why it would be). The vertical lines are intended to be non-committal as to what is inside and what is outside. However, the separation between components in this option became less distinct because the vertical lines blend with the square brackets also used in the examples. On balance, evaluators therefore rejected this option.

## *Question 8: What term should be used for the separator label denoting quantity?*

### Background

Given that qty, quantity, and supply all mean the same thing, our recommendation is that having a single standard term rather than three alternatives is likely to be safest.

### Option 1: supply

Supply, in a general context, is a more ambiguous term than quantity, with multiple meanings (e.g. the amount of a product that is available to customers, provisions, a person that temporarily fills the place of another, the verb “to provide someone with”). However, these alternative meanings are unlikely to be inferred in the context of a prescription. In fact, it was suggested that, in the current context, “supply” could be argued to be less ambiguous than quantity, if we consider the key aim to be differentiating this term from “dose”. That is, plausible misinterpretations of the term “supply” do not involve dangerous confusions with the concept of “dose”. For example, “supply” could be interpreted as an instruction to the pharmacist (e.g. “supply the patient with X doses of the medication”), or in terms of supply chains and how much of the product is actually available to the patient (rather than how much they should take in a single dose – where other options such as “quantity” are more ambiguous). On balance, the panel decided that this option was unlikely to be misinterpreted with dangerous consequences and would therefore be recommended over the other choices. Also, the term “supply” has the fewest characters of all of the options except “qty”, which may increase the overall clarity of a prescription as a result of reduced clutter and the amount of safety-critical information that can be displayed at once on a screen.



### Option 2: supply qty

This option was initially favoured by the evaluators because it balances the reduced ambiguity of Option 4 with the brevity of Option 1. While “qty” is an abbreviation (and these are not typically considered human factors best practice), in this case, it was thought to be a low-risk compromise. However, on balance, the evaluators preferred the less cluttered brevity of “supply”.

### Option 3: quantity

While “quantity” is generally a less ambiguous term than “supply”, the panel judged that, in the context of a prescription, it was more ambiguous (with potentially dangerous consequences) because it is more likely that “quantity” could be confused with “dose”. That is, “quantity” could be interpreted as “how much of the medication should be taken in one dose”.

#### Option 4: supply quantity

This option was considered to be the least ambiguous of all of the options, but was rejected on the basis of being too long.

#### Option 5: qty

“Qty” is the term used in some current prescription software packages. It is more ambiguous than “quantity” (where qty could potentially mean other words containing those three letters, such as “quality”). However, a search indicated that qty appears to be defined as “quantity” so “qty” is probably a low risk abbreviation (though our previous work has indicated that even highly experienced health professionals misinterpret even common abbreviations more than might be expected). However, even assuming that users understand that “qty” means “quantity”, patients could still confuse this with “dose”, and hence this option was rejected by the panel. This option has the advantage of being short – though it is only three characters shorter than the next shortest term, “supply”.

## **Question 9: What formatting guidelines should be recommended for the display of product names?**

### **Background**

The Commission's proposal is that all products should be described by their active ingredients rather than by brand name where practicable (see Question 12 for possible exceptions). To this end, the Commission has proposed that a product name should begin with a list of active ingredients, followed by a de-emphasized brand name where applicable. Question 9 focuses on how the active ingredients and brand names ought to be formatted to fulfil the aim of drawing attention to active ingredients and away from brand names when both are presented together. Note that the use of colour for emphasis has not been included as an option here because some current products use colour to denote other information (e.g. whether a prescription is overdue).

**Option 1: Active ingredients are bold, lowercase, non-italicised. Brand names are non-bold, lowercase, italics. The first letter of every key word in the brand name is a capital (i.e. title case).**

The panel favoured the Option 1 format (e.g. **guaiphenesin** 100 mg + **pseudoephedrine hydrochloride** 30 mg – *Benadryl for the Family Chesty Cough and Nasal Congestion*) because it puts the proper emphasis on the active ingredients as opposed to the brand name. That is, the active ingredients stand out because of the bold text (but are not rendered difficult to read by the use of capitalisation or italics). Also, having the brand name in italics is akin to having it in inverted commas, in that it implies (correctly) that this term is an invented name (hence lowering its importance). This option was overall considered easy to read. Evaluators judged that this format should still work well when some words are in tall man lettering. Note that the first letters of the key words within the brand name are capitalized for this option but other words like “and”, “for”, “the”, etc., are lowercase. This use of title case was considered to highlight the fact that the brand name was a fabricated name and helped to make it more visually distinct from the active ingredients.



**Option 2: Active ingredients are bold, lowercase, non-italicised. Brand names are non-bold, uppercase, non-italicised.**

The panel rejected this option because capitalizing the entire brand name has the effect of highlighting it (e.g. **guaiphenesin** 100 mg + **pseudoephedrine hydrochloride** 30 mg – BENADRYL FOR THE FAMILY CHESTY COUGH AND NASAL CONGESTION). That is, this option acts to draw attention to the brand name at the expense of the active ingredients, which runs counter to the Commission's intention. Having said that, it was acknowledged that using capitals

for the brand name does seem to distinguish it more from the active ingredients. Also, the use of capitals may result in more homogeneous and hence less differentiable word shapes.

**Option 3: Active ingredients are bold, uppercase, non-italicised. Brand names are non-bold, lowercase, non-italicised. The first letter of every key word in the brand name is a capital (i.e. title case).**

While this option does place extra emphasis on the active ingredients, the use of capitals makes the active ingredients harder to read and distinguish. Hence this option was rejected by the panel.

**Option 4: Active ingredients are non-bold, italics, lowercase. Brand names are uppercase, non-bold, non-italicised.**

This option was rejected by the evaluators because it makes the list of active ingredients harder to read and also placed too much emphasis on the brand name. The italics in general were considered less effective than bold text in making the active ingredients stand out in any case.

**Option 5: Active ingredients are bold, lowercase, italics. Brand names are non-bold, non-italicised, lowercase. The first letter of every key word in the brand name is a capital (i.e. title case).**

This option was rejected for the same reason for as Option 4 (the italics make the active ingredients more difficult to read, especially as there is so much italic text).

**Option 6: Active ingredients are bold, lowercase, italicised. Brand names are non-bold, lowercase, non-italicised. Only the first letter of the first word in the brand name is a capital.**

This option was also rejected due to the italics. Also, removing the title case capitalization from the brand names makes them less distinct from the ingredients and less likely to match the product packaging, while also removing one of the cues that indicates that the brand name is a title/fabricated name.



***Question 10: What formatting guidelines should be recommended for the display of prescription elements other than product name?***

**Background**

This question focussed on determining best practice for formatting prescription elements other than product name, with a focus on the dose and supply values. These two values are both needed but it is critical that users do not confuse the two. Hence our key goal in answering this question was to assess which formatting option might result in the lowest chance of dose and supply values being confused.

**Option 1: Dose value is bold; supply value is regular, non-bold**

The evaluators favoured this option because dose is emphasized (as being the more safety-critical value out of dose and supply), while supply is formatted differently. That is, the formatting cues users that dose and supply are different (working with the label and order cues). That is, dose and supply can be discriminated on the basis of (1) their order within the prescription, (2) separator labels, and (3) formatting (bold for dose and non-bold for supply). However, with this option, we also avoid using strategies that reduce readability (such as italics and capitals).



**Option 2: Dose and supply values are bold**

This option was rejected because dose and supply are formatted the same (hence removing a potential discriminatory cue). Also, the option results in too much emphasis on an item of relatively low importance (supply). In addition to this, this option suffers from an overuse of emphasis: bold is used for too many elements of the prescription, which undermines its emphasizing properties.

**Option 3: Dose value is bold and italics; supply value is regular, non-bold**

This option was rejected by the evaluators because of the use of italics for emphasising dose, which may reduce the readability of the dose value. However, it was acknowledged that the italics have the advantage of making the dose more distinct from the drug strength value.

**Option 4: Typical current practice: all non-drug name elements are regular, lowercase**

This option is in common usage in currently available prescription software packages. However evaluators rejected this option because of the lack of

differentiation between dose and supply values (and lack of emphasis for the safety critical dose value).

***Question 11: What human factors recommendations should be provided regarding the order in which the elements in a prescription should be presented on a computer display?***

**Background**

The main rationale for having a consistent order for the elements on a prescription is that it should make it less likely for those elements to be confused with one another. Question 11 is focused on determining what the best practice order should be, on the assumption that a single pre-defined order is best practice.

From a human factors perspective, the factors that should determine the order include:

1. Consistency with work flow (that is, the information ought to be ordered to be consistent with the order in which that information is required to complete relevant tasks).
2. Level of importance to patient safety. The most important information ought to appear earlier (where information that appears later is less conspicuous and also more likely to be obscured (e.g. it runs off the right edge of a window/frame and requires horizontal scrolling to see)).
3. Information ought to be grouped by task, so that when the task is performed, all of the necessary information required to perform the task is as close together as possible (to minimize cognitive workload). Also, co-dependent information (e.g. form and route) ought to be grouped together.

The options below were generated from orders in use in prescription software (Options 2, 3, 4) or according to the principles described above (Option 1).

**Option 1: Drug name/strength, Form, Route, Dose, Frequency, Supply**

Option 1 was generated from the findings of our preliminary partial task analysis, in which the order was mapped onto the tasks to be performed with the information. The panel favoured this option because it fulfilled this mapping most effectively out of all of the options. Drug name/strength must be first (as in all options) as none of the other information can be generated or interpreted without it. Form and route come next, because we need to know both of these before we can determine an appropriate dose (i.e. the dose may change depending on both the form and the route). Also, these two items should be adjacent as they are co-dependent. Frequency and supply follow dose (where both of these will depend on the dose).



The panel also noted the importance of groupings between certain prescription elements and that this ought to be highlighted in the Commission's guidelines. For example, as already noted, dose and frequency naturally group together (in that they

are two elements that are co-dependent). Likewise route and form are naturally co-dependent.

**Option 2: Drug name/strength, Form, Dose, Route, Frequency, Supply**

The panel rejected this option because it does not map onto the human factors considerations described above as effectively as Option 1.

**Option 3: Drug name/strength, Dose, Frequency, Form, Route, Supply**

The panel rejected this option because it does not map onto the human factors considerations described above as effectively as Option 1.

**Option 4: Drug name/strength, Frequency, Form, Dose, Route, Supply**

The panel rejected this option because it does not map onto the human factors considerations described above as effectively as Option 1.

## ***Question 12: What should be the guidelines relating to when the product brand name can be used in place of the list of active ingredients?***

### **Background**

The Commission's current guidelines indicate that a product's brand name can be displayed after the list of active ingredients (see Question 9). However, if the product has four or more ingredients, then one proposal is that the vendor can instead display the brand name only – and does not have to present the active ingredients at all (on the rationale that it is impractical to fit the list of active ingredients onto the display). A competing proposal is that brand names can be used in place of active ingredients when there are three or more active ingredients.

This question focuses on determining which of these options could be regarded as the better practice. That is, at what point would it be safer to display a product using its brand name only instead of its active ingredients?

To answer this question, the evaluation panel reviewed a list of hundreds of products with more than three active ingredients, which specified both the full active ingredient description and the brand name (i.e. illustrative screenshots were not created for this particular question).

### **Option 1: Use brand name as sole descriptor of product only if it has 3 or more active ingredients**

The panel favoured the use of the brand name as the sole descriptor of a product if the product contained three or more active ingredients. The rationales for this judgment were as follows:

- People are thought to be able to hold an average of 4 units of information in short term memory. Given that each ingredient is accompanied by a strength, this suggests that two ingredients is the maximum that an individual would be able to hold in memory (assuming no expertise).
- Even if users were able to consider an ingredient name and strength as a single chunk of information, there is still likely to be cognitive load associated with creating this chunk. Also, with familiarity, users may be able to remember particular products but they are unlikely to be able to gain this level of familiarity with all of the products on the market.
- We carried out informal micro-simulation testing in which we attempted to view and then recall product descriptions. We found that this was extremely difficult for products with three or more active ingredients when they were described solely by their active ingredients (assuming no familiarity with the product).



- This view and recall task was considered to be analogous to reading a drug description and then searching for or writing out that drug description as part of a prescription.
- The arguments here are focussed on the presumption that we need to make the product descriptions as differentiable as possible. However, because describing a product by its active ingredients might have other benefits such as encouraging clinicians to understand what they are prescribing to their patients, we would strongly recommend that even if the key product description is the brand name, users should be able to access the full list of active ingredients via a hover function (bringing up a pop-up box with the ingredient list) or single-click access. We recommend that any list of active ingredients should be formatted with each active ingredient on a separate line.
- One suggestion is that, if the brand name is used, then the number of active ingredients should be given in brackets after the name to indicate the complexity of the product. For example, *Brand Name* (active ingredients: 25).
- One consideration is whether the use of brand names might preclude users from accessing generic or alternate brands. One solution to this would be for the prescription software to automatically flag equivalent products when a brand name was used.
- In sum, our argument is that the brand name is likely to be more memorable and more effective at allowing users to discriminate between products than a list of active ingredients, if there are three or more active ingredients in a product.

### Option 2: Use brand name as sole descriptor of product only if it has 4 or more active ingredients

This option was rejected by the panel for the reasons given above.

## Summary of heuristic evaluation panel recommendations for each of the key questions

Our recommendations for the 12 key questions are summarized below. Note that these recommendations will be more effective if implemented as a set, rather than acted upon in a piecemeal fashion. This is because there are interdependencies between them. For example, “+” will become less effective as a separator for active ingredients in a product if it is also used for other purposes (such as separating components in a multi-component pack).

### **Question 1: How should micrograms be displayed?**

The panel recommended MICROg as the best option.

### **Question 2: How should “greater than” be displayed?**

Across all contexts, “greater than” was considered the safest option by the panel. However the panel recommended that more context-sensitive options would be preferable (for example, using “longer than” in the context of a time period (e.g. longer than 4 hours)).

### **Question 3: How should “less than” be displayed?**

“Less than” was considered the safest option by the panel.

### **Question 4: Is it appropriate to use the “/” symbol in an expression of product strength?**

Yes, the “/” symbol was considered the safest option by the panel.

### **Question 5: Is it appropriate to use the “/” symbol in an expression of rate?**

Yes, the “/” symbol was considered the safest option by the panel.

### **Question 6: Is it appropriate to reserve the “+” symbol for separating the active ingredients in a product?**

Yes, the “+” symbol was considered the safest option by the panel.

**Question 7: Is it appropriate to reserve the “&” symbol to separate multiple components in a multiple component pack?**

The panel’s recommendation was that a bolded ampersand (i.e., **&**) should be used as a separator between components in a multi-component pack description (where the “&” symbol should not be used for any other purpose).

**Question 8: What term should be used for the separator label denoting quantity?**

The panel judged that “supply” was the best option.

**Question 9: What formatting guidelines should be recommended for the display of product names?**

The panel recommended that active ingredients should be presented in bold lowercase, and brand name should be presented in non-bold title case italics (i.e., the first letter of every key word in the brand name should be capitalized).

**Question 10: What formatting guidelines should be recommended for the display of prescription elements other than product name?**

The panel’s preference was that the dose value should be bold and the supply value should be regular and non-bold.

**Question 11: What human factors recommendations should be provided regarding the order in which the elements in a prescription should be presented on a computer display?**

The panel’s preference is for the following order of prescription elements: (1) drug name/strength, (2) form, (3) route, (4) dose, (5) frequency, and (6) supply.

**Question 12: What should be the guidelines relating to when the product brand name can be used in place of the list of active ingredients?**

The panel recommends that a product’s brand name can be used as the sole descriptor of product only if it has three or more active ingredients. However the panel also recommends that, in these cases, the list of active ingredients needs to be easily accessible to the user, for example, via a hover-over or single-click pop-up box.



## Future research recommendations

As previously noted, the recommendations generated by this project should be regarded as strictly preliminary. The key limitations to this advice are that (1) it has no empirical foundation and (2) it is based on inspection of a limited set of exemplars in a limited range of contexts.

We would recommend a follow-up research program with significantly greater scope, which could include the following:

### *1. An expanded task analysis*

This would involve a far more exhaustive investigation into the tasks that are performed using prescription software. The range of contexts investigated would be expanded. For example, it would include pharmacist-centred tasks (hospital and community-based), drug administration contexts beyond the inpatient hospital-based situation, and so on. The scope could be expanded to include printed prescriptions generated by the software, rather than just the on-screen presentation (where printed materials may require different best-practice solutions). Also, displays on devices with restricted screen sizes could be considered (where, again, different best-practice solutions may be needed). The investigation could include more detailed observation of users conducting tasks involving prescription software in a range of representative contexts, in addition to a wider range of interviews with both users (doctors, nurses, pharmacists, and patients) and subject-matter experts. Such an analysis would provide the insights needed for a more nuanced and robust set of recommendations.

### *2. Rapid prototyping of alternative software interfaces*

This approach would involve developing simulations of key elements of software prescription interfaces and conducting informal usability trials to assess the apparent usability of alternative design options. The simulations could vary in fidelity from mock-up screenshots (as used in the present project) to interactive software simulations or real prescription systems (tested using simulated patient data). Users would be asked to perform a variety of representative tasks within the simulation and their performance would be observed under somewhat controlled conditions. Users' reflections on their experiences with the alternative interface elements would also be recorded. This approach allows for rapid identification and elimination of sources of error, where design modifications can be iteratively introduced and the simulation sessions rerun to evaluate the modifications within a relatively short timeframe.

### ***3. Controlled behavioural experiments***

Both the heuristic evaluation approach used in the present study and the rapid prototyping methodology have a qualitative focus. This means that the risk remains that the recommendations generated from the research may not translate into actual performance improvements. Hence, any recommendations arising from those methodologies should also be empirically tested (past experience indicates that even expert recommendations can be wrong). We would therefore recommend that a research program of empirical behavioural experiments be conducted to allow quantitative performance data to be collected under carefully controlled conditions. This would allow for much stronger and more reliable recommendations to be made.

## References

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